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Variability, correlation and path studies for yield and quality traits in irrigated upland rice (*Oryza sativa* L.)

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Abstract
Analysis of variance indicated the existence of significant differences among all genotypes for twenty five yield and quality traits studied in 36 genotypes suggesting the existence of sufficient amount of variability. The highest estimates of PCV and GCV were observed for alkali spreading value (37.0, 35.4), straw yield per plant (34.5, 33.2), harvest index (33.2, 30.9), water uptake (28.7, 27.5), panicle weight (25.7, 25.3), filled seeds per panicle (24.5, 23.6), yield per plant (23.4, 22.5) and head rice recovery (21.3, 20.7). High heritability coupled with high genetic advance as percent of mean exhibited by alkali spreading value (91.4, 69.7), straw yield per plant (92.8, 65.8), harvest index (86.8, 59.3), panicle weight (96.7, 51.3), filled seeds per panicle (95.7, 49.3), panicle density (95.6, 46.2) head rice recovery (94.6, 41.5) and effective tillers (90.6, 36.6) indicating preponderance of additive gene action and these traits can be improved through simple selection. Correlation studies revealed that grain yield per plant has shown significant positive effect with panicle length (0.395), panicle weight (0.312) and effective tillers (0.268) while, head rice recovery exhibited significant positive association with milling percent (0.675) and hulling percent (0.376) at genotypic level. The results of path analysis indicated that panicle density (0.985) followed by straw yield per plant (0.495), effective tillers (0.370) and days to 50% flowering (0.282) had maximum direct effect on grain yield per plant. Milling percent (0.593) had shown direct positive effect on head rice recovery whereas length/breadth ratio (0.105), kernel breadth after cooking (0.033), kernel elongation ratio, volume expansion ratio, alkali spreading value has shown positive effect at phenotypic level and kernel length after cooking (0.0014) at genotypic level. Suggesting that these traits may be considered as prime traits during course of selection to have high yield potential with good quality traits in case of rice.

Keywords: Rice, variability, correlation path analysis, yield, quality

Introduction
Rice is one of the most important food grain crops in the world forms the staple diet of more than 2.7 million people. India is one of the world's largest producer of rice accounting for 20% of all world rice production. Although it is grown all over the world, rice yield still a hot topic in rice breeding despite the increasing grain yield after green revolution (Songet *et al.* 2007) [16]. Enhancing crop yield in one of the top most priorities in crop breeding programmes. Quality traits are yet another important consideration of rice breeding in India. The most important criteria in any crop improvement programmes are the selection of genotypes with all possible desirable quality and yield contributing traits.
Variability in genotypes for yield, its component characters and quality traits forms the basic factor to be considered while selection of parents for successful hybridization programmes. So that desired character combinations may be selected to improve grain quality and higher grain yield. Moreover knowledge of heritability is essential for selection based improvement as it indicates the transmissibility of a character into future generation (Johnson *et al.* 1955) [6]. Selection for one component may simultaneously affect related traits in a favorable direction.
Yield is a complex quantitative character controlled by many gene interactions with environment and is product of many factors called yield components. Selection of parents based on yield alone is often misleading. Hence knowledge about relationship between yield and its contributing characters is needed for an efficient selection strategy for the plant breeders to evolve an economic variety. Path coefficient analysis furnishes information of influence of each contributing trait to yield directly as well as indirectly and also enables breeders to rank the genetic attributes according to their contribution.
The present study was undertaken to derive same useful information on genetic variability character association and path coefficient analysis in a set of thirty six rice genotypes.

Materials and Methods

The experimental material used in the study consisted of 8 parents and 28 F_1 hybrid combinations of rice grown in a completely randomized block design with three replications at Professor Jayashankar Telangana State Agriculture University, Regional Agricultural Research Station, Warangal during *rabi*, 2015-16. Twenty five days old seedlings of each genotype were transplanted in three rows of 2.0 m length by adopting a spacing of 20 cm between rows and 15 cm between the plants at the rate of 20 plants per row. The crop was grown with the application of fertilizers N, P and K at the rate of 120:60:40 Kg /ha respectively. Standard agronomic practices were followed to raise a good crop.

