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Research Article
Estimation of Genotypic and Phenotypic Correlations Coefficients for Yield Related Traits of Rice under Sodic Soil

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Abstract

Background and Objective: Global demand for food is rising because of population growth, increasing affluence and changing dietary habits. Rice is the major source of calories of more than half of the total global population. It is the world's third largest crop after maize and wheat. This research sought to determine the correlations between grain yield and its contributing traits and to measure the direct and indirect effects on grain yield in rice. **Materials and Methods:** On the basis of relationship of grain yield with yield contributing traits, the best genotype can be selected and utilized in breeding program. The estimates of genotypic and phenotypic correlation coefficients between eleven characters were computed together and also the direct and indirect effects of 11 characters viz., days to 50% flowering, days to maturity, plant height (cm), panicle bearing tillers per plant, panicle length (cm), spikelets per panicle, spikelet fertility (%), biological yield per plant (g), harvest-index (%), L/B ratio and grain yield per plant (g) on grain yield per plant estimated by path coefficient analysis using phenotypic and genotypic correlations. **Results:** According to results, the estimates of genotypic correlation coefficients between eleven characters were generally similar in sign but higher in magnitude than the corresponding phenotypic correlation coefficients. The highest positive both phenotypic and genotypic direct effect on grain yield per plant was exerted by biological yield per plant followed by harvest-index. In contrast, high order of negative both phenotypic and genotypic indirect effects were extended by biological yield per plant on grain yield per plant via harvest index, spikelets per panicle (-0.123) and plant height (-0.103). The direct effects of remaining nine characters were too low to be considered important and the rest of the estimates of indirect effects obtained in path analysis were negligible. The estimate of residual factors (0.091) obtained in both the path analysis was low whether it is direct or indirect. **Conclusion:** This represents highly favorable situation for obtaining high response to selection in improving yield and yield components in rice.

Key words: Rice, correlations coefficients, path coefficient analysis, sodic soil, yield components in rice

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice is an important staple food crop for one third of the world's population and occupies almost one-fifth of the total land area covered under cereals[1]. Rice being the staple food for more than 70% of our national population and source of livelihood for 120-150 million rural households is backbone to the Indian Agriculture[2]. It is estimated that 120 million tonnes of rice is required to feed the increasing population by 2020. However, breeding for high yield crops require information on nature and magnitude of variation in the available material, relationship of yield with other agronomic characters and the degree of environmental influence on the expression of these component characters. Since grain yield in rice is quantitative in nature and polygenically controlled, effective yield improvement and simultaneous improvement of yield components are imperative. To enhance the yield productivity, genetic parameters and correlation studies between yield and yield components are per requisite to plan a meaningful breeding programme to develop high yielding inbreds and hybrids[3].

Correlations is helpful in determining the principal components influencing final grain yield, they provide an incomplete representation of the relative importance of direct and indirect influences on the individual factors involved[4,5]. In plant breeding path-coefficient analysis has been used to explain clearly the relations among yield components and assist identification of traits that are useful as selection criteria to improve crop yield[6,7]. The main objective of this was to determine the relationship between yield and yield contributing traits and on the basis of this relationship best genotype for breeding program could be selected.

MATERIALS AND METHODS

The present investigation was carried out at the Department of Genetics and Plant Breeding Research Farm of N.D. University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad. The crosses were made during Kharif, 2016 and the hybrids along with parental lines and check varieties were evaluated during Kharif, 2017.

Experimental materials and procedure: Three testers (males) viz., Gaujrat 70, CSR 43 and Pusa Sugandha 4 were crossed with 13 lines (females) viz., CSR 36, NDRK 2011-1, NDRK 2011-8, NDRK 2011-9, NDRK 2011-10, NDRK 2011-13, NDRK 2011-16, NDRK 2011-17, NDRK 2011-18, NDRK 2011-4, NDRK 2011-19, NDRK 2011-2 and Sarjoo 52 comprising genotypes/varieties of rice in a line × tester mating design. A total of 39 F1s were produced during Kharif, 2012. The resulting set of 39 F1s along with their 16 parents and 2 check varieties (Narendra Usar 3 and CSR 13) were evaluated in Randomized Complete Block Design with three replications. The observations viz., days to 50% flowering, days to maturity, plant height (cm), panicle bearing tillers per plant, panicle length (cm), spikelets per panicle, spikelet fertility (%), biological yield per plant (g), harvest-index (%), L/B ratio and grain yield per plant (g), were recorded on the basis of five randomly selected competitive plants in each plot.

