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GENETIC VARIABILITY AND INTER-RELATIONSHIP ANALYSIS FOR VARIOUS YIELD ATTRIBUTING AND QUALITY TRAITS IN TRADITIONAL GERMPLASM OF RICE (*ORYZA SATIVA* L.)

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Abstract

Estimates of variability, heritability, genetic advance, correlation and path analysis were carried out in rice germplasm for nineteen characters. The highest genotypic coefficient of variation and phenotypic coefficient of variation was observed for number of effective tillers per plant, grain yield per plant and head rice recovery percentage. Estimates of heritability and genetic advance were high for number of effective tillers per plant, number of filled grains per panicle, head rice recovery percentage and grain yield per plant in genotypes indicating the predominance of additive gene action for these traits, hence direct selection may be highly effective. Correlation studies indicated that grain yield per plant had positive *significant* correlation with leaf width, days to 50% flowering, plant height, panicle length, number of filled grains per panicle, 100 seed weight and paddy length. A positive and significant correlation of head rice recovery percentage was also observed with leaf length, leaf width, days to 50% flowering, number of filled grains per panicle and milling percentage. Path analysis indicated that direct selection for days to 50% flowering, 100 seed weight, panicle length, leaf length and milling percentage would likely be effective for increasing grain yield. Direct selection for days to 50% flowering and number of filled grains per panicle would increase head rice recovery percentage.

Key words : *Oryza sativa* L., genetic variability, correlation, path analysis, rice germplasm.

Introduction

Rice is the most consumed cereal grain in the world, constituting the dietary staple food for more than half of the planet's human population. It is considered a model cereal crop in the world due to its relatively small genome size, vast germplasm collection, enormous repertoire of molecular genetic resources, and efficient transformation system (Paterson *et al*., 2005). Grain yield is a complex trait, controlled by many genes, environmentally influenced and determined by the magnitude and nature of their genetic variability in which they grow (Singh *et al.,* 2000). Genetic variability among traits is important for breeding and in selecting desirable types. The low heritability of grain yield characters made selection for high yielding varieties possible usually using various component traits associated with yield (Atlin, 2003). Heritability estimates provide the information on the proportion of variation that is transmissible to the progenies in subsequent generations. Genetic advance provides information on expected genetic gain resulting from selection of superior individuals.

The grain yield is quantitative in nature and an integrated function of a number of component traits. Therefore, selection for yield *per se* may not be much rewarding unless other yield attributing traits are taken into consideration. Correlation study provides a measure of association between characters and helps to identify important characters to be considered while making elucidates selection. Breeding strategy in rice mainly depends upon the degree of associated characters as well as its magnitude and nature of variation (Zahid *et al.,* 2006). Path coefficient analysis partitions the genetic correlation between yield and its component traits into

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direct and indirect effects and hence has effectively been used in identifying useful traits as selection criteria to improve grain yield in rice (Mustafa and Elsheikh, 2007). Development of high yielding varieties requires a thorough understanding of existing genetic variability as well as magnitude and direction of genetic association among the yield contributing characters. The present investigation was undertaken in this context to elucidate information on variability, heritability, genetic advance, character associations and path of effect in traditional rice germplasm of Chhattisgarh, India.

Materials and Methods

The experiment was conducted at the research area of the Department of Plant Breeding and Genetics, Indira Gandhi Krishi Vishwavidyalaya, Raipur during the kharif season 2006-07 under upland, bunded conditions. The breeding material for the study consisted of 96 accessions of rice from Bastar region of Chhattisgarh state in India along with six standard cultivars. The material was grown in a Complete Randomized Block Design with two replications. Each line was grown in plots of three meter long rows at spacing of 20 cm between rows and 15 cm between plants in a row. The nutrients (N:P:K) were applied at the rate of 60, 40 and 20 kg ha^{-1}, as urea, super phosphate and murate of potash, respectively. No plant protection measures were applied. Observations were recorded on five randomly selected plants of each line per replication for 19 traits *viz.,* leaf length, leaf width, days to 50 per cent flowering, number of effective tillers per plant, plant height, panicle length, number of filled grains per panicle, spikelet sterility percentage, 100 seed weight, paddy length, paddy breadth, brown rice length, brown rice breadth, kernel length, kernel breadth, milling percentage, head rice recovery percentage and grain yield per plant.

