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Character association and path coefficient analysis for seed yield and quality traits in rice (*Oryza sativa* L.)

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Abstract
Thirty three genotypes along with three check varieties of rice (*Oryza sativa* L.) were assessed to work out the association among different seed yield and quality traits as well as direct and indirect effects of these traits on seed yield and quality. Seed yield per plant showed highly significant and positive correlation with seeds per panicle and seedling dry weight while, seed yield per plant showed non-significant and negative correlation with germination index and plant height. Non-significant and positive correlations were found for other characters under study. Vigour index showed positive and highly significant correlation with days to 50% flowering and seed germination percentage. Seedling dry weight was found to be significantly correlated with 1000-seed weight. Path analysis identified seeds per panicle and 1000-seed weight as important components having high order of direct effect and 1000-seed weight and seedling dry weight as important components having high order of indirect effect on seed yield per plant. The characters showing significant positive correlation as well as direct and indirect effects on seed yield would be highly effective and efficient in selection of elite genotypes.

Keywords: Character association, path coefficient, physiological quality, rice (*Oryza sativa* L.), seedling dry weight and germination index

Introduction
Rice (*Oryza sativa* L.), the staple food for more than 50% of the world population, forms the breath of life 'prana' for the human civilization. Rice is cultivated world-wide over an area of about 163.20 million ha with an annual production of about 758.90 million tonnes (503.80 million tones, milled basis) and productivity 4.60 tonnes per hectare in 2017-18. About 90% of all rice grown in the world is produced and consumed in the Asian region. It accounts 43% of total grain production and 55% of cereal production in the country. It is high caloric food, which contain 75% starch, 6-7% protein, 2-2.5% fat, 0.8% cellulose and 5-9% ash. In India, rice is grown over an area of about 43.50 million ha which produces 111.01 million tones with an average productivity of 2590 kg/ha. (Anonymous, 2017-18) [2].

Seed yield or economic yield, in almost all the crops, is the complex character, which manifests from multiplicative interactions of several other characters that are termed as yield components. The genetic architecture of seed yield in rice as well as other crops is based on the balance or overall net effect produced by various yield components directly or indirectly by interacting with one another. Therefore, selection for yield *per se* alone would not matter much as such unless accompanied by the selection for various component characters responsible for conditioning it. Thus, identification of important yield components and their association with yield and with each other are very useful for developing efficient breeding strategy for evolving high yielding varieties. The correlation coefficient is the measure of degree of symmetrical association between two variables or characters, which helps us in understanding the nature and magnitude of association among yield and yield components. 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. Taking these issues under consideration the present investigation was carried out to gather some useful information on association among various traits as well as direct and indirect effects of these traits on yield and physiological quality of seed in a set of 30 rice genotypes.

Materials and Methods
The experimental material comprised of 30 genotypes and three check varieties of rice *viz.*, Shusksamrat, Narendra 359, Narendra 2064, grown at the Crop Research Station (CRS)

Masodha, Ayodhya and seed quality parameters were tested in Seed Testing Laboratory of the Seed Technology Section, Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). The experiment was laid out in a Randomized Block Design with three replications during *Kharif* 2016. Plant to plant and row to row spacing was maintained at 15 and 20 cm, respectively. The crop was raised as per recommended package of practices. Five competitive plants were selected randomly from each genotype in each replication and observations were recorded on days to 50% flowering, days for maturity, plant height (cm), panicle length (cm), seeds/panicle, 1000-seed weight (g), seed yield/plant (g), seed germination (%), seedling dry weight (mg), germination index and vigour index. The genotypic and phenotypic correlation co-efficients were estimated as suggested by Burton and de Vane (1953) [3] and path-co-efficient analysis was done according to Dewey and Lu (1959) [4].

Results and Discussion

Seed yield or economic yield, in almost all the crops, is the complex character, which manifests from multiplicative interactions of several other characters that are termed as yield components. The genetic architecture of seed yield in rice as well as other crops is based on the balance or overall net effect produced by various yield components directly or indirectly by interacting with one another. Therefore, selection for yield *per se* alone would not matter much as such unless accompanied by the selection for various component characters responsible for conditioning it. Thus, identification of important yield components and their association with yield and with each other are very useful for developing efficient breeding strategy for evolving high yielding varieties. The correlation coefficient is the measure of degree of symmetrical association between two variables or characters, which helps us in understanding the nature and magnitude of association among yield and yield components.