Estimation of Correlations Coefficients: Association among different characters at genotypic and phenotypic levels was worked out as suggested by Searle[8]:

$$\text{Genotypic correlation coefficients (rg)} = \frac{\text{cov.XY (g)}}{\sqrt{\text{var.XG.var.Yg}}}$$

$$\text{Phenotypic correlation coefficients (rp)} = \frac{\text{cov.XY (p)}}{\sqrt{\text{var.Xp.var.Yp}}}$$

were, ov.XY (g) and Cov.XY (p) denotes genotypic and phenotypic covariance between characters X and Y, respectively. Var.X (g), Var.Y (g) and Var.X (p), Var.Y (p) denotes variance for characters X and Y at genotypic and phenotypic levels, respectively.

Path coefficient analysis: Path coefficient analysis was carried out according to Dewey and Lu[9]. Seed yield was assumed to be dependent variable (effect) which is influenced by all the eleven characters, the independent variables (causes), directly as well as indirectly through other characters. The variation in seed yield unexplained by the eleven causes was presumed to be contributed by a residual factor (x) which is uncorrelated with other factors. Path coefficients were estimated by solving the following simultaneous equation indicating the basic relationship between correlation and path coefficient. The equations used are as follows:

$$r_{ij} = P_{iy} + \sum_{i=1}^{10} r_{ij}\ P_{iy}\ \text{ for } i = 1, 2, \ldots\ldots\ldots.11$$

$$r_{ij} = \sum_{i=1}^{10} r_{ij}\ P_{iy}\ \text{ for } r_{ij} = 1$$

The above equations can be written in the form of matrix:

$$[A]_{11x1} = [B]_{11x1}[C]_{11x1}$$

Where:

A = Column vector of correlations r_{ij}
B = Correlation matrix of r_{ij}
C = Column vector of direct effect, P_{iy}

Residual factor was calculated as follows:

$$P_{xy} = \sqrt{1 - R^2}$$

Where:

$$R^2 = \sum_i P_{iy} \ r_{ij}$$

The r_{ij} i.e., $r_{1.2}$ to $r_{11.12}$ denote correlations between all possible combinations of independent characters P_{1y} to P_{2y} denote direct effects of various characters on character y.

r_{iy} = Correlation coefficient between ith and y characters
P_{iy} = Direct effect of i^{th} character on y

RESULTS AND DISCUSSION

Correlation coefficients: The estimates of phenotypic correlation coefficients computed between eleven characters were presented in Table 1. The grain yield per plant exhibited highly significant and positive correlation with biological yield per plant (0.841). Spikelet fertility (0.172) and had positive and significant association with grain yield per plant. L:B ratio showed highly significant and positive correlation with and negative and significant correlation with spikelets per panicle. Harvest index showed negative correlation of highly significant level with biological yield per plant (-0.654) and spikelet fertility (-0.227) and of significant level with panicle length (-0.189). Biological yield per plant recorded highly significant and positive correlation with and significant correlation with test weight (0.153). Spikelet fertility showed positive association of highly significant degree with and significant degree with spikelets per panicle (0.191) and panicle bearing tillers per plant (0.172) which was also significantly associated with panicle length (0.167) and spikelets per panicle (0.161). Spikelets per panicle recorded positive and significant correlation with days to maturity (0.189) and days to 50% flowering (0.152). Plant height had negative and highly significant correlation with days to 50% flowering (-0.207) and days to maturity (-0.213). There was highly significant correlation between days to maturity and days to 50% flowering. The remaining estimates of phenotypic correlations in this analysis were non-significant.

The estimates of genotypic correlation coefficients between eleven characters presented in Table 2, were generally similar in sign but higher in magnitude than the corresponding phenotypic correlation coefficients.

Path coefficient analysis: The direct and indirect effects of 11 characters on grain yield per plant estimated by path coefficient analysis using phenotypic correlations were given in Table 3.

The highest positive direct effect on grain yield per plant was exerted by biological yield per plant (1.309) followed by harvest-index (0.699). The direct effects of remaining nine characters were too low to be considered important. Biological yield per plant exhibited high order of positive indirect effects on grain yield per plant *via* spikelet fertility (0.346). In contrast, high order of negative indirect effects were extended by biological yield per plant on grain yield per plant via harvest index (-0.856), spikelets per panicle (-0.123) and plant height (-0.103). Harvest-index exhibited high order of negative

Table 1: Estimates of phenotypic correlation coefficients between 12 traits in rice under sodic soil

