Current Journal of Applied Science and Technology

39(48): 545-556, 2020; Article no.CJAST.66347
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Character Association and Path-Coefficient Analysis for Yield and Yield-Related Traits in 112 Genotypes of Rice (*Oryza sativa* L.)

S. K. Singh[1], Pratibha Singh[1], Mounika Korada[1], Amrutlal Ratilal Khaire[1*], D. K. Singh[1], Sonali Vijay Habde[1], Prasanta Kumar Majhi[1] and Rudresha Naik[1]

[1]Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P.-221005, India.

Authors' contributions

This work was carried out in collaboration among all the authors. Authors SKS, PS and MK designed the study and wrote the protocol. Author PS performed statistical analysis and wrote the first draft of manuscript. Authors ARK, DKS, SVH managed the further analyses of the study and improved the manuscript. Authors PKM and RN managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i4831275
Editor(s):
(1) 1. Dr. Chen Chin Chang, Hunan Women's University, China.
Reviewers:
(1) John Kimondo Kariuki, Jomo Kenyatta University of Agriculture and Technology, Kenya.
(2) Marwan Noori Ramadhan, University of Basrah, Iraq.
Complete Peer review History: http://www.sdiarticle4.com/review-history/66347

Original Research Article

Received 20 October 2020
Accepted 28 December 2020
Published 31 December 2020

ABSTRACT

Character association and path coefficients for sixteen different yield and yield-contributing traits were evaluated for 112 rice genotypes at Banaras Hindu University, Varanasi during *Kharif*-2019. The experiment was conducted in alpha lattice design and observations were recorded in five randomly selected plants for sixteen traits. The data were analyzed in WINDOSTAT 9.3 ver. for correlation and path analysis. The correlation analysis showed very strong correlation of grain yield per plot with biomass yield per plot. Days to first flowering showed very strong correlation with days to 50% flowering and days to maturity. Days to 50% flowering showed very strong correlation with days to maturity. Spikelets per panicle showed very strong correlation with grains per panicle and grain weight per panicle. Number of grains per panicle showed very strong correlation with grain weight per panicle. Path-coefficient analysis showed that biomass yield per plot, grain yield per plant, grain

**Corresponding author: E-mail: amrutkhaire4@gmail.com;*

weight per panicle, grains per panicle, spikelets per panicle, harvest index, days to first flowering, days to 50% flowering, days to maturity and panicle length had a high and positive direct effect on grain yield per plot. Correlation and path coefficient analysis envisaged characteristics such as biomass yield per plot, grain weight per panicle, grains per panicle, spikelets per panicle, first flowering, 50 percent flowering and days to maturity showed positive direct effect and very strong correlation with grain yield per plot, indicating the effectiveness of these traits in selection. Path analysis revealed that traits like biomass yield per plot, harvest index, grain yield per panicle exerted highest positive direct effect on grain yield per plot. Thus, these characters which contribute to the grain yield could be exploited for future breeding programmes.

Keywords: Character association; path-coefficients; rice; yield.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a self-pollinated cereal crop belonging to the family Gramineae, with a diploid chromosome number of 2n=24. It is the most important crop of the Indian subcontinent and the staple food for a large population, feeding more than 60% population, especially in Asia. World's population is increasing in geometric proportion. To meet the fastest growing demand for food, there is a necessity for the development of high yielding genotypes with desirable agronomic traits for diverse ecosystems [1]. Crop yield is of prime significance to satisfy the needs attributable to a steady increment in population. Yield is a complex trait and is a result of the interaction of several components [2]. Some of these components affect the yield directly while others contribute indirectly. In a plant breeding program, direct selection for yield maybe sometimes misleading thus indirect selection may supplement the selection criteria and can be reliable. Correlation coefficient and path analysis provide a better understanding of the association of different characters through other related characters by partitioning the correlation coefficients [3]. The present study was aimed at understanding the interrelationship among different traits for the selection of desirable genotypes of rice and understanding the direct and indirect effects concerning yield and its attributing characters. It would be more helpful to choose the relationship between the characteristics that confer higher yields while the selection procedure takes place. Correlation is to calculate the general interaction between two variables and to measure the degree of their relation and their linearity. A correlation estimate is needed to explain how a change in one character will improve other characters simultaneously. Information about the correlation coefficient between the yield and yield attributes is a prerequisite for yield enhancement. But simple correlation studies do not provide adequate information about the contribution of each factor towards yield. Correlation and path analysis together establish the extent of association between yield and its components and also bring out the relative importance of their direct and indirect effects, thus giving a clear understanding of their association with grain yield [4]. This provides the opportunity for the indirect selection of yield contributing traits to enhance grain yield.

2. MATERIALS AND METHODS

2.1 Experimental Material and Layout

The experimental material comprised of 112 rice genotypes and was conducted during *Kharif*-2019 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P India, situated at 25 18' N latitude, 83 03' E longitude of 87 meters above mean sea level after harvesting of wheat. The experimental site consists of sandy loam soil (Inceptisol, typically Ustochrept). The seeds of all 112 rice genotypes were sown on a nursery bed and on attainment of 21 days, seedlings were transplanted in the main field in an alpha lattice design with three replications, each consisting of four blocks. Standard agronomic practices including fertilizer application, irrigation, weeding and plant protection measures were taken up according to the schedule to grow a healthy crop. Each germplasm was grown with the spacing 20 × 15 cm row to row and plant to plant respectively.

