Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(4): 1953-1956
Received: 08-05-2020
Accepted: 10-06-2020

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Genetic variability, character association and path analysis studies for yield components traits in promising rice (*Oryza sativa* L.) genotypes

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Abstract
Nineteen promising rice genotypes were evaluated for variability, correlation and path analysis for yield and yield component traits. High genetic advance as per cent of mean was observed for plant height and grain yield per plant. High estimates of heritability were recorded for days to 50% flowering, plant height, panicle length, productive tillers per plant, spikelets per panicle, spikelet fertility and grain yield per plant. Character associations revealed a positive and significant association of grain yield with days to 50% flowering, plant height, panicle length, productive tillers per plant, the number of spikelets per panicle, spikelet fertility and test weight. Significant and positive association of plant height with panicle length and test weight; panicle length with spikelets per panicle and spikelets fertility; productive tillers per plant with spikelets per panicle, spikelets fertility and test weight; spikelets per panicle with spikelets fertility and test weight; spikelets fertility with test weight indicating a scope for simultaneous improvement of these traits through selection. The path analysis revealed a high positive direct effect of spikelet fertility, moderate positive direct effect of productive tillers per plant and spikelets per panicle in addition to significant and positive association with grain yield per plant. The productive tillers per plant had shown highest positive indirect effect via spikelet fertility on grain yield per plant. Plant height and productive tillers per plant recorded moderate to high PCV, GCV, heritability, genetic advance as per cent of mean in addition to correlation and direct effects of the trait with grain yield, indicating its effectiveness as important selection criteria for yield improvement.

Keywords: Correlation, genetic advance, heritability, improvement, selection

Introduction
Rice (*Oryza sativa* L.) is one of the principal food crop of the world. One-third of the world population and two-thirds of the Indian population is utilizing rice as a staple food. It contributes 43 per cent of caloric requirement and 20-25% of agricultural income. About 90 % of the world's rice is grown in Asia (Pathak *et al*., 2011) [13]. It is the primary source of food and protein for about half of the mankind with an enormous nutritional and economic impact. It is the crucial dietary and food security source of many Asian countries. The two most populous nations namely China and India are the largest producers and consumers of rice (FAOSTAT 2018) [4]. Worldwide rice is grown over an area of 162.76 million hectares with the total production of 495.87 million tonnes with a productivity of 4.55 t/ha. Among rice growing countries, India has largest area under rice cultivation in the world *i.e.* 43.86 million hectares and ranks second in the production with 99.24 million tonnes and the productivity of 2.49 t/ha next to wheat. (Ministry of Agriculture, Government of India, 2018-19) [9]. Grain yield is a complex polygenic quantitative trait, greatly affected by environment. Hence, assessment of variability for the grain yield and yield attributes is essential for the successful yield improvement through breeding. Further, grain yield depends on various component characters and knowledge of correlation with yield and among yield component traits in addition to identification of the direct and indirect effects of the traits on yield would help in effective yield improvement. The present investigation was undertaken in this context to elucidate information on variability, heritability, genetic advance, character associations and path coefficients in promising rice genotypes.

Materials and Methods
Experimental material for the present investigation comprised of 19 rice genotypes [12 advanced promising entries (*viz.*, KJT-5-4, RDN-17-130, IGP-17-28, TKR-24, VDN-1832, SKL-07-40, SKL-07-267, SKL-07-118, SKL-07-115, VDN-1828, RDN-18-109 and KJT TCR 39+ 7 released varieties (*viz.,* Karjat-6, Phule Radha, Kundlika, PDKV Tilak, PKV HMT, Karjat-4 and Ratnagiri-5)] developed by various research stations of Maharashtra, India.

These genotypes were sown during *Kharif* 2019 at Agricultural Research station, Vadgaon maval, Pune in a randomized block design with three replications as a part of State multilocation advanced varietal trial for quality (below 14.0 g test weight). For transplanting the genotypes, nursery was raised separately and 28 days old seedlings were transplanted in the main field with a spacing of 20×15 cm. Standard agronomic practices were followed to raise good crop. Observations were recorded on five randomly selected plants for grain yield per plant (g) and yield component characters namely days to 50% flowering, plant height (cm), panicle length (cm), productive tillers per plant, number of spikelets per panicle, spikelet fertility (%) and test weight (g). However, days to 50 per cent flowering was recorded on plot basis. In contrast, the observations for test weight were obtained from a random grain sample drawn from each plot in each genotype and replication. Analysis of variance was estimated as per the procedure proposed by Panse and Sukhatme (1967) [10]. The data collected was subjected to standard statistical procedures given by Panse and Sukhatme (1978) [11]. Heritability was calculated based on the formula given by Lush (1940) [8] and genetic advance by Johnson *et al.* (1955). The range of heritability was categorized as low (0-30), medium (31-60) and high (> 60) as suggested by Johnson *et al*. (1955) [5]. The genetic advance trait was classified as having high (>20 %), moderate (10- 20%) or low (<10%) genetic advance. Correlation was worked out using the formulae suggested by Falconer (1964) [3]. Partitioning of the correlation coefficients into direct and indirect effects was carried out using the procedure suggested by Wright (1921) and elaborated by Dewey and Lu (1959) [2]. The characterization of path coefficients was carried out as suggested by Lenka and Mishra (1973) [7].

