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Revealing Genetic Variability and Trait Association Studies in Landraces of Rice (*Oryza sativa* L.) Under Controlled and Drought Conditions

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A B S T R A C T

Sixty four landraces were evaluated for 10 yield and its component traits. Analysis of variance showed significant difference among the genotypes to all the characters under both control and low-moisture stress condition. Environmental influence was meagre on expression of characters as evidenced by narrow gap between GCV and PCV for most of the characters. The grain yield had positive and significant association with days to 50 per cent flowering and days to maturity under control condition, while test weight, number of tiller per plant, number of productive tiller per plant, number of spikelet per panicle and per cent spikelet fertility both under control and low-moisture stress conditions at phenotypic level as well as genotypic level. Hence, indirect selection for grain yield could be effectively done through direct selection of yield component characters as indicated above.

Introduction

Rice (*Oryza sativa* L.) is a highly domesticated crop, and domestication processes are reported to be accompanied by genetic erosion, which causes a reduction in genetic diversity among traditional varieties and gradual loss of landraces from the fields (Brush, 2000). An exhaustive survey of genetic variability and detailed understanding of genetic makeup of the crop is an important prerequisite for initiating crop improvement programme. The variability observed in any population could be due to the genetic and environment factors and also due to interaction between these factors. The genetic and environmental components of variation were discussed by Johannsen (1909) who attributed the variation in a segregating population to heritable and non-heritable factors, while the variation within pure lines was attributed to environmental factors. The heritable variations could be further divided into additive and non-additive components. The heritable variations are also divided into dominant and inter-allelic interaction

(Falconer, 1981). The broad sense heritability is the ratio of genotypic variance to the total variance in non-segregating population (Lush, 1945 and Hanson *et al.,* 1956). The genotypic variance includes non-additive components which are not transmitted to next generation. Hence high heritability coupled with high genetic advance was reported to be more useful in practicing selection in a population (Johnson *et al.,* 1955). It is essential to know the degree of mutual association prevailing between yield and its component traits, which forms the basis for selecting desirable genotypes. Correlation studies among these will provide an opportunity to quantify the magnitude and direction of their association along with other direct and indirect components. A study of Correlation and path analysis will thus help in identifying suitable selection criteria for improving yield. Hence the present study was undertaken to assess the variability, correlation and path coefficients in selected landraces of rice.

Materials and Methods

The material for the present study consisted of 64 traditional rice genotypes drawn from the rice germplasm maintained at Organic Farm Research Centre, Zonal Agricultural Research Station, Navile, Shimoga. The investigation was carried out at Organic Farm Research Centre, Navile, Shimoga and University of Agricultural Sciences (UAS), Bangalore. The rice genotypes included in the study were of diverse nature mentioned in Appendix I. The crop for the present investigation was raised in field as well as PVC pipes during *Rabi* season 2012-2013. The experiment was laid out in 8 x 8 Simple Lattice Design. For this design all 64 traditional genotypes were arranged in 8 columns and 8 rows with two replications under control and low-moisture stress condition. Low-moisture stress was imposed by withholding the irrigations from 30 days after transplanting to harvesting and the plants were given lifesaving irrigations only when they showed wilting symptoms, whereas in control plot regular irrigations were given without creating any stress. The spacing maintained was 30 cm between rows and 20 cm between plants within a row and other recommended agronomic practices were adapted to raise the crop. Five plants were selected at random from each entry in the replications for recording the observation on 10 metric characters. The averages of observations recorded on these five plants were considered for statistical analysis. The characters on which observations were recorded as per Standard evaluation system for rice (SES 1996) are Days to 50 per cent flowering, Days to maturity, Plant height (cm), 1000-grain weight (g), Number of tillers per plant, Number of productive tillers per plant (Number of panicles), Number of spikelet per panicle, Per cent spikelet fertility, Grain yield per plant (g), The data of mean value for all the characters were analyzed for their variance following simple lattice design outlined by Cochran and Cox (1957). Correlation coefficients were computed as suggested by Snedecor and Cochran, (1965) and direct and indirect effects of yield components on yield were computed through path coefficient analysis as suggested by Dewey and Lu (1959) using WINDOSTAT software.