Traits	DM	PH	PBTP	PL	SP	SF	TW	BYP	H.I.	LBR	GYP
D50F	0.7898	-0.2068**	0.0731	-0.1501	0.1516*	-0.0153	0.0358	0.0108	-0.0179	-0.0615	-0.0076
DM		-0.2128**	0.0811	-0.1376	0.1891*	0.0452	0.0497	-0.0112	0.0569	-0.0812	0.0252
PH			0.0319	0.2413**	-0.1122	-0.0041	-0.1426	-0.0790	0.0188	-0.0337	-0.0840
PBTP				0.1673*	0.1609*	0.1723*	-0.0641	0.0605	0.0249	-0.0630	0.0854
PL					-0.0843	-0.0126	-0.0997	0.0688	-0.1894*	-0.1345	-0.0543
SP						0.1912*	0.0985	-0.0939	0.0471	-0.1865*	-0.0722
SF							0.2640**	0.2646**	-0.2273**	0.0550	0.1719*
TW								0.1534*	-0.0408	0.2217**	0.1599*
BYP									-0.6538**	0.0389	0.8412**
HI										0.0585	-0.1482
LBR											0.0750

Traits: D50F: Days to 50% flowering, DM: Days to maturity, PH: Plant height (cm), PBTP: Panicle bearing tillers/plant, PL: Panicle length (cm), SP: Spikelets/panicle, SF: Spikelet fertility (%), TW: Test weight (g), BYP: Biological yield/plant (g), HI: Harvest index (%), GYP: Grain yield/plant, LBR: Length: Breadth ratio. *,**Significant at 5 and 1% probability levels, respectively

Table 2: Estimates of genotypic correlation coefficients between 12 traits in rice under sodic soil

Traits	DM	PH	PBTP	PL	SP	SF	TW	BYP	HI	LBR	GYP
D50F	0.8342	-0.2270	0.1236	-0.2841	0.1566	-0.0461	0.0877	0.0048	0.0271	-0.0683	0.0202
DM		-0.2165	0.1391	-0.2741	0.2030	0.0128	0.1040	-0.0162	0.0812	-0.0987	0.0289
PH			0.0306	0.4095	-0.1139	0.0102	-0.1896	-0.0808	0.0316	-0.0395	-0.0907
PBTP				0.3037	0.2247	0.2515	-0.1260	0.1144	0.0440	-0.1274	0.1815
PL					-0.1425	-0.1346	-0.3105	0.1562	-0.1497	-0.2549	0.1249
SP						0.2406	0.1431	-0.1011	0.0662	-0.2036	-0.0829
SF							0.4142	0.3551	-0.3036	0.0737	0.3008
TW								0.2618	0.0045	0.3095	0.3657
BYP									-0.8065	0.0387	0.9222
HI										0.1133	-0.5193
LBR											0.1178

Traits: D50F: Days to 50% flowering, DM: Days to maturity, PH: Plant height (cm), PBTP: Panicle bearing tillers/plant, PL: Panicle length (cm), SP: Spikelets/panicle, SF: Spikelet fertility (%), TW: Test weight (g), BYP: Biological yield plant (g), HI: Harvest index (%), GYP: Grain yield/plant, LBR: Length: Breadth ratio. *,**Significant at 5 and 1% probability levels, respectively

Table 3: Estimates of phenotypic direct and indirect effects of 12 traits on grain yield/plant in rice under sodic soil

Traits	D50F	DM	PH	PBTP	PL	SP	SF	TW	BYP	H.I.	LBR	GYP
D50F	-0.0276*	-0.0218	0.0057	-0.0020	0.0041	-0.0042	0.0004	-0.0010	-0.0003	0.0005	0.0017	-0.0076
DM	0.0148	0.0188*	-0.0040	0.0015	-0.0026	0.0036	0.0008	0.0009	-0.0002	0.0011	-0.0015	0.0252
PH	-0.0019	-0.0020	0.0092*	0.0003	0.0022	-0.0010	0.0000	-0.0013	-0.0007	0.0002	-0.0003	-0.0840
PBTP	-0.0008	-0.0009	-0.0003	-0.0105*	-0.0018	-0.0017	-0.0018	0.0007	-0.0006	-0.0003	0.0007	0.0854
PL	0.0022	0.0020	-0.0036	-0.0025	-0.0149*	0.0013	0.0002	0.0015	-0.0010	0.0028	0.0020	-0.0543
SP	0.0032	0.0041	-0.0024	0.0034	-0.0018	0.0214*	0.0041	0.0021	-0.0020	0.0010	-0.0040	-0.0722
SF	0.0003	-0.0007	0.0001	-0.0028	0.0002	-0.0031	-0.0164*	-0.0043	-0.0043	0.0037	-0.0009	0.1719
TW	-0.0003	-0.0004	0.0012	0.0005	0.0008	-0.0008	-0.0022	-0.0082*	-0.0013	0.0003	-0.0018	0.1599
BYP	0.0142	-0.0147	-0.1034	0.0792	0.0900	-0.1229	0.3464	0.2008	1.3093*	-0.8560	0.0509	0.8412
HI	-0.0125	0.0398	0.0132	0.0174	-0.1324	0.0329	-0.1590	-0.0285	-0.4571	0.6992*	0.0409	-0.1420
LBR	0.0008	0.0010	0.0004	0.0008	0.0017	0.0024	-0.0007	-0.0028	-0.0005	-0.0007	-0.0126*	0.0750