2.2 Observations Recorded

Different quantitative traits *viz.,* Days to first flowering, Days to 50% flowering, Days to maturity, Number of effective tillers per plant, plant height (cm), Panicle length (cm), Number of spikelets per panicle, Number of grains per panicle, Spikelet fertility%, Grain weight per panicle (g), Grain yield per plant (g), 1000-grain weight (g), Grain yield per plot (kg), Biomass yield per plot (kg), Harvest index (%) and Kernel L/B ratio were measured as explained below (Table 1). Most of the traits data were collected on 5 randomly selected plants whereas, Days to first flowering, Days to 50% flowering, Days to maturity, Grain yield per plot (kg), Biomass yield per plot (kg) and Harvest index (%) were collected on plot basis.

Table 1. List of characters and illustration of the recording of data

Sr. No.	Characters	
1	Days to first flowering	Days from seeding to first opening of the inflorescence of plant on the plot basis.
2	Days to 50% flowering	Number of days from seeding to 50 percent of the plants of the plot came to flowering.
3	Days to maturity	Number of days from seeding to grain ripening (85% of the grains in a panicle mature) was recorded
4	Number of effective tillers per plant	The panicle bearing tillers per plant was counted at maturity.
5	Plant height (cm)	Height of plant from ground to the tip of the tallest panicle (awn excluded) was recorded.
6	Panicle length (cm)	Length of the primary panicle from the panicle base to tip was measured in centimeters and recorded.
7	Number of spikelets per panicle	Number of grains per panicle was recorded from the main tiller after the harvesting of plant.
8	Spikelet Fertilty %	Value was obtained by dividing Number of fertile spikelets per panicle by total spikelet per panicle.
9	Grain weight per Panicle (g)	Weight of grains present in a panicle was measuredusing electronic balance.
10	Grain yield per plant (g)	Weight of paddy (rough rice) per plant at 12-14 percent moisture content was recorded using electronic balance.
11	1000-grain weight (g)	Weight of 1000 well developed grains at 12-14 percent moisture content was recorded using an electronic balance.
12	Grain yield per plot (kg)	Weight of paddy per plot at 12-14 percent moisture content was recorded using electronic balance
13	Biomass yield per plot (kg)	Total weight of plant (including grain, straw, foliage etc.) was recorded using electronic balance.
14	Harvest index (%)	Value was obtained by dividing grain yield per plot by biomass yield per plot.
15	Kernel L/B ratio	Value was obtained by dividing kernel length by kernel breadth