Results and Discussion

Variability and genetic parameter

The analysis of variance revealed highly significant difference among the germplasm accessions for all the traits indicating a large amount of variability was present in the set of material for effective selection (Table 1). Earlier workers like Abarshahr *et al.,* (2011) and Osman *et al.,* (2012) have reported the significant differences among the genotypes for all the characters they considered. The

estimates of mean and range for all 10 quantitative traits were indicated in table 2. The magnitude of phenotypic and genotypic coefficient of variations (PCV and GCV) was higher for yield and yield attributing traits but the difference is very less indicates the presence of environmental influence to some degree in the phenotypic expression of the traits (Table 2). The phenotypic and genotypic coefficient of variations were found very high for Grain yield/plant, followed by number of productive tillers per plant in both controlled and drought conditions. These results are in conformity with the findings of earlier workers Nagabhushan (2003) and Pandey *et al.,* (2012). Whereas lowest PCV and GCV were recorded for Days to maturity and Days to fifty percent flowering in both controlled and drought condition. Madhusudhan (2001) also reported the similar results. The occurrence of low estimates of PCV and GCV indicated that selection directly based on these traits would not be much rewarding. The estimates of PCV were slightly higher than corresponding GCV for all the characters under study. Remabai *et al.,* (1992) reported higher phenotypic coefficient of variation for all yield attributing parameters than genotypic coefficient of variation. Das *et al.,* (2001) and Pandey *et al.,* (2012) also noticed higher PCV than their respective GCV for all the traits studied by them.

The high estimates of heritability in broad sense with high genetic advance in per cent mean were observed for plant height, test weight, number of spikelet per panicle, per cent spikelet fertility and grain yield in both control and low-moisture stress condition, while for number of tillers per plant in low-moisture stress and for number of productive tillers per plant in control condition (Table 2).

Similar results were obtained for plant height, test weight, number of spikelets per panicle and grain yield by Das *et al.,* (2001) and Kuldeep *et al.,* (2004) reported high heritability coupled with high genetic advance for yield components, Mall *et al.,* (2005) reported high heritability and genetic advance for plant height, number of tillers per plant and number of spikelet per panicle.

Correlation

The result pertaining to correlation at phenotypic and genotypic levels between grain yield and other related characters are presented first fallowed by correlation among the characters under both control and low-moisture stress conditions. Significant and positive association at phenotypic and genotypic level under control condition was found between grain yield with days to 50% flowering (r=0.255; 0.281), days to maturity (0.334; 0.384), 1000-grain weight (g) (0.399; 0.470), number of tillers per plant (0.359; 0.343), number of productive tillers per plant (0.515; 0.536), number of spikelet per panicle (0.394; 0.403) and per cent spikelet fertility (0.441; 0.432) respectively (Tables 3 and 4). Other yield components, *viz.,* plant height, and panicle length showed non-significant positive association, Under low-moisture stress condition significant and positive association at phenotypic and genotypic level was found between grain yield with 1000-grain weight (g) (0.250; 0.261), number of tillers per plant (0.377; 0.371), number of productive tillers per plant (0.406; 0.389), number of spikelet per panicle (0.391; 0.400), per cent spikelet fertility (0.574; 0.588) respectively, whereas panicle length showed non-significant positive association. On the contrary plant height (-0.175;-0.209) had significantly negative association with grain yield at both the levels. Other yield components, *viz.,* days to 50 % flowering, days to maturity showed non-significant negative association with grain yield (Tables 3 and 4). In general, the genotypic correlation co-efficient were found to be higher than their respective phenotypic correlation coefficients.