A composite sample of 10 plants from the middle row was used to record observation on these plants for plant height, effective tillers, panicle length, flag leaf length, flag leaf width, filled seeds per panicle, test weight, yield per plant except days to 50% flowering which was computed on plot basis. Data was recorded on physical, chemical and cooking quality characters *viz*, hulling percent. milling percent, head rice recovery, kernel length, kernel width, length / breadth ratio, kernel length after cooking, kernel breadth after cooking, elongation ratio, alkali spreading value, volume expansion ratio and water uptake. The seed was dehusked in a satake laboratory huller (Type THU 35A) and polished in a satake rice polisher (Type TM05) and data on head rice recovery was recorded. Observation on hulling and milling were taken. The polished kernel obtained were utilized for the analysis of above 14 seed quality traits. Kernel length and kernel width of 20 whole milled rice were measured by means of dial caliper and length / breadth ratio was computed as per Murthy and Govinda Swamy (1967) [10]. Kernel elongation was determined by soaking 5 g of whole milled rice in 12 ml distilled water for 10 minutes and later cooked for 15 minutes in water bath. Observation on length and breadth of cooked kernels and elongation ratio were recorded with the help of graph sheet to quantify cooking traits. Water uptake, volume expansion ratio, alkali spreading value were estimated by following the standard procedures. The treatment means for all the characters were subjected to analysis of variance techniques on the basis of model proposed by Panse and Sukhatme (1961) [13] phenotypic coefficient of variation (PCV) and genotypic coefficient of variation were calculated by the formula given by Burton (1953) [1]. Heritability in broad sense h^2_b and genetic advance as percent of mean were estimated by the formula given by Lush (1940) [8] and as suggested by Jonnson *et al.* (1955) [6]. The path and correlation coefficient analysis was done following the method of Deway and Lu (1959) [3].

Results and Discussion

Genetic variability in any crop is pre requisite for selection of superior genotypes upon the existing cultivars. The results from analysis of variation for 25 yield and quality traits are presented in Table-1 and analysis of variance indicated the existence of significant differences among all genotypes for all the characters studied suggesting the existence of sufficient amount of variability. The magnitude of variation between genotypes was reflected by high values of mean and range for genotypic traits studied. The estimates of range, mean, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense and genetic advance as percent of mean are presented in Table-2. In general the magnitude of phenotypic coefficient of variation was higher than its corresponding genotypic coefficient of variation for all the traits indicating the influence of environment on manifestation of these traits. The highest estimates of PCV and GCV were observed for alkali spreading value, straw yield per plant, harvest index, water uptake, panicle density, plant height, filled seeds per panicle, head rice recovery and yield per plant. The different between PCV and GCV estimates were relatively low except for kernel elongation ratio and volume expansion ratio indicating less environmental influence on these traits. Moderate PCV and GCV estimates were observed for effective tillers, flag leaf length, flag leaf width, test weight and volume expansion ratio and lowest was observed for hulling percent, kernel elongation ratio, days to 50% flowering, kernel width, kernel length, kernel breadth after cooking, milling percent and panicle length. The selection for these traits would offer very better scope for genetic improvement of the genotypes under study. Need for creation of variability either by hybridization or mutation followed by selection. These results are in consonance with the findings of Venkata Subbaiah *et al.* (2011) [23], Singh *et al.* (2014) [19] for filled seeds per panicle and yield per plant. Singh *et al.* (2014) [19] also reported lower PCV and GCV estimates for kernel width, days to 50% flowering and panicle length. Ravinder babu *et al.* (2012) [14] for kernel width and Dhurai *et al.* (2014) [4] for days to 50% flowering, kernel length, kernel width and length/breadth ratio. High phenotypic variation was composed of high genotypic variation and less of environmental variation which indicated the presence of high genetic variability for different traits and less influence of environment. Therefore selection on the basis of phenotype alone cannot be effective for the improvement of these traits.

The amount of genetic variation considered alone will not be of much use to the breeder unless supplemented with the information on heritability estimate, which gives a measure of heritable portion of the total variation. It has been suggested by Burton and Devane (1953) [2] that GCV along with heritability estimates could provide a better picture of the amount of advance to be expected by phenotypic selection. Since genetic advance is dependent on phenotypic variability and heritability in addition to selection intensity. The heritability estimates in conjunction with genetic advance will be more effective and reliable in predicting the response to selection (Johnson *et al.* 1955) [6].

High estimates of heritability were obtained by most of the characters whereas volume expansion ratio showed moderate heritability. Indicating the major role of additive gene action in inheritance of these traits. Heritability plays an important role in deciding the suitability and strategy for selection of a variety. According to Panse (1957) [12] if a character is governed by non additive gene action it may give heritability but low genetic advance, whereas if it is governed by additive gene action, high heritability (above 60%) along with high genetic advance (above 20%) helps good scope for further improvement. The traits alkali spreading value, straw yield/plant, harvest index, water uptake, panicle weight, filled seeds per panicle, panicle density, head rice recovery, effective tillers, flag leaf length, flag leaf width volume expansion ratio and plant height showed high heritability coupled with high genetic advance. The results are in accordance with the findings of Rukmini Devi *et al.* (2017) [15] for effective tillers, yield/plant, head rice recovery, plant height and filled seeds per panicle, Singh *et al.* (2005) [18] for effective tillers, Dhurai *et al.* (2014) [4] for effective tillers, plant height, yield per plant, filled grains per panicle.

