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Evaluation of Indian Rice Varieties under Direct Seeded and Transplanted Rice Production Systems for Grain Yield and Quality Traits

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ABSTRACT

Direct seeded rice (DSR) require less labour, less water, less input and tend to mature earlier than transplanted rice (TPR). Low input cost in DSR system makes it better alternative than conventional transplanted system of growing rice. We evaluated twenty five rice varieties, developed for TPR system, belonging to different maturity groups and genetic background (basmati, non-basmati and hybrids), in DSR and TPR production system for grain yield, component traits and quality traits through character association and path analysis. The two experiments were laid out in RBD with three replication each at the experimental farm of the Rice Research Station, Haryana Agricultural University, Kaul during Kharif season (June-November) 2012. Plot size was kept at 2 x 0.20 x 5 m^2. Data were recorded on 5 randomly selected plants per genotypes per replication for 12 traits of grain yield and quality. The analysis of variance revealed significant differences amongst the genotypes for all the characters in both the systems. The magnitude of association of grain yield ranged from low (r=-0.32) with plant height to high (r = 0.412) with biological yield under DSR while it varied from low (r = -0.09) with milling percentage to high (r = 0.59) with biological yield under TPR production system. Grain yield significantly correlated with percent filled spikelets, days to maturity, 1000 grain weight and biological yield per plant in both the production systems.

Path analysis showed that harvest index had the maximum positive direct effect on grain yield followed by biological yield under DSR while under TPR system harvest index had positive direct effect on tillers/plant followed by 1000 grain weight and days to 50% flowering. Therefore, character association and path coefficient analysis are important selection indices to identify genotypes and traits which could be used to develop the varieties with higher grain yield and better quality for low cost DSR production system.

Key words: *Correlation coefficient, Low cost-DSR, Path coefficient, Rice and TPR.*

INTRODUCTION

Water crisis and escalating labour costs are threatening rice production. Because of low-input demand, direct seeded production system is an attractive alternative non-conventional technology for growing rice. In DSR system, plants are not pulled from the soil, hence not subjected to stress while re-establishing fine rootlets.

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Traditionally, rice is cultivated in high-input transplanted production system. It's both water consuming and labour intensive due to non-mechanized nature of Indian farming. With rapid industrialization and MNREGA (Mahatma Gandhi National Rural Employment Guarantee, Act), an Indian job guarantee scheme, the agricultural labour either migrating from rural areas to cities or engaged in non-agricultural work under guaranteed employment. This is resulting in non-availability of labour and its increasing costs besides, water being a scarce natural resource. All these concerns are forcing farmers to diversify cultivation to other crops or switch over to direct seeded rice cultivation, a low cost water saving technique demanding less labour. This DSR technique is in practice in several countries of Southeast Asia[19]. At present, 23% of rice is direct-seeded globally[25]. To meet current challenges of non-availability of labour, its increasing costs and water scarcity as well as to overcome stagnated production and low productivity, researchers have to devise alternative production system and evolve genetic materials suitable for the same.

None of the available varieties have been bred for direct seeded cultivation. Evaluation of genetic materials for grain yield and its components in alternative production system is the initial step in any breeding programme. Grain yield is a polygenic trait, highly influenced by environment and many soil factors, hence, direct selection for this character may often be misleading. Since the character association studies alone are not sufficient to depict the clear picture of association analysis, assessment of real contribution of individual character independent of environment towards the grain yield thus imperative. Path coefficient analysis is an important statistic to unravel a realistic picture of a complex situation that exists at correlation level. It quantifies the direct as well as indirect effects of one variable on the dependent variable via other traits. In agriculture, path analysis has been used by the plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield[10]. So, it could play a significant role in the evaluation of genetic materials.

The aim of present experiment was to evaluate 25 rice cultivars developed for conventional transplanting system (TPR) under DSR system and, investigate the influence of DSR production system on genetic parameters such as character association and, direct and indirect effect of yield component traits on grain yield and, to identify genotypes and traits which could be used directly and indirectly via hybridization to create materials for low cost direct seeding production system.

