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Research Note

Correlation and path coefficient analysis for yield and quality traits under organic fertilizer management in rice (*Oryza sativa* L.)

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Abstract
An investigation was carried out in 32 rice genotypes to understand the association among fourteen contributing traits for yield and quality and their direct and indirect influence on the grain yield under organic fertilizer management. The correlation analysis indicated that genotypic correlation coefficient was higher than phenotypic correlation coefficient and grain yield was significantly associated with harvest index, number of grains per panicle and days to maturity. Path coefficient analysis revealed that kernel elongation ratio, kernel length, kernel L/B ratio, kernel breadth, days to maturity, harvest index, panicle length and plant height had positive direct effect on grain yield. Hence, selection based on these traits could help to bring simultaneous improvement of yield and quality traits.

Key words:
Rice, Correlation, path analysis, yield and quality traits.

Rice is an important staple food for two-third of the Indian population. About half of the world's population depends on rice for their survival. The present world rice area, production and productivity is 158.93 mha, 465.03 mt and 4.36 t/ha, respectively. In India, it is being grown in 42.86 mha area with production of 104.32 mt and productivity of 3.59 t/ha and contributes 25% to agricultural GDP (Foreign Agriculture Services/USDA, Office of Global analysis, April 2012). However, the production targets for burgeoning population of the country from limited resources and changed consumer preference towards fine quality have become a great challenge for rice scientists. Green revolution, though paved the way for a substantial increase in rice production leading to self-sufficiency and even surplus for exports, in the recent years deceleration of growth and crop yield from green revolution technologies surfaced and caused serious concern and chain of several problems *viz.*, nitrification, change in soil fertility, pollution, appearance of nutrient deficiencies, increased pest build up, impairment of human health. This necessitated the concept of organic farming or farming with low inorganic fertilizers as a modern technology, methodology and philosophy for adoption and sustainability.

In this paradigm shift, farmers in India are also interested to take up organic farming owing to its huge international demand and premium price for such produce. However, the major constraint for the farmers is that there is no suitable variety bred specifically for organic production (Colley and Dillon, 2004; Robenzon and Rex, 2008). Thus, the thrust is on the development of habitat specific varieties to boost rice production and productivity to meet the production targets. Cecarelli *et al.* (2004) and Murphy and Jones (2007) opined that the most effective way to improve productivity of crops under target environment is use of locally adopted germplasm and selection in the target environment itself. Conventional cultivars, bred for high yield in high-input conventional production systems, may not be well adapted to organic production system (Robenzon and Rex, 2008). Grain yield and quality traits are complex characters associated with number of component characters which are themselves interrelated. Such dependence often affects their relationship with yield, thereby making correlation ineffective. So, there is a need for path analysis that permits the partitioning of the correlation coefficient into its components, one component being the path coefficient that measures the direct effect of a predictor variable upon its response variable; the second component being the response variable through another predictor variable (Dewey and Lu,1959). The information on correlation and path coefficient studies in regular agronomic experiments is meager. Hence, the present investigation was undertaken to study the association interrelationships of different yield and quality attributes in the selected lines of rice.

A field experiment was conducted with 32 rice (*Oryza sativa* L.) genotypes at the wetland farm of S.V Agricultural College, Tirupati which is situated at an altitude of 182.90 m above mean sea level, 13°N latitude and 79°E longitude during *Kharif* 2009. Seeds of the 32 genotypes were sown in raised nursery bed and thirty days old seedlings of each genotype were transplanted by adopting a spacing of 20 cm between rows and 15 cm between plants within row in a randomized block design with three replications. Each genotype was grown in 3 rows with a plot size of 2.4 m^2. The crop was grown with the application of FYM and Neemcake equivalent to 120 kg N ha^{-1}. The recommended agronomical practices and plant protection measures were followed to ensure normal crop. Five competitive plants were selected randomly from the center row of each genotype in each replication and observations were recorded for characters like, number of effective tillers per plant, plant height, panicle length, number of grains per panicle, 1000-grain weight, kernel length, kernel breadth, kernel length/breadth ratio, kernel length after cooking, kernel elongation ratio, harvest index and grain yield per plant except days to 50% flowering and days to maturity, whereas the later two characters were recorded on plot basis. Panicle and grain characters were recorded on five panicles of selected plants. Correlation analysis was computed as per Karl Pearson (1932) and the partitioning of correlation coefficient into direct and indirect effects was carried out using the procedure suggested by Dewey and Lu (1959).