The genotypic and phenotypic coefficient of variation was computed according to the formulae given by Burton and Dewane (1952). Similarly, heritability and genetic advance were calculated by using formula of Hanson *et al*. (1956) and Johnson *et al.* (1955), respectively. Genotypic and phenotypic correlation coefficients among the characters under study for all the possible comparisons were computed as per the formulae suggested by Miller *et al.* (1958). The partitioning of genotypic correlation coefficient of traits into direct and indirect effects was carried out using the procedure suggested by Dewey and Lu (1959).

Results and Discussion

The analysis of variance revealed highly significant differences among all the genotypes for all the characters studied except for hulling percentage (table 1), indicating presence of considerable amount of genetic variation among the study material. The magnitude of variation between genotypes was reflected by high values of mean and range for genotype traits studied (table 2). The results (table 2) revealed that the estimates of phenotypic coefficient of variation (PCV) were slightly higher than those of genotypic coefficient of variation (GCV) for all the traits studied. The extent of the environmental influence on traits is explained by the magnitude of the difference between GCV and PCV. Large differences between GCV and PCV values reflect high environmental influence on the expression of traits. In this study, slight differences indicated minimum environmental influence and consequently greater role of genetic factors on the expression of traits.

High GCV and PCV values (table 2) were observed for number of effective tillers per plant, grain yield per plant and head rice recovery percentage, indicating the presence of ample variation for these characters in the present material which indicated the possibility of yield improvement through selection of these traits. The high magnitude of genetic variability for grain yield was also observed by Sarawgi and Soni (1994) and Debchaudhary and Das (1998). The results were also in agreement with the earlier reports of Sadhukhan and Chattopadhyay (2000); Verma *et al*. (2000) indicating wide scope for improvement in these characters.

In the present study, estimates of broad sense heritability were varied from 20.61 to 97.10% (table 2). Heritability in broad sense was high for all the characters studied except leaf width, brown rice breadth, kernel breadth, hulling percentage and milling percentage. Highest heritability estimate was recorded for plant height followed by paddy length, days to 50 per cent flowering, 100 seed weight and head rice recovery percentage. High heritability suggests high component of heritable portion of variation that can be exploited by breeders in the selection of superior genotypes on the basis of phenotypic performance. Moderate estimate of heritability was observed for leaf width, brown rice breadth, and kernel breadth while, hulling percentage and milling percentage showed low magnitude of heritability. In the present study high heritability was observed for days to 50 per cent flowering and which is in accordance to the findings of Tomar *et al.* (2000), Kavitha and Reddi (2002), Agrawal (2003). The high heritability observed for 100 seed weight is in conformity to the finding of the Agrawal (2003) and Tyagi *et al.* (2004). High estimate of heritability for grain yield per plant has been reported by Tyagi *et al.* (2004) and Shukla *et al.* (2005).

Table 1 : Analysis of variance for morphological and quality characters in 96 rice genotypes.

S. no.	Source of variation	Mean sum of square		
		Replication	**Genotype**	**Error**
	Characters / **Degree of freedom**	**1**	**95**	**95**
1.	Leaf length (cm)	37.09	79.35**	5.42
2.	Leaf width (cm)	0.110	0.040**	0.010
3.	Days to 50% flowering	9.25	145.24**	5.63
4.	Number of effective tillers per plant	12.50	20.72**	1.54
5.	Plant height (cm)	219.25	757.16**	11.22
6.	Panicle length (cm)	2.79	14.84**	1.17
7.	Number of filled grains per panicle	15.25	1431.57**	73.24
8.	Spikelet sterility percentage	9.89	56.51**	5.04
9.	100 seed weight (g)	0.010	0.245**	0.011
10.	Paddy length (mm)	0.827	1.00**	0.032
11.	Paddy breadth (mm)	0.193	0.180**	0.031
12.	Brown rice length (mm)	0.200	0.718**	0.041
13.	Brown rice breadth (mm)	0.262	0.133**	0.026
14.	Kernel length (mm)	0.250	0.649**	0.035
15.	Kernel breadth (mm)	0.247	0.120**	0.022
16.	Hulling percentage	49.2	4.00	2.6
17.	Milling percentage	54.06	5.06**	2.67
18.	Head rice recovery percentage	13.63	320.55**	16.03
19.	Grain yield per plant (g)	52.71	87.12**	7.84