Table.1 Analysis of variance for yield and its component characters in traditional rice genotypes evaluated under control and Low-moisture stress condition

Source of variation	df	Days to 50% flowering		Days to maturity		Plant height(cm)		Panicle length (cm)		Test weight	
		C	S	C	S	C	S	C	S	C	S
Replication	**1**	**0.03**	**31.00**	**1.53**	**116.28**	**82.74**	**63.18**	**23.49**	**29.85**	**0.007**	**13.78**
Genotypes (unadjusted)	**63**	**97.98****	**86.08****	**213.16****	**104.93****	**314.61****	**161.05****	**12.25****	**8.32****	**26.04****	**23.57****
Blocks within adjusted	**14**	**4.66**	**8.30**	**12.04**	**8.41**	**9.74**	**7.39**	**3.32**	**2.21**	**0.91**	**0.95**
Error intra block	**49**	**7.97**	**6.31**	**7.91**	**7.07**	**6.00**	**5.94**	**2.21**	**1.31**	**1.93**	**1.28**
CD (5%)		**5.20**	**5.18**	**5.86**	**5.44**	**5.13**	**5.00**	**3.16**	**2.40**	**2.42**	**2.18**
CV (%)		**2.60**	**2.86**	**2.05**	**2.099**	**3.85**	**4.62**	**10.00**	**8.65**	**6.016**	**5.85**

Source of variation	df	No. of Tiller/plant		No. of Productive Tiller/plant		No. of spikelet per panicle		Per cent of spikelet fertility		Grain yield (g)/plant	
		C	S	C	S	C	S	C	S	C	S
Replication	**1**	**29.24**	**53.24**	**36.99**	**10.90**	**0.15**	**7.94**	**30.88**	**1.56**	**39.32**	**5.89**
Genotypes (unadjusted)	**63**	**28.63****	**52.26****	**20.18***	**22.59****	**707.27****	**463.63****	**122.35****	**331.69****	**39.96****	**26.12****
Blocks within adjusted	**14**	**2.74**	**2.00**	**1.55**	**1.54**	**12.41**	**7.15**	**2.62**	**6.50**	**2.76**	**1.00**
Error intra block	**49**	**3.42**	**1.98**	**2.52**	**1.59**	**18.60**	**9.44**	**15.00**	**7.38**	**2.92**	**1.28**
CD (5%)		**3.61**	**2.83**	**2.96**	**2.52**	**8.17**	**5.95**	**8.17**	**5.37**	**3.41**	**2.20**
CV (%)		**10.43**	**8.62**	**11.78**	**10.89**	**4.55**	**3.53**	**5.07**	**5.45**	**11.70**	**12.23**

C- Control; S- moisture Stress

Table.2 Estimates of range, mean, variability, heritability and genetic advance for yield and its component characters in traditional Rice genotypes evaluated under control and low-moisture stress condition

	CHARACTERS	MEAN ± SE		RANGE		PCV (%)		GCV (%)		h^2 broad sense(%)		GAM (%)	
		C	S	C	S	C	S	C	S	C	S	C	S
1	**Days to 50% flowering**	99.59±2.59	90.16±2.57	80.50-115.50	75.50-105.00	9.93	7.55	9.52	6.98	91.86	85.45	18.44	13.30
2	**Days to maturity**	141.93±2.91	128.96±2.7	116.5-169.5	110.00-149.00	7.42	5.81	7.12	5.41	92.04	86.87	14.07	10.39
3	**Plant height (cm)**	66.21±2.55	53.82±2.49	39.75-97.33	30.75-73.00	19.14	16.99	18.73	16.34	95.75	92.51	37.76	32.38
4	**Panicle length (cm)**	15.42±1.54	13.83±1.19	11.83-20.66	9.25-20.08	17.58	16.03	14.34	13.33	66.52	69.21	24.09	22.86
5	**Test weight(g)**	20.07±1.20	18.57±1.08	13.00-36.00	12.00-34.50	18.55	18.94	17.38	17.99	87.70	90.24	33.53	35.22
6	**No. of tillers per plant**	17.23±1.79	16.33±1.40	7.33-29.00	4.66-28.25	23.17	31.88	20.66	30.69	79.50	92.68	37.95	60.87
7	**No. of Productive tillers per plant**	12.52±1.47	11.54±1.25	5.50-23.25	5.08-20.25	26.78	30.12	23.87	28.08	79.43	86.92	43.82	53.93
8	**No. of spikelet per panicle**	89.33±4.06	83.91±2.96	57.08-150.58	46.83-121.16	21.30	18.31	20.79	17.96	95.24	96.22	41.80	36.30
9	**Per cent of spikelet fertility**	76.31±4.06	49.02±2.67	60.94-93.84	29.26-80.52	10.74	26.55	9.721	25.98	81.79	95.76	18.11	52.38
10	**Grain yield (g)/plant**	14.52±1.70	8.93±1.09	7.96-30.60	2.85-22.32	31.87	41.18	29.64	39.29	86.50	91.04	56.78	77.23

