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Diallel Cross Experiment among Sikkimese Varieties, Indica and Japonica Testers of Rice, *Oryza sativa* L.

IX. Mutual Relationships between the 2 on 34 Characters

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Introduction

Kato *et al.*[16] proposed to divide *Oryza sativa* L. into two sub-species *japonica* and *indica*. Terao *et al.*[24] showed that the *javanica* varieties showed a very high affinity with Japanese varieties. These three major-groups have been genetically recognized by many workers. However, the idea of dividing rice varieties into geographical races is rapidly losing its significance in accordance with the execution of further intensive works[2,8]. The author's aim in these investigation-series was consistently to study varietal differentiations of the cultivated rice in the hope of getting useful information on phylogenetic relationships of *Oryza sativa* L.

The generally accepted origin of *O. sativa* has been the area embracing South Asia, Southeast Asia and China[22]. Morinaga[20] stated that Himalaya is an indigenous centre of rice. Katayama[6] held that Sikkim might be one of the differentiation centres of *O. sativa* into *japonica* and *indica*, and also stated that[7] cultivated rice was originated in the north India, and *japonica* type must have been developed later out of the *indica* type.

Classification and determination of indigenous centre of rice have been looked upon as complex symptoms. In order to confirm the classification of rice varieties, especially Sikkimese rice, and to clarify the relationships between its strains and the type of typical *indica* and *japonica*, the diallel crosses were carried out. In the previous papers, 38 characters were reported, *i.e.*, crossability, pollen and seed fertilities[8], heading date and growing period[9], some morphological characters of plant[10], morphological characters of unhusked[11] and husked grains[12], comparison of unhusked and husked grains[13], surface area and volume of unhusked and husked grains[14], and miscellaneous characters[15]. In the present paper, mutual relationships between the two on 34 characters measured were mainly described. Concluding survey of the present series and the discussions of them from the evolutional point of views are to be published in the papers following hereafter.

Materials and Methods

Thirty eight characters were used in this experimental series (Table 1). But 4 characters, *i.e.*, No. 1 (phenol reaction), No. 5 (heading date), No. 19 (awn length) and No. 26 (grain color), were omitted in the present experiment, because these characters are not responsible for the comparison of the mutual relations in the respective characters. Most of the data were picked out from the previous papers[8–15], and were analyzed. The items used here were as follows; (1) significant relations in the respective characters noted in view of the practical value and of the standard de-

Table 1. Characters used in the diallel cross experiments

Series No.	Character No.	Character name	Unit
I	1	Phenol reaction	+, −
	2	Crossability	%
	3	Pollen fertility	%
	4	Seed fertility	%
II	5	Heading date	
	6	Growing period	days
III	7	No. of seeds per panicle	
	8	Weight of unhusked grains	mg
	9	Panicle length	cm
	10	No. of first rachises per panicle	
	11	No. of tillers per plant	
	12	Plant height	cm
IV	13	Unhusked grain; length	mm
	14	〃 〃 ; width	mm
	15	〃 〃 ; thickness	mm
	16	〃 〃 ; length/width	
	17	〃 〃 ; length/thickness	
	18	〃 〃 ; width/thickness	
	19	Awn length	mm
V	20	Husked grain; length	mm
	21	〃 〃 ; width	mm
	22	〃 〃 ; thickness	mm
	23	〃 〃 ; length/width	
	24	〃 〃 ; length/thickness	
	25	〃 〃 ; width/thickness	
	26	Grain color	W, R
VI	27	Quotient; length	
	28	〃 ; width	
	29	〃 ; thickness	
	30	〃 ; length/width	
	31	〃 ; length/thickness	
	32	〃 ; width/thickness	
VII	33	Unhusked grain; area	mm^2
	34	〃 〃 ; volume	mm^3
	35	Husked grain; area	mm^2
	36	〃 〃 ; volume	mm^3
	37	Quotient; area	
	38	〃 ; volume	

viations (Tables 2 and 3), (2) significant relations in the two respective characters noted in view of the practical value and of the standard deviations (Tables 4, 5 and 6), (3) reciprocal comparisons with parent and hybrid-averages noted in view of the practical value (Tables 7 and 8).