Residual effect: 0.0910, *Direct effects on main diagonal. Traits: D50F: Days to 50% flowering, DM: Days to maturity, PH: Plant height (cm), PBTP: Panicle bearing tillers/plant, PL: Panicle length (cm), SP: Spikelets/panicle, SF: Spikelet fertility (%), TW: Test weight (g), BYP: Biological yield/plant (g), HI: Harvest index (%), GYP: Grain yield/plant, LBR: Length: Breadth ratio

Table 4: Estimates of genotypic direct and indirect effects of 12 traits on grain yield/plant in rice under sodic soil

Traits	D50F	DM	PH	PBTP	PL	SP	SF	TW	BYP	H.I.	LBR	GYP
D50F	-0.0146*	-0.0122	0.0033	-0.0018	0.0041	-0.0023	0.0007	-0.0013	-0.0001	-0.0004	0.0010	0.0202
DM	0.0063	0.0076*	-0.0016	0.0011	-0.0021	0.0015	0.0001	0.0008	-0.0001	0.0006	-0.0008	0.0289
PH	-0.0027	-0.0026	0.0119*	0.0004	0.0049	-0.0014	0.0001	-0.0022	-0.0010	0.0004	-0.0005	-0.0907
PBTP	-0.0025	-0.0028	-0.0006	-0.0201*	-0.0061	-0.0045	-0.0051	0.0025	-0.0023	-0.0009	0.0026	0.1815
PL	0.0041	0.0039	-0.0059	-0.0044	-0.0144*	0.0020	0.0019	0.0045	-0.0022	0.0022	0.0037	0.1249
SP	0.0054	0.0070	-0.0039	0.0077	-0.0049	0.0345*	0.0083	0.0049	-0.0035	0.0023	-0.0070	-0.0829
SF	0.0008	-0.0002	-0.0002	-0.0046	0.0025	-0.0044	-0.0182*	-0.0076	-0.0065	0.0055	-0.0013	0.3008
TW	-0.0023	-0.0027	0.0049	0.0033	0.0081	-0.0037	-0.0107	-0.0259*	-0.0068	-0.0001	-0.0080	0.3657
BYP	0.0071	-0.0240	-0.1199	0.1698	0.2318	-0.1500	0.5271	0.3886	1.4844*	-1.1972	0.0574	0.9222
HI	0.0181	0.0543	0.0212	0.0295	-0.1002	0.0443	-0.2031	0.0030	-0.5395	0.6689*	0.0758	-0.5193
LBR	0.0003	0.0005	0.0002	0.0006	0.0013	0.0010	-0.0004	-0.0015	-0.0002	-0.0006	-0.0050*	0.1178

Residual effect: 0.0584, *Direct effects on main diagonal. Traits: D50F: Days to 50% flowering, DM: Days to maturity, PH: Plant height (cm), PBTP: Panicle bearing tillers/plant, PL: Panicle length (cm), SP: Spikelets/panicle, SF: Spikelet fertility (%), TW: Test weight (g), BYP: Biological yield/plant (g), HI: Harvest index (%), GYP: Grain yield/plant, LBR: Length: Breadth ratio

indirect effect on grain yield per plant via biological yield per plant (-0.457), spikelet fertility (-0.159) and panicle length (-0.132). The rest of the estimates of indirect effects obtained in path analysis were negligible. The estimate of residual factors (0.091) obtained in this path analysis was low.

The direct and indirect effects of 11 characters on grain yield per plant estimated by path coefficient analysis using genotypic correlations are given in Table 4.

