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Studies on correlation and path coefficient analysis for yield and its components in rice (*Oryza sativa* L.) under salt affected soil

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Abstract
The present investigation was under taken with the objectives to find out associations among different characters and to analyze direct and indirect effects of different characters on grain yield. The experiment was conducted during *Kharif* 2015 at Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Faizabad. The experimental materials of rice for this investigation comprised of 20 genotypes as lines (female) and three testers (male) *viz.,* NDR 359, Narendra Usar 2009 and Narendra Usar 3. Each of three testers was crossed with 20 lines during *kharif*, 2014. The experiment was based on evaluation of a line × tester set of 60 hybrids (F_1s) along with their 20 parents and check varieties *viz.,* CSR 43 and IR 28, for thirteen characters *viz.,* days to 50 % flowering, plant height (cm), flag leaf area, (cm^2), panicle bearing tillers per plant, panicle length (cm), spike lets per panicle, grains per panicle, spikelet fertility (%), biological yield per plant (g), harvest index (%), L:B ratio, 1000-grains wt. (g) and grain yield per plant (g) under salt affected soil in randomized block design with three replications under salt affected soil. Grain yield per plant showed positive and significant correlation with flag leaf area, panicle bearing tillers per plant, panicle length, spike lets per panicle, grains per panicle, spikelet fertility, biological yield per plant, harvest index and 1000-grains wt. emerge as most important associates of grain yield in rice. Path analysis identified biological yield and harvest-index as most important direct yield contributing traits. Grains per panicle, spike lets per panicle, panicle bearing tillers per plant, spikelet fertility, harvest index, flag leaf area, 1000 grain weight, panicle length and plant height exhibited high and positive indirect effect on grain yield *via* biological yield per plant. Similarly, considerable positive indirect effects on grain yield per plant were exerted by panicle bearing tillers per plant, grains per panicle and spike lets per panicle *via* harvest-index. Hence, selection based on these characters would be more effective to meet higher grain yield. The residual effect under path analysis was very low and negligible

Keywords: Correlation, path coefficient analysis, salt affected soil, Rice (*Oryza sativa* L.)

Introduction
Rice, *Oryza sativa* L. (2n=24) is a cereal foodstuff which forms an important part of the diet of more than three billion people around the world. It is the principal staple food for more than half of the world's population. It is grown under diverse agro-climatic conditions and over wide geographical range. Drought and salinity are major constraints on crop production and food security and adversely impact the socioeconomic fabric of many developing countries. Water scarcity, declining water quality for irrigation and soil salinity are problems which are becoming more acute. It is estimated that 20% of all cultivated land and nearly half of irrigated land is affected by salt, greatly reducing the yield of crops to well below their genetic potential. There is limited evidence at present that new strategies to enhance crop yield stability on salt affected soil, based on soils remediation are feasible. Salinity-stress effects on crop grown are manifested by impairment of photosynthetic capacity. High amounts of sodium in the soil solution impair cell metabolism and photosynthesis by imposing an osmotic stress on cell water relations and by increasing the toxicity of sodium in the cytosol.

Materials and Methods
The experiment was conducted during *kharif*, 2015 at the Research Farm of Genetics & Plant Breeding, N.D. University of Agriculture and Technology, Kumarganj, Faizabad. The experimental materials of rice for this investigation comprised of 20 genotypes as lines (female) and three testers (male) NDR 359, Narendra Usar 2009 and Narendra Usar 3. Each of three testers was crossed with 20 lines during *kharif* 2014. Thus, total number of 60 hybrids (F_1) were obtained. The total set of eighty five genotypes were grown during *kharif* in 2015 and evaluated along with their parents and two check varieties (CSR 43 and IR28) in Randomized complete block design with three replications, with the spacing of 20 cm row to

row and 15 cm plant to plant. Observations were recorded on randomly selected five plants from each entry in each replication. The data were recorded on days to 50% flowering, plant height (cm), flag leaf area, (cm^2), panicle bearing tillers per plant, panicle length (cm), spike lets per panicle, grains per panicle, spikelet fertility (%), biological yield per plant (g), harvest index (%), L:B ratio, 1000-grains wt. (g) and grain yield per plant (g). Recommended cultural practices were adopted to raise good crop.

Results and Discussion

Mean sum of square due to treatments were significant for all the characters showed presence of variability in the study materials.