In the present paper, the following abbreviations were adopted concerning the grain morphology; L (length), W (width), T (thickness), L/W (ratio of length to width), L/T (ratio of length to thickness), W/T (ratio of width to thickness).

Results

1. Significant relations in the respective characters

Reciprocal relations of 34 characters measured were summarized in view of significant levels, and are shown in Table 2. In the whole strain level, 22/34 characters, *i.e.*, 64.7% of them, showed positive significances. Generally speaking, the larger is the value of the female, the larger is the value of the male.

In the respective strain level, 204 items among 544 cases in the total, *i.e.*, 37.5% of them, were found to be significant. Six among 204 showed negative values, but the remaining (198/204, 97.1%) showed positive values. In other words, almost of them were fixed to be of reasonable values. Generally speaking, the larger is the value of female, the larger is the value of male. In detail, 1 (character No. 6), 2 (Nos. 23, 24), 1 (No. 20), 2 (Nos. 13, 16), 1 (No. 21), 3 (Nos. 4, 8, 17), 2 (Nos. 3, 35), 1 (No. 22), 1 (No. 36), 2 (Nos. 12, 33), 2 (Nos. 10, 34), 3 (Nos. 7, 14, 25), 3 (Nos. 18, 27, 37), 8 (Nos. 2, 11, 15, 28, 30, 31, 32, 38) and 2 (Nos. 9, 29) characters showed significances in 16, 15, 14, 13, 12, 11, 9, 8, 6, 5, 4, 3, 2, 1 and 0 strains, respectively. Average and its standard deviations through the whole characters were found to be 6.00 ± 5.26. Mode was found in 1 (8 characters). It may be noticeable that character No. 6 (=growing period) showed significances through the whole strains.

Concerning the reciprocal relations between the corresponding characters, *i.e.*, 6 sets of grain morphology, L (character Nos. 13, 20 and 27, abbreviated as 13–20–27, and so forth), W (14–21–28), T (15–22–29), L/W (16–23–30), L/T (17–24–31) and W/T (18–25–32), number of significances were compared. Two sets (L, L/W), 1 (L/T), 1 (W), 1 (T) and 1 (W/T) showed significances in 29, 27, 16, 9 and 6 characters, respectively. It may be also noticeable that L and L/W showed significances in 29/34, *i.e.*, 85.3% of them.

In other viewpoints, 1 (strain No. 14), 1 (No. 3), 2 (Nos. 13, 16), 1 (No. 12), 2 (Nos. 7, 10), 2 (Nos. 2, 4), 3 (Nos. 1, 6, 9), 1 (No. 5), 1 (No. 8), 1 (No. 11) and 1 (No. 15) strains showed significances in 20, 17, 16, 15, 14, 13, 11, 10, 9, 8 and 6 characters, respectively. Average and its standard deviations through the whole strains were found to be 12.75 ± 3.64. Mode was found in 11 characters (3 strains). It may be noticeable that No. 14 showed significances in 20/34 characters, *i.e.*, 58.8% of them.

In Table 3, 4 the following relations are shown; reciprocal relations of the practical values (column A), relations between practical values and its standard deviations (B), differences between the maximum and the minimum values for the whole strains and for two testers (C) and the reciprocal relations of standard deviations (D). In column A, 22/34 combinations, *i.e.*, 64.7% of them, showed positive significances. Concerning the reciprocal relations between corresponding characters, *i.e.*, 6 sets of grain morphology, the same results were found in the whole sets. In other words, characters of unhusked (character Nos. 13–18) and husked (20–25) grains showed significances through the whole characters, but characters of comparisons (27–32) showed no significance at all.

