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Studies on some Genetic Parameters of Rice (*Oryza sativa L.*)

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Summary. In order to utilize the available useful variation in breeding rice to improve yield and quality of grain, the performance of a wide range of rice germ plasm comprising 30 varieties was evaluated in northern India, a major rice growing belt. Plant performance revealed high genetic divergence and phenotypic variability in the crop, with the maximum range of variation being for grain number per panicle and the minimum for grain dimensions. There were also significant differences among varietal means for ten phenotypic traits. Genotypic and phenotypic variance contributed profoundly to the variance of the phenotypic traits studied, but, since genetic variability in the traits related to yield was considerable, there is scope for further improvement in yielding ability. Grain number per panicle, number of effective tillers per plant and culm length exhibit high heritability, and genotypic coefficient of variation and therefore a high genetic advance. Thus, selection for these traits would be effective in crop improvement. Moreover, grain number per panicle shows a significant positive correlation with yield, and this trait could profitably form a reliable index for the yielding capacity of this crop.

Introduction

India, the home of rice, has nearly one third of the world's rice acreage but still suffers from a chronic shortage of the cereal (Ramiah, 1970). Improvement in yield and quality of the cereal is of paramount importance to this nation. An effective rice varietal improvement programme must have sound objectives based on the needs of the farmer and the consumer (Beachell and Khush, 1969) and, for a planned breeding programme to improve yield potential, information on genetic variability and interrelationships is necessary (Singh and Mehndiratta, 1969). The Karnal district is a major rice-growing belt of India and the three main varieties grown are IR 8, Basmati 370 and Jhona 349. Basmati, though fine-grained, is a low-yielding and late-maturing variety; Jhona is better yielding with coarser grains than Basmati; and IR8, though high-yielding, matures late and has coarse, bold, broad grains. The economic aim of producing a fine and heavy grained, productive rice, suitable for this area, remains to be achieved (Kaul, 1973; Kaul and Bhan, 1971). Experiments on the induction of mutation and hybridization among these varieties were initiated by the present investigators.

To obtain desirable lines for direct and indirect use in the breeding programme, the performance of a wide range of germ plasm was tested: 30 promising lines of rice from different sources were evaluated for plant performance, interrelationships with yield, heritability estimates, expected genetic advance and genetic and phenotypic coefficients of variation. The results are presented in this paper.

Information on these aspects, though vital for planned breeding and selection programmes (Johnson, Robinson and Comstock, 1955; Hanson, Robinson and Comstock, 1956; Williams, 1964; Briggs and Knowels, 1967; Basu and Asokaraj, 1969; Liang, Walter, Nickell and Koh, 1969; Singh and Mehndiratta, 1969; Povilaitis, 1970 and Mathur, Mathur and Chandola, 1971), is meagre and very inadequate in rice (Grist, 1959; Chandraratna, 1964; Kaul, 1973). The present paper also gives a preliminary idea of the genetic diversity of the various quantitative traits in rice, the importance of which in other crops has been appreciated by breeders from time to time (Harrington, 1940; Wienhues, 1960; Murty and Arunachalam, 1966; Chandrasekhariah, Murty and Arunachalam, 1969; Somayajulu, Joshi and Murty, 1970).

Material and Methods

Thirty promising varieties of rice were grown in the 1971 summer season at the university experimental farm, using a randomized block design with 3 replications. The net individual plot consisted of a single row 5 m. long, with row to row and plant to plant distances of 60 and 20 cm, respectively. Observations were recorded for ten characters, viz., plant height, total number of tillers per plant, number of effective tillers per plant, panicle length, length of top internode, 1,000-grain weight, total number of grains per panicle, number of fertile grains per panicle, yield per plant and length: breadth ratio of grains, and mean values for 30 plants per variety, 10 plants being chosen at random from each replication, were used for further statistical analysis. The plant performances of 21 promising varieties were recorded and are tabulated in Table 1. For the other estimates, 25 varieties were used; of the others, Badsabhog, Prosadbhog, and Manohar Sali (Assam, India) never flowered and Budji and Babar (Kashmir, India) exhibited high seed sterility.

