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Correlation and Path Coefficient Analysis for yield and physiological attributes in Rice (*Oryza sativa* L.) under Saline Soil Conditions

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ABSTRACT

This study performed to determine the association between yield and yield components in eight rice genotypes (*Oryza sativa* L.) under saline conditions. The results indicated that the traits panicle length, number of filled grains per panicle and panicle weight correlated significantly with grain yield, while grain yield was negatively correlated with Na^+/K^+ ratio and Standard Evaluation Score for visual salt injury. Path coefficient analysis revealed that grain yield was associated with number of tillers per plant, number of filled grains per panicle and harvest index with positive direct effects under stressed situation. Information obtained in this study revealed that the traits, number of filled grains per panicle and number of tillers per plant could be used as selection criteria for improvement of grain yield under saline soil conditions.

Key words : Correlation, Path coefficient analysis, Rice, Saline soils.

Rice (***Oryza sativa*** L.) is the most important staple food crop of the world because of being the major source of calories of more than half of the total global population. More than 90% of the world's rice is grown and consumed in Asia, known as rice bowl of the world, where 60% of the earth's people and two third of world's poor live (Khush and Virk, 2000). In India most of the research bounded for irrigated and non-stress environments while a huge fraction of land under rice in country is salt affected, but the prospective for productivity gains in such areas has not been exploited. Rice is one of the most suitable crops for saline soil, though it is considered moderately sensitive to salinity. The common practice is to cultivate rice with elevated level of salt tolerance on salt affected marginal lands. Today, the most economic and sustained way to overcome the problems of food scarcity and salt stress is to develop salt tolerant varieties. Salinity affects rice growth in varying degrees at all stages starting from germination to maturation (Manneh, 2004).

Selection of promising genotypes in a breeding programme is based on various criteria, most importantly final crop yield and its quality. The knowledge of association of yield component traits with yield and salt tolerant physiological traits under with yield under salt stressed environment will be helpful in selection of salt tolerant genotypes and improvement of rice yield. Correlation coefficient is a statistical measure, which is used to find out the degree (strength) and direction of relationship between two or more variables. The association between two variables, which can be directly observed, is termed as phenotypic correlation. It includes both genotypic and environmental effects. Genotypic correlation may be either due to pleiotropy action of genes or due to linkage or more likely both (Falconer, 1989). The pleiotropy or linkage may involve two desirable traits or one desirable and one undesirable trait. The first situation enhances the genetic improvement, whereas the second hinders the progress. The coefficient of correlation expresses association between two variables but tells us nothing about the causal relations of variables. Path-coefficient analysis reveals relative importance of yield-contributing characters thus, is useful in indirect selection. Keeping the above aspects, present experiment intended to construct selection criteria for rice yield improvement under salt stress environments.

MATERIAL AND METHODS

In the present investigation eight genotypes viz., RPBio-226, Swarna (Susceptible), CSR-27, CSR-30, CST-7-1(moderately tolerant), CSRC(S)7-1-4, SR26-B, and CSRC(S)5-2-2-5 (Tolerant) were selected based on their reaction to salinity tolerance and were evaluated during *kharif,* 2010 under salt affected soils of Agricultural Research Station, Machilipatnam. 30 days old seedlings were transplanted in the main field having electrical conductivity of 7.9 dS/m and pH of 7.7 following randomized block design with three replications. The recommended agronomic and plant protection measures were adopted in conducting the experiment.

Statistical analysis

Genotypic and phenotypic correlation coefficients were calculated among 14 traits using the formulae suggested by Al-Jibouri *et al*. (1958) and their significance was tested by using the 'r' table values (Fisher and Yates, 1963) at (n-2) degrees of freedom, where 'n' denotes the number of treatments used in the calculation. To estimate the direct and indirect effects of the component traits on the yield, the statistical tool employed was path coefficient analysis as suggested by Wright (1921) and illustrated by Dewey and Lu (1959). The path coefficients were obtained by solving the 'p' normal equations following the matrix method given by Singh and Chowdhary (1985).

RESULTS AND DISCUSSION

The grain yield or economic yield in almost all the crops, is referred to as super character which results from the multiplicative interactions of several other characters that are termed as yield components. Thus, genetic architecture of grain yield is based on the balance or overall net effect produced by various yield components directly or indirectly by interacting with one another. Therefore, identification of important yield components and information about their association with yield and also with each other is very useful for developing efficient breeding strategy for evolving high yielding varieties. In this respect, the correlation coefficient which provides symmetrical measurement of degree of association between two variables or characters help in understanding the nature and magnitude of association among yield and yield components.