** Significant at 1% level.

The estimates of genetic advance as percent of mean (table 2) were high for spikelet sterility percentage, number of effective tillers per plant, grain yield per plant, head rice recovery percentage and number of filled grains per panicle; moderate for leaf length, plant height and 100 seed weight. These results were supported by earlier findings of Tyagi *et al.* (2004) and Singh *et al.* (2005). Since high heritability does not always indicate high genetic gain, heritability with genetic advance should be used in predicting selection of superior genotypes (Ali *et al*., 2002). In this study, estimates of heritability and genetic advance were high for number of effective tillers per plant, number of filled grains per panicle, head rice recovery percentage and grain yield per plant in genotypes indicating the predominance of additive gene action for these traits, hence direct selection may be highly effective. Similar findings were reported by Ganesan *et al*. (1995), Rather *et al.* (1998) and Lalitha *et al.* (1999) for grain yield per plant and number of effective tillers per plant. The remaining traits had high heritability coupled with low to moderate genetic advance indicating the presence of both additive and non-additive gene effects in controlling these traits.

The genotypic and phenotypic correlations for yield and yield components are presented in table 3. Inter-relationship analysis indicated that the genotypic and the phenotypic correlation coefficients showed similar trend but genotypic correlation coefficients were of higher in magnitude than the corresponding phenotypic correlation coefficients which might be due to the masking or modifying effect of environment on character association at the genetic level (Sarawgi *et al.,* 1997 and Zahid *et al.,* 2006). Grain yield per plant had significant and positive correlation with leaf width, days to 50 per cent flowering, plant height, panicle length, number of filled grains per panicle, 100 seed weight and paddy length at both genotypic and phenotypic level. It had shown significant and positive association with leaf length and head rice recovery percentage at genotypic level only. This indicates the relative utility of all these traits for selection with respect to grain yield.

Genotypic correlation reflects either the pleiotropic action of genes or linkage or more likely both. The phenotypic correlation includes both genotypic and environmental effects and provides information about total

Table 2 : Genetic parameters of variation for morphological and quality traits.

Characters	Mean	Range		GCV(%)	PCV(%)	h^2 (bs)(%)	GA as % ofmean
		Min	Max				
LL (cm)	45.29	31.15	57.65	13.42	14.37	87.20	25.81
LW (cm)	1.14	0.90	1.65	10.68	13.90	59.00	16.66
DF	92.75	76.00	110.50	9.01	9.36	92.50	17.85
ET/P	11.04	5.00	18.00	28.06	30.23	86.20	53.62
PH (cm)	131.35	77.15	163.75	14.70	14.92	97.10	29.84
PaL (cm)	25.48	19.30	34.85	10.26	11.10	85.40	19.54
FG/Pa	140.85	71.00	183.00	18.50	19.47	90.30	36.22
SPS %	10.67	3.40	23.40	47.54	51.99	83.60	89.59
TW (g)	2.47	1.15	3.15	13.88	14.53	91.40	27.13
PL (mm)	8.31	6.00	10.00	8.39	8.67	93.70	16.73
PB (mm)	2.87	2.15	3.55	9.50	11.34	70.20	16.38
BRL (mm)	6.52	4.5	8.10	8.93	9.46	89.10	17.33
BRB (mm)	2.50	1.80	3.00	9.24	11.31	66.70	15.60
KL (mm)	5.90	4.00	7.40	9.38	9.91	89.60	18.31
KB (mm)	2.33	1.70	2.90	9.48	11.49	68.00	16.31
Hull %	79.56	73.82	82.03	1.04	2.29	20.61	1.00
Mill %	71.94	65.77	75.10	1.52	2.73	31.00	1.73
HRR %	51.73	24.70	66.14	23.85	25.08	90.50	46.74
GY/P (g)	25.29	12.00	45.15	24.90	27.25	83.50	46.85

Note : LL - Leaf length, **LW -** Leaf width, **DF -** Days to 50% flowering, **FG/Pa -** Number of filled grains per panicle, **PH -** Plant height; **PaL -** Panicle length, **ET/P –** Number of effective tillers per plant, **SPS % -** Spikelet sterility percentage, **TW -**100 seed weight, **PL -** Paddy length, **PB -** Paddy breadth, **BRL -** Brown rice length, **BRB -** Brown rice breadth, **KL -** Kernel length, **KB -** Kernel breadth, **Hull %**- Hulling percentage, **Mill % -** Milling percentage, **HRR % -** Head rice recovery percentage, **GY/P -** Grain yield per plant.