Genetic coefficients of variation were estimated by the formula suggested by Burton (1952), dividing the square root of the genotypic variance by the population mean and multiplying by 100. Heritability was calculated in the broad sense by the formula suggested by Hanson et

Table 1. *Morphological data of some rice varieties (Mean values of 30 observations)*

Characters Varieties	Plant height cm	Total number of tillers	Number of effective tillers	Panicle length cm	Length of top internode cm	1,000-grain weight gm	Total number of grains/panicle	Number of fertile grains/panicle	Yield/plant	Grain length cm	Grain breadth cm	Grain L/B ratio	Source
	1	2	3	4	5	6	7	8	9	10	11	12	13
Parmal	160.4	16.3	13.8	25.9	37.5	19.4	132.4	122.8	40.9	0.92	0.23	4.00	Local
Jaya	97.7	9.8	9.1	23.9	30.9	28.9	138.7	128.6	36.6	0.90	0.32	2.81	Andhra (India)
Basmati 370	143.9	14.7	14.0	29.7	42.7	20.5	92.3	88.1	26.5	0.93	0.23	4.04	Local
Jhona 349	132.7	15.4	12.4	27.1	35.5	19.7	107.8	103.1	31.1	0.91	0.24	3.79	Local
IR 8	78.0	13.2	12.1	23.4	30.0	29.5	80.2	75.3	29.3	0.90	0.31	2.90	Philippines
Euribe	78.3	7.7	4.2	12.6	22.9	32.1	45.3	34.2	8.6	0.96	0.33	2.91	Italy
Delta	81.6	9.3	7.0	15.1	26.2	37.5	43.6	35.7	12.4	1.06	0.34	3.06	France
Cristal	72.1	14.4	12.2	13.5	23.9	25.0	41.4	38.1	13.7	0.80	0.32	2.50	France
Ballila	63.0	6.8	5.1	10.2	20.6	23.1	34.1	30.2	4.8	0.70	0.34	2.06	Italy
Rohini	109.9	9.1	9.0	25.3	30.3	23.1	158.3	143.6	30.5	0.90	0.30	3.00	Kerala (India)
Aswathi	97.4	10.5	9.4	23.0	39.4	24.4	141.9	127.4	32.8	0.86	0.31	2.77	Kerala (India)
Dubaichinga	153.9	15.9	14.9	24.1	31.3	20.2	143.9	135.1	44.5	0.78	0.28	2.78	Assam (India)
Basanta bahar	133.6	15.5	11.3	23.4	33.3	14.1	145.6	135.1	29.2	0.84	0.24	3.50	Assam (India)
China 1039	110.2	15.8	15.8	19.1	30.0	24.5	80.4	71.8	24.4	0.91	0.32	2.53	Kashmir
Nova 66	111.4	9.2	5.0	21.4	34.5	24.2	141.4	125.5	27.7	0.77	0.32	2.41	U.S.A.
Saturn	110.7	8.2	5.1	20.3	32.5	24.3	105.7	94.5	19.1	0.80	0.31	2.59	U.S.A.
Dawn	130.0	8.5	4.3	25.3	35.6	22.0	141.7	129.2	24.3	0.93	0.25	3.72	U.S.A.
Starbonnet	124.8	6.1	4.1	22.7	38.7	22.2	197.3	184.5	25.2	0.89	0.25	3.56	U.S.A.
Blue belle	116.6	6.1	3.8	25.0	37.3	23.5	197.9	182.0	27.0	0.92	0.25	3.68	U.S.A.
Semi-dwarf Basmati	146.3	14.1	13.5	30.5	40.6	23.4	104.1	88.7	29.9	0.98	0.27	3.63	Andhra
Larbeul	122.7	12.3	8.9	23.4	40.4	23.6	121.4	87.1	25.2	0.82	0.30	2.73	Kashmir
CD Value at 5%	5.10	4.62	4.83	2.28	3.89	4.81	43.17	42.41	14.50	—	—	0.16	

al. (1956). Expected genetic advance was estimated by the formula given by Lush (1949) and Johnson et al. (1955). For other statistical computations, methods outlined by Woolf (1968) were followed.