The results of analysis of variance based on 32 genotypes for fourteen characters revealed significant differences among the genotypes for all the yield and yield components (Table 1) indicating that there is a wide variability present in the material. Genotypic correlations in general were high as compared to their phenotypic correlations indicated strong inherent association between the characters. Genotypic and phenotypic correlation coefficients of the characters studied are presented in Table 2. Grain yield showed positive significant correlation with harvest index (r_g=0.6863**), number of grains per panicle (r_g=0.3893*) and days to maturity (r_g=0.3768*). This indicated that all these characters were important for yield improvement. Similar results earlier reported by Shashidhar *et al.,* (2005) and Krishna Tandekar *et al.,* (2008) for harvest index; Krishna Naik *et al.,* (2005), Chandra *et al.,* (2009) and Akhtar *et al.,*(2011) for number of grains per panicle and Krishna Naik *et al.,* (2005) for days to maturity. It indicated that grain yield could be increased whenever there was an increase in characters that showed positive and significant association with grain yield. Hence, these characters could be considered as criteria for higher yield as these were mutually and directly associated with grain yield.

It was observed that days to 50 per cent flowering (Rao and Shrivastava,1999), number of effective tillers per plant, panicle length, kernel length, kernel breadth, kernel L/B ratio, kernel length after cooking, kernel elongation ratio were recorded non-significant positive association with grain yield. Days to 50 per cent flowering had significant positive association with days to maturity (r_g=0.9038**) (Madhavilatha, 2002). Days to maturity and kernel breadth showed significant negative association with plant height (r_g= -0.3769*) (Rao and Shrivastava, 1999) and kernel L/B ratio (-0.8141**) (Sarkar *et al.,* 2007) while number of effective tillers per plant had association with kernel length after cooking (r_g=0.5154**) and number of grains per panicle with harvest index (r_g=0.3971*). Similar results were also obtained by Yogameenakshi *et al.,* (2004). Kernel length registered significant positive association with kernel L/B ratio (r_g= 0.7481**), kernel length after cooking (r_g= 0.3964*), 1000-grain weight (r_g= 0.5439**) and harvest index (r_g= 0.3986*) indicating that the increase in these characters could be positive with an increase in kernel length. These results were in agreement with the finding of Sarkar *et al.* (2007) for kernel L/B ratio, kernel length after cooking and 1000-grain weight. Kernel length after cooking positively correlated with kernel elongation ratio (r_g= 0.7517**). Similar findings were reported by Sarkar *et al.,* (2007). Correlation studies concluded that harvest index, number of grains per panicle and days to maturity showed positive and significant association with grain yield and also among themselves indicating that simultaneous selection for these characters would result in improvement of yield.

Path coefficient analysis (Table 3) revealed that kernel elongation ratio (p_g=40.8273) exerted the highest direct effect on grain yield followed by kernel length (p_g= 20.9569), kernel L/B ratio (p_g= 13.5408), kernel breadth (p_g= 9.2930), days to maturity (p_g= 3.2107), harvest index (p_g= 0.8411), panicle length (p_g= 0.5355) and plant height (p_g= 0.5119), indicating that selection for these characters are likely to bring about an overall improvement in grain yield directly. Similar results were also noticed by Tarasatyavathi *et al.,* (2001) for kernel elongation ratio; Jogindar Reddy (2004) for kernel length and kernel breadth; Shivani Dhote (2002) for kernel L/B ratio; Debchoudhary and Das (1998) for days to maturity; Shashidhar *et al.,* (2005) for harvest index; Vinothini and Ananda Kumar (2005) for panicle length; Manonmani and Ranganathan (2006) for plant height. Whereas traits days to 50 per cent flowering, 1000-grain weight, number of grains per panicle, kernel length after cooking and number of effective tillers per plant showed negative direct effects on grain yield. Results were agreement with Swain and Reddy (2006) for days to 50 per cent flowering, 1000-grain weight and number of grains per panicle; Chitra *et al.,* (2005) for number of effective tillers per plant.