In the present investigation, simple correlation coefficients were computed among 11 characters (Table 1 & 2)**.** The seed yield per plant exhibited highly significant and positive association with seeds per panicle and seedling dry weight at phenotypic as well as genotypic levels Akram (1993) [1]. Thus, seeds per panicle and seedling dry weight emerged as most important association of seed yield per plant in rice. The strong positive associations of seed yield with the seven characters mentioned above have also been reported by Shivani *et al.* (2000) [11], Raut *et al.* (2009) [8], Saravanana and Sabesan (2009) [10], Wattoo *et al.* (2010) [12] and Sarangi *et al.* (2013).

The genotypic correlation coefficients between different characters were generally similar in nature to the corresponding phenotypic correlation coefficients in the present investigation. However, the genotypic correlations were greater in magnitude than their corresponding phenotypic correlations. Similar results have also been reported in rice by various workers Shivani and Reddy (2000) [11] and Wattoo *et al.* (2010) [12].

Path coefficient analysis is a tool to partition the observed correlation coefficient into direct and indirect effects of yield components on grain yield. Path analysis provides clear picture of character associations for formulating efficient selection strategy. The concept of Path coefficient analysis was developed which differs from simple correlation in that it points out the causes and their relative importance, whereas, the later measures simply the mutual association ignoring the causation.

The results of path coefficient analysis carried out using simple correlation coefficients among 11 characters are given in table 3 & 4. At phenotypic as well as genotypic levels, seed per panicle exhibited very high positive direct effect on seed yield per plant, followed by 1000-seed weight and seedling dry weight. Similar results were also reported by Kiani (2012) [5] and Patil *et.al.* (2014) [7]. The high direct effect of seeds per panicle possessing highly significant positive association with seed yield per plant highlighted the importance of this trait for rice improvement. Thus seeds per panicle followed by 1000-seed weight and seedling dry weight emerged as most important direct contributor towards the seed yield. Direct effects of remaining characters on seed yield per plant were too low to be considered. The highest positive indirect effect on seed yield per plant was exerted by seedling dry weight via 1000-seed weight followed by 1000 seed weight *via* seedling dry weight, days to 50% flowering and days to maturity *via* seed per panicle. Similar results have also been reported by Nayak *et al.* (2001) [6].

Table 1: Estimate of phenotypic correlation coefficients among different characters in rice germplasm

Characters	Days to maturity	Plant height (cm)	Panicle length (cm)	Seeds/ panicle	1000-seed weight (g)	Seed germination (%)	Seedling dry weight (mg)	Germination index	Vigour index	Seed yield/ plant
Days to 50% flowering	0.975**	0.310	0.089	0.130	-0.315	0.298	-0.310	-0.052	0.936**	0.070
Days to maturity		0.254	0.096	0.117	-0.315	0.285	-0.337*	-0.034	0.079	0.049
Plant height (cm)			0.146	0.039	-0.366*	0.105	-0.349*	-0.223	-0.123	-0.001
Panicle length (cm)				0.078	-0.113	0.007	-0.192	-0.180	-0.027	0.087
Seeds/panicle					-0.225	-0.002	0.119	-0.225	0.002	0.734**
1000-grain weight (g)						0.049	0.760**	-0.063	0.209	0.209
Seed germination (%)							-0.095	-0.005	0.558**	0.058
Seedling dry weight (mg)								-0.200	0.039	0.443**
Germination index									0.224	-0.284
Vigour index										0.029

*,** Significant at 5 (%)and 1 (%) probability levels, respectively.

Table 2: Estimate of genotypic correlation coefficients between different characters in rice.

Characters	Days to maturity	Plant height (cm)	Panicle length (cm)	Seeds/ panicle	1000-seed weight (g)	Seed germination (%)	Seedling dry weight (mg)	Germination index	Vigour index	Seed yield/ plant
Days to 50% flowering	0.985	0.314	0.110	0.149	-0.328	0.312	-0.315	-0.060	0.099	0.072
Days to maturity		0.263	0.128	0.131	-0.325	0.294	-0.341	-0.055	0.087	0.054
Plant height (cm)			0.168	0.041	-0.386	0.123	-0.356	-0.284	-0.15	-0.002
Panicle length (cm)				0.154	-0.140	0.001	-0.229	-0.300	-0.027	0.106
Seeds/panicle					-0.232	-0.006	0.148	-0.259	0.020	0.847
1000-grain weight (g)						0.059	0.783	-0.057	0.219	0.220
Seed germination (%)							-0.100	0.037	0.590	0.064
Seedling dry weight (mg)								-0.251	0.042	0.454
Germination index									0.310	-0.385
Vigour index										0.034

*,** Significant at 5 (%)and 1 (%) probability levels, respectively.