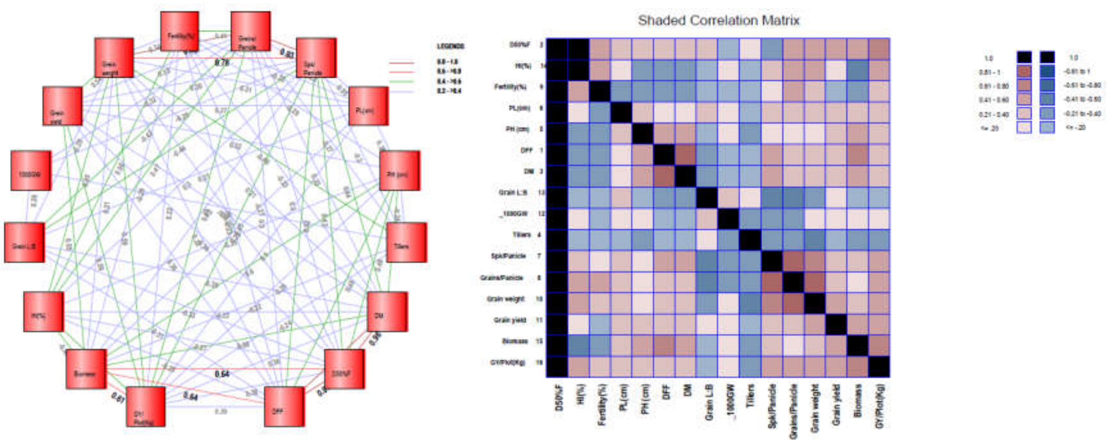

Fig. 1. Genotypic correlation matrix for rice in grain yield (kg) per plot

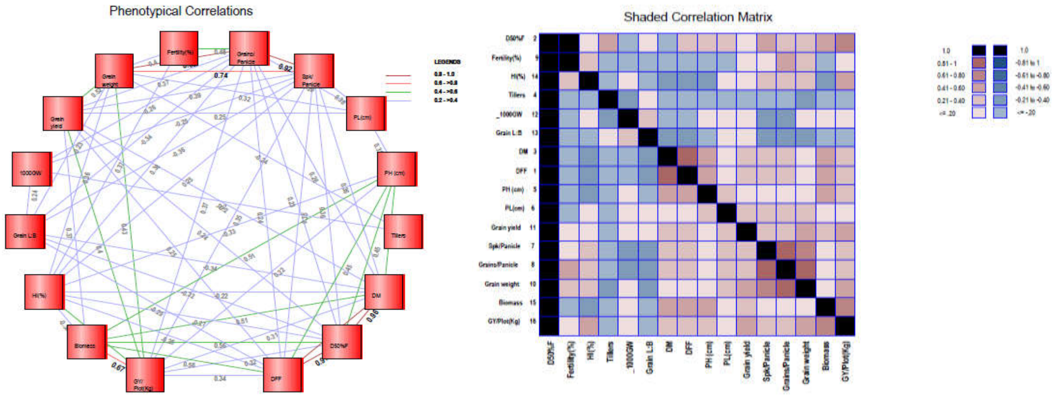

Fig. 2. Phenotypic correlation matrix for rice grain yield (kg) per plot

2.3 Statistical Analysis

(a) The simple correlation coefficients between pairs of characters were calculated according to the formula suggested by Searle [5].

$$r\,(X_1X_2) = cov(X_1X_2)/\surd V(X_1)(X_2)$$

Where, X_1 = character 1; X_2 = character 2; $r(X_1X_2)$ = correlation between characters X_1 and X_2; $cov(X_1X_2)$ = covariance between X_1 and X_2; $V(X_1)$ = variance of X_1; $V(X_2)$ = variance of X_2

Correlation coefficient values were categorized as very weak (<0.30), moderately weak (0.30-0.49), moderately strong (0.50-0.64) and very strong (>0.65) [6].

(b) Path-coefficients were obtained by solving a set of simultaneous equations suggested by Wright [7].

$$r(X_1Y) = P(X_1Y) + r(X_1X_2)P(X_2Y) + r(X_1X_6)P(X_5Y)$$

$$r(X_2Y) = r(X_2X_1)P(X_1Y) + P(X_2Y) + r(X_2X_3)P(X_3Y) + r(X_2X_6)P(X_5Y)$$

$$r\,(X_5Y) = r(X_5X_1)P(X_1Y) + r(X_5X_2)P(X_2Y) + r(X_5X_3)P(X_3Y) + r(X_5Y)$$

where, $r(X_1Y)$ to $r(X_5Y)$ denotes the coefficient of correlation between independent characters X_1 to X_5 and dependent character Y; $r(X_1X_2)$ to $r(X_4X_5)$ denotes the coefficient of correlation between all possible combination of independent characters; $P(X_1Y)$ to $P(X_5Y)$ denotes direct effects of character X_1 to X_5 on Y. The mean data after computing for each character was subjected to statistical analysis using software WINDOSTAT 9.3 version for analysis of variance (ANOVA), genetic parameters, character association and path coefficient analysis according to the formula suggested by Burton [8] and Johnson et al. [9].

Path coefficient values were categorized as negligible (0.00-0.09), low (0.1-0.19), moderate (0.2-0.29), high (0.3-0.99) and very high (>1) [10].

2.4 Genotypic Correlation

The inherent or heritable association between two variables is known as genotypic correlation and this may be either due to pleiotropic action of genes or due to linkage.

2.5 Phenotypic Correlation

The association between two variables that can be directly observed is termed phenotypic correlation. It includes both genotypic and environmental effects.

3. RESULTS AND DISCUSSION

The analysis of variance exhibited the presence of significant differences among the tested genotypes for all characters indicating the presence of a significant amount of variability. Phenotypic and genotypic association among yield and yield components *viz.*, days to first flowering, days to fifty percent flowering, days to maturity, number of effective tillers per plant, plant height (cm), panicle length (cm), number of spikelets per panicle, number of grains per panicle, spikelet fertility%, grain weight per panicle (g), grain yield per plant (g), 1000 grain weight (g), grain yield per plot (kg), biomass yield per plot (kg), harvest index (%) and kernel L/B ratio. were computed separately for rice genotypes.

Table 2. Genotypic (above the diagonal) and phenotypic (below the diagonal) correlation coefficients between yield and its component traits in 112 genotypes of rice (*Oryza sativa* L.)