association between the observable characters. The significant environmental association indicates that per se improvement in the character by manupulating certain environmental factors would also be effective. The observed positive correlation of grain yield with various traits were supported by earlier workers *viz.,* Rao and Srivastava (1999), Rajeshwari and Nandrajan (2004) for number of filled grains per panicle; Sharma and Dubey (1997) for panicle length; Basavaraja *et al.* (1997) for plant height; Rao and Srivastava (1999) and Rajeshwari and Nandrajan (2004) for days to 50% flowering; Chakraborty *et al.* (2001) for 100 seed weight; Kaul and Kumar (1982) for paddy length.

The positive and significant association of head rice recovery percentage was observed with leaf length, leaf width, days to 50% flowering, number of filled grains per panicle, spikelet sterility percentage and milling percentage at both genotypic and phenotypic levels. Head rice recovery percentage was also significantly negatively associated at both phenotypic and genotypic level with number of effective tillers per plant, 100 seed weight, paddy breadth, brown rice breadth and kernel breadth. In the present study, significant positive association of head rice recovery percentage with milling percentage was in agreement with the findings of Choudhary and Motiramani (2003), indicating that this character can also be considered to achieve better results for improving yield as well as quality.

Path co-efficient analysis provides an effective means of finding out the direct and indirect causes of association and presents a critical examination of the specific forces acting to produce a given correlation and also measures the relative importance of each causal factor. The results of direct and indirect effects of yield components on grain yield per plant have been presented in Table 4. Path coefficient analysis revealed that brown rice breadth expressed highest positive direct effect on grain yield per plant followed by 100 grain weight, leaf width, number of effective tillers per plant, paddy length, days to 50 per cent flowering, leaf length, milling percentage, panicle length, head rice recovery percentage. The correlation analysis did not reveal any association of grain yield per plant with brown rice breadth. This may be due to high negative indirect effects via kernel breadth and paddy

Table 3 : Phenotypic (P), Genotypic (G) and Environmental (E) correlation coefficients for morphological and quality traits.

