Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(1): 200-204
Received: 15-11-2018
Accepted: 17-12-2018

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Genetic variability, heritability, genetic advance and correlation studies for yield and component traits in rice (*Oryza sativa* L.)

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Abstract
The present study was conducted to estimate the phenotypic and genotypic coefficients of variation, broad sense heritability, genetic gain and correlations in rice during kharif season 2016-17 at Norman E. Borlaug Crop Research Centre Pantnagar, Uttarakhand, India. Thirteen rice genotypes along with their thirty F1 developed by using line × tester mating design were evaluated in randomized complete block design with three replications for yield and yield components namely days to 50% flowering, days to maturity, plant height at maturity, numbers of tillers per plant, number of panicle per plant, panicle length number of grains per panicle, grain length, Grain width, 1000 grain weight and grain yield per plant. Analysis of variance showed significant differences among the genotypes were observed for all the characters under study which is essential to achieve crop improvement through selection. Highest GCV and PCV estimates was obtained for grain yield per plant. High Broad sense heritability and correspondingly high genetic advance was obtained for grain yield per plant and number of grains per panicle suggesting that selection for these character may be effective. Grain yield per plant showed positive and significant phenotypic and genotypic association with number of tillers per plant (0.749, 0.838), number of panicles per plant (0.784, 0.843), panicle length (0.479, 0.572) and number of grains per panicle (0.521, 0.543). 1000 grain weight (0.313) showed significant positive genotypic association with grain yield per plant therefore these characters can be used for grain yield selection.

Keywords: Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability, genetic advance, correlation

Introduction
Rice accounts for more than 40% of food grain production in India and is the bedrock of our national food security. Rice can provide on an average 75% calories with 55% protein in their daily diet [Bhuiyan 2002] [1]. The area under rice cultivation in India was 43.5 million hectares with a production of 104.32 million tonnes during 2016-2017 (Directorate of economics and statistics Report, 2016-17). The world population is expected to reach 8 billion by 2030 and rice production must be increased by 50% in order to meet the growing demand (Khush and Brar, 2002) [2]. To achieve this target rice breeder need to develop high yielding heterotic cultivar. Generally hybrids between more genetically diverse parents produce show greater heterosis hybrids. Efficiency of selection depends upon the presence of variability in the breeding population. Relative magnitude of phenotypic, genotypic and environmental coefficient of variation helps to assess level and nature of variability present in the population. Selection for character showing higher value of genotypic coefficient of variation is rewarding. heritability enables us to predict the degree of correspondence between phenotypic value of the genotype and its breeding value. High heritability with high genetic advance indicate that the heritability is most likely due to additive gene effects and selection for such character will be effective. The knowledge of character association is of prime importance for enhancement of economic yield as direct selection for yield may not be effective.

Material and Methods
The present study was conducted at Norman E. Borlaug Crop Research Centre, Pantnagar, Uttarakhand, India. The basic experimental material comprised of ten lines *viz.*, PR113, Pant Sugandh Dhan 17, UPR 3912-21-2-1, UPR 3654-5-1-2, UPRI 2015-2, UPR 3037-2-2-1-3, UPR 3905-22-2-2-1, UPR 2760-10-1-2, UPR 2015-5 and Pant Dhan 26 and three testers *viz.* HKR 47, Pant Dhan 24 and NDR 359.The Line × tester mating design was used to generate thirty crosses during kharif 2015-16. The experimental material consisted of 43 genotypes i.e., 10 lines, 3 testers, 30 F_1's. The experimental material was laid out in a Randomized Block Design (RBD) with three replications.

The seeds of all 43 genotypes were sown in the poly house at Norman E. Borloug Crop Research Centre. twenty one days old seedling were transplanted in the main field in a single row of 3m length and spacing of 30 cm was kept between two entries with plant to plant spacing of 15cm. Observations were recorded on the whole plot basis in respect of days to 50 percent flowering, Days to Maturity, However, plant height, number of tillers per plant, number of panicles, panicle length, number of grains per panicle, Grain length, Grain width, 1000 grain weight and grain yield per plant were recorded on the basis of five randomly selected competitive plants from the F_1 crosses, lines and the testers. Analysis of variance was carried out as per Panse and Sukhatme (1985). Estimation of Phenotypic, genotypic and environmental coefficient of variation was done according to Burton (1952) [3]. Heritability in broad sense was calculated according to Allard (1960) [4]. General formula used for calculating genetic advance was G.A. $=K \times \sigma p \times H_b$. Where, K= selection differential expressed in standard unit, σp= phenotypic standard deviation calculated as square root of phenotypic variance, H_b= heritability in broad sense (σ^2g/σ^2p). The correlation coefficients at genotypic and phenotypic levels were estimated from the analysis of variance and covariance as suggested by Searle (1961) [5].