Grain 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 grain 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 components and information about their association with yield and with each other are very useful for developing efficient breeding strategy for evolving high yielding varieties/hybrids. 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, phenotypic and genotypic correlation coefficients were computed among thirteen characters (Table 2). Grain yield per plant showed positive and significant correlation with flag leaf area, panicle bearing tillers per plant, panicle length, spike lets per panicle, grains per panicle, spikelet fertility, biological yield per plant, harvest index and 1000-grains wt. at phenotypic and genotypic levels. Therefore, these characters emerged as most important associates of grain yield in rice. The strong positive association of grain yield with the characters mentioned above has also being reported in rice by earlier workers (Ramkrishnan *et al.* 2006, Nandan *et al.* 2010; Akhtar *et al.* 2011, Kumar *et al.* 2011; Bhadur *et al.* 2011; Rangare *et al.* 2012; Krishnamurthy and Kumar, 2012) [10, 9, 1, 7, 3, 11, 6].

Days to 50% flowering showed significant and positive association with plant height and negative significant association with 1000 grain weight. Flag leaf area exhibited highly significant and positive association with Panicle bearing tillers per plant, panicle length, spike lets per panicle, grains per panicle, spikelet fertility, biological yield per plant and grain yield per plant. Panicle bearing tillers per plant exhibited highly significant and positive correlation with panicle length, spike lets per panicle, grains per panicle, spikelet fertility, biological yield per plant, harvest index, 1000 grain weight and grain yield per plant. Panicle length revealed significant and positive correlation with spike lets per panicle, grains per panicle, spikelet fertility, biological yield per plant, L: B ratio and grain yield per plant. Spike lets per panicle revealed significant and positive correlation with grains per panicle, spikelet fertility, biological yield per plant, harvest index, 1000 grain weight and grain yield per plant. Grains per panicle revealed significant and positive correlation with spikelet fertility, biological yield per plant, harvest index, 1000 grain weight and grain yield per plant. Biological yield reported significant and positive correlation with harvest-index, 1000 grain weight and grain yield per plant. Harvest index exhibited significant and positive correlation with 1000 grain weight and grain yield per plant. L: B ratio showed negative significant association with 1000 grain weight. The association of yield with different morphological and physiological traits has also been reported in rice by Bhadur *et al.* (2011) [3], Rangare *et al.* (2012) [11] and Krishnamurthy and Kumar (2012) [6].

In the present study, majority of significant estimates of correlations between yield and yield components were positive in nature. Thus, selection practiced for improving these traits individually or simultaneously would bring improvement in other due to correlated response. This suggested that selection would be quite efficient in improving yield and yield components.

In the present investigation, phenotypic and genotypic direct and indirect effect of 13 characters on grain yield per plant in rice (*Oryza sativa* L.) under salt affected soil were presented in Table 3. 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 clearer picture of character associations for formulating efficient selection strategy. Path coefficient analysis 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 concept of path coefficient was developed by Wright (1921) [12] and technique was first used for plant selection by Dewey and Lu (1959) [4]. Path analysis has emerged as a powerful and widely used technique for understanding the direct and indirect contributions of different characters to economic yield in crop plants so that the relative importance of various yield contributing characters can be assessed.

In the present study, the path coefficient analysis was carried out using correlation coefficients between thirteen characters. The high positive direct effects on grain yield per plant were exerted by biological yield per plant and harvest-index at both the levels genotypic and phenotypic (Table 3). Thus, harvest-index and biological yield per plant emerged as most important direct yield components on which emphasis should be given during simultaneous selection aimed at improving grain yield in rice. These characters have also been identified as major direct contributors towards grain yield by Akhtar *et al.* 2011 Kumar *et al.* 2011; Bhadur *et al.* 2011; Rangare *et al.* 2012; Krishnamurthy and Kumar, 2012 and Kumar and Verma 2015 [1, 7, 6, 11, 6, 8]. The direct effects of remaining characters were too low to be considered important.

In phenotypic path coefficient analysis, high order positive indirect effects on grain yield per plant were exerted by grains per panicle, spike lets per panicle, panicle bearing tillers per plant, spikelet fertility, harvest index, flag leaf area, 1000 grain weight, panicle length and plant height *via* biological yield per plant. Similarly, considerable positive indirect effects on grain yield per plant were exerted by panicle bearing tillers per plant, grains per panicle and spike lets per panicle *via* harvest-index. In contrast high order negative indirect effects on grain yield per plant were recorded by L: B ratio *via* biological yield per plant.

At genotypic level, high order positive indirect effects on grain yield per plant *via* biological yield per plant were exerted by grains per panicle, followed by spike lets per panicle, panicle bearing tillers per plant, spikelet fertility, harvest index, flag leaf area, 1000 grain weight and panicle length and plant height. Similarly, considerable positive indirect effects on grain yield per plant *via* spike lets per panicle were exerted by grains per panicle, biological yield per plant and panicle bearing tillers per plant. Panicle bearing tillers per plant, grains per panicle and spike lets per panicle showed considerable positive indirect effects on grain yield per plant *via* harvest-index. In contrast, high order negative indirect effects on grain yield per plant *via* grains per panicle were recorded by spike lets per panicle, biological yield per plant, panicle bearing tillers per plant, spikelet fertility and harvest index while L:B ratio exerted considerable negative indirect effects on grain yield per plant *via* biological yield per plant. Zahid *et al.* (2006) [13], Kishore *et al.* (2007) [5] and Babar *et al.* (2009) [2] have also identified biological yield and harvest-index as important direct and indirect yield contributing characters. The indirect effects of remaining characters were too low to be considered important.