Char.	LW (cm)	DF	ET/P	PH (cm)	PaL (cm)	FG/Pa	SPS %	TW (g)	PL (mm)	PB (mm)	BRL (mm)	BRB (mm)	KL (mm)	KB (mm)	Mill %	HRR %	GY/P (g)
LL																	
P	0.358**	0.480**	-0.480**	0.699**	0.303**	0.528**	0.209*	-0.061	0.025	0.012	0.079	-0.016	0.057	-0.031	0.047	0.209*	0.190
G	0.391**	0.552**	-0.546**	0.746**	0.344**	0.571**	0.236*	-0.056	0.022	0.043	0.087	-0.078	0.070	-0.083	0.112	0.250*	0.256*
E	0.340**	-0.162	-0.047	0.203*	0.040	0.197	0.052	-0.105	0.061	0.237*	0.015	0.212*	-0.040	0.164	-0.039	-0.120	-0.198
LW																	
P		0.286**	-0.329**	0.340**	0.257*	0.480**	0.228*	0.147	0.037	0.202*	0.047	0.140	0.043	0.180	0.148	0.252*	0.365**
G		0.396**	-0.477**	0.427**	0.357**	0.632**	0.298**	0.192	0.044	0.248*	0.068	0.139	0.060	0.175	0.456**	0.384**	0.537**
E		-0.035	0.048	0.157	0.015	0.091	0.072	0.034	0.025	0.121	-0.011	0.142	-0.003	0.191	-0.089	-0.146	-0.044
DF																	
P			-0.326**	0.355**	0.205*	0.537**	0.463**	-0.143	0.034	0.089	0.086	-0.121	0.094	-0.142	0.228*	0.623**	0.214*
G			-0.353**	0.375**	0.236*	0.584**	0.514**	-0.168	0.046	0.109	0.083	-0.167	0.099	-0.168	0.443**	0.677**	0.234*
E			-0.105	-0.004	-0.047	0.034	0.100	0.144	-0.130	0.004	0.128	0.068	0.042	-0.052	-0.042	0.045	0.071
ET/P																	
P				-0.383**	-0.292**	-0.429**	-0.027	-0.050	0.024	0.112	-0.009	-0.084	-0.006	-0.048	-0.035	-0.203*	0.070
G				-0.417**	-0.355**	-0.472**	-0.012	-0.059	0.037	0.113	0.012	-0.090	0.017	-0.059	-0.123	-0.214*	0.086
E				-0.024	0.089	-0.109	-0.111	0.019	-0.097	0.117	-0.159	-0.076	-0.176	-0.012	0.092	-0.117	-0.021
PH																	
P					0.284**	0.361**	-0.049	0.005	-0.011	0.165	-0.024	0.128	-0.030	0.101	-0.061	0.118	0.269**
G					0.296**	0.381**	-0.060	0.010	-0.013	0.200	-0.033	0.143	-0.033	0.105	-0.121	0.126	0.298**
E					0.219*	0.088	0.063	-0.103	0.025	0.005	0.107	0.126	0.019	0.156	0.040	-0.013	0.016
PaL																	
P						0.207*	0.160	0.010	0.345**	0.159	0.376**	-0.174	0.396**	-0.168	-0.060	0.108	0.206*
G						0.228*	0.200	0.009	0.379**	0.192	0.408**	-0.181	0.430**	-0.199	-0.065	0.128	0.227*
E						0.051	-0.057	0.023	0.068	0.051	0.159	-0.171	0.158	-0.073	-0.083	-0.038	0.094
FG/Pa																	
P							0.200	-0.114	0.035	0.094	0.087	-0.125	0.089	-0.112	0.352**	0.491**	0.382**
G							0.211*	-0.126	0.047	0.132	0.093	-0.161	0.099	-0.136	0.687**	0.549**	0.437**
E							0.129	0.005	-0.105	0.063	0.039	0.000	0.001	-0.027	-0.042	-0.055	0.020
SPS%																	
P								-0.021	0.084	0.073	0.144	-0.088	0.130	-0.123	0.175	0.355**	0.000
G								-0.015	0.104	0.078	0.162	-0.087	0.121	-0.126	0.322**	0.398**	0.018
E								-0.060	-0.076	0.061	0.026	-0.100	0.193	-0.121	0.033	0.070	-0.089
TW																	
P									0.352**	0.650**	0.212*	0.588**	0.274**	0.622**	-0.014	-0.294**	0.253*

Table 3 continued....

G									0.384**	0.804**	0.236*	0.744**	0.313**	0.773**	-0.102	-0.336**	0.283**
E									-0.049	0.041	-0.008	0.040	-0.101	0.074	0.164	0.126	0.053
PL																	
P										0.101	0.835**	-0.185	0.894**	-0.157	-0.073	0.056	0.201*
G										0.146	0.913**	-0.264**	0.969**	-0.239*	-0.082	0.056	0.230*
E										0.124	0.011	0.168	0.068	0.240*	-0.136	0.062	-0.023
PB																	
P											-0.208*	0.863**	-0.201*	0.852**	0.047	-0.175	0.129
G											-0.288**	0.974**	-0.240*	0.980**	-0.032	-0.244*	0.159
E											0.110	0.624**	-0.061	0.569**	0.138	0.115	0.032
BRL																	
P												-0.243*	0.925**	-0.253*	-0.104	0.074	0.134
G												-0.339**	0.987**	-0.341**	-0.099	0.070	0.148
E												0.098	0.409**	0.067	-0.188	0.108	0.049
BRB																	
P													-0.263**	0.939**	0.054	-0.203*	0.093
G													-0.324**	0.988**	0.097	-0.305**	0.124
E													-0.065	0.837**	0.020	0.188	0.003
KL																	
P														-0.238*	-0.077	0.086	0.164
G														-0.286**	-0.065	0.092	0.190
E														-0.081	-0.160	0.027	-0.005
KB																	
P															0.071	-0.210*	0.138
G															0.146	-0.308**	0.182
E															0.008	0.181	0.003
Mill %																	
P																0.368**	0.195
G																0.549**	0.384**
E																0.303**	-0.002
HRR%																	
P																	0.109
G																	0.107
E																	-0.002

Note :- LL - Leaf length, **LW -** Leaf width, **DF** - Days to 50% flowering, **FG/Pa -** Number of filled grains per panicle, **PH -** Plant height; **PaL -** Panicle length, **ET/P –** Number of effective tillers per plant, **SPS %-** Spikelet sterility percentage, **TW** -100 seed weight, **PL -** Paddy length, **PB -** Paddy breadth, **BRL** -Brown rice length, **BRB -** Brown rice breadth, **KL -** Kernel length, **KB -** Kernel breadth, **Mill % -** Milling percentage, **HRR % -** Head rice recovery percentage, **GY/P -** Grain yield per plant.