Table.3 Estimates of phenotypic correlation for yield and root related traits under control and low-moisture stress condition

Traits	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	1	0.543**	0.341**	0.157	-0.194*	0.274**	0.338**	0.296**	0.202*	-0.079	-0.180*	-0.232**	-0.070	0.255**
X2	0.601**	1	0.283**	-0.010	-0.170	0.324**	0.461**	0.363**	0.185*	0.083	-0.250**	-0.222*	-0.162	0.334**
X3	-0.042	-0.185*	1	0.451**	-0.041	0.312**	0.168	-0.008	0.042	0.055	-0.084	0.006	-0.080	0.079
X4	-0.025	-0.271**	0.448**	1	0.112	-0.074	-0.144	0.073	0.263**	0.122	-0.029	0.175*	-0.142	0.138
X5	-0.047	-0.154	0.004	0.106	1	-0.056	-0.086	-0.298**	-0.084	0.183*	0.062	0.152	0.073	0.399**
X6	-0.026	0.109	-0.253**	-0.087	-0.101	1	0.793**	0.004	0.113	0.015	-0.056	-0.082	0.064	0.359**
X7	-0.079	0.088	-0.228**	-0.079	-0.115	0.807**	1	0.219*	0.182*	0.121	-0.131	-0.167	0.047	0.515**
X8	0.116	0.310**	-0.133	0.114	-0.280**	0.013	0.044	1	0.153	-0.005	-0.142	-0.197*	-0.153	0.394**
X9	0.173*	-0.060	-0.044	0.147	0.036	-0.087	-0.068	0.156	1	0.107	-0.142	-0.008	-0.155	0.441**
X10	-0.066	-0.063	-0.137	-0.137	0.149	0.163	-0.021	-0.005	0.085	1	0.094	0.322**	0.333**	0.137
X11	-0.262**	-0.287**	0.015	-0.006	0.091	-0.044	-0.055	-0.025	-0.015	0.107	1	0.643**	0.588**	-0.135
X12	-0.119	-0.068	0.004	-0.012	0.087	-0.046	-0.074	-0.096	0.008	0.273**	0.631**	1	0.575**	-0.106
X13	-0.205*	-0.080	-0.052	-0.127	0.082	0.064	0.058	-0.052	0.026	0.308**	0.466**	0.598**	1	-0.087
X14	-0.060	-0.029	-0.175*	0.147	0.250**	0.377**	0.406**	0.391**	0.574**	0.144	0.066	0.016	0.045	1

**Significance at 1 %, *Significance at 5 % (Above diagonal control; below diagonal low-moisture stress).

Where,

X_1 - Days to 50 per cent flowering
X_2 - Days to maturity
X_3 - Plant height
X_4 - Panicle length(cm)
X_5 -1000-grain weight (g)
X_6 - No. of tiller per plant
X_7- No. of productive tiller per plant
X_8- No. of spikelet per panicle
X_9- Per cent of spikelet fertility
X_{10} - Root length (cm)
X_{11}- Root number
X_{12}- Root volume(cc)
X_{13}- Dry root weight (g)
X_{14}- Grain yield (g) per plant

Table.4 Estimates of genotypic correlation for grain yield and root related traits under control and low-moisture stress condition