Table 1: Analysis of variance (mean squares) for grain yield and quality traits in rice (*Oryza sativa* L)

S. No	Characters	Replication (d.f=1)	Treatments (d.f=35)	Error (d.f=35)
1	Days to 50% flowering	1.68	83.34**	2.22
2	Plant height (cm)	0.125	14.66**	2.01
3	Effective tillers	6.57	215.3**	10.6
4	Panicle length (cm)	0.31	11.72**	0.77
5	Flag leaf length (cm)	1.00	30.47**	1.54
6	Flag leaf width (cm)	0.133	0.117**	0.018
7	Panicle weight (g)	0.69	2.99**	0.04
8	Panicle density	0.02	9.33**	0.21
9	Filled seeds /Panicle	4.01	6423.9**	140.6
10	Test weight (g)	0.07	22.72**	0.29
11	Yield/Plant (g)	18.0	119.8**	4.26
12	Straw yield/plant (g)	0.18	162.9**	6.11
13	HI	0.0000	0.015**	0.001

*Significant at 5% level
** Significant at 1 % level

Table 1: Analysis of variance (mean squares) for grain yield and quality traits in rice (*Oryza sativa* L)

S. No	Characters	Replication (d.f=1)	Treatments (d.f=26)	Error (d.f=26)
1	Hulling percent (%)	0.028	15.40**	2.24
2	Milling percent (%)	7.16	89.77**	2.84
3	Head rice recovery	1.27	185.6**	5.1
4	Kernel length (mm)	0.002	0.318**	0.029
5	Kernel width (mm)	0.009	0.026**	0.005
6	L/B ratio	0.014	0.145**	0.01
7	Kernel length after cooking (mm)	0.11	0.512**	0.076
8	Kernel breadth after cooking (mm)	0.011	0.076**	0.176
9	Kernel elongation ratio	0.003	0.009**	0.004
10	Alkali spreading value	0.375	3.385**	0.152
11	Volume expansion ratio	0.005	0.191**	0.57
12	Water uptake	4851.5	4177.1**	186.9

*Significant at 5% level
** Significant at 1 % level

Table 2: Components of genetic parameters for yield and quality traits in rice (*Oryza sativa* L)

Character	Mean	Range	PV	GV	PCV	GCV	Heritability in broad sense (%)	Genetic advance over mean (%)
Days to 50% flowering	102	93 - 121	42.8	40.56	6.42	6.25	94.8	12.53
Plant height (cm)	95.84	76.4 - 118.7	8.34	6.33	23.4	20.42	75.9	20.7
Effective tillers	12.3	8.5 - 19	112.9	102.33	11.09	10.56	90.6	36.6
Panicle length (cm)	24.7	19.2 - 29.7	6.25	5.47	10.10	9.46	87.6	18.23
Flag leaf length (cm)	29.37	22.2 - 39.0	16.0	14.47	13.6	12.95	90.4	25.4
Flag leaf width (cm)	1.56	1.0 - 2.05	0.068	0.049	16.79	14.28	72.3	25.0
Panicle weight (g)	4.79	2.58 - 7.52	1.52	1.47	25.7	25.31	96.7	51.3
Panicle density	9.31	5 - 13.9	4.77	4.56	23.46	22.9	95.6	46.2
Filled seeds /Panicle	229	136 - 325	3282.3	3141.6	24.47	23.6	95.7	49.3
Test weight (g)	19.7	13.9 - 26.7	17.03	2.74	11.51	11.21	97.5	34.63
Yield/Plant (g)	33.6	18.5 - 49.2	62.04	57.78	23.4	22.5	93.1	44.9
Straw yield/plant (g)	26.7	14.1 - 51.0	84.5	78.4	34.5	33.2	92.8	65.8
HI	0.277	0.15- 0.52	0.008	0.007	33.21	30.95	86.8	59.3

Table 2: Components of genetic parameters for quality traits in rice (*Oryza sativa* L)

Character	Mean	Range	PV	GV	PCV	GCV	Heritability in broad sense (%)	Genetic advance over mean (%)
Hulling percent (%)	78.46	70.9 - 82.3	8.82	6.59	3.79	3.27	74.6	5.82
Milling percent (%)	66.5	42.1 - 80.0	46.3	43.5	10.23	9.92	93.9	19.8
Head rice recovery (%)	45.9	25.5 - 68.8	95.4	90.21	21.29	20.7	94.6	41.8
Kernel length (mm)	5.22	4.59 - 6.15	0.174	0.145	7.99	7.29	83.2	13.7
Kernel width (mm)	1.69	1.45 - 1.99	0.016	0.010	7.495	5.95	63.1	9.7
L/B ratio	3.04	2.45 - 3.85	0.078	0.068	9.20	8.55	86.3	16.4
Kernel length after cooking (mm)	5.69	4.83 - 6.65	0.295	0.218	9.546	8.216	74.1	14.6
Kernel breadth after cooking (mm)	2.175	1.93 - 2.83	0.047	0.029	9.96	7.86	62.3	12.7
Kernel elongation ratio	1.092	0.98 - 1.27	0.007	0.003	7.503	4.65	38.4	5.9
Alkali spreading value	3.59	2.0 - 7.0	1.77	1.62	37.03	35.4	91.4	69.7
Volume expansion ratio	1.653	1.20 - 2.65	0.124	0.067	21.32	15.65	53.9	23.7
Water uptake (ml)	162.5	91 - 281	2182	1995	28.74	27.48	91.4	54.1