The genotypic correlation coefficients between different characters were generally similar in sign or nature to the corresponding phenotypic correlation coefficients in the experiment. The estimates of genotypic correlation coefficients showed close parallelism in direction with their corresponding phenotypic correlation coefficients. However, genotypic correlations were higher in magnitude than the corresponding phenotypic correlations. The occurrence of higher estimates of genotypic correlations than the corresponding phenotypic correlations between yield and yield components in rice has also been reported by Reddy *et al*. (1997).

Correlation between grain yield and other attributes

In the present study, Panicle length (0.8321) registered highest positive significant genotypic association with grain yield followed by number of filled grains per panicle (0.7841), panicle weight (0.7507), spikelet fertility per cent (0.7475), harvest index (0.7320), SPAD chlorophyll meter readings (0.6178), number of tillers per plant (0.5882) and number of productive tillers per plant (0.4373) in the decreasing order of magnitude (Table 1). Similar findings were reported by Thirumeni and Subramanian (1999), Natarajan *et al.* (2005b) and Seetharam *et al.* (2009) for number of tillers per plant. While, Ravindra Babu (1996) and Chandra *et al.* (2009) also observed significant positive association between grain yield and number of productive tillers per plant under saline soil conditions. Babu *et al*. (2006) for panicle length and Seetharam *et al.* (2009) for panicle weight reported similar type of positive association with grain yield. Further, Sajjad (1990), Buu and Tuan (1991), Natarajan *et al.* (2005) and Chandra *et al.* (2009) for number of filled grains panicle^{-1}; Seetharam *et al.* (2009) for spikelet fertility; Natarajan *et al.* (2005) and Chandra *et al.* (2009) for 1000-grain weight ; Sajjad (1990) and Balan *et al.* (1999) for harvest index revealed strong positive association with grain yield under similar soil environment. In accordance to the current findings, Gregorio *et al.* (1997) reported strong negative association between Standard Evaluation score (SES) for visual damage symptoms and grain yield. Similarly, Asch *et al.* (2000) also observed that

Table 1. Genotypic (r_g) and phenotypic (r_p) correlation coefficients among grain yield and its components in rice under saline soils