In column B, 10/34 (=29.4%) and 8/34 (=23.5%) characters showed significances in female and male parents, respectively. In detail, only 3 characters showed significances both in the female

Table 2. Synopses of significant relations found in 34 characters

	Series No.	I				II		III						IV						
	Character No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Table No.	Parent	1	—	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Parental level	—	3	3	3	—	4	3	3	3	10	10	10	3	3	3	10	10	10	—
	Diallel	—	2	5	8	2	3	2	6	8	9	13	14	2	6	7	9	12	13	8
	Correl. coef.	—	4	6	9	—	4	4	4	4	11	11	11	4	4	4	11	11	11	—
	Diagonal	—	—	7	10	—	5	5	7	—	12	—	15	5						—
Strain No.	1	—		***	*	—	***		**					**	*		***	***		—
	2	—			**	—	***				**		*	**			***	*		—
	3	—	_***	**	**	—	***		*					**		*	***	**		—
	4	—				—	***		***				*	*			***	*		—
	5	—		***		—	*	*			*						*	*		—
	6	—		*	**	—	**		***					***			**			—
	7	—			**	—	***	*	**				*	***			*			—
	8	—		***		—	***													—
	9	—		*		—	***		*					*			*	*		—
	10	—		**	**	—	***		**					*			***	***		—
	11	—		**	***	—	***					_*		*						—
	12	—			***	—	***		**		*			**			***	**	*	—
	13	—				—	**		**				**	**	*		**	*		—
	14	—		**	***	—	***		***					***	*		***	*		—
	15	—			*	—	***	*			**									—
	16	—			***	—	***		**			_**		***			**	*	**	—
	Whole	—		***	***	—	***	***	***		***		**	***	***	*	***	***	*	—

	Series No.	V							VI						VII						
	Character No.	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Table No.	Parent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Parental level	3	3	3	9	9	9	—	3	3	3	8	8	8	3	3	3	3	3	3
	Diallel	2	5	6	8	11	12	7	2	5	6	7	10	11	2	5	6	7	9	10
	Correl. coef.	4	4	4	10	10	10	—	4	4	4	9	9	9	4	4	4	8	8	8
	Diagonal							—												
Strain No.	1	***			***	**		—												
	2	***	**	***	***	***	*	—												
	3	***		*	**	**		—							*	*	***	*		
	4	***	**		***	**		—								*	**	*		
	5	*	*		***	**		—												
	6	***	***	*	***	**		—												
	7	***	***		***	***		—							**	*	***			
	8		**		**	*		—	***			_*	_*	_*						
	9	*	*		***	*		—										*		
	10	***	**	**	**	***		—									**	*		
	11	*			**			—											*	
	12	***	***	***	***	***		—									***	**		
	13	***	**	*	**	***		—	*						***	*	**			
	14	*	***	**	**	***	**	—		*					**		***	*	***	*
	15					*		—									**			
	16	***	**	**	***	***	**	—							*		**			
	Whole	***	***	***	***	***	***	—							***		***	***		

***, **, *, — and blank; significant at 0.1%, 1% and 5% levels, no pertinent data and no significant, respectively.

d.f.; 13 and 118 in the respective strain and the whole combinations, respectively.

Table 3. Synopses of significant relations found in the four references in 34 characters; reciprocal relations of practical values (A), relations between practical values and its standard deviations (B), differences between the maximum and the minimum values through the whole strains and for testers (C) and reciprocal relations of standard deviations (D)

Series No.	Character No.	A	B		C		D
			Female	Male	Whole	Tester	
I	2		**	*	*		*
	3	***	−***	−**			
	4	***		−**			
II	6	***	−**	−**	***	***	***
III	7	***					
	8	***				**	*
	9				*		
	10	***					
	11						
	12	**					
IV	13	***	*			−**	
	14	***					
	15	*	*				
	16	***	**				
	17	***		−*			
	18	*					
V	20	***					
	21	***		*			
	22	***		***			
	23	***	***				
	24	***		−*			
	25	***					
VI	27						
	28						
	29		−***				
	30						
	31						
	32						
VII	33	***					
	34		**			−*	
	35	***					
	36	***					
	37						
	38		−*				

***, **, *; significant at 0.1%, 1% and 5% levels, respectively.
d.f.; 12 in C-Tester and 14 in the other columns, respectively.

and male parents. Twelve characters showed significances only at female or male parents. The remaining 19 characters did not show any significance in both the female and the male parents.

In column C, 3/34 (=8.8%) characters showed significances in both the female and male parents. In detail, 1 character showed significances in the both differences for the whole strains and for two testers. Five characters showed significances only in the differences of whole strains or of testers. The remaining 28 characters showed no significance in the both differences for the whole strains and for two testers.