Characters	Days to first flowering	Days to 50% flowering	Days to maturity	Number of effective tillers per plant	Plant height (cm)	Panicle length (cm)	No. of spikelets per panicle	No. of grains per panicle	Spikelet fertility (%)	Grain weight per panicle (g)	Grain yield per plant (g)	1000-grain weight (g)	Biomass yield per plot (kg)	Harvest index (%)	Kernel L/B ratio
Days to first flowering	1.0000	0.9717**	0.9364**	-0.1168	0.4799**	0.1082	0.4234**	0.3029**	-0.2339**	0.2207**	0.3585**	-0.1158	0.6416**	-0.2530**	-0.3106**
Days to 50% flowering	0.9719**	1.0000	0.9644**	-0.1708	0.4826**	0.0838	0.4342**	0.3000**	-0.2746**	0.2230**	0.3441**	-0.0753	0.6406**	-0.2667**	-0.3340**
Days to maturity	0.9370**	0.9647**	1.0000	-0.1443	0.4525**	0.0475	0.4436**	0.3264**	-0.2300**	0.2113**	0.2960**	-0.1622	0.5886**	-0.2236**	-0.3567**
Number of effective tillers per plant	-0.0775	-0.1140	-0.0961	1.0000	-0.2416**	-0.1746	-0.2970**	-0.2734**	-0.0851	-0.4639**	-0.1516	-0.2569**	-0.2168**	-0.0507	0.1003
Plant height (cm)	0.4518**	0.4541**	0.4259**	-0.1468	1.0000	0.3822**	0.1354	0.0323	-0.2772**	0.1787	0.3197**	0.1169	0.5957**	-0.3461**	-0.0287
Panicle length (cm)	0.0825	0.0633	0.0350	-0.0848	0.3072**	1.0000	0.3543**	0.2400**	-0.2231**	0.3126**	0.2657**	0.1355	0.2905**	0.0148	0.2135**
No. of spikelets per panicle	0.3468**	0.3553**	0.3633**	-0.1508	0.1244	0.3817**	1.0000	0.9293**	0.0469	0.7792**	0.3887**	-0.2944**	0.2018**	0.2994**	-0.4358**
No. of grains per panicle	0.2374**	0.2345**	0.2559**	-0.1329	0.0306	0.2854**	0.9161**	1.0000	0.4095**	0.8321**	0.3452**	-0.3229**	0.0868	0.4652**	-0.4232**
Spikelet fertility (%)	-0.1567	-0.1839**	-0.1540	-0.0296	-0.1974**	-0.1087	0.1063	0.4785**	1.0000	0.3424**	-0.0088	-0.1468	-0.2855**	0.5558**	-0.0603
Grain weight per panicle (g)	0.1661	0.1675	0.1585	-0.2412**	0.1229	0.3152**	0.7438**	0.8210**	0.3959**	1.0000	0.5435**	0.1263	0.2097**	0.4520**	-0.2756**
Grain yield per plant (g)	0.2488**	0.2380**	0.2038**	-0.0756	0.1923**	0.2533**	0.3927**	0.3723**	0.0875	0.5162**	1.0000	0.1681**	0.5531**	0.0779	0.1213
1000-grain weight (g)	-0.1090	-0.0699	-0.1535	-0.2023**	0.1032	0.1079	-0.2467**	-0.2566**	-0.0869	0.1044	0.1129	1.0000	0.1372	0.0188	0.2776**
Biomass yield per plot (kg)	0.5623**	0.5602**	0.5137**	-0.1264	0.5085**	0.1841**	0.1529	0.0658	-0.1797**	0.1534	0.3732**	0.1023	1.0000	-0.4196**	-0.1502
Harvest index (%)	-0.2535**	-0.2671**	-0.2243**	-0.0385	-0.3276**	0.0134	0.2517**	0.3769**	0.3738**	0.3582**	0.0596	0.0174	-0.3817**	1.0000	-0.0341

Characters		Days to first flowering	Days to 50% flowering	Days to maturity	Number of effective tillers per plant	Plant height (cm)	Panicle length (cm)	No. of spikelets per panicle	No. of grains per panicle	Spikelet fertility (%)	Grain weight per panicle (g)	Grain yield per plant (g)	1000-grain weight (g)	Biomass yield per plot (kg)	Harvest index (%)	Kernel L/B ratio
Kernel L/B ratio		-0.2937**	-0.3156**	-0.3368**	0.0680	-0.0297	0.1429	-0.3611**	-0.3417**	-0.0576	-0.2280**	0.0771	0.2420**	-0.1210	-0.0289	1.0000
Grain yield per plot (kg)	G	0.3919**	0.3777**	0.3612**	-0.2443**	0.2608**	0.3008**	0.4525**	0.4931**	0.2218**	0.5857**	0.5911**	0.1298	0.6122**	0.4499**	-0.1703
	P	0.3388**	0.3247**	0.3102**	-0.1441	0.2233**	0.1999**	0.3522**	0.3702**	0.1315**	0.4261**	0.4002**	0.0967	0.6750**	0.4113**	-0.1364

***Significant at 1% level; P : at Phenotypic level, G : at Genotypic level, ns: not significant*

3.1 Correlation Coefficient Analysis

Correlation coefficient analysis is widely used to measure the degree and direction of relationships between various traits including grain yield. Analysis of the correlation coefficient is commonly used to calculate the level and orientation of relations between different characteristics, including the grain yield. The results are presented in Table 2. They provide basic information extremely useful to the breeder for a proper understanding of the nature and association of the traits. The genotypic correlations, in general, were higher than the corresponding phenotypic correlations (Table 2). The characteristic relationship showed the close link between grain yield per plot and biomass yield per plot (0.6750**) at phenotypic level. Similarly, days to first flowering showed very strong correlation with days to 50% flowering (0.9717** and 0.9719**) and days to maturity (0.9364** and 0.9370**), This is because the environment has a changing impact on the genetic interaction of characteristics. This has been verified by the results of Reddy et al. [11], Saravanan and Sabesan [12] and Reddy et al. [13] for days to maturity. Grains per panicle exhibited a strong association with grain weight per panicle (0.8321** and 0.8210**) at genotypic and phenotypic levels respectively. This indicated that effective selection could be made for these traits compared to others. This indicates the relative utility of both traits for selection concerning grain yield. The observed positive correlation of grain yield with various traits was supported by Rajeshwari and Nandrajan [14]. While, days to first flowering (-0.3106**) and days to maturity (-0.3560**) demonstrated a negative correlation with the kernel L/B ratio but these traits showed a significant positive association with grains per panicle. It suggests that, priority should be given to these traits while making selection for yield improvement. The correlation of number of spikelets per panicle exhibited positive and significant association with panicle length and biological yield per plant. Similar results were reported by Seyoum et al. [15] and Reddy et al. [13].