Results

Table 1 indicates that the phenotypic characters studied exhibit a wide range of variation, the range for various traits being: plant height 63.0 to 160.4 cm; total number of tillers 6.1 to 16.3; number of effective tillers 4.1 to 15.8; panicle length 10.2 to 30.5 cm; length of top internode 20.6 to 40.6 cm; 1.000-grain weight 14.1 to 37.5 g; grain number per panicle 34.1 to 197.9; fertile grains per panicle 30.2 to 184.5; grain yield per plant 4.8 to 44.5 g; grain length 0.70 to 1.06 cm; grain breadth 0.23 to 0.34 cm; and length: breadth of the grains 2.06 to 4.04. The range of variation was greatest for grain number per panicle and smallest for grain dimensions. Thus the divergence in the phenotypic traits studied is quite appreciable. Except for grain shape (L/B), which has been reported to be least liable to environmental fluctuations (Chandraratna, 1964), the other characters studied are reported to exhibit polygenic inheritance (Grist, 1959; Chandraratna, 1964; Kaul, 1973) and, naturally, environmental influence over these traits is profound. Moreover, some of the varieties studied here are nitrogen responsive and the phenotypic variation related to nitrogen dose in these varieties can be significant (Sarthe et al., 1969; Kaul, 1973).

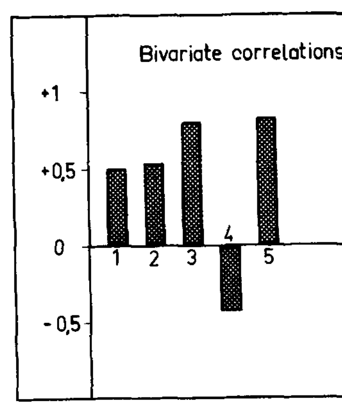

Fig. 1. Correlation coefficient value(r) between plant yield and culm length(1), effective tiller number(2), panicle length(3), 1,000 grain weight(4), and fertile grain number(5)

Results of the analysis of variance for the phenotypic traits studied are presented in Table 2. They indicate that the differences among the varietal means are highly significant for all the 10 characters. Error, phenotypic and genotypic variances for different characters are given in Table 3. The phenotypic variance was taken as the sum of error variance and genotypic variance and the latter was calculated by subtracting the error mean square from varietal mean square and dividing the remainder by the number of replications. The genetic coefficient of variability (Table 4) was highest for the number of fertile grains per plant, followed, in descending order, by total grains per plant, number of effective tillers per plant, yield per plant, total number of tillers per plant, 1,000-grain weight, culm length, panicle length, L/B ratio of grains and length of top internode.

Estimates of variance and its components indicated higher values of variance in grain number per panicle and culm length, moderate values in number of tillers per plant, panicle length and length of top internode, and the lowest values for grain shape (Table 3). These values alone are not helpful in determining the heritable portions of variation (Falconer, 1960): for this, an estimate of heritability of these traits is necessary. These values, as tabulated in Table 4, were high for culm length, grain shape, panicle length, length of top internode, 1,000-grain weight and grains per panicle, and moderate for tiller number and yield per plant. Characters with higher heritability values are not subject to a great amount of non-heritable or environmental variability; instead they are genetically fixed. Such values for quantitative traits are useful to plant breeders who can make selections for these traits on a phenotypic basis. However, Johnson et al. (1955), from their studies with soyabeans, have suggested that heritability, together with genetic advance is more useful in predicting the result of selecting the best individual. These values were also computed and are given in Table 4.