Table 4 : Path coefficient analysis showing direct and indirect effects of different characters on grain yield per plant.

	LL	LW	DF	ET/P	PH	PaL	FG/Pa	SPS%	TW	PL	PB	BRL	BRB	KL	KB	Mill%	HRR%	GY/P
LL	**0.499**	0.397	0.319	-0.534	-0.010	0.062	-0.202	-0.215	-0.116	0.017	0.084	0.000	-0.204	-0.113	0.213	0.056	0.003	0.256
LW	0.195	**1.014**	0.229	-0.466	-0.006	0.064	-0.223	-0.272	0.399	0.034	-0.481	0.000	0.363	-0.098	-0.448	0.226	0.005	0.537
DF	0.275	0.402	**0.577**	-0.345	-0.005	0.043	-0.206	-0.469	-0.348	0.035	0.212	0.000	-0.438	-0.161	0.432	0.220	0.009	0.234
ET/P	-0.273	-0.484	-0.204	**0.977**	0.006	-0.064	0.167	0.011	-0.122	0.028	0.220	0.000	-0.235	-0.027	0.151	-0.061	-0.003	0.086
PH	0.372	0.433	0.216	-0.408	**-0.013**	0.053	-0.135	0.054	0.021	-0.010	-0.387	0.000	0.375	0.054	-0.270	-0.060	0.002	0.298
PaL	0.172	0.363	0.136	-0.347	-0.004	**0.180**	-0.081	-0.183	0.018	0.290	0.372	0.002	-0.472	-0.701	0.512	-0.032	0.002	0.227
FG/Pa	0.285	0.641	0.377	-0.461	-0.005	0.041	**-0.353**	-0.193	-0.262	0.036	0.255	0.000	-0.422	-0.162	0.350	0.341	0.007	0.437
SPS %	0.118	0.302	0.296	-0.011	0.001	0.036	-0.075	**-0.913**	-0.032	0.079	0.152	0.001	-0.227	-0.198	0.323	0.160	0.005	0.018
TW	-0.028	0.195	-0.097	-0.057	0.000	0.002	0.045	0.014	**2.077**	0.294	-1.559	0.001	1.946	-0.510	-1.983	-0.051	-0.005	0.283
PL	0.011	0.045	0.027	0.036	0.000	0.068	-0.017	-0.094	0.798	**0.767**	0.283	0.004	-0.690	-1.579	0.612	-0.041	0.001	0.230
PB	-0.022	0.251	-0.063	-0.111	-0.003	-0.035	0.046	0.071	1.669	-0.112	**-1.940**	-0.001	2.547	0.391	-2.513	-0.016	-0.003	0.159
BRL	0.043	0.069	0.048	0.012	0.000	0.074	-0.033	-0.148	0.489	0.700	0.559	**0.004**	-0.887	-1.608	0.874	-0.049	0.001	0.148
BRB	-0.039	0.141	-0.097	-0.088	-0.002	-0.033	0.057	0.079	1.545	-0.202	-1.890	-0.001	**2.616**	0.528	-2.535	0.048	-0.004	0.124
KL	0.035	0.061	0.057	0.016	0.000	0.078	-0.035	-0.111	0.651	0.743	0.466	0.004	-0.847	**-1.629**	0.733	-0.032	0.001	0.190
KB	-0.041	0.177	-0.097	-0.058	-0.001	-0.036	0.048	0.115	1.606	-0.183	-1.901	-0.001	2.585	0.466	**-2.565**	0.073	-0.004	0.182
Mill %	0.056	0.462	0.256	-0.120	0.002	-0.012	-0.243	-0.294	-0.212	-0.063	0.063	0.000	0.254	0.106	-0.375	**0.497**	0.007	0.384
HRR %	0.125	0.390	0.391	-0.209	-0.002	0.023	-0.194	-0.364	-0.699	0.043	0.473	0.000	-0.797	-0.150	0.791	0.273	**0.014**	0.107