In the present study, path analysis identified grain yield per plant followed by biological yield per plant and harvest-index as most important direct as well as indirect yield contributing traits or components which merit due consideration at time of devising selection strategy aimed at developing high yielding varieties/hybrids in rice. In contrary to most of the previous reports in rice, comparatively small proportion of direct and indirect effects of different characters attained high order values in the present study. Majority of the estimates of direct and indirect effects were too low to be considered of any consequence. This may be attributed to presence of very high genetic variability and diversity in the rice genotypes. The existence of different character combinations in diverse rice genotypes might have led to different types of character association in different lines. Thus, presence of several contrasting types of character associations or inter-relationships might have resulted into cancellation of contrasting associations by each other ultimately leading to lowering of the net impact or effect.

Table 1: Analysis of variance for randomized block design for 13 characters in rice under salt affected soil

Characters	Sources of variation		
	Replications	Treatments	Error
d. f.	2	82	164
Days to 50% flowering	0.01	92.67**	1.00
Plant height (cm)	0.82	136.27**	3.83
Flag leaf area (cm^2)	0.83	20.29**	1.10
Panicle bearing tillers per plant	0.10	11.01**	0.74
Panicle length (cm)	0.77	11.08**	0.75
Spike lets per panicle	44.97	1380.94**	26.11
Grains per panicle	8.30	1177.00**	19.81
Spikelet fertility (%)	5.74	28.29**	2.21
Biological yield per plant (g)	0.21	167.42**	2.00
Harvest-index (%)	0.09	10.80**	1.76
L:B ratio	0.04	1.22**	0.08
1000-grains weight (g)	0.37	6.19**	0.44
Grains yield per plant (g)	0.09	34.71**	0.95

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

Table 2: Estimate of phenotypic and genotypic correlation coefficients between 13characters in rice (*Oryza sativa* L.) under salt affected soil

Characters		Days to 50% flowering	Plant height (cm)	Flag leaf area (cm^2)	panicle bearing tillers per plant	Panicle length (cm)	Spike lets per panicle	Grains per panicle	Spikelet fertility (%)	Biological yield per plant (g)	Harvest index (%)	L:B ratio	1000-grain weight (g)	Grain yield per plant(g)
Days to 50% flowering	G	1.000	0.518	-0.124	0.026	-0.096	0.102	0.066	-0.047	0.037	0.052	0.157	-0.249	0.040
	P	1.000	0.491**	-0.123	0.028	-0.090	0.100	0.065	-0.035	0.033	0.021	0.135	-0.228*	0.031
Plant height (cm)	G		1.000	0.199	0.222	-0.045	0.166	0.161	0.117	0.121	0.183	-0.221	0.263	0.143
	P		1.000	0.179	0.197	-0.042	0.152	0.148	0.106	0.115	0.131	-0.206	0.209*	0.132
Flag leaf area (cm^2)	G			1.000	0.458	0.318	0.436	0.468	0.431	0.374	0.268	-0.080	0.119	0.382
	P			1.000	0.385**	0.256*	0.399**	0.427**	0.336**	0.339**	0.195	-0.046	0.099	0.339**
Panicle bearing tillers per plant	G				1.000	0.472	0.818	0.855	0.666	0.827	0.658	0.006	0.386	0.872
	P				1.000	0.375**	0.734**	0.764**	0.542**	0.770**	0.557**	0.000	0.318**	0.808**
Panicle length (cm)	G					1.000	0.309	0.381	0.547	0.287	0.247	0.413	0.008	0.316
	P					1.000	0.262*	0.333**	0.461**	0.262*	0.186	0.328**	-0.002	0.282**
Spike lets per panicle	G						1.000	0.990	0.563	0.848	0.563	-0.019	0.327	0.874
	P						1.000	0.976**	0.493**	0.822**	0.458**	-0.022	0.297**	0.834**
Grains per panicle	G							1.000	0.673	0.881	0.591	-0.028	0.335	0.909
	P							1.000	0.639**	0.858**	0.474**	-0.021	0.298**	0.869**
Spikelet fertility (%)	G								1.000	0.690	0.422	-0.039	0.217	0.700
	P								1.000	0.620**	0.291**	-0.033	0.184	0.614**
Biological yield per plant (g)	G									1.000	0.429	-0.133	0.348	0.983
	P									1.000	0.414**	-0.126	0.308**	0.976**
Harvest-index (%)	G										1.000	-0.017	0.394	0.587
	P										1.000	-0.051	0.281*	0.594**
L:B ratio	G											1.000	-0.345	-0.115
	P											1.000	-0.283*	-0.114
1000- grain weight (g)	G												1.000	0.395
	P												1.000	0.342**
Grain yield per plant (g)	G													1.000
	P													1.000