Traits	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	1	0.561**	0.358**	0.213*	-0.221*	0.317**	0.407**	0.318**	0.239**	-0.085	-0.199*	-0.258**	-0.093	0.281**
X2	0.643**	1	0.295**	0.009	-0.172	0.365**	0.539**	0.402**	0.226**	0.085	-0.260**	-0.236**	-0.177*	0.384**
X3	-0.035	-0.181*	1	0.539**	-0.039	0.330**	0.163	-0.017	0.035	0.053	-0.097	0.001	-0.109	0.045
X4	0.005	-0.317**	0.499**	1	0.186*	-0.178*	-0.392**	0.007	0.256**	0.136	-0.059	0.227**	-0.205*	0.082
X5	-0.047	-0.123	-0.015	0.116	1	-0.047	-0.088	-0.317**	-0.089	0.209*	0.068	0.166	0.082	0.470**
X6	0.009	0.165	-0.314**	-0.226*	-0.149	1	0.859**	-0.018	0.116	0.011	-0.081	-0.098	0.069	0.343**
X7	-0.064	0.150	-0.280**	-0.139	-0.161	0.844**	1	0.230**	0.186*	0.131	-0.175*	-0.198*	0.027	0.536**
X8	0.131	0.330**	-0.136	0.110	-0.300**	0.017	0.045	1	0.138	-0.001	-0.141	-0.199*	-0.154	0.403**
X9	0.198*	-0.056	-0.055	0.203*	0.025	-0.093	-0.078	0.163	1	0.102	-0.167	-0.011	-0.182*	0.432**
X10	-0.081	-0.080	-0.142	-0.167	0.171	0.178*	-0.020	-0.002	0.105	1	0.089	0.324**	0.337**	0.141
X11	-0.273**	-0.306**	0.016	0.001	0.091	-0.048	-0.065	-0.023	-0.011	0.106	1	0.646**	0.597**	-0.169
X12	-0.129	-0.067	0.001	-0.036	0.091	-0.051	-0.081	-0.097	0.012	0.271**	0.643**	1	0.589**	-0.123
X13	-0.220**	-0.093	-0.047	-0.218*	0.090	0.048	0.050	-0.062	0.049	0.317**	0.487**	0.635**	1	-0.131
X14	-0.053	-0.016	-0.209*	0.136	0.261**	0.371**	0.389**	0.400**	0.588**	0.163	0.073	0.014	0.054	1

** Significance at 1 %, * Significance at 5 % (above diagonal control; below diagonal low-moisture stress).

Where,

X_1 - Days to 50 per cent flowering
X_2 - Days to maturity
X_3 - Plant height
X_4 - Panicle Length(cm)
X_5 -1000-grain weight (g)
X_6 - No. of tiller per plant
X_7- No. of productive tiller per plant
X_8- No. of spikelet per panicle
X_9- Per cent of spikelet fertility
X_{10} - Root length (cm)
X_{11}- Root number
X_{12}- Root volume (cc)
X_{13}- Dry root weight (g)
X_{14}- Grain yield (g) per plant

Table.5 Estimates of direct and indirect effects of yield components on grain yield at phenotypic level under control condition

Traits	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1	0.014	0.007	0.004	0.002	-0.002	0.003	0.004	0.004	0.002	-0.001	-0.002	-0.003	-0.001
X2	0.018	0.033	0.009	-0.004	-0.005	0.010	0.015	0.012	0.006	0.002	-0.008	-0.007	-0.005
X3	0.005	0.004	0.001	0.006	-0.001	0.004	0.002	0.000	0.001	0.001	-0.001	0.000	-0.001
X4	0.001	-0.001	0.004	0.010	0.001	-0.008	-0.001	0.007	0.002	0.001	-0.003	0.002	-0.001
X5	-0.118	-0.104	-0.025	0.068	0.610	-0.034	-0.053	-0.181	-0.051	0.112	0.038	0.092	0.044
X6	0.018	0.021	0.021	-0.005	-0.003	0.067	0.053	0.003	0.007	0.001	-0.003	-0.005	0.004
X7	0.114	0.156	0.057	-0.048	-0.029	0.269	0.339	0.074	0.602	0.041	-0.044	-0.056	0.016
X8	0.126	0.154	-0.003	0.031	-0.126	0.001	0.093	0.425	0.065	-0.002	-0.060	-0.084	-0.065
X9	0.072	0.065	0.015	0.093	-0.029	0.040	0.064	0.054	0.354	0.038	-0.050	-0.002	-0.055
X10	0.003	-0.003	-0.002	-0.005	-0.008	-0.007	-0.005	0.000	-0.004	-0.045	-0.004	-0.014	-0.015
X11	-0.005	-0.008	-0.002	-0.001	0.002	-0.001	-0.004	-0.004	-0.004	0.003	0.031	0.020	0.018
X12	0.010	0.010	-0.003	-0.008	-0.006	0.003	0.007	0.009	0.004	-0.014	-0.029	-0.045	-0.026
X13	0.001	0.003	0.002	0.003	-0.001	-0.001	-0.001	0.003	0.003	-0.007	-0.001	-0.001	-0.002
r value	0.255	0.334	0.079	0.137	0.398	0.357	0.515	0.393	0.443	0.138	-0.137	-0.105	-0.083