Residual effect = 0.0473, **Note** – Diagonal values are direct effects

Note:- LL - Leaf length, **LW -** Leaf width, **DF** - Days to 50% flowering, **FG/Pa -** Number of filled grains per panicle, **PH -** Plant height, **PaL -** Panicle length, **ET/P –** Number of effective tillers per plant, **SPS %-** Spikelet sterility percentage; **TW -**100 seed weight; **PL -** Paddy length; **PB -** Paddy breadth, **BRL -**Brown rice length, **BRB -** Brown rice breadth, **KL -** Kernel length, **KB -** Kernel breadth, **Mill % -** Milling percentage, **HRR % -** Head rice recovery percentage, **GY/P -** Grain yield per plant.

breadth. The characters leaf length, leaf width, days to 50% flowering, panicle length, 100 seed weight, paddy length and milling percentage had positive direct effect and exhibited significant positive correlation with grain yield, indicating the true relationship among these traits. This may indicate that the direct selection for panicle length, 100 seed weight, paddy length and milling percentage would likely be effective in increasing grain yield.

The direct and indirect effect of different morphological and quality characters on the head rice recovery percentage has been presented in Table 5. The highest positive direct effect on head rice recovery percentage was estimated for paddy breadth followed by kernel breadth, paddy length, brown rice length, number of filled grains per panicle, days to 50 per cent flowering, leaf length, spikelet sterility percentage, grain yield per plant and panicle length. The characters paddy breadth, brown rice breadth and kernel breadth exhibited negative correlation with head rice recovery percentage. This may be due to the presence of negative indirect effect of paddy breadth *via* 100 grain weight, brown rice breadth, brown rice length, paddy length and plant height; the negative indirect effect of brown rice breadth *via* 100 grain weight, paddy breadth and brown rice length; paddy kernel breadth exhibited negative correlation with head rice recovery due to negative indirect effect of 100 grain weight, brown rice breadth, paddy length and brown rice length. The characters days to 50 per cent flowering, leaf length and number of filled grains per panicle exhibited positive direct effects and also revealed significant positive correlation with head rice recovery percentage indicating a true relationship among these traits.

The direct selection of days to 50 per cent flowering, panicle length, 100 grain weight, paddy length, leaf length

Table 5 : Path coefficient analysis showing direct and indirect effects of different characters on head rice recovery percentage.