In column D, 3/34 (=8.8%) characters showed positive significances. In detail, 1 and 2 characters showed positive significances at 0.1% and 5% levels, respectively, but the remaining 31 characters showed no significance even at 5% level.

2. Significant relations in two respective characters

Relations of 47 combinations measured were summarized in view of significant levels, and are shown in Tables 4 and 5. Characters of No. 2 to No. 18 (mainly plant morphology) and No. 20 to No. 38 (only grain morphology) were used in Table 4 and Table 5, respectively.

Table 4: In the whole strain level, 18/24 combinations, *i.e.*, 75.0% of them, showed significances. Generally speaking, the larger is the practical value of one character, the larger is the practical value of another character.

In the respective strain level, 190/384 combinations, *i.e.*, 49.5% of them, showed significances. In other words, about a half of them showed significances. Sixteen among 190 (=8.4%) showed negative values. In detail, 4 (character Nos. 7·10, 9·12, 14·15, 16·17), 1 (Nos. 7·9), 1 (Nos. 9·10), 3 (Nos. 8·9, 10·12, 17·18), 1 (Nos. 7·12), 2 (Nos. 3·4, 11·12), 1 (Nos. 7·8), 4 (Nos. 8·10, 9·11, 13·14, 13·15), 1 (Nos. 16·18), 2 (Nos. 2·4, 8·12), 3 (Nos. 2·3, 7·11, 10·11) and 1 (Nos. 8·11) combinations showed significances in 16, 15, 14, 10, 9, 8, 6, 5, 4, 3, 2 and 0 cases, respectively. Average and its standard deviations through the whole combinations were found to be 7.92±5.24. Modes were found in 16 and 5 (4 combinations each). It may be divided into two groups, *i.e.*, the larger and the smaller groups showing the gap between 11 to 13. Six combinations and 18 combinations belonged to the former and the latter groups, respectively.

In other view points, 2 (strain Nos. 11, 14), 1 (No. 16), 3 (Nos. 1, 6, 15), 3 (Nos. 4, 5, 9), 2 (Nos. 3, 7), 2 (Nos. 2, 10), 2 (Nos. 8, 12) and 1 (No. 13) strains showed significances in 16, 15, 13, 12, 11, 10, 9 and 8 combinations, respectively. Average and its standard deviations through the whole strains were found to be 11.88±2.42. Modes were found in 12 and 13 (3 strains each). It may be noticeable that strain Nos. 11 and 14 showed significances in 16/24 combinations, *i.e.*, 66.7% of them.

Table 5: In the whole strain level, 22/23 combinations, *i.e.*, 95.7% of them, showed significances. Generally speaking, the larger is the practical value of one character, the larger is the practical value of another character.

In the respective strain level, 290/368 combinations, *i.e.*, 78.9% of them, showed significances. In other words, about the three fourths of them showed significances. Twenty eight among 290 (=9.7%) showed negative values. In detail, 12 (character Nos. 23·24, 28·29, 30·31, 31·32, 13·20, 14·21, 15·22, 16·23, 17·24, 33·34, 33·35, 37·38), 2 (Nos. 18·25, 35·36), 1 (Nos. 21·22), 1 (Nos. 20·21), 1 (Nos. 34·36), 1 (Nos. 27·28), 1 (Nos. 20·22), 1 (Nos. 23·25), 1 (Nos. 24·25), 1 (Nos. 27·29) and 1 (Nos. 30·32) showed significances in 16, 15, 14, 13, 11, 8, 7, 6, 5, 3 and 1 combinations, respectively. Average and its standard deviations through the whole combinations were found to be 12.61±4.93. Mode was found in 16 (12 combinations).

In other viewpoints, 2 (strain Nos. 13, 15), 6 (Nos. 3, 5, 6, 7, 14, 16), 1 (No. 10), 6 (Nos. 1, 2, 4, 8, 11, 12) and 1 (No. 9) showed significances in 20, 19, 18, 17 and 16 combinations, respectively. Average and its standard deviations through the whole strains were found to be 18.13±1.26. Modes were found in 17 and 19 (6 strains each). It may be noticeable that strain Nos. 13 and 15 showed significances in 20/23 combinations, *i.e.*, 87.0% of them.