Table 3: Phenotypic and genotypic correlation coefficient for yield traits in rice (*Oryza sativa* L)

Characters		Days to 50% flowering	Plant height (cm)	Effective tillers	Panicle length (cm)	Flag leaf length(cm)	Flag leaf width(cm)	Panicle weight(g)	Panicle density	Filled seeds /Panicle	Test weight (g)	Straw yield/plant (g)	HI
Days to 50% flowering	P	1.0000	0.4270**	0.0423	0.1726	0.3091**	0.1200	0.219	0.0474	0.1036	-0.1008	0.6270**	0.5685**
	G	1.0000	0.4599**	-0.0169	0.2092	0.3325**	0.1414	0.043	0.499	0.1169	-0.1164	0.6607**	0.6154**
Plant height(cm)	P		1.0000	0.3538**	0.7805**	0.7316**	0.5297**	0.7504**	0.2985**	0.5743**	0.3406**	0.3355**	0.2869*
	G		1.0000	-0.4405**	0.8496**	0.8075**	0.6666**	0.8060**	0.3236**	0.6072**	0.3720**	0.3667**	0.2948*
Effective tillers	P			1.0000	-0.2877*	-0.2446*	-0.2684*	0.3096**	-0.1236	-0.2015	-0.1978	-0.0606	-0.0364
	G			1.0000	-0.3979*	-0.2928*	-0.2820*	-0.3669**	-0.1462	-0.2695	-0.2110	-0.0859	-0.386
Panicle length (cm)	P				1.0000	0.5939**	0.5626**	0.7364**	0.0118	0.3826**	0.5911**	0.2331*	0.1855
	G				1.0000	0.6547**	0.6965**	0.7803**	0.0368	0.3927**	0.6381**	0.2657*	0.1902
Flag leaf length(cm)	P					1.0000	0.6921**	0.6369**	0.3461**	0.5324**	0.2950*	0.4820**	0.4179**
	G					1.0000	0.7845**	0.6772**	0.3577**	0.5564**	0.3080*	0.5145**	0.4721**
Flag leaf width(cm)	P						1.0000	0.5556**	0.3122**	0.4825**	0.1858	0.4699**	0.3974**
	G						1.0000	0.6542**	0.3362**	0.5411**	0.236	0.5878*	0.5406**
Panicle weight(g)	P							1.0000	0.5157**	0.7494**	0.3697**	0.0535	0.0022
	G							1.0000	0.5289**	0.7672**	0.3722**	0.0577	-0.0152
Panicle density	P								1.0000	0.9190**	0.4898**	-0.0672	-0.0909
	G								1.0000	-0.9282**	-0.5090**	-0.0733	-0.0855
Filled seeds /Panicle	P									1.0000	-0.2297	0.0119	-0.0297
	G									1.0000	-0.2382	0.0064	-0.0162
Test weight(g)	P										1.0000	0.0577	0.0288
	G										1.0000	0.0748	0.0355
Straw yield/plant(g)	P											1.0000	0.9346**
	G											1.00000	1.0014**
HI	P												1.0000
	G												1.0000
Grain Yield/Plant (g)	P	-0.0588	0.1785	0.2077**	0.3624**	0.1607	0.2670**	0.3021**	0.0388	0.1603	0.2017**	0.1788	0.1539
	G	-0.0708	0.1778	0.2677**	0.3953**	0.1595	0.3193**	0.3127**	0.0374	0.1602	0.2067**	0.1597	0.1315

* & ** Significant at 5 % and 1 % level respectively

P -phenotypic correlation coefficient

G- genotypic correlation coefficient

Table 3: Phenotypic and genotypic path coefficient analysis for yield traits in rice (*Oryza sativa* L)

Characters		Days to 50% flowering	Plant height (cm)	Effective tillers	Panicle length (cm)	Flag leaf length(cm)	Flag leaf width(cm)	Panicle Weight (g)	Panicle density	Filled seeds /Panicle	Test weight (g)	Straw yield/plant (g)	HI
Days to 50% flowering	P	0.2818	-0.1203	0.0119	-0.0487	-0.0871	-0.0338	-0.0062	-0.0134	-0.0292	-0.0284	-0.1767	-0.1602
	G	0.2766	-0.0471	0.0385	-0.4762	-0.7569	-0.3218	-0.0554	-0.1136	-0.2661	0.2649	-1.5041	-1.4011
Plant height(cm)	P	-0.0256	-0.0600	0.0212	-0.0468	-0.0439	-0.0318	0.0450	-0.0179	-0.0345	-0.0204	-0.0201	-0.0172
	G	0.1480	0.3219	-0.1418	0.2735	0.2599	0.2146	0.2594	0.1042	0.1954	0.1198	0.1180	0.0949
Effective tillers	P	-0.0156	-0.1309	0.3701	-0.1065	-0.0905	-0.0993	-0.1146	-0.0457	-0.0746	-0.0732	-0.0224	-0.0135
	G	-0.0144	-0.3756	0.8526	-0.3392	-0.2497	-0.2404	-0.3128	-0.1247	-0.2297	-0.1799	-0.0732	-0.0329
Panicle length (cm)	P	0.1375	0.6217	-0.2292	0.7965	0.4731	0.4481	0.5865	0.0094	0.3048	0.4708	0.1857	0.1478
	G	1.1854	4.8143	-2.2544	5.6665	3.7100	3.9469	4.4216	0.2088	2.2254	3.6158	1.5056	1.0777
Flag leaf length(cm)	P	-0.0975	-0.2307	0.0771	-0.1873	-0.3153	-0.2182	-0.2008	-0.1091	-0.1679	-0.0930	-0.1520	-0.1318
	G	-0.0067	-0.0163	0.0059	-0.0132	-0.0201	0.0158	-0.0136	-0.0072	-0.0112	-0.0062	-0.0104	-0.0095