Residual effect=0.471

Where,

X_1 - Days to 50 per cent flowering
X_2 - Days to maturity
X_3 - Plant height
X_4 - Panicle Length(cm)
X_5 -1000-grain weight (g)
X_6 - No. of tiller per plant
X_7- No. of productive tiller per plant
X_8- No. of spikelet per panicle
X_9- Per cent of spikelet fertility
X_{10} - Root length (cm)
X_{11}- Root number
X_{12}- Root volume (cc)
X_{13}- Dry root weight (g)

Table.6 Estimates of direct and indirect effects of yield components on grain yield at phenotypic level under low-moisture stress condition

Traits	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1	-0.150	-0.090	0.006	0.003	0.007	0.004	0.012	-0.017	-0.026	0.010	0.039	0.018	0.031
X2	-0.014	-0.023	0.004	0.006	0.003	-0.002	-0.002	-0.007	0.001	0.001	0.006	0.001	0.001
X3	-0.001	-0.004	0.022	0.010	0.001	-0.005	-0.005	-0.003	-0.001	-0.003	0.004	0.001	-0.001
X4	0.004	0.004	-0.007	-0.010	-0.001	0.001	0.001	-0.001	-0.002	0.002	0.001	0.002	0.002
X5	-0.018	-0.061	0.001	0.042	0.398	-0.040	-0.046	-0.116	0.014	0.059	0.036	0.034	0.033
X6	-0.006	0.028	-0.065	-0.022	-0.025	0.256	0.206	0.003	-0.022	0.041	-0.011	-0.011	0.016
X7	-0.021	0.024	-0.062	-0.021	-0.031	0.219	0.272	0.012	-0.018	-0.005	-0.015	-0.020	0.016
X8	0.050	0.134	-0.057	0.049	-0.121	0.005	0.019	0.432	0.067	-0.002	-0.011	-0.041	-0.022
X9	0.097	-0.034	-0.025	0.082	0.020	-0.049	-0.038	0.088	0.563	0.047	-0.008	0.004	0.015
X10	-0.001	-0.001	-0.002	-0.002	0.002	0.003	0.000	0.000	0.001	0.001	0.002	0.004	0.005
X11	-0.008	-0.009	0.005	-0.002	0.003	-0.001	-0.001	-0.008	-0.005	0.003	0.032	0.020	0.015
X12	-0.008	-0.004	0.003	-0.009	0.006	-0.003	-0.005	-0.007	0.006	0.019	0.045	0.072	0.043
X13	0.021	0.008	0.005	0.013	-0.008	-0.006	-0.006	0.005	-0.002	-0.032	-0.048	-0.062	-0.104
r value	-0.060	-0.028	-0.175	0.148	0.248	0.375	0.402	0.391	0.574	0.144	0.067	0.016	0.045

Residual effect=0.444

Where,

X_1 - Days to 50 per cent flowering
X_2 - Days to maturity
X_3 - Plant height
X_4 - Panicle Length(cm)
X_5 -1000-grain weight (g)
X_6 - No. of tiller per plant
X_7- No. of productive tiller per plant
X_8- No. of spikelet per panicle
X_9- Per cent of spikelet fertility
X_{10} - Root length (cm)
X_{11}- Root number
X_{12}- Root volume (cc)
X_{13}- Dry root weight (g)