	LL	LW	DF	ET/P	PH	PaL	FG/Pa	SPS%	TW	PL	PB	BRL	BRB	KL	KB	Mill%	GY/P	HRR%
LL	**0.133**	-0.019	0.194	0.054	-0.442	0.019	0.202	0.027	0.114	0.023	-0.085	0.062	0.100	-0.056	-0.091	-0.007	0.021	0.250
LW	0.052	**-0.048**	0.139	0.047	-0.253	0.020	0.224	0.034	-0.392	0.048	0.485	0.048	-0.177	-0.049	0.191	-0.030	0.043	0.384
DF	0.074	-0.019	**0.352**	0.035	-0.222	0.013	0.207	0.059	0.342	0.050	-0.214	0.059	0.214	-0.080	-0.184	-0.029	0.019	0.677
ET/P	0.073	0.023	-0.124	**-0.098**	0.247	-0.020	-0.167	-0.001	0.120	0.040	-0.221	0.009	0.115	-0.014	-0.064	0.008	0.007	-0.214
PH	0.099	-0.020	0.132	0.041	**-0.593**	0.017	0.135	-0.007	-0.021	-0.014	0.390	-0.023	-0.183	0.027	0.115	0.008	0.024	0.126
PaL	0.046	-0.017	0.083	0.035	-0.175	**0.056**	0.081	0.023	-0.017	0.411	-0.375	0.291	0.231	-0.348	-0.218	0.004	0.018	0.128
FG/Pa	0.076	-0.030	0.206	0.046	-0.226	0.013	**0.354**	0.024	0.257	0.052	-0.257	0.066	0.206	-0.080	-0.149	-0.045	0.035	0.549
SPS %	0.031	-0.014	0.181	0.001	0.035	0.011	0.075	**0.115**	0.032	0.113	-0.153	0.116	0.111	-0.098	-0.137	-0.021	0.001	0.398
TW	-0.007	-0.009	-0.059	0.006	-0.006	0.000	-0.045	-0.002	**-2.040**	0.417	1.572	0.168	-0.951	-0.254	0.844	0.007	0.023	-0.336
PL	0.003	-0.002	0.016	-0.004	0.008	0.021	0.017	0.012	-0.784	**1.087**	-0.285	0.650	0.337	-0.784	-0.260	0.005	0.019	0.056
PB	-0.006	-0.012	-0.039	0.011	-0.118	-0.011	-0.047	-0.009	-1.640	-0.159	**1.956**	-0.205	-1.245	0.194	1.069	0.002	0.013	-0.244
BRL	0.012	-0.003	0.029	-0.001	0.019	0.023	0.033	0.019	-0.481	0.992	-0.564	**0.712**	0.434	-0.799	-0.372	0.006	0.012	0.070
BRB	-0.010	-0.007	-0.059	0.009	-0.085	-0.010	-0.057	-0.010	-1.518	-0.287	1.904	-0.241	**-1.278**	0.262	1.079	-0.006	0.010	-0.305
KL	0.009	-0.003	0.035	-0.002	0.020	0.024	0.035	0.014	-0.639	1.053	-0.470	0.703	0.414	**-0.809**	-0.312	0.004	0.015	0.092
KB	-0.011	-0.008	-0.059	0.006	-0.062	-0.011	-0.048	-0.015	-1.577	-0.259	1.916	-0.243	-1.263	0.231	**1.092**	-0.009	0.015	-0.308
Mill %	0.015	-0.022	0.156	0.012	0.072	-0.004	0.244	0.037	0.208	-0.089	-0.064	-0.071	-0.124	0.053	0.160	**-0.065**	0.031	0.549
GY/P	0.034	-0.026	0.083	-0.008	-0.177	0.013	0.155	0.002	-0.576	0.250	0.311	0.106	-0.158	-0.154	0.199	-0.025	**0.081**	0.107

Residual effect = 0.2816, Note – Diagonal values are direct effects

Note :- LL - Leaf length, **LW -** Leaf width, **DF -** Days to 50% flowering, **FG/Pa -** Number of filled grains per panicle, **PH -** Plant height, **PaL -** Panicle length, **ET/P –** Number of effective tillers per plant, **SPS %-** Spikelet sterility percentage, **TW -** 100 seed weight, **PL -** Paddy length, **PB -** Paddy breadth, **BRL -** Brown rice length, **BRB -** Brown rice breadth, **KL -** Kernel length; **KB -** Kernel breadth, **Mill % -** Milling percentage, **HRR % -** Head rice recovery percentage, **GY/P -** Grain yield per plant.

and milling percentage for grain yield; days to 50 per cent flowering, filled grain per panicle and leaf length for head rice recovery percentage could be used as selection criterion for their improvement, whereas it is logical to select the plants having less spikelet sterility percentage for improvement in seed yield. However, the characters plant height, number of filled grains per panicle also expressed considerable indirect effect through one or more characters on grain yield per plant, hence they should also be given consideration in the selection criteria. The overall result of association analysis and path coefficient in the present studies indicated that there might be independent genes predominantely responsible for expression of these variables *viz.,* grain yield per plant and head rice recovery percentage although to some extent common genes may have also played a considerable role in their expression as seen in case of days to 50 per cent flowering and leaf length.

Conclusion

Results of the present investigation on variability, heritability and genetic advance indicated a scope for improvement of grain yield through selection. High heritability coupled with high genetic advance was noticed for number of effective tillers per plant, number of filled grains per panicle, head rice recovery percentage and grain yield per plant, indicating selection may be effective for improvement. Significant positive association of head rice recovery percentage with milling percentage indicated that this character can also be considered to achieve better results for improving yield as well as quality. The path coefficient analysis revealed that days to 50% flowering and leaf length could be used as selection criteria for the simultaneous improvement of grain yield per plant and head rice recovery percentage. The direct selection of days to 50% flowering, 100 seed weight, paddy length, leaf length and milling percentage for grain yield; days to 50%

flowering and filled grains per panicle for head rice recovery percentage could be used as selection criterion for improvement.

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