Flag leaf width(cm)	P	-0.0008	-00036	0.0018	-0.0039	-0.0048	-0.0069	-0.0038	-0.0021	-0.0033	-0.0013	-0.0032	-0.0027
	G	-0.04428	-2.0882	0.8835	-2.1821	-2.4577	-3.1327	-2.0495	-1.0533	-1.6952	-0.7317	-1.8414	-1.6937
Panicle weight(g)	P	0.0022	0.0740	-0.0305	0.0726	0.0628	0.0549	0.0986	0.0508	0.0739	0.0365	0.0053	0.0002
	G	-0.0182	-0.6047	0.2752	-0.5854	-0.5081	-0.4908	-0.7502	-0.3968	-0.5756	-0.2793	-0.0432	0.0114
Panicle density	P	0.0467	0.2940	-0.1218	0.0116	0.3410	0.3076	0.5080	0.9851	0.9053	-0.4825	-0.0662	-0.0895
	G	0.3345	2.1683	-0.9799	0.2469	2.3966	2.2528	3.5441	6.7006	6.2194	-3.4108	-0.4915	-0.5726
Filled seeds /Panicle	P	-0.0822	-0.4554	0.1598	-0.3034	-0.4221	-0.3825	-0.5942	-0.7287	-0.7928	0.1821	-0.0094	0.0236
	G	-0.6827	-3.5465	1.5739	-2.2939	-3.2498	-3.1607	-4.4812	-5.4214	-5.8409	1.3913	-0.0375	0.0946
Test weight(g)	P	-0.0129	0.0435	-0.0253	0.0755	0.0377	0.0237	0.0472	-0.0626	-0.0293	0.1277	0.0074	0.0037
	G	0.6809	-0.2587	0.1467	-0.4436	-0.2141	-0.1624	-0.2588	0.3539	0.1656	-0.6952	-0.0520	-0.0247
Straw yield/plant(g)	P	0.3108	0.1663	-0.0301	0.1156	0.2389	0.2329	0.0265	-0.0333	0.0059	0.0286	0.4957	0.4633
	G	0.4309	0.2437	-0.0571	0.1765	0.3418	0.3905	0.0383	-0.0487	0.0043	0.0497	0.6644	0.6654
HI	P	0.0396	-0.0200	0.0025	-0.0129	-0.0291	-0.0277	-0.0002	0.0063	0.0021	-0.0020	-0.0651	-0.0697
	G	1.1830	0.5666	-0.0742	0.3656	0.9075	1.0392	-0.0292	-0.1643	-0.0311	0.0683	1.9250	1.922
Grain Yield/Plant (g)	P	-0.0588	0.1785	0.2077	0.3624	0.1607	0.2670	0.3021	0.0388	0.1603	0.2017	0.1788	0.1539
	G	-0.0708	0.1788	0.2688	0.3953	0.1595	0.3193	0.3127	0.0374	0.1602	0.2067	0.1597	0.1315

Phenotypic residual effect = 0.7979 Genotypic residual effect: 0.1432

Table 4: Phenotypic and genotypic correlation coefficient for quality traits in rice (*Oryza sativa.* L)