Appendix.1 List of 64 traditional rice genotypes are taken for investigation

Sl. No	GENOTYES	Sl. No	GENOTYES
1	DODDAMULLARE	33	ANDRABASUMATHI
2	CHINA-988*	34	HMT
3	SKAU-98*	35	KOUGISAALE
4	K-336*	36	CHINANAPUNNI
5	SKAU-23*	37	BI-33*
6	MGD-101*	38	NMS-2*
7	CH-1007*	39	BADASHIPARIMALAKKI
8	WAZULKREER	40	MATTAKHARA
9	JAYA199*	41	ABHILASHA
10	SRI-214*	42	NAVALAISAALE
11	KYASARI-202*	43	MUKKANNA
12	UMA-213*	44	ATHNALU
13	SALAMSANNA	45	MYSORE MALLIGE
14	SK339*	46	BANGARADAGUNDU
15	ZADAGI	47	BANGLARICE
16	SKAU-334*	48	ELATAGYAGIDDA
17	CHAMPAKALI	49	BANGARU SANNA
18	J-192*	50	JEERISANNA
19	BANAVASISELECTION	51	PADMAREKHA
20	ASHOKA-228F*	52	KUSHIADIKSHAM
21	JEERGA	53	IR-64*
22	ANEKOMBINABATTA	54	AZUCENA
23	HUGGIBHATTA	55	MALLIGE
24	SALAMBATTIBHARA	56	KICHADISAAMBA
25	DAPPA BATTA	57	BASUMATHI
26	KH-10/NMS-2*	58	BURMABLACK
27	KAGGA	59	DELHIBASUMATHI
28	KUDUVEKALANJI	60	DODDIGA
29	GOWRISANNA	61	KADUVALAI
30	MADILAISAAMBA	62	KARIMUNDAGA
31	INTIN	63	SAMPIGE
32	KEMPUKHARU	64	DODDIBHATTA

* Improved lines/varieties used as checks

This was in conformity with the findings of Shashidhar *et al.,* (2005) and Muthuramu *et al.,* (2010). Hence, indirect selection for grain yield could be effectively done through direct selection of yield component characters as indicated above.

Direct and indirect effects

Ten out of 14 characters had positive and direct effect on grain yield at phenotypic level under control condition. The characters which had positive direct effects are days to 50 percent flowering (0.014), days to maturity (0.033), plant height (0.001), panicle length (0.010), 1000-grain weight (0.610), number of tillers per plant (0.067), number of productive tillers per plant (0.339), number of spikelet per panicle (0.425), per cent spikelet fertility (0.354) and root number (0.031). Other characters *viz.,* root length (-0.045), root volume (-0.045) and dry root weight (-0.002) had negative direct effects on grain yield (Table 5). Nine out of 14 characters had positive and direct effect on grain yield at phenotypic level under low-moisture stress condition. The characters which had positive direct effects are plant height (0.022), 1000-grain weight (0.398), number of tillers per plant (0.256), number of productive tillers per plant (0.272), number of spikelet per panicle (0.432), per cent spikelet fertility (0.563), This result agrees with the research findings of Yogameenakshi *et al.,* (2004) and Panwar *et al.,* (2007). Other characters *viz.,* days to 50 per cent flowering (-0.150), days to maturity (-0.023), panicle length (-0.010) and dry root weight (-0.104) had negative direct effects on grain yield (Table 6). 1000-grain weight (0.610) in control and per cent spikelet fertility (0.563) in low-moisture stress condition had the highest positive direct effect, the forgone discussion on path coefficient analysis has clearly demonstrated that due weightage to days to 50 per cent flowering, plant height, test weight, number of productive tiller per plant, per cent spikelet fertility, are helpful in increasing the grain yield in rice through selection under low-moisture stress conditions. The residual effect (0.47 in control and 0.44 in low-moisture stress) was low, indicating that much of the variation in yield has been accounted by the characters studied and that the choice of characters was appropriate.

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