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Genetic Divergence Among Rice Strains

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Summary. For screening better types among 10 strains with the help of the D^2 statistic, an experiment was conducted in randomized block design with three replications. 10 plants in each plot were randomly selected and observations were recorded on final plant height, heading duration, effective tillers, number of grains per panicle, yield per plant and 100 grain weight.

The observations were analyzed and found to be significant at 1% level.

In the study of distance relations the contribution of grain number per panicle to D^2 values was found to be maximum. Again, this technique also helped in grouping the 10 strains into four clusters, viz. A, B, C and D, of which B possessed six strains out of 10; A possessed two and C and D one each.

Group A comprised 2 selections from the same cross. Group D was composed of a selection from a cross involving Dular and Taichung Native-1 as parents. Group B possessed Dular, two selections from a cross involving Dular as one of the parents, Dharial and N.C.-1626. The constituents of A are expected to be transgressive segregates.

Group A was maximally distantly related with D followed in order by C and B. The distance between B and C was small.

Group D was found to be the best of all strains studied, followed by B, C and A.

Introduction

The plant breeder is interested to know the genetic divergence among the varieties or strains available because crosses involving distantly related parents within the same species provide him with a broad spectrum of variability to ensure the efficiency of selection towards better types. The use of diverse germ plasm as a significant factor contributing to high yield has been stressed by many workers using crops like maize, *Nicotiana* and cotton (Griffing and Lindstrom, 1954; Matzinger, Mann and Cockerham, 1962; and, Hawkins, Pracock and Ballard, 1965).

With the help of Mahalanobi's D^2 statistic, genetic divergence among varieties can be easily measured. This technique also helps the breeder in comparing a huge number of varieties together by clustering them into a few groups. Screening of selections from a cross involving two distantly related parents is made easier with this method. This technique has, therefore, been adopted by many workers for classification problems (Hotelling, 1931; Wilks, 1932; Fisher, 1936; Rao, 1952; Anderson, 1958), and for finding the genetic divergence and relationship among strains or varieties (Murty and Anand, 1966; Murty and Tiwari, 1967; Anand and Murty, 1968; Singh und Bains, 1968; and, Singh and Gupta, 1968).

Application of the D^2 statistic to finding parents with better combining ability or screening out better types from among various existing strains has not previously been done in rice. As a preliminary, therefore, a trial was undertaken of a few rice strains to select out better types and to assess the contribution of different characters to distance relation under summer conditions of culture.

Materials and Methods

The experiment was conducted at Narendrapur Farm of the R. K. Mission using 10 strains, of which four were pure lines and the rest were selections from F_4 generation of two rice crosses. The strains were:

A. Pure lines	B. Selections from F_4 generation
1. Dular	5. $D \times T - 5/2$
2. Satika	6. $D \times T - 10/3$
3. Dharial	7. $T_3 \times T - 5/3$
4. N.C.-1626	8. $D \times T - 6/5$
	9. $T_3 \times T - 1/1$
	10. $T_3 \times T - 6/3$

D = Dular, T = Taichung Native-1 and T_3 = Tainan-3.

These 10 strains were grown in three replications in a randomized block design with 10 plots per block of 7.20 sq. metres, and 4 rows in each plot. Each row contained 12 plants with 15 cm. spacing between the plants. The rows were also spaced 15 cm. apart.

The seedlings were raised in petridishes and transplanted to the field on the 25th February, 1969, at the age of 50 days with one plant per hill. Cultural operations were in accordance with the usual practice of rice cultivation.

10 plants per strain were randomly selected in each block and observations were recorded on them for the following characters:

1. Final plant height in cm. (x_1)
2. Heading duration in days (x_2)
3. Number of effective tillers (x_3)
4. Number of grains per panicle (x_4)
5. Grain yield per plant in gm. (x_5) and
6. 100 grain weight in gm. (x_6).

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Statistical Analysis

The observations were first analyzed by Variance Analysis to ascertain whether significant differences existed at varietal level.