The expected genetic advance, expressed as the percentage of mean, varied from 34.33 to 68.56 per cent; the highest value was for the number of fertile grains per panicle (68.56 per cent), which was very

Table 2. *Values of 'F' from ANOVA for the various plant characters*

Character	F Values	
	Block	Treatment
Culm length	46.21**	221.41**
Total number of tillers per plant	12.17**	5.02**
Number of effective tillers per plant	5.36**	5.64**
Panicle length	16.45**	40.54**
Length of top internode	6.09**	20.38**
1,000-grain weight	0	15.64**
Total number of grains per panicle	8.36**	9.09**
Number of fertile grains per panicle	5.05*	8.38**
Yield per plant	8.58**	3.57**
L/B ratio of grains		104.00**

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

Table 3. *Estimates of phenotypic, genotypic and error variances for different characters*

Character	Phenotypic Variance	Genotypic Variance	Error Variance
Culm length	662.81	653.90	8.91
Total number of tillers per plant	18.60	10.65	7.95
Number of effective tillers per plant	22.04	13.39	8.65
Panicle length	27.36	25.44	1.93
Length of top internode	41.84	36.24	5.61
1,000-grain weight	50.46	41.88	8.58
Total number of grains per panicle	2575.75	1881.63	694.12
Number of fertile grains per panicle	2310.76	1643.23	667.53
Yield per plant	145.16	67.03	78.13
L/B ratio of grains	0.36	0.35	0.01

Table 4. *Estimates of heritability, genetic advance, genetic coefficient of variability and phenotypic coefficient of variability*

Character	Heritability (h^2) in per cent	Genetic advance	Expected genetic advance in percentage of mean	Genetic coefficient of variation in per cent	Phenotypic coefficient of variation in per cent	Mean values
Culm length	98.67	52.33	53.81	26.29	26.47	97.25
Total number of tillers per plant	57.26	5.06	42.38	27.30	36.09	11.95
Number of effective tillers per plant	60.75	5.51	56.52	37.53	48.15	9.75
Panicle length	92.98	10.02	44.32	22.31	23.13	22.61
Length of top internode	86.61	11.54	34.33	17.91	19.24	33.61
1,000-grain weight	82.96	12.14	50.08	26.69	29.30	24.24
Total number of grains per panicle	73.05	76.32	67.66	38.45	44.99	112.79
Number of fertile grains per panicle	71.13	70.31	68.56	39.53	46.87	102.55
Yield per plant	46.18	11.47	42.48	30.32	44.63	27.00
L/B ratio of grains	97.22	1.20	37.50	18.41	18.73	3.20

closely followed by the total number of grains per panicle (67.66 per cent), and lowest is for the length of top internode (34.33 per cent). However, 42.48 per cent expected genetic advance for yield per plant is quite significant. The grain number per panicle and the culm length showed high genetic advance together with high heritability values (Table 4).

The grain yield per plant was negatively correlated with 1,000-grain weight and positively with plant height, number of effective tiller per plant, panicle length and number of fertile grains per panicle; all correlation values being highly significant (Table 5).

Table 5. *Regression equations and correlations between yield per plant and other quantitative characters*

Character	Correlation coefficient	Regression equation
Culm length	+0.52**	$0.17\,x + 7.50$
Number of effective tillers per plant	+0.56**	$1.33\,x + 13.01$
Panicle length	+0.79**	$1.49\,x - 6.62$
1,000-grain weight	−0.42*	$0.60\,x + 41.62$
Number of fertile grains per panicle	+0.80**	$0.18\,x + 7.52$

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

Discussion

Rice possesses a tremendous capacity to tolerate climatic stress and is subjected to rigorous human selection, mostly for productivity and quality of grains but other components of yield also appear to have accumulated considerable variation (Table 1). Diverse agroecological conditions in the various rice growing areas may also have resulted in substantial genetic divergence in the crop, for Clausen and Hiesey (1958) demonstrated that even a single component of the environment could cause differences between and within plant races. The various agronomic practices suited to different regions of cultivation and the wide range of rice varieties grown by man for the common purpose and same end product has also contributed to its diversity under human selection. Evolution in the *O. sativa* group has been accelerated by the disturbance of its habitat by man (Anderson and Stebbins, 1954). Murty and Arunachalam (1966) stated that genetic drift and selection in different environments could cause greater diversity than geographical distance. Since inbreeding alters the genetic architecture of a population, it modifies the adaptive value as well. It is likely, therefore, that the variability and consequent adaptability of rice over a wide range of conditions is due to its genetic heterogeneity and physiological homeostasis.