Characters		**Hulling percent (%)**	**Milling percent (%)**	**Kernel length (mm)**	**Kernel width (mm)**	**L/ B ratio**	**Kernel length after cooking (mm)**	**Kernel breadth after cooking (mm)**	**Kernel elongation ratio**	**Volume expansion ratio**	**Water uptake**	**Alkali spreading value**
Hulling percent (%)	P	1.0000	0.5498**	0.1837	-0.1424	-0.0937	-0.4274**	-0.2646*	-0.3581**	-0.1879	-0.2788*	-0.1914
	G	1.0000	0.5642**	-0.2782	-0.2594	-0.0970	-0.5083**	-0.2589	-0.5122**	-0.3041	-0.3416**	-0.2464
Milling percent (%)	P		1.0000	-0.3475**	-0.1328	-0.2515*	-0.3749**	-0.1281	-0.1143	-0.0489	-0.1982	-0.0510
	G		1.0000	-0.3980**	-0.2095	-0.2597*	-0.4189**	-0.1154	-0.1516	-0.0904	-0.1995	-0.0475
Kernel length (mm)	P			1.0000	0.2111	0.6228**	0.6645**	0.3957**	-0.2050	0.0945	0.3713**	0.2833*
	G			1.0000	0.2255	0.6804**	0.7892**	0.5097**	-0.1130	0.0724	0.4547**	0.3047*
Kernel width (mm)	P				1.0000	-0.5317**	0.3567**	0.3826**	0.1912	0.2947*	0.4911**	0.3748**
	G				1.0000	-0.5604**	0.6531**	0.9024**	0.8276	0.3727*	0.6084**	0.4881**
L/B ratio	P					1.0000	0.2200	0.0090	-0.3623**	-0.1327	-0.0960	-0.1117
	G					1.0000	0.2260	-0.0694	-0.5866**	-0.1796	-0.845	-0.1135
Kernel length after cooking (mm)	P						1.0000	0.5206	0.5814**	0.2800*	0.6825**	0.4478**
	G						1.0000	0.5256**	0.5422**	0.3946*	0.8691**	0.5584**
Kernel breadth after cooking (mm)	P							1.0000	0.2706	0.0313	0.5601**	0.6553**
	G							1.0000	0.1536	0.2269	0.8200**	0.8086**
Kernel elongation ratio	P								1.0000	0.2472*	0.4959**	0.2849**
	G								1.0000	0.5391*	0.8417**	0.5480**
Volume expansion ratio	P									1.0000	0.1885	-0.0089
	G									1.0000	0.2739	-0.0167
Water uptake	P										1.0000	0.6399**
	G										1.0000	0.7336**
Alkali spreading value	P											1.0000
	G											1.0000
Head rice recovery	P	0.3476**	0.6485**	-0.3389	-0.1378	-0.2188	-0.3782	-0.1282	-0.1223	-0.0618	-0.2177	-0.0713
	G	0.3763**	0.6754**	-0.4032	-0.1626	-0.2465	-0.4514	-0.1714	-0.1942	-0.1504	-0.2314	-0.0840

*Significant at 5 % level **Significant at 1 % level

P represents phenotypic correlation coefficient **G** represents genotypic correlation coefficient

Table 4: Phenotypic and genotypic path coefficient analysis for quality traits in rice (*Oryza sativa* L)

Characters		Hulling percent (%)	Milling percent (%)	Kernel length (mm)	Kernel width (mm)	L/ B ratio	Kernel length after cooking (mm)	Kernel breadth after cooking (mm)	Kernel elongation ratio	Volume expansion ratio	Water uptake	Alkali spreading value
Hulling percent (%)	P	-0.0554	-0.0305	0.0102	0.0079	0.0052	0.0237	0.0147	0.0198	0.0104	0.0154	0.0106
	G	-0.0788	-0.0439	0.0216	0.0202	0.0075	0.0395	0.0201	0.0398	0.0237	0.0266	0.0192
Milling percent (%)	P	0.3261	0.5932	-0.2061	0.0788	-0.1492	-0.2224	-0.0760	-0.0678	-0.0290	-0.1176	-0.0303
	G	0.3515	0.6230	-0.2479	-0.1305	-0.1618	-0.2609	-0.0719	-0.0944	-0.0563	-0.1234	-0.0296
Kernel length (mm)	P	-0.0201	-0.0380	0.1094	0.0231	0.0681	0.0727	0.0433	-0.0224	0.0103	0.0406	0.0310
	G	-0.0292	0.0418	-0.1051	-0.0237	-0.0715	-0.0830	-0.0536	0.0119	-0.0076	-0.0478	-0.0320
Kernel width (mm)	P	0.0119	0.0111	-0.0177	-0.0839	0.0446	-0.0299	-0.0321	-0.0160	-0.0247	-0.0412	-0.0315
	G	0.0213	0.0172	-0.0186	-0.0823	0.0461	-0.0538	-0.0743	-0.0681	-0.0307	-0.0501	-0.0402
L/B ratio	P	0.0099	0.0265	-0.0656	0.0560	0.1053	-0.0232	-0.0010	0.0382	0.0140	0.0101	0.0118
	G	0.0095	0.0256	-0.0670	0.0551	-0.0984	-0.0222	0.0068	0.0577	0.0177	0.0083	0.0112
Kernel length after cooking (mm)	P	0.1094	0.0959	-0.1700	-0.0913	-0.0563	-0.2559	-0.1332	-0.1488	-0.0716	-0.1746	-0.1146
	G	-0.0007	-0.0006	0.0011	0.0009	0.0003	0.0014	0.0008	0.0008	0.0006	0.0013	0.0008
Kernel breadth after cooking (mm)	P	-0.0088	-0.0043	0.0132	0.0128	0.0003	0.0174	0.0334	0.0090	0.0010	0.0187	0.0219
	G	-0.0348	-0.0155	0.0685	0.1212	-0.0093	0.0706	0.1343	0.0206	0.0305	0.1102	0.1086
Kernel elongation ratio	P	-0.0231	-0.0074	-0.0132	0.0124	-0.0234	-0.0376	0.0175	0.0646	0.0160	0.0320	0.0184
	G	0.0077	0.0023	0.0017	-0.0125	0.0088	-0.0082	-0.0023	-0.0150	-0.0081	-0.0127	-0.0082
Volume expansion ratio	P	-0.0029	-0.0008	0.0015	0.0046	-0.0021	0.0044	0.0005	0.0039	0.0157	0.0030	-0.0001
	G	0.0315	0.0094	-0.0075	-0.0386	0.0186	-0.0408	-0.0235	-0.0558	-0.1035	-0.0283	0.0017
Water uptake	P	0.0054	0.0038	-0.0072	-0.0095	0.0019	-0.0132	-0.0108	-0.0096	0.0037	-0.0194	-0.0124
	G	0.0221	0.0129	-0.0294	-0.0393	0.0055	-0.0562	-0.0530	-0.0544	-0.0177	-0.0646	-0.0474
Alkali spreading value	P	-0.0046	-0.0012	0.0068	0.0089	-0.0027	0.0107	0.0156	0.0068	-0.0002	0.0153	0.0239
	G	0.0168	0.0032	-0.0207	-0.0332	0.0077	-0.0380	-0.0550	-0.0373	0.0011	0.0499	-0.0680
Head rice recovery (%)	P	0.3476	0.6485	-0.3389	-0.1378	-0.2188	-0.3782	-0.1282	-0.1223	-0.0618	-0.2177	-0.0713
	G	0.3763	0.6754	-0.4031	-0.1626	-0.2465	-0.4514	-0.1714	-0.1942	-0.1504	-0.2314	-0.0840