Days to first flowering and days to fifty percent flowering showed a positive association with grains per panicle and number of spikelets per panicle reflecting that decrease in grain dimensions leads to increase in the number of grains and spikelets in late flowering and late maturing genotypes. The number of effective tillers per plant indicated negative significant association with 1000-grain weight (-0.2569** and -0.2023** at genotypic and phenotypic levels respectively) and grain weight per panicle (-0.4639** and -0.2412** at genotypic and phenotypic levels respectively) indicating raise in number of effective tillers reduces the grain weight in an individual panicle may be due to scarcity of available resources which are required for growth and development of rice crop. Mutual association between different yield components at genotypic and phenotypic levels is shown in Table 2 (Figs 1 and 2 respectively). These inferences were found in accordance with the results obtained by Pratap et al. [16], Singh et al. [17], Allam et al. [18], Priya et al. [19], Singh et al. [20], Kumar et al. [21], Sudeepthi et al. [22] and Parimala et al. [23].

3.2 Path-coefficient Analysis

The Path coefficient analysis provides effective methods for finding the specific and indirect causes of a combination and provides a critical assessment of the specific functional capacity to produce a given combination and measures the equal significance of each causal factor. Therefore, a study of the direct and indirect effects of grain yield characteristics on each crop was conducted in the current study and the results obtained are presented in Table 3. The path-coefficient analysis helps in the partitioning correlation coefficients into direct and indirect effects of independent variables on the dependent variable. As grain yield is a complex character influenced by several factors, selection based on simple correlation without taking into consideration the component characters is not effective. Therefore, path analysis is of great importance in any plant breeding program. Correlation in combination with path analysis will give better insight into the cause and effect relationship of different pairs of characters. The path-coefficient analysis revealed that the traits like biomass yield per plot (0.612 and 0.675), grain yield per plant (0.591 and 0.400), grain weight per panicle (0.586 and 0.426), grains per panicle (0.493 and 0.370), spikelets per panicle (0.453 and 0.352), harvest index (0.450 and 0.411), days to first flowering (0.392 and 0.339), days to 50% flowering (0.378 and 0.325), days to maturity (0.361 and 0.310) had a high and positive direct effect on grain yield of a plot at both genotypic & phenotypic levels respectively. Whereas days to first flowering had a negative direct effect and days to maturity showed negative indirect effect through days to first flowering (-0.019 and -0.067), panicle length (-0.001 and -0.003) and spikelets per panicle (-0.009 and -0.026) at genotypic and phenotypic levels respectively, indicating fewer days for flowering and more days for maturation (*i.e.,* a greater difference between flowering and maturity) is effective in increasing grain yield. The number of effective tillers per plant exhibited a negative indirect effect with grain yield per plot through grain weight per panicle. Similar findings were also reported by Nandan et al. [24], Kumar et al. [25], Kumar et al. [26] and Katiyar et al. [27]. A perusal of these results revealed low residual effect (0.139) indicating that variables studied in the present experiment explained about 86.10 per cent of variability for grain yield per plot and therefore, other attributes besides the characters studied are also contributing for grain yield per plot and only 13.90 per cent of variability is of unexplained variation.

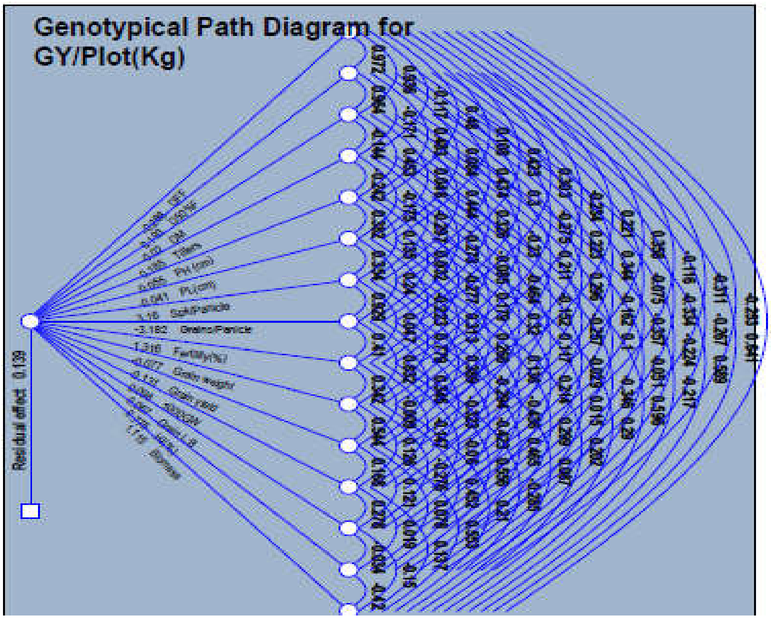

Fig. 3. Path diagram depicting estimates of genotypic path for rice grain yield (kg) per plot