Results and Discussion

Analysis of variance

Existence of variability is a prerequisite to achieve crop improvement through selection. Variability occurs due to difference in the genetic constitution of the individuals of the population or due to difference in the environment in which they are grown. Presence of high magnitude of genetic variability is of foremost importance to a plant breeder to start any breeding programme. Results of analysis of variance sowed the presence of highly significant genetic variations among the genotypes for all the eleven characters under study (table 1).

Table 1: Analysis of variance for different character in rice genotypes

SI. No.	Character	Mean sum of square		
		Replication	Treatments	Error
	df	2	42	84
1	Days to 50% flowering	3.223837	4.517857*	2.828004
2	Days to maturity	1.39895	8.848214**	3.014431
3	Number of tillers per plant	26.84575	150.6715**	10.12272
4	Plant height	238.6584	520.0446**	12.73730
5	Number of panicles per plant	13.03198	150.0694**	6.300828
6	Panicle length	10.77471	56.82986**	4.960224
7	Number of grains per panicle	456.3779	2846.813**	62.43548
8	Grain length	0.0018622	.6499256**	0.0015948
9	Grain width	0.00144568	0.0351741**	0.00059094
10	1000 grain weight	1.525345	5.136347**	1.288831
11	Grain yield per plant	168.8387	4308.326**	30.04160

The general mean, coefficient of variation, critical difference at 1% and at 5% level of significance, range of variation, standard error mean, genotypic coefficient of variation (gcv), phenotypic coefficient of variation (pcv) and environmental coefficient of variation (ecv) for the eleven characters under study are presented in Table 2. Days to 50% flowering ranged from 82-90 days with a general mean of 85.953 days. Coefficient of variation for this character was 1.956. The female parent with minimum days to 50% flowering was Pant Dhan 26 and the male parent was Pant Dhan 24. Days to maturity ranged from 120-132 days with a general mean of 126.186 days. Coefficient of variation for this character was 1.376. The parents with minimum days to maturity are UPR 3037-2-2-1-3 among the lines and HKR 47 among the testers. Number of tillers per plant ranged from 14-49 with a general mean of 28.147. Coefficient of variation for this character was 11.303. PR 113 among the lines and HKR 47 among the testers were found to have maximum number of tillers per plant. Plant height ranged from 92-157.55cm with a general mean of 125.687cm. Coefficient of variation for this character was 2.839. The shortest female parent was PR 113 and the shortest male parent was NDR 359. Number of panicles per plant ranged from 13-45 with a general mean of 25.503. Coefficient of variation for this character was 9.842. The highest number of panicles per plant was observed for PR 113 among the lines and HKR 47 among the testers. Panicle length ranged from24.77-46.67 cm with a general mean of 34.855cm. Coefficient of variation for this character was 6.389. Female parent Pant sugandh Dhan 17 and male parent Pant Dhan 24 were found to have longest panicle. Number of grains per panicle ranged from 105-235 with a general mean of 165.162. Coefficient of variation for this character was 4.784. Maximum number of grains per panicle was observed for Pant sugandh Dhan 17 among the lines and Pant Dhan 24 among the testers. length ranged from 9-11.9 cm with a general mean of 9.433cm. Coefficient of variation for this character was 0.423. Female parent Pant Sugandh Dhan 17 and male parent Pant Dhan 24 were found to have highest mean value for grain length. Grain width ranged from 2.1-2.66cm with a general mean of 2.366cm. Coefficient of variation for this character was 1.027. Highest mean value for Grain width was observed for female parent UPR 3654-5-1-2 and male parent HKR 47. 1000 grain weight ranged from 20.12-31.2gwith a general mean of 25.648g. Coefficient of variation for this character was 4.426. Highest 1000 grain weight was observed in UPR 2760-10-1-2 among the lines and NDR 359 among the testers. Grain yield per plant ranged from 50.18-195.98g with a general mean of 108.423g. Coefficient of variation for this character was 5.054. Highest grain yield per plant was observed for female parent PR 113 male parent Pant Dhan 24. The results were in general agreement with the findings of Tiwari *et al*. (2011) [6], Saleem *et al.* (2005) [7], Kumar *et al*. (2015) [8].