The dispersion matrix supplied by variance and covariance analysis was then passed through pivotal condensation to render the characters uncorrelated and to produce linear functions for each character.

These functions ($Y's$) were then converted into standard deviation unity and used to transform varietal mean values to give an uncorrelated set of variables.

The differences (dij) corresponding to transformed mean values for each pair of strains were squared and added to give the D^2 values between the two members of the pair.

$$(dij)^2 = D^2$$

In this way the strains were paired in all types of combinations and corresponding D^2 values were obtained.

For clustering, the pair showing the smallest D^2 values was used as starter and gradually strains were added to it, on the basis that the average D^2 values due to addition of a new one must be smaller than when any other strain was added. When a sharp increase on addition of a further new strain was noticed, clustering was stopped and once again a new clustering or grouping in the same fashion was begun.

After clustering, the intra- and inter- cluster relationships were studied and the mutual relationships between the clusters and their distances were represented diagrammatically using D-values.

A similar technique has been followed by Rao (1952), Singh and Bains (1968), Anand and Murty (1968) and Singh and Gupta (1968).

Results

The strains were analyzed for all the characters and found to differ significantly at 1% level (Table 2).

The six characters were studied in all types of combinations, taking two together, to give a 6 × 6 dispersion matrix (Table 3).

The 6 × 6 dispersion matrix was passed through pivotal condensation and functions ($Y's$) for all characters were obtained. Again, with the help of the respective standard deviation values, these functions were converted into standard deviation unity, presented in Table 4.

Functions ($Y's$) were used to transform the original mean values of Table 1 into an uncorrelated set of variables ($y's$). These transformed mean values, presented in Table 5, were used to find out the statistical distance between any two strains. The 90 D^2-values obtained by taking two strains together have been presented in Table 6 in increasing order of merit. This shows that the smallest distance occurs between $T_3 \times T$-1/1 and $T_3 \times T$-6/3, and the next smallest between Dular and $D \times T$-5/2. The strain $D \times T$-10/3 is most distantly related with $T_3 \times T$-6/3, the D^2 value for which is 65.00.

By the clustering technique, these 10 strains were grouped into 3 clusters, presented in Table 7, which shows that the B group is biggest in size and possesses six strains out of 10. Group A includes only two strains and the remaining two strains are in the third cluster. However, because the average D^2 values between the last two are very high (8.88), they have been clustered into two separate groups, each consisting of just one strain.

In Table 8, within- and between- group distances have been presented in the form of average D^2. C

Table 1. *Mean values of strains*

		Plant height (cm.) (X_1)	Heading duration (days) (X_2)	Effective tillers No. (X_3)	No. of grains/ panicle (X_4)	Yield/plant (gm.) (X_5)	100 grain wt. (gm.) (X_6)
(1)	Dular	91.1167	86.7667	5.6667	61.7333	6.1667	2.2000
(2)	Satika	72.8800	84.3333	9.2333	49.1000	3.7000	1.9333
(3)	Dharial	90.0733	93.2333	6.6333	89.0667	9.4333	2.5000
(4)	N. C. 1626	95.7800	97.2333	6.4667	89.5333	8.9667	2.0333
(5)	$D \times T$ 5/2	73.5367	96.2667	6.3667	59.2333	8.6667	2.2333
(6)	$D \times T$ 10/3	51.3967	105.8000	12.8833	38.9000	8.1000	2.0667
(7)	$T_3 \times T$ 5/3	60.9800	99.3333	6.4667	22.5667	3.3667	2.3667
(8)	$D \times T$ 6/5	53.5433	103.5333	6.4667	32.7667	6.5667	2.0667
(9)	$T_3 \times T$ 1/1	72.4467	111.8000	4.2000	22.7667	2.0000	1.9333
(10)	$T_3 \times T$ 6/3	80.3000	115.5000	3.8333	27.9000	1.9000	1.9667

Table 2. *Variance analysis*

Source of variance	D. F.	Plant height M. S.	Heading duration M. S.	No. of effective tillers M. S.	No. of grains/ panicle	Yield/plant M. S.	100 grain wt. M. S.
Block	2	168.90	29.10	2.55	237.20*	13.90	0.05
Strain	9	722.20**	304.80**	20.04**	1905.00**	25.80**	0.11**
Error	18	31.10	14.10	1.68	65.60	4.20	0.02

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

and D have failed to reveal any within-group distance, as each consists of only one strain viz., Satika and $D \times T$-10/3 respectively.

