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Characters association and their direct and indirect effects on grain yield in rice (*Oryza sativa*)

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In India, rice (*Oryza sativa* L) occupies 43.97 million hectare (22%) of cropped area with annual production of 105.2 million tonnes and productivity of 2.37 tonnes/ha compare to world's average of 2.9 tonnes/ha (Anonymous 2013). Northern Indian states Haryana, Punjab, and Western UP with assured irrigation account for higher productivity are famous for basmati rice production. In Haryana, about 2/3 of the area, largest in the country is under basmati cultivation dominated by cultivar such as PUSA 1121. Due to the adoption of PUSA 1121 in recent years, similar is the trend in Punjab where about 84% of 7.5 lakh ha. basmati area is occupied by this variety (APEDA 2013). It's the world's longest grain basmati variety, an excellent example of postgraduate student's work at Indian Agricultural Research Institute, New Delhi (Sarial 1995), released for cultivation in 2003 contributing INR 11600 crores annually in forex earning (Anonymous 2012). PUSA 1121 has also been found suitable under low input, water saving SRI cultivation (Ghritlahre and Sarial 2011, Ghritlahre *et al.* 2012). These widely adapted cultivars and input efficient practices would play a significant role to augment production and productivity of rice in country which is far less than the world's average. However, rice yield is a highly complex quantitatively controlled trait influenced by its components traits, direct selection for genetic improvement in yield often misleads the plant breeder. The product moment coefficients between yield and its component traits often exhibit a complex chain of interacting characters relationship. Path coefficient analysis furnishes information of influence of each contributing characters to yield directly as well as indirectly and also enables breeders to rank the genetic attributes according to their contributions. The present investigation therefore, was carried out with the aim to assess the extent of association between yield and its component traits and partition it into direct and indirect effects using path coefficient analysis.

The experimental material consisted of forty nine genotypes of scented and non-scented rice belonging to different maturity groups. The experiment was conducted in a randomized block design with three replications during (*kharif*) rainy season of 2010 at CCS Haryana Agricultural University, Rice Research Station, Kaul. Seeds of rice genotypes were sown in raised nursery bed on 16 June, 2010 and the seedlings were transplanted in the main field at the rate of one seedling per hill on 28 July, 2010 after 42 days, with a spacing of 20 cm × 15 cm. The plot size was 1.5 × 0.2 × 3 sq m. The delay in transplanting was due to the occurrence of natural floods in the region. Seedlings remained submerged in the flood water for 3-4 days resulting in stunted growth and delayed recovery for transplanting. The data were recorded on five randomly selected plants per genotype per replication for various quantitative traits (Table 1). The analysis of variance for different characters was done on the basis of the model described by Panse and Sukhatme (1967). Path coefficient was analysed following method proposed by Dewey and Lu (1959).

Characters association

The analysis of variance showed that the mean squares due to genotypes were significant ($P<0.01$) for all quantitative character studied indicating that genotypes differed amongst themselves. Of the hundred and five [n (n-1)/2] correlation coefficients computed for 15 quantitative traits, 82 'r' values were found to be statistically significant irrespective of their direction of association (Table 1). In general, genetic correlation coefficients recorded higher magnitude than the phenotypic correlation coefficients in all cases. This indicated that, eventhough there were inherent association between the characters studied, the relationship between the traits was under the influence of environment and genotype-environment interaction. The phenotypic correlation reflects observed relationship between traits (r_p). The phenotypic correlation coefficients for most of the traits were low. Those characters that showed genotypic correlation with seed yield would be of limited use in direct selection for seed yield, since selection is usually based on phenotypic expression of the trait.

The correlation coefficient analysis between grain yield

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Table 1 Phenotypic correlation coefficients among 15 quantitative traits in rice

Traits	GY	DTF	DTM	PTHT	T/PT	PLTH	PWT	S/PAN	FSPK	TWT	BYD	HI	H %	M %	HRR
GY	1														
DTF	–0.481**	1													
DTM	–0.086	0.618**	1												
PT HT	–0.535**	0.629**	0.418**	1											
T/PT	–0.190*	0.297**	0.187*	0.474**	1										
P LTH	–0.104	0.349**	0.264**	0.390**	0.198*	1									
P WT	0.846**	–0.421**	0.044	–0.543**	–0.293**	0.014	1								
S/ PAN		0.574**	–0.279**	–0.141	–0.532**	–0.332**	–0.021	0.637**	1						
FSPK	0.409**	–0.338**	–0.031	–0.220**	–0.072	–0.206*	0.432**	0.101	1						
T WT	0.646**	–0.505**	–0.192*	–0.641**	–0.326**	–0.230**	0.641**	0.397**	0.409**	1					
B YD	0.417**	0.221**	0.359**	0.350**	0.278**	0.256**	0.236**	0.069	0.068	–0.009	1				
H. I.	0.812**	–0.682**	–0.319**	–0.785**	–0.375**	–0.293**	0.756**	0.561**	0.437**	0.691**	–0.154	1			
H %	0.620**	–0.441**	–0.065	–0.524**	–0.188*	–0.184*	0.607**	0.349**	0.496**	0.645**	0.072	0.624**	1		
M %	0.310**	–0.302**	–0.090	–0.310**	–0.086	–0.033	0.319**	0.172*	0.286**	0.365**	–0.003	0.341**	0.522**	1	
HRR	0.322**	–0.328**	–0.088	–0.366**	–0.197*	–0.110	0.344**	0.117	0.276**	0.419**	–0.023	0.366**	0.529**	0.837**	1