*, ** Significant at 5% and 1% probability levels, respectively

Table 3. Estimate of phenotypic and genotypic direct and indirect effect of 13 characters on grain yield per plant in rice (*Oryza sativa* L.) under salt affected soil

Characters		Days to 50% flowering	Plant height (cm)	Flag leaf area (cm^2)	panicle bearing tillers per plant	Panicle length (cm)	Spike lets per panicle	Grains per panicle	Spikelet fertility (%)	Biological yield per plant (g)	Harvest index (%)	L:B ratio	1000-grain weight (g)	Grain yield per plant(g)
Days to 50% flowering	G	-0.013	0.005	0.001	-0.001	-0.002	0.015	-0.011	0.000	0.035	0.011	0.001	0.000	0.040
	P	-0.006	0.003	0.001	0.000	-0.001	-0.005	0.005	0.001	0.029	0.005	0.001	-0.002	0.031
Plant height (cm)	G	-0.007	0.009	-0.002	-0.005	-0.001	0.025	-0.028	0.001	0.112	0.040	-0.001	0.000	0.143
	P	-0.003	0.006	-0.002	0.000	0.000	-0.007	0.011	-0.002	0.100	0.029	-0.002	0.002	0.132
Flag leaf area (cm^2)	G	0.002	0.002	-0.009	-0.011	0.008	0.065	-0.081	0.003	0.347	0.058	0.000	0.000	0.382
	P	0.001	0.001	-0.011	-0.001	0.002	-0.019	0.033	-0.005	0.295	0.043	0.000	0.001	0.339
Panicle bearing tillers per plant	G	0.000	0.002	-0.004	-0.024	0.011	0.122	-0.148	0.004	0.767	0.142	0.000	0.000	0.872
	P	0.000	0.001	-0.004	-0.002	0.003	-0.036	0.058	-0.009	0.669	0.125	0.000	0.002	0.808
Panicle length (cm)	G	0.001	0.000	-0.003	-0.011	0.024	0.046	-0.066	0.004	0.267	0.053	0.002	0.000	0.316
	P	0.001	0.000	-0.003	-0.001	0.008	-0.013	0.025	-0.007	0.228	0.042	0.003	0.000	0.282
Spike lets per panicle	G	-0.001	0.002	-0.004	-0.019	0.007	0.149	-0.171	0.004	0.787	0.121	0.000	0.000	0.874
	P	-0.001	0.001	-0.004	-0.002	0.002	-0.049	0.074	-0.008	0.715	0.102	0.000	0.002	0.834
Grains per panicle	G	-0.001	0.001	-0.004	-0.020	0.009	0.147	-0.173	0.004	0.818	0.127	0.000	0.000	0.909
	P	0.000	0.001	-0.005	-0.002	0.003	-0.048	0.076	-0.010	0.746	0.106	0.000	0.002	0.869
Spikelet fertility (%)	G	0.001	0.001	-0.004	-0.016	0.013	0.084	-0.117	0.006	0.640	0.091	0.000	0.000	0.700
	P	0.000	0.001	-0.004	-0.001	0.004	-0.024	0.049	-0.016	0.539	0.065	0.000	0.001	0.614
Biological yield per plant (g)	G	0.000	0.001	-0.004	-0.020	0.007	0.126	-0.153	0.004	0.928	0.093	-0.001	0.000	0.983
	P	0.000	0.001	-0.004	-0.002	0.002	-0.040	0.065	-0.010	0.870	0.093	-0.001	0.002	0.976
Harvest-index (%)	G	-0.001	0.002	-0.003	-0.016	0.006	0.084	-0.102	0.003	0.398	0.216	0.000	0.000	0.587
	P	0.000	0.001	-0.002	-0.001	0.001	-0.022	0.036	-0.005	0.360	0.224	0.000	0.002	0.594
L:B ratio	G	-0.002	-0.002	0.001	0.000	0.010	-0.003	0.005	0.000	-0.123	-0.004	0.004	0.000	-0.115
	P	-0.001	-0.001	0.000	0.000	0.003	0.001	-0.002	0.001	-0.110	-0.011	0.008	-0.002	-0.114
1000-grain weight (g)	G	0.003	0.002	-0.001	-0.009	0.000	0.049	-0.058	0.001	0.323	0.085	-0.001	0.001	0.395
	P	0.001	0.001	-0.001	-0.001	0.000	-0.014	0.023	-0.003	0.268	0.063	-0.002	0.007	0.342

Residual = 0.056, Bold figures indicate direct effect

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