Results and Discussion

The results on analysis of variance (ANOVA) for yield and yield component traits revealed highly significant mean squares due to genotypes for all traits studied, indicating the existence of sufficient variation among the genotypes and therefore an ample scope for effective selection (Table 1). The results on mean, range, Phenotypic Coefficient of Variation (PCV), Genotypic Coefficient of Variation (GCV), heritability and genetic advance as per cent of mean for the yield and yield component traits are furnished in Table 2. A perusal of these results revealed maximum range of variability for the trait number of spikelets per panicle (196.62-279.67) while minimum range (5.40-7.48) was recorded for the number of productive tillers per plant.

In the present study, heritability estimates for the various traits studied ranged from 38.91 (test weight) to 89.91 (days to 50% flowering). High estimates of heritability (> 60%) were recorded for all the traits excepts test weight which indicated that these characters were less influenced by environmental conditions and phenotypic selection would be effective for these characters. Similar results were reported Srilakshmi *et al.* (2018) [18]. A high genetic advance as per cent of mean (>20%) was observed for plant height and grain yield per plant. The results are in accordance with the reports of Srilakshmi *et al.* (2018) [18]. Further, moderate estimates (10-20%) of genetic advance as per cent of mean were observed for days to 50% flowering, panicle length, productive tillers per plant, number of spikelets per panicle and spikelet fertility. The only trait recorded low genetic advance as per cent of mean was the test weight. The results are in agreement with findings of Srilakshmi *et al.* (2018) [18] for days to 50% flowering and panicle length and Karande *et al.* (2015) for spikelet fertility.

Higher PCV, compared to GCV were recorded for all the traits studied in the present investigation, indicating the influence of the environment. Similar findings were reported earlier by Tiwari *et al.* (2019). High phenotypic and genotypic coefficients of variation (>20%) was not recorded for any trait. Similar results were reported earlier by Srilakshmi *et al.* (2018) [18]. Further, moderate estimates (10-20%) of PCV and GCV were observed for traits like plant height (PCV=18.31 and GCV=16.50), productive tillers per plant (PCV=11.82 and GCV=10.29) and grain yield per plant (PCV=18.44 and GCV=16.19). These results are in accordance with the findings of Ravikanth *et al.* (2018) [14] and Sudeepthi *et al.* (2020) [20] for plant height and productive tillers per plant. In contrast, in the present study low (<10%) estimates of genotypic and phenotypic coefficients of variation were observed for days to 50% flowering, panicle length and spikelet fertility, spikelets per panicle, spikelet fertility and test weight indicating low variability for these characters and therefore little scope for the improvement of these traits. Similar findings were reported earlier by Sudeepthi *et al.* (2017) [19] and Sudeepthi *et al.* (2020) [20] for days to 50% flowering, panicle length and spikelet fertility.

High heritability coupled with high genetic advance as per cent of means was recorded for plant height and grain yield per plant, which is indicating that heritability observed was due to additive gene effects and therefore the selection would be effective for these traits. However, days to 50% flowering, panicle length, productive tillers per plant, spikelets per panicle and spikelet fertility had recorded a high heritability coupled with moderate genetic advance as per cent of mean indicating the role of additive and non- additive gene effects for the characters. Further, the information on genetic variation along with heritability and genetic advance estimates has been reported to give a better idea about the efficiency of selection (Burton, 1953) [1]. In the present study, moderate GCV and PCV coupled with a high heritability and high genetic advance as per cent of mean was observed for the plant height and grain yield per plant indicating the pre-ponderance of an additive gene action and therefore the scope for improvement of the trait through selection.