*, ** Significant at 5% and 1% level of significance, respectively. GY, Grain yield; DTF, Days to flowering; DTM, Days to maturity; PT HT, Plant height; T/PT, Effective tillers/plant; P LTH, Panicle length; P WT, Panicle weight; S/PAN, Number of spikelets/panicle; F SPK, Per cent filled spikelets; T WT, Test weight; B YD, Biological yield/plant; H I, Harvest index; H%, Hulling per cent; M%, Milling per cent; HRR, Head rice recovery per cent

and its component traits indicated that grain yield was found to be positively and significantly associated with panicle weight, spikelets per panicle, per cent filled spikelets, test grain weight, biological yield per plant, harvest index, hulling per cent, milling per cent and head rice recovery per cent. Grain yield per plant had negative and significant correlation with days to 50% flowering, plant height and effective tillers per plant. The negative correlation however, imposed problems in combining important yield components in one genotype. To overcome negative association, suitable recombination through breaking undesirable linkages may be obtained by bi-parental mating, mutation breeding or diallel selective mating. The magnitude of association ranged from low (r = 0.19) for effective tillers per plant to high (r = 0.846) for panicle weight. Correlation between per cent filled spikelets and grain yield was found to be positive by several workers (Girish *et al.* 2006, Nandan *et al.* 2010 and Bagheri *et al.* 2011). Positive correlation of grain yield/plant and harvest index was also observed by Chakraborty *et al.* (2010). Positive correlation of grain yield and spikelets per panicle was confirmed by Nandan *et al.* (2010) and Bagheri *et al.* (2011). Positive correlation of grain yield with biological yield/plant was observed by Girish *et al.* (2006) and grain yield with panicle weight by Allah *et al.* (2010). Contradictory to the present findings, positive correlation of grain yield with days to flowering, days to maturity, and number of effective tillers per plant was reported by Singh *et al.* (2007).

Direct and indirect effects

Grain yield is a polygenic trait, besides, it is influenced by many other traits, hence, direct selection for this character may often be misleading. Since the correlation studies alone are not sufficient to make the picture of association analysis very clear, assessment of real contribution of individual character towards the grain yield become essential. It has also been suggested that yield components have either a direct or indirect effect on seed yield or both. Therefore, it was essential to determine the effect of yield components on seed yield. Consequently path coefficient analysis provides a clear and more realistic picture of a complex situation that exists at correlation level. It measures the direct as well as indirect effects of one variable on the dependent variable through the other traits. Thus, it is possible to calculate both direct and indirect effects of yield components on seed yield (Table 2).

Days to 50% flowering had moderately high positive direct effect but it had negative effect on yield which is mainly due to harvest index followed by days to 75 % maturity and plant height. Positive direct effect of days to flowering with yield was also confirmed by Nandan *et al.* (2010). Days to maturity had negative effect on grain yield via harvest index (–0.356) followed by plant height (–0.125) and its direct effect was also negative (–0.213). However positive direct effect was recorded by Watoo *et al.* (2010). Plant height affect negatively on grain yield mainly via harvest index and its maximum negative direct effect (–0.229). Effective tillers per plant with low positive direct effect and panicle length with a very low positive direct effect also affects negatively on grain yield mainly due to their indirect effect via harvest index. Positive direct effect of effective tillers per plant was also in agreement with the findings of Bagheri *et al.* (2011). Bagheri *et al.* (2011) also confirmed positive direct effect of panicle weight with yield. Panicle weight having the highest indirect effect via harvest index (0.656) and by its direct effect (0.168) contributed maximum towards grain yield. It also had a low negative indirect effect (–0.113) via milling per cent. Allah

Table 2 Direct and indirect effects on grain yield of its components and other yield contributing traits in rice