MATERIAL AND METHODS

The experimental materials consisted of twenty five genotypes of which 19 were released varieties and 6 advanced breeding lines belonging to different maturity groups and genetic background (basmati, non-basmati and hybrid). They were evaluated in two experiments during kharif season (June-November) 2012 at the experimental farm of rice research station, CCS Haryana Agricultural University campus, Kaul situated at latitude 29^0 51' N, longitude 76^0 39' E and altitude 230.87 m above msl. It falls in sub-tropical region of North India and is located in North Eastern part of Haryana, which is the heart of the rice-growing region, called 'Rice Bowl of Haryana'. The soil was clay loam. Of the two experiments, one of direct seeded and second of transplanting production systems were carried out in a randomized complete block design with three replications each. Plot size was kept at 2 x 0.20 x 5 m^2. Under direct-seeding, the seeds after priming for 24 hours were dibbled on 30 June, 2012 in the puddled soil in dry field in rows 20 cm apart at a seed rate of 25 kg/ha. The field was irrigated lightly immediately after sowing and again five days after sowing to ensure germination. Simultaneously, for transplanting sowing was done on raised nursery bed, the same day as for direct seeding. Seedlings were transplanted on 27 July, 2012 in the main field. One seedling per hill was maintained in a spacing of 15 cm. In direct seeded experiment thinning was carried out after two weeks to maintain one seedling per hill spaced at 15 cm. Hand weeding/hoeing twice at 30 and 50 DAS was also done to control weeds in direct seeding. After initial light irrigation at 0 and 5 DAS for germination, subsequent irrigations were applied at 10 days interval throughout the crop period, delaying the irrigation by one day with 1 cm of rainfall (if it occurred before irrigation). The irrigation was stopped 10 days prior to harvest. Fertilizers applications were given as per conventional method. In transplanting method, irrigation was given up to 5-cm depth one day after disappearance of ponded water for the crop growth period from planting till maturity. Phenotyping was done on 5 randomly selected plants per genotype per replication for 12 quantitative traits. The analysis of variance for different characters was done on the basis of the model described by Panse and Sukhatme[21]. Path coefficient was derived following the method proposed by Dewey and Lu[10].

RESULTS AND DISCUSSION

Influence of production systems in character association

The analysis of variance showed that the mean squares due to genotypes were significant ($P<0.01$) in both experiments for all quantitative character studied indicating that genotypes differed amongst themselves. Of the seventy two [n (n-1)/2] product moment coefficients (r) computed for 12 quantitative traits in each experiment , 48 values in transplanted and 30 under direct seeded production system were found to be statistically significant irrespective of their direction of association (Table 1 & 2). In general, magnitude of "r" was greater in TPR than DSR environment. Genotypic correlation coefficients were also greater than phenotypic correlation coefficient among all the trait combinations. This indicated that, even though there were inherent associations between the characters studied, the relationship between the traits was influenced highly by production system environment. The phenotypic correlation reflects observed relationship between traits (r_p). Those characters that showed genotypic correlation (r_g) with grain yield would be of limited use in direct selection for grain yield, since selection is usually based on phenotypic expression of the trait. The magnitude of association of grain yield with its component traits ranged from low (r = 0.069 to 0.699) under direct seeded production system while the range was greater (0.088 to 0.801) under transplanted production system.