These intra- and inter-group distances have been presented in a diagrammatic manner in Fig. 1, which shows that Group A is far from D, whereas B is nearer to A. The distance relation between C and D is more or less the same as that between A and B. The distances between A, C and B, D are of the medium type.

Table 9 shows the average contribution of different characters to distance relation expressed in percentages. The contribution of y_4, i. e. number of grains per panicle, is maximum (77.04%). The relative contributions of the other characters are much less and are more or less identical.

The group means presented in Table 10 show that Group D possesses the lowest height and group B the largest, with A and C expressing values more or less nearer that of B. In heading duration, A is later than all others and C the earliest, B and D falling uniformly midway between the two. Regarding the number of effective tillers, D leads, followed by C, B and A in that sequence. Group B possesses the maximum number of grains per panicle and A the least, with C and D lying in between the two. For yield per plant, B and D rank more or less together, followed by C and then A. The difference between the highest and lowest values for yield is very large. Group B possesses the highest 100 grain-weight followed by D, A and C, respectively, in order of merit.

Discussion

In the study of distance relation, the 10 strains under trial, formed 4 clusters, A, B, C and D. Of these, B was the largest and possessed six strains out of 10, whereas group A consisted of two. Only one

Table 3. *Standard deviation, variance and covariance*

	X_1	X_2	X_3	X_4	X_5	X_6
X_1	722.20 (26.873)	−163.40	−57.50	850.10	26.70	1.40
X_2		304.80 (17.458)	−20.70	−443.20	−34.60	−2.00
X_3			20.01 (4.472)	15.00	9.20	−0.02
X_4				1905.00 (43.646)	172.80	5.60
X_5					25.80 (5.079)	0.80
X_6						0.11 (0.331)

Figures in ( ) are standard deviation.
X_1 — Plant height, X_2 — Heading duration, X_3 — Effective tiller number, X_4 — No. of grains/panicle, X_5 — Yield/plant, X_6 — 100 grain wt.

Table 4. *Functions for transformation*

	X_1	X_2	X_3	X_4	X_5	X_6
Y_1	1.0 (.0372)					
Y_2	.2258 (.0084)	1.0 (.0573)				
Y_3	.1108 (.0041)	.1247 (.0071)	1.0 (.2236)			
Y_4	−1.4703 −(.0547)	−3608 (.0207)	−4.5645 −(1.0207)	1.0 (0.0229)		
Y_5	.1710 (.0064)	−.0466 −(.0027)	.0791 (.0401)	−.1781 −(.0041)	1.0 (.1968)	
Y_6	.0001 (.0000)	.0082 (.0005)	.0373 (.0083)	.0044 (.0001)	−.0634 −(.0123)	1.0 (3.0211)

Figures in ( ) have been converted into standard deviation unity

Table 5. *Transformed Mean Values*

Sl. No.		Plant Height y_1	Heading duration y_2	No. of effective tillers y_3	No. of grains/ panicle y_4	Yield/ plant y_5	100 grain wt. y_6
1.	Dular	3.3895	5.7371	2.2567	−7.5583	1.5546	6.6671
2.	Satika	2.7111	5.4445	2.9622	−10.5408	1.1358	5.9189
3.	Dharial	3.3507	6.0989	2.5145	−7.7281	2.0821	7.5474
4.	N. C. 1626	3.5630	6.3761	2.5291	−7.7768	2.0073	6.1438
5.	D × T 5/2	2.7356	6.1338	2.4086	−7.1719	1.9287	6.7472
6.	$D \times T$ 10/3	1.9120	6.4940	3.8426	−12.8805	1.9944	6.3078
7.	$T_3 \times T$ 5/3	2.2685	6.2050	2.4013	−7.3632	.9515	7.2143
8.	$D \times T$ 6/5	1.9918	6.3823	2.4006	−6.6359	1.4805	6.2717
9.	$T_3 \times T$ 1/1	2.6950	7.0147	2.0299	−5.4140	.6305	5.9092
10.	$T_3 \times T$ 6/3	2.9872	7.2927	2.0064	−5.2752	.6152	6.0106