Traits	DTF	DTM	P HT	T/PT	PLT	P WT	S/PAN	F SPK	T WT	B YD	H. I.	H %	M %	HRR	Total
DTF	**0.206**	–0.178	–0.165	0.077	0.03	–0.077	–0.007	–0.012	–0.069	0.19	–0.618	–0.043	0.102	–0.039	**–0.603**
DTM	0.173	**–0.213**	–0.125	0.049	0.026	–0.005	–0.004	–0.001	–0.025	0.264	–0.356	–0.01	0.063	–0.016	**–0.180**
P HT	0.149	–0.116	**–0.229**	0.104	0.027	–0.115	–0.013	–0.007	–0.089	0.209	–0.7	–0.059	0.12	–0.042	**–0.762**
T/PT	0.133	–0.088	–0.201	**0.119**	0.025	–0.123	–0.018	–0.005	–0.095	0.147	–0.674	–0.037	0.044	–0.018	**–0.790**
P LT	0.118	–0.107	–0.116	0.057	**0.053**	–0.023	–0.001	–0.009	–0.042	0.154	–0.344	–0.03	0.032	–0.015	**–0.273**
P WT	–0.095	0.006	0.157	–0.087	–0.007	**0.168**	0.017	0.015	0.09	0.047	0.656	0.065	–0.113	0.039	**0.957**
S/PAN	–0.065	0.034	0.14	–0.096	–0.003	0.131	**0.022**	0.003	0.055	0.011	0.517	0.039	–0.065	0.019	**0.744**
F SPK	–0.079	0.009	0.053	–0.018	–0.016	0.083	0.002	**0.03**	0.053	0.049	0.363	0.052	–0.102	0.031	**0.511**
T WT	–0.127	0.048	0.184	–0.101	–0.02	0.136	0.011	0.014	**–0.111**	0.037	0.661	0.069	–0.122	0.05	**0.876**
B YD	0.087	–0.124	–0.106	0.039	0.018	0.017	0.001	0.003	–0.009	**0.452**	–0.265	0.003	0.023	–0.006	**0.133**
HI	–0.164	0.098	0.206	–0.103	–0.023	0.142	0.015	0.014	–0.095	0.154	**0.777**	0.068	–0.138	0.046	**0.878**
H%	–0.099	0.024	0.151	–0.049	–0.017	0.122	0.01	0.018	0.087	0.014	0.596	**0.089**	–0.176	0.055	**0.822**
M%	–0.107	0.069	0.14	–0.027	–0.009	0.097	0.007	0.016	–0.069	0.053	0.545	0.08	**–0.196**	0.059	**0.690**
HRR	–0.125	0.054	0.15	–0.034	–0.013	0.102	0.007	0.015	–0.087	0.04	0.562	0.076	–0.182	**0.064**	**0.721**

Residual = 0.005234; The main diagonal **(bold)** is direct effects. DTF, Days to flowering; DTM, Days to maturity; PT HT, Plant height; T/PT, Effective tillers/plant; PLTH, Panicle length; PWT, Panicle weight; S/PAN, Number of spikelets/panicle; FSPK, Per cent filled spikelets; TWT, Test weight; BYD, Biological yield/plant; HI, Harvest index; H%, Hulling per cent; M%, Milling per cent; HRR, Head rice recovery per cent

et al. (2010) also reported a positive direct effect of panicle weight with grain yield. Number of spikelets/panicle and per cent filled spikelets even though having low direct effects, they had positive effect on grain yield mainly due to their indirect effects (0.517) and (0.363), respectively via harvest index. The direct effect of test grain weight was negative; however it exerted a high positive indirect effect mainly via harvest index (0.661) towards grain yield. Contrary to the present findings, positive direct effect of test weight was reported by Bagheri *et al.* (2011). Biological yield per plant although had the second highest direct effect (0.452) also had a negative indirect effect via harvest index and therefore, had low contribution towards grain yield. Harvest index having the highest direct effect (0.777) also had positive direct effect via plant height (0.206) and biological yield per plant. High direct effect of harvest index was also confirmed by Nandan *et al.* (2010). Even though, a low direct effect was recorded for hulling per cent, it had a high positive indirect effect via harvest index (0.596) followed by plant height and panicle weight. Relatively low negative indirect contribution of this character on grain yield was through milling per cent. Nandan *et al.* (2010) reported a positive direct effect of hulling per cent towards grain yield. Milling per cent though having negative direct effect yet, it had high positive indirect effect towards grain yield via harvest index (0.545). Similarly head rice recovery although having low direct effect, it had a high positive indirect effect via harvest index (0.562) and plant height (0.15) towards grain yield.

SUMMARY

The study suggest that panicle weight and test grain weight with highest indirect effect via harvest index while harvest index with its highest direct effect were the most influencing characters and hence, should form prominent components of selection index for enhancing grain yield.

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