Both Tables: In the whole strain level, 40/47 combinations, *i.e.*, 85.1% of them, showed significances. It was clearly confirmed that combinations of the latter table (=whole grain char-

Table 4. Synopses of significant relations found in 24 combinations in view of the practical values

Table No.		Series No.	I			III														IV					
		Character Nos.	2 3	2 4	3 4	7 8	7 9	7 10	7 11	7 12	8 9	8 10	8 11	8 12	9 10	9 11	9 12	10 11	10 12	11 12	13 14	13 15	14 15	16 17	16 18	17 18
Parent		Value										***								_**			***	_*	
		Diagonal										23								14			17	20	
Hybrid		Cor. coef.	11	12	13	16	16	16	20	20	20	24	24	24	27	27	27	31	31	31	15	15	15	18	18	18
		Diagonal			14	17	18	19		21	22	25		26	28	29	30		32	33			16	19		
Strain No.	1						***	***		*	*				*		*	*	***	*	_*			***	***		***
	2						***	***		**							**		**	*		_*		***	***		***
	3			***			***	***			*				***	*	*							***	***	*	***
	4					*	***	***		**	*			*	***		***		**					**	***		*
	5			**		*	***	***			*			*	***		**		*	*				***	***		
	6					*	***	***		***	**	**		*	***		***		***	*				***	***		
	7					**	***	***			*	*			***		**			*				***	***		***
	8	_**						***		*						*	**							***	***	**	***
	9			**			***	***	*	*					***	**	***		**	**				***	***		
	10			***			***	***			**	*			***		***			*				***	***		
	11	_**	_*	**		*	***	***		***	*				*		***		*			*		**	***	_**	*
	12						***	***							**		***				_*	_***		***	***		*
	13		**				***	***							***		**				_*			***	***		
	14		*	*			***	***	**		**	*			**	*	*		*		_**	_*		***	***		*
	15			*		_**	***	***		**		_**			***		***		**		_**			***	***	_**	
	16			***			***	***		*	*				***	*	***	*	***	**		_*		***	***		**
	Whole			***		***	***	***		***	***	***		**	***	***	***		***	***	_**	_*		***	***		***

***, **, *; significant at 0.1%, 1% and 5% levels, respectively.

d.f.; 14, 28 and 238 in parent, respective strain and the whole combinations, respectively.

Table 5. Synopses of significant relations found in 23 combinations in view of the practical values

Table No.		Series No.	V						VI											VII				
		Character Nos.	20 21	20 22	21 22	23 24	23 25	24 25	27 28	27 29	28 29	30 31	30 32	31 32	13 20	14 21	15 22	16 23	17 24	18 25	33 34	35 36	33 35	34 36	37 38
	Parent	Value	_**		*	***	_*							**	***	***	***	***	***	***	***	***	***	***	***
		Diagonal				14												15							
	Hybrid	Cor. coef.	13	13	13	15	15	15	12	12	12	13	13	13	14	14	14	16	16	16	11	11	11	12	12
		Diagonal				16												17							
Strain No.	1		_**	_**	*	**		*			*	**		***	***	***	**	***	***		***	***	***		***
	2		_***	_***	***	***		**			***	***		***	***	**	*	***	***	*	***		***		***
	3			_***	***	***			*	*	***	***		**	***	***	***	***	***	**	***	***	***	**	***
	4		_**		**	***					*	***		*	***	**	***	***	***	***	***	***	***	***	***
	5		_***		*	***	_**		**		**	***		***	***	***	***	***	***	***	***	***	***	**	***
	6		_***		***	***	_***	_*			***	***		***	***	***	***	***	***	***	***	***	**	***	***
	7		_*		***	***			*	*	***	***		***	***	**	***	***	***	***	***	***	***	*	***
	8					***			***	*	***	***	**	***	***	*	*	***	***	**	***	***	**		***
	9		_***			***					***	***		***	***	***	**	***	***	***	***	***	**	***	***
	10		_**		***	***			**		***	***		***	***	***	***	***	***	***	***	***	***	***	***
	11				*	***	_**				***	***		***	***	***	*	***	**	***	***	***	***	***	***
	12		_*	_*	***	***					***	***		***	***	***	***	***	***	***	***	***	*		***
	13		_***	_*	***	***	_**		*		***	***		***	***	***	***	***	***	***	***	***	***	*	***
	14		_***		***	***	_**		*		***	***		***	***	***	***	***	***	***	***	***	***	***	***
	15		_***	_**	*	***	_***	_**	*		***	***		***	***	***	*	***	***	***	***	***	***		***
	16		_***	_**	***	***		**			**	***		***	***	***	***	***	***	***	***	***	***	***	***
	Whole		_***	_***	***	***	_***		***	**	***	***	**	***	***	***	***	***	***	***	***	***	***	***	***