Table 6. *D^2 values in increasing order*

1		2		3		4		5		6		7		8		9		10	
5	.91	6	8.88	1	1.23	1	1.04	1	.91	2	8.88	5	1.43	5	1.33	10	.19	9	.19
4	1.04	4	10.23	5	1.36	5	1.49	8	1.33	4	30.54	8	1.80	7	1.80	8	3.38	8	4.64
3	1.23	1	10.67	4	2.10	3	2.10	3	1.36	3	32.08	1	2.54	9	3.38	5	6.40	5	7.54
7	2.54	3	12.50	7	2.72	8	4.08	7	1.43	1	33.92	3	2.72	1	3.40	7	6.58	7	7.78
8	3.40	7	12.30	8	4.12	7	4.15	4	1.49	7	34.64	4	4.15	4	4.08	1	8.19	1	9.17
9	8.19	5	13.45	10	12.35	9	8.94	9	6.40	5	35.65	9	6.58	3	4.12	4	8.94	4	9.82
10	9.17	8	17.20	2	12.50	10	9.82	10	7.54	8	41.36	19	7.78	10	4.64	3	12.76	3	12.35
2	10.67	9	29.87	9	12.76	2	10.23	2	13.45	9	61.94	2	12.90	2	17.20	2	29.87	2	32.41
6	33.92	10	32.41	6	32.08	6	30.54	6	35.65	10	65.00	6	34.64	6	41.36	6	61.94	6	65.00

1 = Dular 3 = Dharial 5 = $D \times T$ 5/2 7 = $T_3 \times T$ 5/3 9 = $T_3 \times T$ 1/1
2 = Satika 4 = N. C. 1626 6 = $D \times T$ 10/3 8 = $D \times T$ 6/5 10 = $T_3 \times T$ 6/3

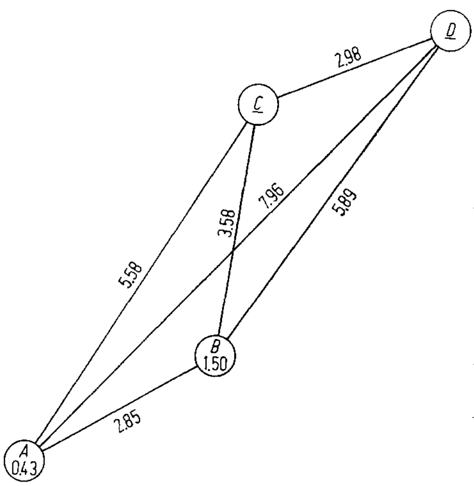

Fig. 1. Clusters and their inter-relationship

Table 7. *Clustering among strains*

Group added to a cluster	D^2	No. of terms	Increase in D^2	Average D^2	Cluster	Group
10, 9	.19	1	–	0.19	10, 9	A
8	8.21	3	4.01	2.74		
1, 5	.91	1		.91	1, 5, 4, 3, 7, 8	B
4	3.44	3	1.26	1.15		
3	8.13	6	1.56	1.35		
7	18.97	10	2.71	1.90		
8	33.70	15	2.95	2.25		
2	110.65	21	12.82	5.27		
2, 6	8.88	1	–	8.88		C, D.