Table 2: Analysis in rice genotypes with respect to different characters

SI no.	Characters	gm	cv	CD at 1%	CD at 5%	SEm ±	Range of variation	gcv	pcv	Ecv
1	Days to 50% flowering	85.953	1.956	3.619	2.7305	.9709	82-90	0.872	2.142	1.956
2	Days to maturity	126.186	1.376	3.737	2.819	1.0026	120-132	1.105	1.764	1.375
3	Number of tillers per plant	28.147	11.303	6.847	5.166	1.836	14-49	24.317	26.814	11.303
4	Plant height(cm)	125.687	2.839	7.6808	5.7949	2.0605	92-157.55	10.34	10.75	2.8395
5	Number of panicles per plant	25.503	9.842	5.402	4.0757	1.449	13-45	27.144	28.873	9.8425
6	Panicle length (cm)	34.855	6.389	4.793	3.616	1.2858	24.77-46.67	11.919	13.533	6.389
7	Number of grains per panicle	165.1628	4.7841	17.00529	12.83003	4.561998	105-235	18.445	19.0558	4.784
8	Grain length (cm)	9.433	0.4233	0.08954	0.06484	0.02305	9-11.9	4.928	4.946	0.423
9	Grain width (cm)	2.366	1.0271	0.05231	0.03947	0.01403	2.1-2.66	4.53	4.652	1.027
10	1000 grain weight (gm)	25.6488	4.426	2.443240	1.843359	.6554	20.12-31.2	4.416	6.251	4.426
11	Grain yield per plant (gm)	108.4236	5.0548	11.79499	8.898997	3.1642	50.18-195.98	34.829	35.194	5.054

The magnitude of phenotypic coefficient of variation were higher than genotypic coefficient of variation and environmental coefficient of variation were higher than genotypic coefficient of variation and environmental coefficient of variation for all the characters under study. Grain yield per plant (35.19%) exhibited highest phenotypic coefficient of variation followed by number of panicles per plant (28.87%), number of tillers per plant (26.81%), number of grains per panicle (19.058%), panicle length (13.533%), plant height (10.75%), 1000 grain weight (6.251%), grain length (4.946%), grain width (4.652%) and days to 50% flowering (2.142%). The lowest phenotypic coefficient of variance was observed for days to maturity (1.764%). Grain yield per plant (34.829%) exhibited highest genotypic coefficient of variation followed by number of panicles per plant (27.144%), number of tillers per plant (24.317%), number of grains per panicle (18.445%), panicle length (11.919%), plant height (10.34%), grain length (4.928%), grain width (4.513%), 1000 grain weight (4.416%) and days to maturity (1.105%). The lowest genotypic coefficient of variance was observed for days to 50% flowering (0.872%). The range of environmental coefficient of variation was observed from 0.423% for grain length to 11.30% for number of tillers per plant. Similar findings also reported by Nuruzzaman *et al*. (2002) [9], Umadevi *et al*. (2009) [10]

Estimation of heritability and genetic advance

The estimation of broad sense heritability and genetic advance under selection for all the eleven characters under study is presented in the table 3. High heritability was observed for all the characters except days to 50% flowering (16.02%) and days to maturity (39.20%). Highest value of genetic advance was observed for grain yield per plant (76.986) followed by number of grains per panicle (60.748) and plant height (25.832). Akinwale *et al*. (2011) [11], El-Malky *et al*. (2003) [12].

Table 3: Estimation of broad sense heritability and genetic advance for different characters in rice genotypes

SI no.	Characters	Heritability in broad sense (%)	Genetic advance
1	Days to 50% flowering	16.602	0.629
2	Days to maturity	39.20	1.798
3	Number of tillers per plant	82.23	12.786
4	Plant height	92.995	25.832
5	Number of panicles per plant	88.381	13.406
6	Panicle length	77.706	7.550
7	Number of grains per panicle	93.69	60.748
8	Grain length	99.53	0.955
9	Grain width	95.83	0.216
10	1000 grain weight	74.922	3.497
11	Grain yield per plant	97.93	76.986

Character Association

Direct selection for high yield may not be effective as yield is a complex character governed by the cumulative effects of various component characters. Therefore, improvement in yield can be obtained by practicing selection of yield contributing traits that are associated with yield directly or indirectly. In plant breeding, generally estimates of three types of correlation coefficients i.e. genotypic, phenotypic and environmental are used to study association between characters. Studies on character association are helpful in two ways. First, it helps in the selection of character associated with highest expression of yield and secondly, it helps us to achieve improvement in one character without sacrificing much in other traits. Higher value of genotypic correlation coefficient than phenotypic correlation coefficient indicates strong genetic association between the characters involved and the lower value of phenotypic correlation coefficient is due to significant interaction of environment. Higher values of phenotypic correlation coefficients indicate that association between two characters is not only due to the genes but also due to the influence of environment. If the values of genotypic and phenotypic correlation coefficients are insignificant it indicates that the two characters are independent of each other. Number of tillers per plant exhibited highly significant and positive phenotypic correlation with number of panicles per plant (0.980) and grain yield per plant (0.749). Number of tillers per plant exhibited highly significant and positive genotypic association