***, **, *; significant at 0.1%, 1% and 5% levels, respectively.

d.f.; 14, 28 and 238 in parent, respective strain and the whole combinations, respectively.

acters) showed more remarkable significances than those of the former table (=plant morphology).

In the respective strain level, 480/752 combinations, *i.e.*, 63.8% of them, showed significances. Forty four among 480 (=9.2%) showed negative values. It was also clearly recognized that combinations of grain characters showed more remarkable significances than those of the plant morphology. In detail, 16, 3, 2, 1, 1, 3, 1, 3, 1, 2, 5, 1, 3, 3, 1 and 1 cases showed significances in 16, 15, 14, 13, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1 and 0 combinations, respectively. Average and its standard deviations through the whole combinations were found to be 10.21 ± 5.57. Mode was found in 16 (16 combinations).

In other viewpoints, 1 (strain No. 14), 1 (No. 16), 2 (Nos. 11, 15), 1 (No. 6), 1 (No. 5), 3 (Nos. 1, 3, 7), 1 (No. 4), 3 (Nos. 9, 10, 13), 1 (No. 2) and 2 (Nos. 8, 12) showed significances in 35, 34, 33, 32, 31, 30, 29, 28, 27 and 26 combinations, respectively. Average and its standard deviations through the whole strains were found to be 29.82 ± 2.81. Modes were found in 28 and 30 (3 strains each). It may be noticeable that No. 14 showed significances in 35/47 combinations, *i.e.*, 74.5% of them.

Concerning the relationships between the corresponding combinations, *i.e.*, 6 sets of grain characters, significances in the data were compared. Average and its standard deviations found in L vs. W (character Nos. 13·14–20·21–27·28), L vs. T (13·15–20·22–27·29), W vs. T (14·15–21·22–28·29), L/W vs. L/T (16·17–23·24–30·31), L/W vs. W/T (16·18–23·25–30·32) and L/T vs. W/T (17·18–24·25–31·32) were found to be 1.56 ± 0.89, 0.94 ± 0.77, 2.88 ± 0.33, 3.00 ± 0.00, 0.69 ± 0.79 and 1.94 ± 0.68, respectively. They may be divided into 3 groups, *i.e.*, the large, the middle and the small significant groups. The relations L/W vs. L/T and W vs. T, L/T vs. W/T and L vs. W, and L vs. T and L/W vs. W/T, belonged to the first, the second and the last groups, respectively.

In the strain level, the respective strains showed significances as follows, in the order from No. 1 to No. 16; 12, 12, 12, 9, 10, 10, 11, 11, 7, 8, 11, 12, 12, 13, 14 and 12 in the whole relations (=18). Average and its standard deviations through the whole combinations and the whole strains were found to be 11.00 ± 1.77.

In Table 6, 4 relations are shown in view of the two respective combinations, reciprocal relations of practical values (column A), standard deviations (B), differences between the maximum and the minimum values for the whole strains (C) and these for two testers (D). In column A, 40/47 combinations, *i.e.*, 85.1% of them, showed significances. Concerning the reciprocal relations between corresponding characters, *i.e.*, 6 sets of grain morphology, number of significances were compared. Two sets, *i.e.*, L/W vs. W/T (16·18–23·25–30·32) and L/T vs. W/T (17·18–24·25–31·32), showed significances in 2 cases. The remaining 4 sets showed significances in 3 cases.