Robinson (1966) recommended that germ plasm pools be created to provide a reservoir of gene complexes and to form new bases for profitable selection studies. In fact, such germ plasm offers an array of material for incorporation into breeding programmes, with the possibility of extending economic production from a wider genetic base. Since most of the characters considered are quantitatively inherited (Chandraratna, 1964; Grist, 1959) and are subject to different degrees of non-heritable variability, the magnitude of heritable variability, more particularly its genetic component, is the most important aspect of the genetic constitution of the breeding material which has a close bearing on the response to selection. This necessitated working out, in the present investigation, various estimates of variability for some of the quantitative characters in rice which are otherwise very meagrely documented (Grist, 1959; Chandraratna, 1964; Kaul, 1973).

For this determination, it was necessary to divide the total phenotypic variance of the metric characters into its components, as these are the basis for a genetic analysis and the dimensions of these components decide the breeding behaviour of the population and the choice of selection techniques. Thus, the phenotypic variance was broadly partitioned into the separate contributions made by the genotype and the environment and it appears that the contributions of both these factors are equally profound and discrete (Table 3). There is a large genotypic coefficient of variation for all the traits studied in the varieties and it was highest for the number of fertile grains per plant (Table 4). Considerable genetic variability in most of the plant characters related to yield exists in rice so that there is scope for further improvement of these characters in the crop. This is possible if the amount of heritable variation is known. This can be determined through estimates of heritability and genetic gain. Naturally, heritability estimates calculated in the broad sense could be useful when high genetic gain in a particular trait is also possible. However, heritability is a property not only of a character but also of the population and of the environmental circumstances to which the individuals are subjected to, so its value depends upon the magnitude of all the components of variance. A change in any of these will affect the heritability estimates. Since all the genetic components are influenced by the gene frequencies (which differ from one population to another according to the past history of the population) and the environmental variance is dependent upon the conditions of culture or management, more variable conditions reduce heritability and more uniform conditions increase it; the values of heritability computed here for rice refer to the populations grown under local conditions and to the characters studied. However, such values found for other populations of rice in other situations are liable to be more or less similar according to how far the structure of the population and the environmental conditions are similar to those studied here.

It was found that the heritability values are high for culm length, grain shape, panicle length, 1,000-

grain weight and grains per panicle and moderate for tiller number and total grain yield per plant. However, Sarthe, Sharma and Shrivastava (1969) reported very low (2.7%) heritability for grain yield per plant and moderate (38.0%) for grain number in five high-yielding varieties of rice. The disparity in the heritability values might possibly be due to the reasons mentioned above.

A knowledge of the genetic advance produced by applying selection pressure to a population is useful in designing an effective breeding programme. It was found that grain number per panicle, number of effective tillers per plant and culm length had a high heritability and genotypic coefficient of variation and, therefore, high genetic advance. This is a good indication that the variation in these traits is attributable to a high degree of additive genetic effect. It appears that selection for these characters should be effective and satisfactory for practical purposes. The values are comparatively high for panicle length and grain-number so selection for these characters will also be of interest and importance to a plant breeder. Selection for other genetic parameters appears to be less effective in rice.

The 1,000-grain weight has a low genetic advance and is negatively correlated with grain yield per plant. On the other hand, the number of fertile grains per panicle is a highly heritable trait with a high genetic advance and is positively correlated with grain yield. Therefore, grain number could form a better and more reliable index for the yielding capacity of a rice plant.

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