Character associations for yield and yield component traits were studied in the present investigation and the results are presented in Table 3. A perusal of these results revealed a positive and significant association of grain yield with days to 50% flowering, plant height, panicle length, productive tillers per plant, the number of spikelets per panicle, spikelet fertility and test weight. Similar results were reported by Tiwari *et al.* (2019) and Sudeepthi *et al.* (2020) [20]. Studies on inter-character associations for the yield component traits revealed significant and positive association of days to 50% flowering with the productive tillers per plant (Tejaswini *et al.* 2018), spikelets per panicle (Sreedhar and Reddy, 2019) [17] and spikkelet fertility. The trait plant height has significant and positive association with panicle length and test weight ; panicle length has significant association with spikelets per panicle (Patel *et al.* 2014) [12] and spikelets fertility (Sravan *et al.* 2012) [16]; productive tillers per plant has strong association with spikelets per panicle (Patel *et al*. 2014) [12], spikelets fertility (Seyoum *et al*. 2012) [15] and test weight; spikelets per panicle has significant association with spikelets fertility and test weight; spikelets fertility had strong relationship with test weight in the present investigation, indicating a scope for simultaneous improvement of these traits through selection. In contrast, non significant negative association was observed only for the traits days to 50% flowering with plant height. Their association with grain yield per plant was however a significant and positive, indicating a need for balanced selection for these traits while effecting improvement for grain yield.

Path Coefficient Analysis provides an effective means of finding out the direct and indirect causes of association and presents a critical examination of the specific forces acting to produce a given correlation. It also measures the relative importance of each causal factor. Hence, the study of direct and indirect effects of traits on the grain yield per plant was undertaken in the present investigation and the results obtained are presented in Table 4. A perusal of these results revealed low residual effect (0.290) indicating that variables studied in the present experiment explained about 71.0 per cent of variability for grain yield per plant and therefore, other attributes besides the characters studied are also contributing for grain yield per plant.

Table 1: ANOVA for morphological traits in rice

Source of variation	Degrees of freedom	Mean sum of squares							
		Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Productive tillers per plant	Spikelets per panicle	Spikelet fertility	Test weight (g)	Grain yield per plant (g)
Replication	2	26.5	55.0	1.2	0.22	6.4	34.4	0.4	14.9
Treatment	18	211.7**	601.0**	16.2**	1.3**	1,289.1**	193.3**	1.5**	33.2**
Error	36	7.6	42.9	1.2	0.1	200.9	15.9	0.5	3.0

Table 2: Genetic parameters for yield and yield components in rice

S. No.	Characters	Mean	Range		PCV (%)	GCV (%)	Heritability (broad sense) (%)	Genetic Advance as per cent of Mean
			Minimum	Maximum				
1.	Days to 50% flowering	108.49	95.33	130.00	8.02	7.60	89.91	14.85
2.	Plant height (cm)	82.66	56.90	121.80	18.31	16.50	81.25	30.64
3.	Panicle length (cm)	23.50	19.23	27.00	10.66	9.51	79.59	17.47
4.	Productive tillers per plant	6.27	5.40	7.48	11.82	10.29	75.74	18.44
5.	Spikelets per panicle	237.91	196.62	279.67	9.98	8.01	64.35	13.23
6.	Spikelet fertility	83.24	70.51	92.71	10.41	9.24	78.73	16.88
7.	Test weight (g)	13.42	11.35	13.98	6.95	4.34	38.91	5.57
8	Grain yield per plant (g)	19.62	11.95	24.66	18.44	16.19	77.05	29.27

Table 3: Correlation matrix for yield and yield component traits in rice

S. No.	Character	Days to 50% Flowering	Plant height (cm)	Panicle length (cm)	Productive tillers per plant	Spikelets per panicle	Spikelet fertility	Test weight (g)	Grain yield per plant (g)
1	Days to 50% Flowering	1.00							
2	Plant height (cm)	-0.021^{NS}	1.00						
3	Panicle length (cm)	0.207^{NS}	0.328*	1.00					
4	Productive tillers per plant	0.261*	0.136^{NS}	0.232^{NS}	1.00				
5	Spikelets per panicle	0.383**	0.217^{NS}	0.436**	0.337*	1.00			
6	Spikelet fertility	0.303*	0.089^{NS}	0.449**	0.664**	0.581**	1.00		
7	Test weight (g)	0.154^{NS}	0.438**	0.243^{NS}	0.390**	0.267*	0.263*	1.00	
8	Grain yield per plant (g)	0.365**	0.301*	0.377**	0.683**	0.613**	0.738**	0.423**	1.00

*Significant at 5 % level, **Significant at 1 % level

Table 4: Direct and indirect effects (genotypic path coefficients) of yield and yield components on grain yield in rice