The association of grain yield with its component traits further indicated that it was significantly positive and didn't differ for traits namely percent filled spikelets, days to maturity, 1000 grain weight and biological yield per plant under both the production systems. However, grain yield association with traits varied in production systems which was significantly positive in case of days to flowering, plant height and tillers per plant under TPR conditions and, harvest index and milling percent under DSR production system. It was significantly negative with plant height under DSR production system only while significantly positive under TPR. The negative association however, imposed problems in combining important yield components in one genotype. To overcome such constraints, suitable recombination through breaking undesirable linkages may be created by effecting bi-parental mating, mutation breeding or diallel selective mating. Hulling per cent, head rice recovery, days to flowering and tillers/plant under TPR and all quality parameters under DSR production system showed no association with grain yield. Pandya and Sarial[20] also reported significant positive association of grain yield with percent filled spikelets, 1000 grain weight, and biological yield per plant, harvest index, hulling percent, milling percent and head rice recovery percent. However, they also found significant negative association of grain yield with days to 50% flowering, plant height and effective tillers per plant. Yaqoob *et al*.[33] observed positive association of grain yield with tillers per plant in some Chinese hybrid rice under dry conditions. Several workers reported positive association of grain yield with number of effective tillers per plant, days to flowering and days to maturity[23,27]. Osman *et al*.[18] observed positive associations of grain yield with per cent filled spikelets and 1000 grain weight. Sravan *et al*.[29] reported positive association of grain yield/plant with harvest index, biological yield/plant, 1000 grain weight and percent filled spikelets in rainfed upland rice production system. Positive association of grain yield per plant and harvest index was also observed by Chakraborty *et al*.[9], grain yield with biological yield/plant by Girish *et al.*[12], grain yield with test grain weight by Akter *et al.*[3] and Vaithiyalingan and Nadarajan[30] and grain yield with percent filled spikelets by Nandan *et al.*[17] and Bagheri *et al.*[7]. Akhtar *et al*.[2] reported negative association of grain yield with plant height. Whereas, Girish *et al.*[12] and Eradasappa *et al.*[11] found positive association of grain yield with plant height.

Table 1: Phenotypic (below diagonal) & Genotypic (above diagonal) product moment coefficients among 12 quantitative characters in TPR production systems:

	DTF	DTM	PT HT	T/PT	F SPK	T WT	B YD	GY	H.I.	H %	M %	HRR
DTF	**1**	0.801	0.625	0.554	-0.665	-0.240	0.504	0.336	-0.353	-0.326	-0.508	-0.341
DTM	0.757**	**1**	0.827	0.473	-0.554	-0.175	0.583	0.324	-0.398	-0.408	-0.509	-0.310
PT HT	0.329**	0.310**	**1**	0.702	-0.347	-0.647	0.912	0.455	-0.684	-0.451	-0.696	-0.654
T/PT	0.315**	0.340**	0.173	**1**	-0.335	-0.523	0.439	0.736	-0.197	-0.228	-0.252	-0.195
F SPK	-0.368**	-0.298**	-0.056	-0.094	**1**	0.125	-0.512	0.129	0.467	0.636	0.691	0.405
T WT	-0.230*	-0.155	-0.314**	-0.314**	0.086	**1**	-0.394	0.100	0.501	-0.118	-0.024	0.237
B YD	0.486**	0.536**	0.517**	0.260*	-0.249*	-0.375**	**1**	0.629	-0.695	-0.326	-0.591	-0.354
GY	0.315**	0.267*	0.285*	0.385**	0.104**	0.088**	0.591**	**1**	0.001	0.064	-0.125	0.163
H.I.	-0.313**	-0.368**	-0.283*	-0.139	0.212	0.437**	-0.652**	0.025	**1**	0.504	0.681	0.547
H %	-0.301**	-0.385**	-0.074	-0.113	0.340**	-0.116	-0.299**	0.098	0.467**	**1**	0.854	0.656
M %	-0.468**	-0.460**	-0.337**	-0.104	0.354**	-0.030	-0.550**	-0.092	0.598**	0.801**	**1**	0.781
HRR	-0.335**	-0.284*	-0.375**	-0.081	0.216	0.227*	-0.345**	0.159	0.476**	0.583**	0.728**	**1**

*, **- significant at 5% and 1% level of significance, respectively

GY = Grain yield
B YD = Biological yield/plant
M % = Milling per cent
DTF = Days to flowering
H. I. = Harvest index
HRR = Head rice recovery per cent
DTM = Days to maturity
H % = Hulling per cent
PT HT = Plant height
F SPK = Per cent filled spikelets
T/PT = Effective tillers/plant
TWT= 1000 grain weight

Table 2: Phenotypic (below diagonal) & Genotypic (above diagonal) product moment coefficients among 12 quantitative characters in DSR production systems:

	DTF	DTM	PT HT	T/PT	F SPK	T WT	B YD	GY	H.I.	H %	M %	HRR
DTF	**1**	0.729	-0.390	-0.625	-0.458	-0.047	0.172	0.160	-0.095	-0.509	-0.429	0.128
DTM	0.699**	**1**	-0.227	-0.368	-0.339	-0.077	0.143	0.271	0.049	-0.674	-0.342	-0.000
PT HT	-0.369**	-0.228*	**1**	0.823	0.527	-0.366	0.314	-0.340	-0.632	0.205	-0.167	-0.164
T/PT	-0.418**	-0.224*	0.604**	**1**	0.499	-0.271	0.121	-0.141	-0.273	0.063	-0.167	-0.164
F SPK	-0.338**	-0.239*	0.355**	0.082	**1**	-0.165	0.125	0.077	-0.150	0.464	0.487	0.226
T WT	-0.065	-0.072	-0.325**	-0.203	-0.030	**1**	-0.021	0.388	0.341	0.202	0.227	0.181
B YD	0.153	0.125	0.299**	0.180	0.066	-0.001	**1**	0.420	-0.657	0.184	0.157	-0.067
GY	0.140	0.234*	-0.316**	-0.082	0.069**	0.350**	0.412**	**1**	0.391	0.176	0.360	0.125
H.I.	-0.096	0.031	-0.568**	-0.294**	-0.045	0.257*	-0.663**	0.364**	**1**	-0.035	0.237	0.266
H %	-0.408**	-0.552**	0.193	0.065	0.309**	0.170	0.146	0.127	-0.050	**1**	0.613	0.151
M %	-0.339**	-0.273*	-0.098	0.070	0.256*	0.140	0.114	0.299**	0.193	0.575**	**1**	0.287
HRR	0.130	0.005	-0.162	-0.211	0.192	0.188	-0.047	0.122	0.205	0.195	0.273*	**1**

*, **- significant at 5% and 1% level of significance, respectively

GY = Grain yield
B YD = Biological yield/plant
M % = Milling per cent
DTF = Days to flowering
H. I. = Harvest index
HRR = Head rice recovery per cent
DTM = Days to maturity
H % = Hulling per cent
PT HT = Plant height
F SPK = Per cent filled spikelets
T/PT = Effective tillers/plant
T WT = 1000 grain weight

Direct and indirect effects

Grain yield is a polygenic trait, highly influenced by environment as well as by many other traits, hence, direct selection for this character may often be misleading. Since the character association studies alone are not sufficient to depict the picture of association analysis clear, assessment of real contribution of individual character independent of environment towards the grain yield thus imperative. Path coefficient analysis is an important statistic to unravel a realistic picture of a complex situation that exists at correlation level. It quantifies the direct as well as indirect effects of one variable on the dependent variable via other traits.

We have considered here grain yield as main effect dependent variable. Rest of the eleven variables were considered as independent cause of the effect. Accordingly, the independent variables were days to 50 % flowering, days to maturity, plant height, number of effective tillers/plant, per cent filled spikelets, 1000 grain weight, biological yield per plant, harvest index, hulling per cent, milling per cent and head rice recovery per cent. The direct and indirect cause and effects data were presented in Table 3 for TPR and Table 4 for DSR production systems. The results obtained in two production systems were similar only for five of the twelve variables and different for others. Five variables that had similar trend in both the production systems were 1000 grain weight, biological yield per plant and hulling % with positive direct effect contribution while day to maturity and head rice recovery percent negative though the magnitude did vary.