Character		PH(cm)	DFF	TT	PT	PL (cm)	PW (g)	NFG/P	SF (%)	TW (g)	SES	RSR	HI (%)	N^+/K^+ R	SPAD	GY (g)
PH (cm)	r_g	1.0000	0.0614	0.2240	0.3701	0.4420*	0.7484**	0.3825	0.7647**	0.3119	-0.2914	0.3759	0.6030	-0.6576**	0.4948*	0.5352**
	r_p	1.0000	0.0419	0.1748	0.2727	0.3094	0.6849**	0.3823	0.5531**	0.2675	-0.2590	0.3399	0.2637	-0.5976**	0.4141*	0.4832*
DFF	r_g		1.0000	0.4867**	0.3873	0.2254	0.1842	-0.0147	-0.0209	-0.0310	-0.1526	-0.1407	0.2990	-0.1434	0.1890	0.0501
	r_p		1.0000	0.3312	0.2889	0.1825	0.1559	0.0034	0.0507	-0.0499	-0.0873	-0.1249	0.0681	-0.1378	0.1514	0.0597
TT	r_g			1.0000	0.8719**	0.7161**	0.4467*	0.5671**	0.2686	0.3304	-0.2033	-0.0551	0.3025	-0.4930*	0.4849*	0.5882**
	r_p			1.0000	0.7754**	0.4245*	0.2672	0.4141*	0.1542	0.2180	-0.1082	-0.0690	0.0808	-0.3585	0.4427*	0.4265*
PT	r_g				1.0000	0.6080**	0.4697*	0.5995**	0.3437	0.2627	-0.3910	-0.0353	0.3820	-0.4886*	0.5357**	0.4373*
	r_p				1.0000	0.4776*	0.3298	0.5180**	0.2384	0.1698	-0.2478	-0.0718	0.1664	-0.4065*	0.4493*	0.3263
PL (cm)	r_g					1.0000	0.6909**	0.8177**	0.7022**	0.5822**	-0.4067*	0.3364	0.6922**	-0.8632**	0.6675**	0.8321**
	r_p					1.0000	0.5863**	0.6618**	0.5403**	0.4777*	-0.3343	0.2937	0.3696	-0.7450**	0.5048*	0.7014**
PW (g)	r_g						1.0000	0.6609**	0.9247**	0.5038*	-0.3892	0.5609**	0.7583**	-0.7570**	0.6555**	0.7507**
	r_p						1.0000	0.6082**	0.7352**	0.4523*	-0.3422	0.5075*	0.4166*	-0.7012**	0.5349**	0.6788**
$NFGP^{-1}$	r_g							1.0000	0.6783**	0.5312**	-0.4746*	0.4387*	0.9293**	-0.8171**	0.8351**	0.7841**
	r_p							1.0000	0.5394**	0.4257*	-0.3667	0.3745	0.3677	-0.7526**	0.6870**	0.7036**
SF (%)	r_g								1.0000	0.5911**	-0.5142*	0.5565**	0.7660**	-0.7631**	0.5336**	0.7475**
	r_p								1.0000	0.4381*	-0.3872	0.4570*	0.4034	-0.6543**	0.4065*	0.6062**
TW (g)	r_g									1.0000	-0.0211	0.2183	0.4711*	-0.4764*	0.3150	0.5785**
	r_p									1.0000	-0.0252	0.2026	0.2242	-0.4319*	0.2611	0.4979*
SES	r_g										1.0000	-0.5372**	-0.9519**	0.4733*	-0.6397**	-0.2943
	r_p										1.0000	-0.5115	-0.4376*	0.4111*	-0.4772*	-0.2453
RSR	r_g											1.0000	0.8417**	-0.3558	0.4335*	0.5312**
	r_p											1.0000	0.3589	-0.3310	0.3477	0.4940*
HI (%)	r_g												1.0000	-0.9670**	0.8147**	0.7320**
	r_p												1.0000	-0.4422*	0.3812	0.3450
N^+/K^+ R	r_g													1.0000	-0.7461**	-0.8312**
	r_p													1.0000	-0.6659**	-0.7685**
SPAD	r_g														1.0000	0.6178**
	r_p														1.0000	0.5185**

* Significant at p=0.05; ** Significant at p=0.01;

PH (cm): Plant height;DFF: Days to 50% flowering; TT: Number of tillers $plant^{-1}$; PT: Number of productive tillers $plant^{-1}$; PL (cm): Panicle length; PW(g): Panicle weight; $NFGP^{-1}$: Number of filled $grainspanicle^{-1}$; SF (%): Spikelet fertility per cent; TW (g): 1000-grain weight; GY (g): Grain yield (g $plant^{-1}$); SES: SES for visual salt injury; RSR: Root /shoot ratio; HI (%): Harvest index per cent;Na^+/K^+ R: Sodium Potassium ratio; SPAD: SPAD chlorophyll meter reading.

Table 2.Genotypic(G) and phenotypic(P) direct and indirect effects among grain yield, its components and physiological traits in rice under saline soils