S. No.	Character	Days to 50% Flowering	Plant height (cm)	Panicle length (cm)	Productive tillers per plant	Spikelets per panicle	Spikelet fertility	Test weight (g)	Grain yield per plant (g)
1	Days to 50% Flowering	0.089	-0.003	-0.010	0.078	0.089	0.111	0.012	0.365**
2	Plant height (cm)	-0.002	0.161	-0.016	0.041	0.050	0.033	0.033	0.301*
3	Panicle length (cm)	0.018	0.053	-0.047	0.069	0.101	0.164	0.018	0.377**
4	Productive tillers per plant	0.023	0.022	-0.011	0.298	0.078	0.242	0.030	0.683**
5	Spikelets per panicle	0.034	0.035	-0.021	0.101	0.232	0.212	0.020	0.613**
6	Spikelet fertility	0.027	0.014	-0.021	0.198	0.135	0.365	0.020	0.738**
7	Test weight (g)	0.014	0.071	-0.012	0.116	0.062	0.096	0.076	0.423**
Diagonal values indicate direct effect,				Residual effect =0.290					

*Significant at 5 % level, ** Significant at 1 % level

Direct effects: A detailed analysis of the direct and indirect effects revealed a high (>0.3) positive direct effect of the trait spikelet fertility (0.365) in addition to significant and positive association with grain yield per plant. High direct effects of the traits therefore appear to be the main factor for their association with grain yield per plant. Hence, the traits should be considered as an important selection criteria in all rice improvement programmes and direct selection for the traits is recommended for yield improvement. The results are contradictry with the findings of Umarani *et al.* (2019) and Sudeepthi *et al.* (2020) [20] who reported high direct effect of the traits such as number of ear bearing (productive) tillers per plant, number of grains (spikelets) per panicle and test weight on grain yield per plant. Moderate positive direct effect was observed for the the character productive tillers per plant (0.298) and spikelets per panicle (0.232). The trait plant height showed low direct effect (0.161) on grain yield per plant. The traits days to 50% flowering and test weight had recorded very low or neglegible positive direct effects on grain yield per plant. The character panicle length recorded very low or neglegible negative direct effect on grain yield per plant. These findings are in agreement with Tejaswini *et al.* (2018) for days to 50% flowering and Umarani *et al.* (2019) for the total number of grains per panicle. Sudeepthi *et al.* (2020) [20] reported very low or neglegible direct effect of days to 50% flowering on grain yield. However, association of these traits was noticed to be positive and significant with grain yield per plant indicating indirect effects to be the cause of correlation and hence, the need for consideration of indirect causal factors during selections for yield improvement through these traits.

Indirect effects: The character productive tillers per plant had shown highest but moderate positive indirect effect (0.242) via spikelet fertility on grain yield per plant. The trait spikelets per panicle had moderate positive indirect effect via spikelet fertility (0.212) and low positive indirect effect via productive tillers per plant (0.101) on grain yield per plant. The character spikelet fertility had low positive indirect effect via productive tillers per plant (0.198) and spikelets per panicle (0.135) on grain yield per plant. The trait panicle length had low positive indirect effect via spikelet fertility (0.164) and spikelets per panicle (0.101) on grain yield per plant. The character test weight had low positive indirect effect via productive tillers per plant (0.116) on grain yield per plant. The character days to 50% flowering had low positive indirect effect via spikelet fertility (0.111) on grain yield per plant. In present investigation, the trait spikelet fertility has more contributed directly or indirectly via other charcater, the main reason for that was due to heavy rains (almost double 1260 mm to 2314 mm) received in this year during flowering of the varieties. Some varieties had low spikelet fertility percentage due to heavy rains.

Results of the present investigation on genetic variability, character association and path analysis studies indicated the scope for improvement of grain yield and its components through selection of plant height and productive tillers per plant as they recorded moderate to high PCV, GCV, heritability, genetic advance as per cent of mean in addition to correlation and direct effects of the trait with grain yield indicating its effectiveness as important selection criterion for yield improvement. After that, panicle length and spikelet fertility characters could be considered for improvement in grain yield of rice.

Declaration: The authors declare no conflict of interest.

Acknowledgment

The financial assistance received from Mahatma Phule Krishi Vidyapeeth, Rahuri and Government of Maharashtra, for the study is gratefully acknowledged. The authors are thankful to the Rice Specialist, Regional Agricultural Research Station, Karjat, Dist- Raigad for making available advanced genotypes from all the research station of Maharashtra, formulation of state multilocation advanced varietal trial – quality (below 14.0 g test weight) to conduct at Agricultural Research Station, Vadgaon maval, Pune, Maharashtra, India.

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