With regards to differential response of variables, it was observed that under DSR production system, harvest index had contributed maximum positive direct effect on grain yield/plant followed by biological yield/plant, plant height and days to 50 % flowering. However, days to 50 % flowering had maximum positive indirect effect contribution on grain yield via biological yield (0.218) followed by effective tillers per plant (0.074) and maximum negative indirect effect which was mainly due to harvest index (-0.143) followed by plant height (-0.138). Grain test weight, hulling percent and percent filled spikelets recorded minimum positive direct effect. Head rice recovery percent exhibited the maximum negative direct effect on grain yield followed by days to maturity, tillers/plant and milling % while days to maturity had negative effect on grain yield via plant height (-0.080) and positive indirect effect through days to flowering (0.205) and biological yield/plot (0.181). Test weight had positive indirect effect on grain yield via harvest index (0.510) and negative effect via plant height (-0.129). Biological yield/plant had maximum positive effect via plant height (0.111) and maximum negative effect due to harvest index (-0.981) on grain yield. Harvest index had high positive direct effect on grain yield mainly due to negative indirect effect of biological yield (-0.832) followed by plant height (-0.223) and positive indirect via tillers per plant.

Under TPR production system, effective number of tillers per plant contributed maximum positive direct effect on grain yield followed by 1000 grain weight and biological yield and minimum positive direct effect by hulling and milling percent. While, harvest index recorded maximum negative direct effect on grain yield followed by head rice recovery percent, days to flowering and plant height. Days to 50 % flowering and days to maturity had negative effect contribution on grain yield due to indirect positive effect of tillers/plant (0.720, 0.614) followed by biological yield (0.459, 0.531) while indirect negative through milling percent (0.357, 0.358) followed by 1000 grain weight (0.288, 0.210), respectively. Per cent filled spikelets had contributed negative effect on grain yield mainly due to indirect negative effect of biological yield (-0.467) and tillers per plant (-0.436). These findings are parallel to those of Pandya and Sarial[20] who reported direct positive effect of biological/plant, percent filled spikelets, effective number of tillers/plant, harvest index and hulling percent, on grain yield/plant. They also found that days to maturity and plant height effect negatively the grain yield mainly via harvest index. Positive direct effect of days to flowering with yield was also confirmed by Patil and Sarawgi *et al.*[23] and Nandan *et al.*[17] under transplanted conditions. Negative direct effect of days to maturity on grain yield were reported by Abarshahr *et al.*[1] under optimum and stress irrigation regimes, while positive direct effect was reported by Watoo *et al.*[32]. Abarshahr *et al.*[1] reported a negative direct effect of plant height on grain yield/plant. Positive direct effect of effective tillers/plant under transplanted condition was also in agreement with the findings of Patil and Sarawgi[23] and Bagheri *et al.*[7] while, negative direct effect under direct seeded condition was in agreement with those of Akhtar *et al.*[2]. Many researchers reported positive direct effect of per cent filled spikelets on grain yield[4,7]. Osman *et al.*[18] found similar results in DSR conditions. Positive direct effect of 1000 grain weight was divulged by Patil and Sarawgi[23] and Bagheri *et al.*[7]. Osman *et al.*[18] and Akhtar *et al.*[2] reported similar findings under DSR conditions. Sravan *et al.*[29] found positive direct effect of biological yield/plant on grain yield/plant. Positive direct effect of harvest index on grain yield/plant under DSR conditions was observed by Sravan *et al.*[29]. Relatively low negative indirect contribution of hulling percent on grain yield was through milling per cent reported under DSR production system. Nandan *et al.*[17] reported a positive direct effect of hulling per cent towards grain yield.

The study thus revealed that character association and contribution of independent variables on dependent grain yield varied in production systems. In conventional transplanted production system water crisis and escalating labour costs are threatening rice production thus; non-conventional direct seeded technology is becoming an alternative choice. Evaluation of TPR cultivars in DSR and the later influence on genetic parameters indicated differential improvement strategy and traits those should form components of selection index for evolving varieties. Harvest index and biological yield under DSR while tillers/plant and 1000 grain weight under TPR production system found to be prominent yield contributing variables. So, these traits should form the basis of selection index for enhancing grain yield.