Kernel elongation ratio and plant height showed high positive indirect effects via kernel breadth on grain yield. Similar finding were recorded by Swain and Reddy, (2006) for plant height. Harvest index and number of grains per panicle had highest positive direct effects besides showing high positive indirect effects via kernel length and kernel L/B ratio (Kavitha and Sree Rama Reddi, 2001) and ultimately resulted in significant positive correlation with grain yield. Kernel length had showed high positive indirect effect through days to 50 per cent flowering (Swain and Reddy, 2006), kernel L/B ratio (Madhavilatha, 2002) and harvest index (Ganesan *et al.,* 1997). Kernel breadth had high indirect effect on grain yield via days to 50 per cent flowering (Swain and Reddy, 2006) and kernel elongation ratio. Days to maturity exerted highest positive indirect effect through kernel L/B ratio, kernel length after cooking, kernel elongation ratio and moderate indirect effect via 1000-grain weight (Madhavilatha, 2002) which ultimately resulted in significant positive correlation with grain yield. Path analysis concluded that kernel elongation ratio, kernel length, kernel L/B ratio kernel breadth, days to maturity, harvest index, panicle length and plant height were most important characters which could be used as selection criteria for effective improvement of grain yield. Therefore, due weightage should be given on these characters during selection for pedigree breeding work.

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Table 1. Analysis of variance for fourteen characters in 32 rice genotypes

Character	Mean sum of squares		
	Replications (df=2)	**Treatments (df=31)**	**Error (df=62)**
Days to 50% flowering	5.281	363.826**	2.076
Days to maturity	6.125	371.559**	2.587
Number of effective tillers per plant	5.750	1094.276**	3.681
Plant height (cm)	0.104	8.607**	0.606
Panicle length (cm)	2.207	21.620**	1.095
Number of grains per panicle	5.75	2622.702**	70.440
Kernel length (mm)	0.009	0.101**	0.007
Kernel breadth (mm)	0.016	0.210**	0.018
Kernel L/B ratio	0.002	1.756**	0.001
Kernel length after cooking (mm)	0.008	0.054**	0.003
Kernel elongation ratio	8.335	29.770**	2.066
1000-grain weight(g)	20.609	115.178**	19.038
Harvest index (%)	0.132	0.479**	0.049
Grain yield per plant (g)	10.7021	45.181**	3.855

* Significant at 5%

Table 2. Phenotypic (r_p) and Genotypic (r_g) correlation coefficients among grain yield per plant and its components in rice