The highest positive direct effect on grain yield per plant was exerted by biological yield per plant (1.484) followed by harvest-index (0.669). The direct effects of remaining nine characters were too low to be considered important. Biological yield per plant exhibited high order of positive indirect effects on grain yield per plant *via* spikelet fertility (0.527), panicle length (0.232) and panicle bearing tillers per plant (0.170). In contrast, high order of negative indirect effects were extended by biological yield per plant on grain yield per plant via harvest index (-1.197), spikelets per panicle (-0.150) and plant height (-0.120). Harvest-index exhibited high order of negative indirect effect on grain yield per plant via biological yield per plant (-0.540), spikelet fertility (-0.203) and panicle length (-0.100). The rest of the estimates of indirect effects obtained in path analysis were negligible. The estimate of residual factors (0.058) obtained in this path analysis was low.

Correlation coefficients: In the present investigation, phenotypic and genotypic correlation coefficients were computed among 11 characters (Table 1, 2). Grain yield per plant showed highly significant and positive phenotypic correlation and very high order positive genotypic correlation with biological yield per plant. Spikelet fertility showed significant and positive phenotypic and high order positive genotypic association with grain yield per plant. Therefore, these characters emerged as most important associates of grain yield in rice in under sodic soil conditions. The strong positive associations of grain yield with the biological yield per plant, Spikelet fertility and 1000-grain weight as mentioned above have also been reported in rice earlier by many scientists[10-16].

Plant height was positively correlated with panicle length and negatively correlated with days to 50% flowering and days to maturity. This indicated that the taller genotypes possessed greater panicle length besides having early flowering which appears logical. The association of plant height with different morphological and physiological traits has also been reported[17]. Among the panicle characters, panicle bearing tillers per plant exhibited positive and strong association at both levels with panicle length, spikelet fertility and spikelets per panicle. This indicated favorable condition for improving panicle traits biological yield during simultaneous selection. Biological yield per plant recorded positive association at phenotypic as well as genotypic level with spikelet fertility.

The seed traits exhibited significant and positive association with spikelet fertility which was also positively correlated with panicle length. Many scientists also reported that the positive associations between these characters[18-20].

In the present study, majority of significant estimates of correlations between yield and yield components were positive in nature. Out of 20 significant estimates among the total 66 correlations obtained between different character pairs, 15 correlation coefficients were positive in nature, while, 5 estimates were negative. This represents highly favorable situation for obtaining high response to selection in improving yield and yield components in rice. 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.

Harvest index showed unfavorable negative association with biological yield per plant, spikelet fertility and panicle length. In order to take care of occurrence of negative correlations along with majority of positive correlations between important yield components, a reasonable compromise would be required for attaining their proper balance for obtaining maximum combined contribution towards manifestation of grain yield. However, occurrence of positive and significant or non-significant correlations for 55 out of 66 character pairs revealed a far less complex situation in respect of character associations encountered in the present study than generally encountered in rice. This would make easier to attain proper balance between yield and yield components in context of rice genotypes used in present study. The estimates of correlation coefficients obtained in present study are broadly in conformity with previous reports in rice[21-23].

Path coefficient analysis: 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[24] and technique was first used for plant selection by Dewey and Lu[9]. 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 phenotypic and genotypic correlation coefficients between twelve characters. The very high positive direct effects on grain yield per plant were exerted by biological yield per plant followed by harvest-index at phenotypic and genotypic level (Table 3, 4). Thus, biological yield per plant and harvest-index 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[10-13,15,25]. The direct effects of remaining 9 characters were too low to be considered important.

Biological yield per plant exhibited very high order positive indirect effects on grain yield via spikelet fertility %, but biological yield per plant exhibited high order and negative indirect effects on grain yield via harvest index, spikelet fertility % and plant height. Harvest index exhibited high order and positive indirect effect on grain yield via biological yield per plant, spikelet fertility and plant height. Biological yield and harvest-index is also identified as important direct and indirect yield contributing characters[26,27]. The indirect effects of remaining characters were too low to be considered important.

CONCLUSION

It was concluded that the moderate estimates of genotypic and phenotypic coefficient of variation and high heritability in broad sense along with high genetic advance in per cent of mean was recorded for spikelets per panicle, L:B ratio and biological yield per plant. This indicated that improving these traits through selection in context of present material would be reasonable is the significant finding of the study. Remaining characters had either low GCV and PCV or low to moderate heritability to emerge as poor indices of selection under sodic soil.

SIGNIFICANCE STATEMENT

The salient findings of the study is that out of 20 significant estimates among the total 66 correlations obtained between different character pairs, 15 correlation coefficients were positive in nature, while, 5 estimates were negative. This represents highly favorable situation for obtaining high response to selection in improving yield and yield components in rice. Biological yield per plant and harvest-index emerged as most important direct yield components on which emphasis should be given during simultaneous selection aimed at improving grain yield in rice.

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