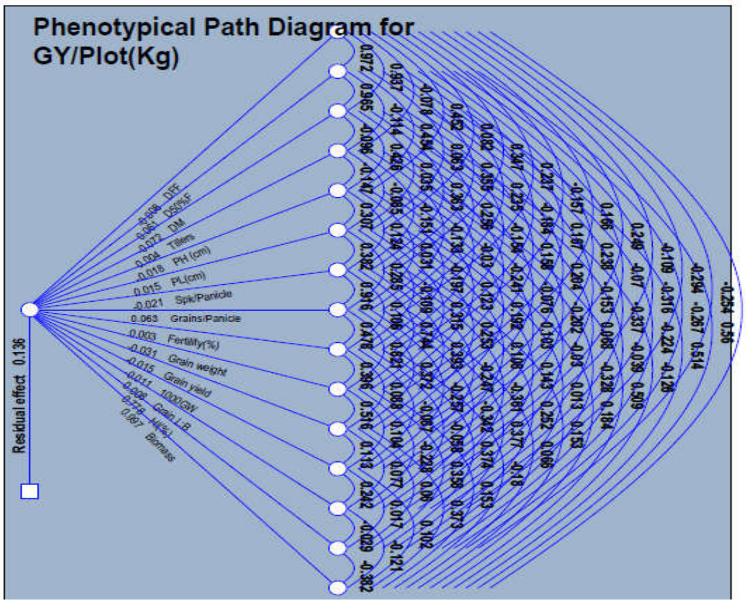

Fig. 4. Path diagram depicting estimates of phenotypic path for rice grain yield (kg) per plot

Table 3. Direct and indirect effects of component traits attributing to yield per plot (kg) at genotypic and phenotypic levels

Path Matrix with Characters		Days to first flowering	Days to 50% flowering	Days to maturity	Number of effective tillers per plant	Plant height (cm)	Panicle length (cm)	No. of spikelets per panicle	No. of grains per panicle	Spikelet fertility (%)	Grain weight per panicle (g)	Grain yield per plant (g)	1000-grain weight (g)	Biomass yield per plot (kg)	Harvest index (%)	Kernel L/B ratio
Days to first flowering	G	-0.266	-0.258	-0.249	0.031	-0.128	-0.029	-0.113	-0.081	0.062	-0.059	-0.095	0.031	-0.171	0.067	0.083
	P	-0.008	-0.007	-0.007	0.001	-0.003	-0.001	-0.003	-0.002	0.001	-0.001	-0.002	0.001	-0.004	0.002	0.002
Days to 50% flowering	G	0.187	0.193	0.186	-0.033	0.093	0.016	0.084	0.058	-0.053	0.043	0.066	-0.015	0.123	-0.051	-0.064
	P	0.060	0.061	0.059	-0.007	0.028	0.004	0.022	0.014	-0.011	0.010	0.015	-0.004	0.034	-0.016	-0.019
Days to maturity	G	-0.019	-0.020	-0.020	0.003	-0.009	-0.001	-0.009	-0.007	0.005	-0.004	-0.006	0.003	-0.012	0.005	0.007
	P	-0.067	-0.069	-0.072	0.007	-0.031	-0.003	-0.026	-0.018	0.011	-0.011	-0.015	0.011	-0.037	0.016	0.024
Number of effective tillers per plant	G	-0.022	-0.032	-0.027	0.185	-0.045	-0.032	-0.055	-0.051	-0.016	-0.086	-0.028	-0.048	-0.040	-0.009	0.019
	P	0.000	0.000	0.000	0.004	-0.001	0.000	-0.001	-0.001	0.000	-0.001	0.000	-0.001	-0.001	0.000	0.000
Plant height (cm)	G	0.026	0.026	0.025	-0.013	0.055	0.021	0.007	0.002	-0.015	0.010	0.018	0.006	0.033	-0.019	-0.002
	P	-0.008	-0.008	-0.008	0.003	-0.018	-0.006	-0.002	-0.001	0.004	-0.002	-0.003	-0.002	-0.009	0.006	0.001
Panicle length (cm)	G	-0.004	-0.003	-0.002	0.007	-0.016	-0.041	-0.014	-0.010	0.009	-0.013	-0.011	-0.006	-0.012	-0.001	-0.009
	P	0.001	0.001	0.001	-0.001	0.005	0.015	0.006	0.004	-0.002	0.005	0.004	0.002	0.003	0.000	0.002
No. of spikelets per panicle	G	1.338	1.372	1.402	-0.938	0.428	1.120	3.160	2.936	0.148	2.462	1.228	-0.930	0.638	0.946	-1.377
	P	-0.007	-0.007	-0.008	0.003	-0.003	-0.008	-0.021	-0.019	-0.002	-0.015	-0.008	0.005	-0.003	-0.005	0.008
No. of grains per panicle	G	-0.964	-0.955	-1.039	0.870	-0.103	-0.764	-2.957	-3.182	-1.303	-2.648	-1.098	1.028	-0.276	-1.480	1.347
	P	0.015	0.015	0.016	-0.008	0.002	0.018	0.058	0.063	0.030	0.052	0.023	-0.016	0.004	0.024	-0.021
Spikelet fertility (%)	G	-0.308	-0.361	-0.303	-0.112	-0.365	-0.294	0.062	0.539	1.316	0.451	-0.012	-0.193	-0.376	0.731	-0.079
	P	0.000	-0.001	0.000	0.000	-0.001	0.000	0.000	0.001	0.003	0.001	0.000	0.000	-0.001	0.001	0.000
Grain	G	-0.017	-0.017	-0.016	0.036	-0.014	-0.024	-0.060	-0.064	-0.027	-0.077	-0.042	-0.010	-0.016	-0.035	0.021