Characters		Days to maturity	Plant height	Number of effective tillers/	Panicle length	Number of grains / panicle	Kernel length	Kernel breadth	Kernel length/ breadth ratio	Kernel length after cooking	Kernel Elongation ratio	1000 grain weight	Harvest index	Grain yield/ plant
Days to 50%	r_p	0.8868**	-0.2503	-0.0324	0.1742	0.2362	-0.0690	-0.1325	0.0533	0.0346	0.0974	-0.2222	-0.0732	0.2702
	r_g	0.9038**	-0.2552	-0.0299	0.1907	0.2488	-0.0950	-0.1457	0.0517	0.0344	0.1195	-0.2671	-0.0810	0.3097
Days to maturity	r_p		-0.3723*	-0.0660	0.0812	0.2976	-0.0576	-0.2382	0.1423	-0.0277	0.0213	-0.1736	0.0002	0.3214*
	r_g		-0.3769*	-0.0757	0.0957	0.3072	-0.0623	-0.2703	0.1587	-0.0285	0.0202	-0.2288	0.0169	0.3768*
Plant height	r_p			-0.0130	0.2648	0.0117	-0.0356	0.0496	-0.0801	-0.2262	-0.1804	0.1688	-0.1540	-0.2073
	r_g			-0.0147	0.2865	0.0142	-0.0523	0.0562	-0.0905	-0.2270	-0.1918	0.2093	-0.1871	-0.2367
Number of effective	r_p				0.1588	0.0000	0.2315	0.0313	0.1589	0.4983**	0.2915	0.2546	0.0931	0.1258
	r_g				0.2205	-0.0091	0.2876	0.0219	0.1801	0.5154**	0.3268	0.3148	0.1890	0.1294
Panicle length	r_p					0.2550	-0.0475	0.0504	-0.0591	-0.0316	0.0085	-0.0702	0.2054	0.0123
	r_g					0.2905	-0.0710	0.0608	-0.0849	-0.0341	0.0105	-0.0094	0.2629	0.0593
Number of grains /	r_p						0.1765	-0.0868	0.2103	-0.1606	-0.2842	-0.1764	0.2607*	0.3388*
	r_g						0.2242	-0.1434	0.2480	-0.1713	-0.3315	-0.2656	0.3971*	0.3893*
Kernel length	r_p							-0.0840	0.6567**	0.3407*	-0.4312*	0.4046*	0.2511*	0.1724
	r_g							-0.1194	0.7481**	0.3964*	-0.3128	0.5439**	0.3986*	0.2496
Kernel breadth	r_p								-0.6943**	0.0206	0.0671	-0.0004	-0.0327	0.0557
	r_g								-0.8141**	0.0208	0.1319	-0.0576	-0.0275	0.1260
Kernel length/	r_p									0.2065	-0.3371	0.2498*	0.1713	0.0936
	r_g									0.2361	-0.2839	0.3630*	0.3140	0.0955
Kernel length	r_p										0.6836**	0.2765	0.1143	0.1466
	r_g										0.7517**	0.3406	0.1539	0.1637
Kernel Elongation	r_p											-0.0282	-0.0731	0.0387
	r_g											-0.0300	-0.1455	0.0138
1000 grain weight	r_p												0.0325	-0.1061
	r_g												0.1288	-0.1521
Harvest index	r_p													0.4681**
	r_g													0.6863**

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

Table 3. Phenotypic (P) and Genotypic (G) path co-efficient analysis for grain yield per plant and its components in rice