In column B, 19/47 (=40.4%) and 21/47 (=44.7%) combinations showed significances in the female and the male parents, respectively. Twelve combinations showed significances in both sexes. Sixteen combinations showed significances in one sex. The remaining 19 combinations showed no significance in both sexes.

In column C, 12/47 (=25.5%) and 14/47 (=29.8%) combinations showed significances in the female and the male parents, respectively. Eight combinations showed significances in both sexes. Ten combinations showed significances in one sex. The remaining 29 combinations showed no significances in both sexes.

In column D, 10/47 (=21.3%) and 11/47 (=23.4%) combinations showed significances in the female and the male parents, respectively. Three combinations showed significances in both sexes. Fifteen combinations showed significances in one sex. The remaining 29 combinations showed no significance in both sexes.

Table 6. Synopses of significant relations found in four references in 47 combinations; reciprocal relations of practical values (A), standard deviations (B), differences between the maximum and the minimum values through the whole strains (C) and those for the testers (D)

Series No.	Character Nos.	A	B		C		D	
			Female	Male	Female	Male	Female	Male
I	2·3							
	2·4		−***					
	3·4	***		*				
III	7·8	***						
	7·9	***	**	*				**
	7·10	***	*	***		**		
	7·11			−*				
	7·12	***					**	
	8·9	***						−*
	8·10	***						
	8·11							
	8·12	**	*					−*
	9·10	***	*	*		***		
	9·11	***						
	9·12	***					*	
	10·11							
	10·12	***	**					
	11·12	***						
IV	13·14	−**		**		**		
	13·15	−*						
	14·15	***	***		*		*	
	16·17	***	***	***	***	*	**	*
	16·18							
	17·18	***	*		*			
V	20·21	−***	**	***	*	***		
	20·22	−***						
	21·22	***		*				
	23·24	***	***	***	***	***	*	
	23·25	−***		***		*		
	24·25			*				***
VI	27·28	***						
	27·29	**						
	28·29	***	**					
	30·31	***		**		*		
	30·32	**						
	31·32	***	*	*	**			***
	13·20	***	***	***	*	***		
	14·21	***		**		***		*
	15·22	***						
	16·23	***	***	***	***	*	***	***
	17·24	***	***	***	*	***	*	
	18·25	***						*

(continued)

	33·34	***	***	*	***		**	
	35·36	***	***	**	**	**	**	*
VII	33·35	***		***				
	34·36	***						**
	37·38	***	***		*	**	***	

***, **, *; significant at 0.1%, 1% and 5% levels, respectively.
d.f.; 12 in D and 14 in the other columns, respectively.

3. Comparisons of parental value with value of hybrid-average

To make clear relations between parents and the respective strain-averages, the differences between them were compared. In these calculation, the following marks were used; + ··· value of hybrid-average in the respective characters was larger than those of the respective pure-line-strain, − ··· it was smaller than those of the respective pure-line-strain, = ··· it was the same as those of the respective pure-line-strain. For example, panicle lengths of strain No. 1 (♀), when it was used for crossing, and strain No. 1, when it was used for the parent, were 25.6 cm and 24.3 cm, respectively. So, this relation was illustrated as +. These calculations were done through 33 characters (excepting 1 character from the previous chapter, *i.e.*, character No. 2=crossability). In the total, 610/1,056 cases, *i.e.*, 57.8% of them, showed + marks. In other words, values of

Table 7. Reciprocal comparisons of practical value with value of hybrid-average; + (value of hybrid-average larger than those of parent), − (smaller than those of the parent) and = (same as those of the parent); left (female) and right (male)