Phenotypic residual effect = 0.7422 Genotypic residual effect =0.7163 **P**-phenotypic path coefficient **G**- genotypic path coefficient

Correlation studies

The estimates of correlation studies revealed that (Table-3), in general 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 masking or modifying effect of environment (Singh 1980) [17]. Very close values of genotypic and phenotypic correlation were also observed between some traits.

Grain yield per plant had highest significant positive correlation with effective tillers, panicle length, flag leaf width weight at phenotypic and genotypic level indicating the importance of the characters for yield improvement. This was in agreement with earlier reports of Krishana Veni *et al.* (2013) [9], Rukmini Devi *et al.* (2017) [15] for effective tillers and panicle length, Singh *et al.* (2014) [19] for effective tillers.

Grain yield per plant had negative association with day to 50% flowering. Similar results for days to 50% flowering was reported by Kole *et al.* (2008) [7] and Rukmini Devi *et al.* (2017) [15] when characters having direct bearing on yield are selected, their association with other characters are to be considered simultaneously as this will indirectly affect yield.

Significant positive association of day to 50% flowering with plant height, flag leaf length, straw yield per plant and harvest index was observed both at phenotypic and genotypic level. Plant height had recorded significant positive association with panicle length, flag leaf length, flag leaf width, panicle weight, panicle density, filled seeds per panicle, test weight, straw yield and harvest index and significant negative association with effective tillers at genotypic level.

Significant positive association was observed for panicle length with flag leaf length, flag leaf width, panicle weight, filled grain per panicle, test weight and straw yield per plant, while negative significant association was observed for effective tillers with panicle length, flag leaf length and flag leaf width at phenotypic and genotypic level while panicle weight at genotypic level.

Significant negative association was observed for panicle density with filled seeds and test weight. Flag leaf length, flag leaf width panicle weight, filled seeds per panicle, test weight and straw yield per plant had significant positive association with panicle length. These results are in agreement with findings of Kiani and Nematzadeh (2012) [5] for panicle length with HI. Straw yield per plant had significant positive association with harvest index (Kole *et al.* 2008) [7].

Correlation coefficient studies among grain quality characters between head rice recovery and quality traits were computed (Table-4). Correlation estimates showed the possibility of improvement of a character through selection for other character.

Head rice recovery had significant positive direct association with hulling and milling percent at phenotypic and genotypic level indicated that hulling percent, milling percent and head rice recovery are important quality attributes for rice that enhances commercial successes of a variety. Simultaneous improvement of these three quality traits *viz*; hulling percent, milling percent and head rice recovery can be made with the selection of a single traits is either hulling percent, milling percent or head rice recovery.

Head rice recovery showed negative significant association with kernel length, kernel width, length/breadth ratio and volume expansion ratio and negative non significant association with kernel length after cooking, kernel breadth after cooking, kernel elongation ratio, water uptake and alkali spreading value, hulling percent had significant positive association with milling percent and significant negative association with kernel length after cooking, kernel elongation ratio, water uptake while milling percent showed significant negative association with kernel length, length/breadth ratio and kernel length after cooking. In the present study the positive significant correlation of hulling percent with milling percent and head rice recovery indicated that genotypes with high hulling percent also showed higher estimates for milled rice and head rice. Kernel length is one of the important character and it had manifested significant positive association with length/breadth ratio, kernel length after cooking, kernel width after cooking, water uptake and alkali spreading value.