Path Matrix with Characters		Days to first flowering	Days to 50% flowering	Days to maturity	Number of effective tillers per plant	Plant height (cm)	Panicle length (cm)	No. of spikelets per panicle	No. of grains per panicle	Spikelet fertility (%)	Grain weight per panicle (g)	Grain yield per plant (g)	1000-grain weight (g)	Biomass yield per plot (kg)	Harvest index (%)	Kernel L/B ratio
weight per panicle (g)	P	-0.005	-0.005	-0.005	0.008	-0.004	-0.010	-0.023	-0.026	-0.012	-0.031	-0.016	-0.003	-0.005	-0.011	0.007
Grain yield per plant (g)	G	-0.047	-0.045	-0.039	0.020	-0.042	-0.035	-0.051	-0.045	0.001	-0.071	-0.131	-0.022	-0.072	-0.010	-0.016
	P	-0.004	-0.004	-0.003	0.001	-0.003	-0.004	-0.006	-0.006	-0.001	-0.008	-0.015	-0.002	-0.006	-0.001	-0.001
1000-grain weight (g)	G	-0.011	-0.007	-0.016	-0.025	0.012	0.013	-0.029	-0.032	-0.014	0.012	0.017	0.098	0.014	0.002	0.027
	P	0.001	0.001	0.002	0.002	-0.001	-0.001	0.003	0.003	0.001	-0.001	-0.001	-0.011	-0.001	0.000	-0.003
Biomass yield per plot (kg)	G	0.715	0.714	0.656	-0.242	0.664	0.324	0.225	0.097	-0.318	0.234	0.617	0.153	1.115	-0.468	-0.168
	P	0.561	0.559	0.512	-0.126	0.507	0.184	0.153	0.066	-0.179	0.153	0.372	0.102	0.997	-0.381	-0.121
Harvest index (%)	G	-0.196	-0.207	-0.173	-0.039	-0.268	0.012	0.232	0.361	0.431	0.350	0.060	0.015	-0.325	0.775	-0.027
	P	-0.197	-0.208	-0.174	-0.030	-0.255	0.010	0.196	0.293	0.291	0.279	0.046	0.014	-0.297	0.778	-0.023
Kernel L/B ratio	G	-0.021	-0.022	-0.024	0.007	-0.002	0.014	-0.029	-0.028	-0.004	-0.018	0.008	0.019	-0.010	-0.002	0.067
	P	-0.002	-0.003	-0.003	0.001	0.000	0.001	-0.003	-0.003	-0.001	-0.002	0.001	0.002	-0.001	0.000	0.008
Grain yield per plot (kg)	G	0.392	0.378	0.361	-0.244	0.261	0.301	0.453	0.493	0.222	0.586	0.591	0.130	0.612	0.450	-0.170
	P	0.339	0.325	0.310	-0.144	0.223	0.200	0.352	0.370	0.132	0.426	0.400	0.097	0.675	0.411	-0.136

P: at phenotypic level, G: at genotypic level, Diagonal values indicate direct effects, Residual effect at Genotypic level = 0.1386 and R^2 = 0.9808 and Residual effect at Phenotypic level = 0.136 and R^2 = 0.981

4. CONCLUSION

Character association studies revealed that biomass yield per plot, spikelets per panicle and grains per panicle and number of effective tillers per plant can be used as selection indices for improving yield. Besides, path coefficient analysis revealed that biomass yield per plot, grain yield per plant, grain weight per panicle, grains per panicle, spikelets per panicle, harvest index and panicle length exerted a positive direct effect on grain yield per plot, indicating that selection for these characters is likely to bring about an overall improvement in grain yield per plot directly.