Table 3: Direct and indirect effects of different characters on seed yield per plant at phenotypic level in rice germplasm

Character	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle length (cm)	Seeds/ panicle	1000-seed weight (g)	Seed germination (%)	Seedling dry weight (mg)	Germination index	Vigour index	Correlation with seed yield/plant (g)
Days to 50% flowering	0.0635	0.0157	0.0321	0.0069	0.0996	-0.0997	0.0225	-0.0621	-0.0004	-0.0078	0.0703
Days to maturity	0.0620	0.0161	0.0263	0.0075	0.0896	-0.0989	0.0216	-0.0674	-0.0002	-0.0066	0.0499
Plant height (cm)	0.0197	0.0041	0.1034	0.0113	0.0300	-0.1158	0.0079	-0.0698	-0.0017	0.0103	-0.0003
Panicle length (cm)	0.0057	0.0016	0.0151	0.0776	0.0602	-0.0357	0.0005	-0.0384	-0.0014	0.0023	0.0874
Seeds/panicle	0.0082	0.0019	0.0041	0.0061	0.7639	-0.0712	-0.0001	0.0238	-0.0017	0.0002	0.7347
1000-seed weight (g)	-0.0200	-0.0051	-0.0379	-0.0088	-0.1722	0.3160	0.0037	0.1521	-0.0005	-0.0175	0.2098
Seed germination (%)	0.0189	0.0046	0.0109	0.0006	-0.0018	0.0155	0.0756	-0.0191	0.000	-0.0467	0.0585
Seedling dry weight (mg)	-0.0197	-0.0054	-0.0361	-0.0149	-0.0909	0.2404	-0.0072	0.1999	-0.0015	-0.0033	0.4430
Germination index	-0.0033	-0.0005	-0.0231	-0.0140	-0.1719	-0.0201	-0.0004	-0.0401	0.0078	-0.0187	-0.2841
Vigour index	0.0059	0.0013	-0.0127	-0.0021	0.0022	0.0662	0.0422	0.0079	0.0017	-0.0835	0.0293

Residual factors: 0.315, Bold figures represent direct effects

Table 4: Direct and indirect effects of different characters on seed yield per plant at genotypic level of rice germplasm.

Character	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle length (cm)	Seeds/ Panicle	1000-Seed weight (g)	Seed Germination (%)	Seedling dry weight (mg)	Germination index	Vigour index	Correlation with seed yield/plant (g)
Days to 50% flowering	0.0249	0.0178	0.0299	-0.0053	0.1518	-0.2211	0.0227	0.0609	0.0046	-0.0139	0.0722
Days to maturity	0.0245	0.0179	0.0250	-0.0062	0.1330	-0.2194	0.0214	0.0659	0.0042	-0.0122	0.0543
Plant height (cm)	0.0078	0.0047	0.0949	-0.0081	0.0424	-0.2605	0.0090	0.0688	0.0217	0.0162	0.0029
Panicle length (cm)	0.0027	0.0023	0.0159	-0.0483	0.1568	-0.0946	0.0000	0.0443	0.0230	0.0039	0.1061
Seeds/panicle	-0.0037	0.0024	0.0039	-0.0074	1.0141	-0.1570	-0.0043	-0.0286	0.0198	-0.0028	0.8475
1000-seed weight (g)	-0.0081	-0.0058	-0.0367	0.0067	-0.2361	0.6741	0.0043	-0.1513	0.0043	-0.0307	0.2205
Seed germination (%)	0.0077	0.0053	0.0117	0.000	-0.0070	0.0398	0.0728	0.0194	-0.0029	-0.0826	0.0643
Seedling dry weight (mg)	-0.0079	-0.0061	-0.0338	0.0110	0.1505	0.5279	-0.0073	-0.1932	0.0192	-0.0059	0.4544
Germination index	-0.0015	-0.0010	-0.0269	0.0145	-0.2633	-0.0386	0.0037	0.0485	-0.0765	-0.0434	-0.386
Vigour index	0.0025	0.0016	-0.0109	0.0013	0.0207	0.1481	0.0429	-0.0082	-0.0237	-0.1400	0.0342

Residual factors: 0.229, Bold figures represent direct effects.

Conclusion

The characters such as seeds per panicle, seedling dry weight and 1000- seed weight, showing significant positive correlation as well as direct and indirect effects on seed yield would be highly effective and efficient in selection of elite genotypes.

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