Kernel width exhibited significant negative association with length/breadth ratio and significant positive association with kernel length after cooking, kernel width after cooking, volume expansion ratio, water uptake, alkali spreading value. Similar results of negative association of kernel width with length/breadth ratio also reported by Nirmala Devi *et al.* (2015) [11]. Length/breadth ratio is a good indicator of kernel length after cooking. The higher the length/breadth ratio, more will be kernel length after cooking, selection of these significantly and positively correlated traits will improve the overall quality traits. Negative significant association of length/breadth ratio with kernel elongation ratio was observed. Kernel length after cooking had significant positive association with kernel elongation ratio, volume expansion ration, water uptake and alkali spreading value.

The character volume expansion ratio showed positive significant association with alkali spreading value at genotypic level while water uptake exhibited significant positive association with alkali spreading value.

Similar findings of kernel length with kernel length after cooking, length/breadth ratio and significant negative association with length/breadth ratio was earlier reported by Krishna Veni *et al.* (2013) [9].

Path analysis

Considering grain yield as effect and other quantitative characters as causes genotypic correlation coefficients were portioned by using method of path analysis to find out direct and indirect effect of yield contributing characters towards grain yield (Table-4). From the path analysis it was revealed that panicle density (0.98), panicle length (0.79), straw yield (0.49), effective tillers (0.37) and days to 50% flowering (0.28) had positive direct effects on grain yield per plant, while flag leaf length, flag leaf width, panicle weight, filled seeds per panicle had shown negative direct effect on yield per plant. Days to 50% flowering manifested positive indirect effect on grain yield per plant through effective tillers and negative indirect effects through plant height, panicle length, flag leaf length, flag leaf width, panicle weight, panicle density, filled seeds per panicle, straw yield and harvest index.

Effective tillers had positive indirect effect through days to 50% flowering, plant height, flag leaf length, flag leaf width, filled seeds per panicle, test weight, straw yield and harvest index. Positive indirect effect of filled seeds per panicle was observed with effective tillers, test weight and harvest index and negative indirect effect through days to 50% flowering, plant height, while panicle density exhibited positive indirect effect with day to 50% flowering, plant height, panicle length, flag leaf length, flag leaf width, panicle weight, filled seeds per panicle. Similar results were reported by Vanisree *et al.*

(2013) [22] for effective tillers, Vinodhini and Ananda Kumar (2005) [24] for test weight. Panicle length had positive indirect effect through days to 50% flowering, plant height, flag leaf length, flag leaf width, panicle weight, filled seeds per panicle, test weight, straw yield per plant and harvest index.

Filled seeds per panicle had showed positive indirect effect through effective tillers, test weight and harvest index, while straw yield per plant had positive indirect effect through days to 50% flowering, plant height, panicle length, flag leaf length, flag leaf width, panicle weight, filled seeds per panicle, test weight and harvest index to grain yield per plant.

Panicle density had indirect positive effect through days to 50% flowering, plant height, panicle length, flag leaf length, flag leaf width panicle weight, filled seeds per panicle at phenotypic and genotypic level which have resulted in high contribution of panicle density to grain yield/plant.

Considering head rice recovery as effect and other quality traits as causes, path analysis revealed that milling percent and hulling percent had direct effect on head rice recovery. Kernel length had positive indirect effect through milling percent, elongation ratio at genotypic level.

Milling percent had negative indirect effect through kernel length, length/breadth ratio, kernel length after cooking, kernel breadth after cooking, kernel elongation ratio and positive indirect effect through hulling percent, length/breadth ratio had indirect positive effect on head rice recovery through hulling percent, milling percent, kernel width, kernel elongation ratio, volume expansion ratio, water uptake and alkali spreading value and negative effect through kernel length, kernel elongation ratio and kernel breadth after cooking.

Conclusions

From the experimental findings it could be accomplished that, there is adequate genetic variability under study. High heritability coupled with high genetic advance as percent of mean exhibited by alkali spreading value, straw yield per plant, harvest index, water uptake, panicle weight, filled seeds per panicle, panicle density, head rice recovery effective tillers, flag leaf length, flag leaf width, volume expansion ratio and plant height implying additive gene action. Therefore these characters needs top priority during selection. Based on correlation and path studies revealed that panicle length, panicle weight, effective tillers and among quality traits head rice recovery, milling percent can be used as selection indices to achieve high grain yield with good quality traits. Considering all the parameters together it could be suggested that the characters like effective tillers, panicle length, panicle density, straw yield per plant, filled seeds per panicle, plant height, milling percent, head rice recovery, alkali spreading value, volume expansion ratio and days to 50% flowering may be given due importance during selections in rice breeding programmes.

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