ACKNOWLEDGEMENT

Authors thankfully acknowledge IRRI AGRRi Alliance Project, Banaras Hindu University, Varanasi for providing the requisite germplasm and financial support to get this work accomplished.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Khan R, Senapati BK, Sangeeta PL, Samim Ahammad, SK. Correlation and path analysis studies in recombinant inbred lines (F_8) of Langulmota/sambamahsuri derivatives, Journal of Pharmaconosy and Phytochemistry. 2020; 9(2): 218-223.
2. Sarawgi AK, Rastogi NK, Soni DK. Correlation and path analysis in rice accessions from Madhya Pradesh. Field Crops Res. 1997; 52:161-167.
3. Dixet P, Dubey DK. Path analysis in lentil (Lens culinaris Med.), Lens Newsletter. 1984;1:15-17.
4. Babu VR, Shreya K, Dangi KS, Usharani G, Shankar AS. Correlation and path analysis studies in popular rice hybrids of India. International Journal of Scientific and Research Publication. 2012; 2(3): 1-5.
5. Searle SR. Phenotypic, genetic and environmental correlations. Biometrics. 1961;17(3):474-480.
6. Searle S.R. The value of indirect selection. I. Mass selection. Biometrics. 1965;21: 682-707.
7. Wright S. Correlation and causation. Journal of Agriculture Research. 1934; 20:557-585.
8. Burton GW. Quantitative inheritance in grasses. Proceedings of 6th Grassland Congress Journal. 1952;1:277-281.
9. Johnson HW, Robinson HF, Comstock RE. Estimates of genetic and environmental variability in soybean. Agronomy Journal. 1955;47(7):314-318.
10. Lenka D, Mishra B. Path coefficient analysis of yield in rice varieties. Ind. J. Agric. Sci. 1973;43:376-379.
11. Reddy YM, Yadav SC, Reddy S, Lavanya GR, Suresh BG. Character association and component analysis in rice. Oryza. 2008;45(3): 239-241.
12. Saravanan K, Sabesan T. Association analysis and path analysis for yield and its contributing traits in rice (*Oryza sativa* L.). Intl. J. Plant Sci. 2009;3(2): 27-29.
13. Reddy GE, Suresh BG, Sravan T, Reddy PA. Interrelationship and Cause-Effect Analysis of Rice Genotypes in North East Plain Zone. The Bioscan. 2013;8(4):1141-1144.
14. Rajeshwari S, Nadarajan N. Correlation between yield and yield components in rice (*Oryza sativa* L.) Agric. Sci. Dig. 2004;24: 280-282.
15. Seyoum M, Alamerew S, Bantte K. Genetic variability, heritability correlation coefficient and path analysis for yield and yield related traits in upland rice (*Oryza sativa* L.). Journal of Plant Sciences. 2012; 7(1):13-22.
16. Pratap N, Singh PK, Shekhar R, Soni SK, Mall AK. Genetic variability, character association and diversity analyses for economic traits in rice (*Oryza sativa* L.). SAARC Journal of Agriculture. 2012; 10(2): 83-94.
17. Singh AK, Nandan R, Singh PK. Genetic variability and association analysis in rice germplasm under rainfed conditions. Crops Research. 2013;47(1-3):7-11.
18. Allam CR, Jaiswal HK, Qamar A. Character association and path analysis studies of yield and quality parameters in basmati rice (*Oryza sativa* L.). The Bioscan. 2015;9(4):1733-1737.
19. Priya CS, Suneetha Y, Babu DR, Rao VR. Inter-relationship and path analysis for yield And quality characters in rice (*Oryza sativa* L.). International Journal of Science, Environment and Technology. 2017; 6(1):381-390.

20. Singh SK, Vennela PR, Singh R, Gayatonde V, Singh DK. Studies on character association, path analysis and genetic variability in rice (*Oryza sativa* L.) genotypes. International Journal of Current Microbiology and Applied Sciences. 2018; 7(5):2702-2712.
21. Kumar A, Kumar S, Singh S, Prasad J, Jeena AS, Upreti MC. Studies on character association among quality traits and yield components in Basmati rice (*Oryza sativa* L.). Journal of Applied and Natural Science. 2020; 12(3): 292-298. Available:https://doi.org/10.31018/jans.v12i3.2294
22. Sudeepthi K, Srinivas T, Kumar BR, Jyothula DPB, Umar SN. Assessment of genetic variability, character association and path analysis for yield and yield component traits in rice (*Oryza sativa* L.). Electronic Journal of Plant Breeding. 2020; 11(01):144-148.
23. Parimala K, Raju CS, Prasad AH, Kumar SS, Reddy SN. Studies on genetic parameters, correlation and path analysis in rice (*Oryza sativa* L.). Journal of Pharmacognosy and Phytochemistry. 2020;9(1):414-417.
24. Nandan R, Sweta, Singh SK. Character Association and Path Analysis in Rice (*Oryza sativa* L.) Genotypes. World Journal of Agricultural Sciences. 2010; 6(2): 201-206.
25. Kumar G, Dwivedi DK, Maurya H, Yadav VK. Correlation and path coefficient analysis of thirteen rice genotypes for grain yield and other yield attributing traits. Journal of Pharmacognosy and Phytochemistry. 2018a;7(3):3506-3510.
26. Kumar S, Chauhan MP, Tomar A, Kasana, RK, Kumar N. Correlation and path coefficient analysis in rice. The Pharma Innovation Journal, 2018b;7(6): 20-26.
27. Katiyar D, Srivastava, KK, Prakash S, Kumar M, Gupta M. Study correlation coefficients and path analysis for yield and its component characters in rice (*Oryza sativa* L.). Journal of Pharmacognosy and Phytochemistry. 2019;8(1): 1783-1787.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/66347