Table 8. *Intra- and inter-cluster average D^2*

Groups	Strains	A	B	C	D
A	10, 9	0.19	8.13	31.14	63.46
B	1, 5, 4, 3, 7, 8	8.13	2.25	12.83	34.70
C	2	31.14	12.83	–	8.88
D	6	63.46	34.70		–

Table 9. *Average contribution of different characters to distance relation*

Characters	in percentage
Plant height (Y_1)	4.87
Heading duration (Y_2)	4.35
Effective tillers (Y_3)	4.15
No. of grains/panicle (Y_4)	77.04
Yield/plant (Y_5)	4.80
100 grain wt. (Y_6)	4.78

strain each could be located in the groups C and D in this study.

The large group size of B is the cause of high within-the-group distance in this group; it was very small in group A. The groups C and D revealed no such intra-group distance presumably due to their size limitation in this study with such a low number of strains.

$T_3 \times T$-1/1 and $T_3 \times T$-6/3, which constituted group A, had the same origin, both of them being two selections from Tainan-3 × Taichung Native-1 cross. The very small within-the-group distance and mean values for different characters indicate that there is no need to continue both of these in further generations. If this is desired, either one of the two would serve the purpose. The third selection, $T_3 \times T$-5/3, from the same cross lay in group B. This signifies that all the selections from the same cross may not necessarily form a single cluster. This generally occurs when the parents crossed are distantly related (Singh and Gupta, 1968). According to the results obtained by previous workers in crops like upland cotton (Singh and Gupta, 1968) and linseed (Anand and Murty, 1968), the selection from a cross would either fall into the parental groups or belong to those groups which would not be very distantly related. In the present study, too, $T_3 \times T$-5/3 fell within a group which was not distantly related to A.

Dular, Dharial, N. C.-1626, $D \times T$-5/2, and $D \times T$-6/5, in addition to $T_3 \times T$-5/3, comprised group

Table 10. *Group mean*

Group	Strains present		No. of strains	Plant height cm. X_1	Heading duration days X_2	No. of effective tillers X_3	No. of grains/ panicle X_4	Yield/ plant (gm.) X_5	100 grain wt. (gm.) X_6
A	$T_3 \times T$ 6/3	(10)	2	76.3734	113.6500	4.0166	25.3334	1.9500	1.9500
	$T_3 \times T$ 1/1	(9)							
B	Dular	(1)	6	77.5050	96.0611	6.3445	59.1500	7.1945	2.2333
	$D \times T$ 5/2	(5)							
	N. C. 1626	(4)							
	Dharial	(3)							
	$T_3 \times T$ 5/3	(7)							
	$D \times T$ 6/5	(8)							
C	Satika	(2)	1	72.8800	84.3333	9.2333	49.1000	3.7000	1.9335
D	$D \times T$ 10/3	(6)	1	51.3967	105.8000	12.8833	38.9000	8.1000	2.0667

B. Dular, Dharial, and N. C.-1626 may thus be regarded as statistically closely related, so that crosses involving any two of these as parents may not produce any better offspring. $D \times T$-5/2 and $D \times T$-6/5 were two selections from a cross involving Dular as one of the parents. Hence, it is not unusual to find these two selections within the same group as Dular itself.

The third selection, $D \times T$-10/3, involving Dular and Taichung Native-1 as parents, formed a separate group, viz. D. Statistically, D was found to be the maximum distantly related with A, but moderately with B. Hence, this selection $D \times T$-10/3 should either be a transgressive segregate or belong to a group which would also possess Taichung Native-1 (not in trial).

Group C, represented in the present study by only one strain, Satika, was far from A, but nearer to D; B lay in between the latter two. If the trial was made with more strains, other members closely related with Satika could be found and the size of C could be enlarged.

Using yield as the criterion for selection, group D was found to possess the best group means, followed by B, C and A. Group D, though possessing a lower value with respect to yield attributing factors like 100 grain weight and grain number per panicle, gave a higher yield than group B, due to higher tiller number. Group A revealed the lowest values for all yield attributes and also for yield.

In the study of distance relation, the contributions of different characters to D^2 values were found to vary. Grain number per panicle contributed the maximum, which proved that the strains varied considerably more in this character than in the others.

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