with grain yield per plant (0.838) and days to 50% flowering. Similar results were also obtained by Prasad *et al*. (1988) [13]. Plant height was found to have highly significant and positive phenotypic correlation with panicle length (0.511) and number of grains per panicle (0.554).). Plant height was found to have highly significant and positive genotypic correlation with panicle length (0.636) and number of grains per panicle (0.605). Similar findings were obtained by Augustina *et al*. (2015) [14], Lakshmi *et al*. (2014) [15]. Number of panicles per plant showed highly significant and positive phenotypic correlation with grain yield per plant (0.784).Number of panicles per plant showed highly significant and positive genotypic association with grain yield per plant (0.843). Similar findings were obtained by Mustafa *et al*. (2007) [16]. Panicle length exhibited highly significant and positive phenotypic correlation with number of grains per panicle (0.886) and grain yield per plant (0.479).Panicle length exhibited highly significant and positive genotypic correlation with grain yield per plant (0.572). Similar results were obtained by Khan *et al*. (2009) [17], Hefena *et al*. (2016) [18]. Number of grains per panicle was found to have highly significant and positive phenotypic correlation with grain yield per plant (0.521). Number of grains per panicle was found to have highly significant and positive genotypic correlation with grain yield per plant (0.543). Similar results were reported by Wattoo *et al*. (2010) [19]. Grain length showed significant and negative phenotypic correlation with grain width (-0.330).Grain length showed significant and negative genotypic correlation with grain width (-0.338) and 1000 grain weight (-0.304). 1000 grain weight exhibited significant and positive genotypic association with grain yield per plant (0.313).Based on genotypic correlation coefficient, Days to 50% flowering showed highly significant and positive correlation with number of tillers per plant (0.556), number of panicles per plant (0.588) and grain length (0.468). This character also showed highly significant and negative correlation with 1000 grain weight (-0.622) and significant and negative correlation with panicle length (-0.383) and number of grains per panicle (-0.356). Similar findings were obtained by Akter *et al*. (2010) [20] [table 4(a), 4(b)]

Table 4(a): Inter character association (phenotypic) between different character pairs in rice

Characters	Days to maturity	Number of tillers per plant	Plant height	Number of panicles per plant	Panicle length	Number of grains per panicle	Grain length	Grain width	1000 grain weight	Grain yield per plant
Days to 50% flowering	-0.0213	0.253	-0.122	0.248	-0.130	-0.125	0.186	-0.041	-0.110	0.082
Days to maturity	1.000	0.046	0.083	0.054	0.162	0.155	-0.144	0.143	-0.040	0.127
Number of tillers per plant		1.00	-0.222	0.980**	0.013	-0.028	-0.088	-0.075	0.003	0.749**
Plant height			1.000	-0.204	0.511**	0.554**	0.137	0.183	0.091	0.137
Number of panicles per plant				1.000	0.029	-0.011	-0.057	-0.071	0.030	0.784**
Panicle length					1.000	0.886**	0.261	-0.031	0.100	0.479**
Number of grains per panicle						1.000	0.263	-0.055	0.141	0.521**
Grain length							1.000	-0.330*	-0.202	0.041
Grain width								1.000	0.0008	-0.097
1000 grain weight									1.000	0.216
Grain yield per plant										1.000

Table 4(b): Inter character association (genotypic) between different character pairs in rice

Characters	Days to maturity	Number of tillers per plant	Plant height	Number of panicles per plant	Panicle length	Number of grains per panicle	Grain length	Grain width	1000 grain weight	Grain yield per plant
Days to 50% flowering	-0.131	0.556**	-0.250	0.588**	-0.383*	-0.356*	0.468**	-0.132	-0.622**	0.197
Days to maturity	1.000	0.169	0.086	0.162	0.265	0.245	-0.255	0.173	-0.084	0.205
Number of tillers per plant		1.00	-0.260	1.002	-0.007	-0.009	-0.101	-0.080	0.078	0.838**
Plant height			1.000	-0.225	0.636**	0.605**	0.138	0.192	0.131	0.141
Number of panicles per plant				1.000	0.018	0.004	-0.063	-0.078	0.085	0.843**
Panicle length					1.000	1.038	0.294	-0.055	0.182	0.572**
Number of grains per panicle						1.000	0.270	-0.061	0.214	0.543**
Grain length							1.000	-0.338*	-0.304*	0.040
Grain width								1.000	0.072	-0.101
1000 grain weight									1.000	0.313*
Grain yield per plant										1.000

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