Table 3: Direct and indirect effects on grain yield of its components and other yield contributing characters in TPR production systems:

	DTF	DTM	PT HT	T/PT	F SPK	T WT	B YD	H.I.	H %	M %	HRR
DTF	**-0.193**	-0.128	-0.035	0.720	0.083	-0.288	0.459	0.136	-0.176	-0.357	0.115
DTM	-0.154	**-0.160**	-0.046	0.614	0.069	-0.210	0.531	0.154	-0.221	-0.358	0.105
PT HT	-0.120	-0.132	**-0.055**	0.912	0.043	-0.775	0.831	0.264	-0.244	-0.489	0.221
T/PT	-0.107	-0.076	-0.039	**1.300**	0.042	-0.626	0.400	0.076	-0.123	-0.177	0.066
F SPK	0.128	0.089	0.019	-0.436	**-0.124**	0.149	-0.467	-0.180	0.344	0.486	-0.137
T WT	0.046	0.028	0.036	-0.679	-0.015	**1.197**	-0.359	-0.193	-0.064	-0.017	-0.080
B YD	-0.097	-0.093	-0.051	0.570	0.064	-0.471	**0.911**	0.269	-0.176	-0.416	0.119
H.I.	0.068	0.064	0.038	-0.257	-0.058	0.599	-0.634	**-0.386**	0.272	0.479	-0.184
H %	0.063	0.065	0.025	-0.297	-0.079	-0.142	-0.297	-0.195	**0.541**	0.600	-0.221
M %	0.098	0.082	0.039	-0.328	-0.086	-0.029	-0.539	-0.263	0.462	**0.703**	-0.263
HRR	0.066	0.050	0.036	-0.254	-0.050	0.284	-0.323	-0.211	0.355	0.549	**-0.337**

Residual = 0.17501

The main diagonal (bold) is direct effects

DTF = Days to flowering B YD = Biological yield/plant HRR = Head rice recovery per cent
DTM = Days to maturity H. I. = Harvest index
PT HT = Plant height H % = Hulling per cent
T/PT = Effective tillers/plant F SPK = Per cent filled spikelets
T WT = 1000 grain weight M % = Milling per cent

Table 4: Direct and indirect effects on grain yield of its components and other yield contributing characters in DSR production systems:

	DTF	DTM	PT HT	T/PT	F SPK	T WT	B YD	H.I.	H %	M %	HRR
DTF	**0.280**	-0.109	-0.138	0.074	-0.001	-0.002	0.218	-0.143	-0.004	0.011	-0.027
DTM	0.205	**-0.150**	-0.080	0.044	-0.001	-0.003	0.181	0.073	-0.006	0.009	0.000
PT HT	-0.109	0.034	**0.353**	-0.098	0.001	-0.017	0.398	-0.944	0.002	0.004	0.034
T/PT	-0.175	0.055	0.290	**-0.119**	0.001	-0.012	0.153	-0.408	0.001	0.000	0.072
F SPK	-0.128	0.051	0.186	-0.059	**0.003**	-0.007	0.159	-0.225	0.004	-0.012	-0.047
T WT	-0.013	0.011	-0.129	0.032	0.000	**0.045**	-0.026	0.510	0.002	-0.006	-0.038
B YD	0.048	-0.021	0.111	-0.014	0.000	-0.001	**1.267**	-0.981	0.002	-0.004	0.014
H.I.	-0.027	-0.007	-0.223	0.032	0.000	0.015	-0.832	**1.494**	0.000	-0.006	-0.056
H %	-0.143	0.101	0.072	-0.007	0.001	0.009	0.234	-0.053	**0.009**	-0.015	-0.032
M %	-0.120	0.051	-0.059	0.002	0.001	0.010	0.199	0.355	0.005	**-0.025**	-0.060
HRR	0.036	0.000	-0.058	0.041	0.001	0.008	-0.085	0.397	0.001	-0.007	**-0.209**

Residual = 0.00138

The main diagonal (bold) is direct effects

DTF = Days to flowering
DTM = Days to maturity
PT HT = Plant height
T/PT = Effective tillers/plant
T WT = 1000 grain weight
B YD = Biological yield/plant
H. I. = Harvest index
H % = Hulling per cent
F SPK = Per cent filled spikelets
M % = Milling per cent
HRR = Head rice recovery per cent

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