Character		PH (cm)	DFF	TT	PT	PL (cm)	PW (g)	NFG/P	SF (%)	TW (g)	SES	RSR	HI (%)	N^+/K^+ R	SPAD	GY (g)
PH (cm)	r_g	**0.3313**	0.0203	0.0742	0.1226	0.1464	0.2480	0.1267	0.2534	0.1033	-0.0966	0.1245	0.1998	-0.2179	0.1640	0.5352
	r_p	**0.0313**	0.0013	0.0055	0.0085	0.0097	0.0214	0.0120	0.0173	0.0084	-0.0081	0.0106	0.0082	-0.0187	0.0130	0.4832
DFF	r_g	-0.0151	**-0.2464**	-0.1199	-0.0954	-0.0555	-0.0454	0.0036	0.0051	0.0076	0.0376	0.0347	-0.0737	0.0353	-0.0466	0.0501
	r_p	-0.0009	**-0.0214**	-0.0071	-0.0062	-0.0039	-0.0033	-0.0001	-0.0011	0.0011	0.0019	0.0027	-0.0015	0.0029	-0.0032	0.0597
TT	r_g	0.2127	0.4621	**0.9493**	0.8277	0.6798	0.4241	0.5383	0.2550	0.3136	-0.1930	-0.0523	0.2872	-0.4680	0.4603	0.5882
	r_p	0.0641	0.1215	**0.3668**	0.2845	0.1557	0.0980	0.1519	0.0566	0.0800	-0.0397	-0.0253	0.0297	-0.1315	0.1624	0.4265
PT	r_g	-0.2847	-0.2979	-0.6705	**-0.7690**	-0.4676	-0.3612	-0.4610	-0.2643	-0.2020	0.3007	0.0272	-0.2937	0.3758	-0.4120	0.4373
	r_p	-0.0602	-0.0638	-0.1712	**-0.2208**	-0.1055	-0.0728	-0.1144	-0.0526	-0.0375	0.0547	0.0159	-0.0367	0.0897	-0.0992	0.3263
PL (cm)	r_g	0.0636	0.0324	0.1030	0.0875	**0.1439**	0.0994	0.1177	0.1010	0.0838	-0.0585	0.0484	0.0996	-0.1242	0.0960	0.8321
	r_p	0.0528	0.0311	0.0724	0.0815	**0.1706**	0.1000	0.1129	0.0922	0.0815	-0.0570	0.0501	0.0631	-0.1271	0.0862	0.7014
PW (g)	r_g	0.2669	0.0657	0.1593	0.1675	0.2464	**0.3566**	0.2357	0.3298	0.1797	-0.1388	0.2000	0.2704	-0.2700	0.2336	0.7507
	r_p	0.0329	0.0075	0.0129	0.0159	0.0282	**0.0481**	0.0292	0.0354	0.0217	-0.0165	0.0244	0.0200	-0.0337	0.0258	0.6788
$NFGP^{-1}$	r_g	0.1547	-0.0059	0.2294	0.2425	0.3307	0.2673	**0.4045**	0.2744	0.2148	-0.1920	0.1774	0.3759	-0.3305	0.3378	0.7841
	r_p	0.0767	0.0007	0.0830	0.1039	0.1327	0.1219	**0.2005**	0.1081	0.0854	-0.0735	0.0751	0.0737	-0.1509	0.1377	0.7036
SF (%)	r_g	-0.2285	0.0062	-0.0803	-0.1027	-0.2098	-0.2763	-0.2027	**-0.2988**	-0.1766	0.1537	-0.1663	-0.2289	0.2280	-0.1594	0.7475
	r_p	0.0252	0.0023	0.0070	0.0109	0.0246	0.0335	0.0246	**0.0455**	0.0199	-0.0176	0.0208	0.0184	-0.0298	0.0185	0.6062
TW (g)	r_g	0.0092	-0.0009	0.0097	0.0077	0.0171	0.0148	0.0156	0.0174	**0.0294**	-0.0006	0.0064	0.0139	-0.0140	0.0093	0.5785
	r_p	0.0095	-0.0018	0.0077	0.0060	0.0170	0.0161	0.0151	0.0156	**0.0355**	-0.0009	0.0072	0.0080	-0.0153	0.0093	0.4979
SES	r_g	0.0208	0.0109	0.0145	0.0279	0.0290	0.0278	0.0339	0.0367	0.0015	**-0.0713**	0.0383	0.0679	-0.0338	0.0456	-0.2943
	r_p	-0.0459	-0.0155	-0.0192	-0.0440	-0.0593	-0.0607	-0.0650	-0.0687	-0.0045	**0.1774**	-0.0907	-0.0776	0.0729	-0.0846	-0.2453
RSR	r_g	0.0138	-0.0052	-0.0020	-0.0013	0.0124	0.0207	0.0162	0.0205	0.0080	-0.0198	**0.0368**	0.0310	-0.0131	0.0160	0.5312
	r_p	0.1066	-0.0392	-0.0216	-0.0225	0.0922	0.1592	0.1175	0.1434	0.0636	-0.1605	**0.3138**	0.1126	-0.1039	0.1091	0.4940
HI (%)	r_g	0.1358	0.0673	0.0681	0.0860	0.1559	0.1707	0.2092	0.1725	0.1061	-0.2143	0.1895	**0.2252**	-0.2177	0.1834	0.7320
	r_p	-0.0016	-0.0004	-0.0005	-0.0010	-0.0022	-0.0025	-0.0022	-0.0024	-0.0013	0.0026	-0.0021	**-0.0059**	0.0026	-0.0023	0.3450
N^+/K^+ R	r_g	0.0190	0.0041	0.0142	0.0141	0.0249	0.0218	0.0236	0.0220	0.0137	-0.0137	0.0103	0.0279	**-0.0289**	0.0214	-0.8312
	r_p	0.2455	0.0566	0.1473	0.1670	0.3060	0.2880	0.3091	0.2688	0.1774	-0.1689	0.1360	0.1817	**-0.4108**	0.2735	-0.7685
SPAD	r_g	-0.1642	-0.0627	-0.1609	-0.1778	-0.2215	-0.2175	-0.2771	-0.1771	-0.1045	0.2123	-0.1438	-0.2703	0.2476	**-0.3318**	0.6178
	r_p	-0.0528	-0.0193	-0.0565	-0.0573	-0.0644	-0.0683	-0.0877	-0.0519	-0.0333	0.0609	-0.0444	-0.0486	0.0850	**-0.1276**	0.5185