Characters		Days to 50% flowering	Days to maturity	Plant height	Number of effective tillers/ plant	Panicle length	Number of grains / panicle	Kernel length	Kernel breadth	Kernel length/ breadth ratio	Kernel length after cooking	Kernel Elongation ratio	1000 grain weight	Harvest index	Grain yield/ plant
Days to 50% flowering	P	**-0.0712**	0.3627	-0.0265	-0.0029	-0.0340	0.0290	-0.0769	-0.0810	0.0337	-0.0568	0.1819	0.0444	-0.0323	0.2702
	G	**-3.3629**	2.9018	-0.1306	0.0059	0.1021	-0.2162	-1.9913	-1.3539	0.6995	-1.4356	4.8795	0.2796	-0.0682	0.3097
Days to maturity	P	-0.0632	**0.4090**	-0.0394	-0.0058	-0.0158	0.0366	-0.0642	-0.1456	0.0898	0.0455	0.0398	0.0347	0.0001	0.3214*
	G	-3.0393	**3.2107**	-0.1930	0.0149	0.0513	-0.2669	-1.3046	-2.5122	2.1490	1.1869	0.8264	0.2394	0.0142	0.3768*
Plant height	P	0.0178	-0.1523	**0.1058**	-0.0011	-0.0516	0.0014	-0.0397	0.0303	-0.0505	0.3711	-0.3369	-0.0337	-0.0680	-0.2073
	G	0.8581	-1.2103	**0.5119**	0.0029	0.1534	-0.0124	-1.0967	0.5226	-1.2253	9.4670	-7.8317	-0.2191	-0.1573	-0.2367
Number of effective tillers/ plant	P	0.0023	-0.0270	-0.0014	**0.0884**	-0.0310	0.0000	0.2580	0.0191	0.1003	-0.8176	0.5444	-0.0509	0.0411	0.1258
	G	0.1007	-0.2429	-0.0075	**-0.1970**	0.1181	0.0079	6.0278	0.2031	2.4392	-21.4932	13.3438	-0.3295	0.1590	0.1294
Panicle length	P	-0.0124	0.0332	0.0280	0.0140	**-0.1950**	0.0313	-0.0530	0.0308	-0.0373	0.0519	0.0159	0.0140	0.0907	0.0123
	G	-0.6413	0.3074	0.1467	-0.0434	**0.5355**	-0.2525	-1.4890	0.5646	-1.1499	1.4220	0.4283	0.0098	0.2212	0.0593
Number of grains / panicle	P	-0.0168	0.1217	0.0012	0.0000	-0.0497	**0.1228**	0.1968	-0.0530	0.1328	0.2634	-0.5307	0.0352	0.1151	0.3388*
	G	-0.8368	0.9862	0.0073	0.0018	0.1556	**-0.8690**	4.6986	-1.3329	3.3582	7.1417	-13.5333	0.2780	0.3340	0.3893*
Kernel length	P	0.0049	-0.0236	-0.0038	0.0205	0.0093	0.0217	**1.1146**	-0.0513	0.4146	-0.5591	-0.8053	-0.0808	0.1108	0.1724
	G	0.3195	-0.1999	-0.0268	-0.0567	-0.0380	-0.1948	**20.9569**	-1.1098	10.1302	-16.5280	-12.7691	-0.5692	0.3353	0.2496
Kernel breadth	P	0.0094	-0.0974	0.0052	0.0028	-0.0098	-0.0107	-0.0936	**0.6111**	-0.4383	-0.0338	0.1252	0.0001	-0.0144	0.0557
	G	0.4899	-0.8680	0.0288	-0.0043	0.0325	0.1246	-2.5028	**9.2930**	-11.0238	-0.8679	5.3867	0.0603	-0.0231	0.1260
Kernel length/ breadth ratio	P	-0.0038	0.0582	-0.0085	0.0141	0.0115	0.0258	0.7319	-0.4243	**0.6313**	-0.3388	-0.6296	-0.0499	0.0756	0.0936
	G	-0.1737	0.5096	-0.0463	-0.0355	-0.0455	-0.2155	15.6784	-7.5656	**13.5408**	-9.8432	-11.5920	-0.3799	0.2641	0.0955
Kernel length after cooking	P	-0.0025	-0.0113	-0.0239	0.0441	0.0062	-0.0197	0.3798	0.0126	0.1303	**-1.6407**	1.2766	-0.0552	0.0505	0.1466
	G	-0.1158	-0.0914	-0.1162	-0.1016	-0.0183	0.1488	8.3065	0.1934	3.1963	**-0.4170**	30.6882	-0.3564	0.1294	0.1637
Kernel Elongation ratio	P	-0.0069	0.0087	-0.0191	0.0258	-0.0017	-0.0349	-0.4806	0.0410	-0.2128	-1.1216	**1.8675**	0.0056	-0.0323	0.0387
	G	-0.4019	0.0650	-0.0982	-0.0644	0.0056	0.2881	-6.5544	1.2261	-3.8446	-31.3437	**40.8273**	0.0314	-0.1224	0.0138
1000 grain weight	P	0.0158	-0.0710	0.0179	0.0225	0.0137	-0.0217	0.4509	-0.0002	0.1577	-0.4536	-0.0526	**-0.1998**	0.0144	-0.1061
	G	0.8983	-0.7346	0.1072	-0.0620	-0.0050	0.2308	11.3974	-0.5355	4.9155	-14.2027	-1.2234	**-1.0465**	0.1084	-0.1521
Harvest index	P	0.0052	0.0001	-0.0163	0.0082	-0.0401	0.0320	0.2798	-0.0200	0.1081	-0.1876	-0.1365	-0.0065	**0.4414**	0.4681**
	G	0.2726	0.0541	-0.0958	-0.0372	0.1408	-0.3451	8.3534	-0.2554	4.2512	-6.4174	-5.9413	-0.1348	**0.8411**	0.6863**

Residual effect (phenotypic) = 0.1364, Residual effect (Genotypic) = 0.1454, Bold: Direct effects, Normal: Indirect effect * Significant at P = 0.05 level, ** Significant at P = 0.01 level