Residual effect: 0.0637

PH (cm): Plant height; DFF: Days to 50% flowering; TT: Number of tillers $plant^{-1}$; PT: Number of productive tillers $plant^{-1}$; PL (cm): Panicle length; PW(g): Panicle weight; $NFGP^{-1}$: Number of filled grains $panicle^{-1}$; SF (%): Spikelet fertility per cent; TW (g): 1000-grain weight; GY (g): Grain yield (g $plant^{-1}$); SES: SES for visual salt injury; RSR: Root /shoot ratio; HI (%): Harvest index per cent; Na^+/K^+ R: Sodium Potassium ratio; SPAD: SPAD chlorophyll meter reading.

Na^+/K^+ ratio strongly associated with grain yield but in the negative direction.

From the above discussion it was clear that, panicle length, number of filled grains per panicle, panicle weight, spikelet fertility per cent and harvest index would help to improve the grain yield coupled with salt tolerance in rice, because these traits had positive association with grain yield. Similarly, selecting the plants with low Na^+/K^+ ratio and SES for visual salt injury symptoms would help for yield improvement along with salt tolerance, since, these traits had negative association with grain yield.

Direct effects of different yield components on yield:

Correlation studies permit only a measure of relationship between two traits. The actual contribution of an attribute and its influence through other characters could be arrived at only by way of partitioning the genotypic correlation coefficient into direct and indirect effects by path coefficient analysis. This will be very much helpful in giving due weightage to important yield attributes under selection process. In the present study, path coefficient analysis was performed among eight parents for grain yield and physiological attributes were furnished in table 2.

Among the yield attributes, the trait number of tillers per plant (0.9493) had the highest positive direct effect followed by number of filled grains per panicle (0.4045), panicle weight (0.3566), plant height (0.3313). While the direct effects of harvest index (0.2252) were moderate and it was low for panicle length (0.1439). Conversely, highest negative direct effects were exerted on grain yield by productive tillers per plant (-0.7690) followed by days to 50 per cent flowering (-2464) and spikelet fertility per cent (-0.2988). Similarly, the direct effects of component traits on grain yield were reported earlier by Deepa Sankar *et al.* (2006) for panicle length, Chitra *et al.* (2005) for harvest index, Mohana Krishna *et al.* (2009) for number of grains per panicle and Reddy *et al.* (1997) for plant height. Thus, direct selection for these traits will be rewarding for yield improvement under saline soils.

Similar results were found for number of grains per panicle by Choudhury and Das (1998), Yogameenakshi *et al.* (2004) and Panwar *et al.* (2007) and for test-weight by Suman *et al.* (2006), Bhattacharyya *et al.* (2007), Habib *et al.* (2007) and Kole *et al.* (2008). Individual plants with more number of tillers per plant and number of filled grains per panicle with higher panicle weight have to be selected in the segregating generations for further improvement of rice under saline condition.

Commencing the experimental findings it could be accomplished that grain yield per plant exhibited a very strong positive association with panicle length, number of filled grains per panicle, panicle weight, spikelet fertility per cent, harvest index at phenotypic and genotypic level which indicated that these traits were the strongest associates of grain yield per plant. However, significant negative correlation was observed in case of Na^+/K^+ ratio and SES for visual salt injury symptoms. The genetic reasons for this type of negative association may be linkage or pleiotropy. Path analysis identified that number of filled grains per panicle and number of tillers per plant as major direct contributors to grain yield. Thus a genotype with higher number of filled grains per panicle could be either selected from existing genotypes or evolved by breeding program for genetic improvement of yield in rice under saline soil conditions.

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