Combination	Character No.																	
	3	4	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22
++	1	2	9	14	14	14	16	9	13	8	9	10	7	4	4	8	8	11
+−	0	0	0	1	0	1	0	1	1	0	3	1	0	1	2	2	1	0
+=	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
−+	0	0	0	0	0	1	0	1	1	0	1	3	1	2	1	2	1	0
−−	15	14	7	1	2	0	0	5	1	6	3	2	7	9	7	4	4	3
−=	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
=+	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
=−	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
==	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Combination	Character No.															Total
	23	24	25	27	28	29	30	31	32	33	34	35	36	37	38	
++	7	3	7	6	4	4	7	6	5	11	12	10	11	3	3	260
+−	0	0	2	0	2	2	1	1	1	1	1	1	0	1	0	27
+=	0	1	0	2	2	3	2	1	0	0	0	0	0	3	4	20
−+	1	2	1	0	3	1	1	3	1	1	0	0	2	1	2	33
−−	7	10	5	4	2	3	2	4	4	3	3	4	3	3	3	150
−=	0	0	0	0	1	2	1	0	2	0	0	1	0	0	1	11
=+	1	0	0	1	0	0	2	1	1	0	0	0	0	2	1	10
=−	0	0	1	0	2	1	0	0	0	0	0	0	0	0	2	8
==	0	0	0	3	0	0	0	0	2	0	0	0	0	3	0	9

parental average were larger than those of the respective pure-line. Nextly, 379/1,056 cases, *i.e.*, 35.9% of them, showed − marks. The remaining 67 cases, *i.e.*, 6.3% of them, showed = marks.

To make clear the reciprocal relations in these sense, combinations of the female and the male parents were calculated, and are shown in Table 7. In this table, + (female) and + (male) combinations are shown as ++ marks, and so forth. Figure in this table means number of strains (16 in each character). Combinations in the order from ++ to == were calculated as 49.2, 5.1, 3.8, 6.3, 28.4, 2.1, 1.9, 1.5 and 1.7% in the whole, respectively.

They may be divided into 2 groups, *i.e.*, homogeneous and heterogeneous groups. The homogeneous combinations meant ++, −− and == ones. The heterogeneous combinations meant +−, +=, −+, −=, =+ and =− ones. The former ones were found in 419/528 combinations, *i.e.*, 79.4% of them. The latter ones found in 109/528 combinations, *i.e.*, 20.6% of them. It was noticeable that character No. 10 showed ++ marks in the whole strains, and character Nos. 3 and 4 showed −− marks in the most strains.

In detail, 5 (character Nos. 3, 4, 6, 8, 10), 3 (Nos. 7, 22, 34), 9 (Nos. 9, 11, 12, 13, 16, 23, 33, 35, 36), 3 (Nos. 17, 24, 27), 5 (Nos. 14, 15, 20, 21, 25), 2 (Nos. 18, 32), 1 (No. 31), 2 (Nos. 30, 37), 1 (No. 29) and 2 (Nos. 28, 38) showed homogeneous combinations in 16, 15, 14, 13, 12, 11, 10, 9, 7 and 6 characters, respectively. Average and its standard deviations were found to be 12.91±2.57. Mode was found in 14 (9 characters).

Concerning the relationships between the corresponding combinations, *i.e.*, 6 sets of grain characters, the combinations of data were compared. One set (L, 13–20–27), 1 (L/W, 16–23–30), 1 (L/T, 17–24–31), 2 (T, 15–22–29, W/T, 18–25–32) and 1 (W, 14–21–28) showed homogeneous

Table 8. Reciprocal comparisons of practical value with the value of hybrid-average; +(value of hybrid-average larger than those of the parent), −(smaller than those of the parent) and =(same as those of the parent); left (female) and right (male)

Strain No.	Combination								
	++	+−	+=	−+	−−	−=	=+	=−	==
1	15	2	2	0	11	2	1	0	0
2	24	0	1	0	8	0	0	0	0
3	19	0	0	1	11	0	0	1	1
4	15	0	0	1	13	2	0	0	2
5	13	1	4	0	15	0	0	0	0
6	13	4	2	3	8	1	1	1	0
7	20	2	0	4	5	1	1	0	0
8	19	0	1	3	8	2	0	0	0
9	14	6	0	4	5	0	2	1	1
10	13	1	0	4	15	0	0	0	0
11	20	0	0	1	10	0	0	2	0
12	14	6	2	2	5	0	2	1	1
13	17	1	3	1	9	0	1	0	1
14	16	2	1	3	6	1	1	2	1
15	9	0	3	3	14	2	0	0	2
16	19	2	1	3	7	0	1	0	0
Total	260	27	20	33	150	11	10	8	9

combinations in 39, 37, 36, 34 and 30 cases, respectively. It was noticeable that set of L characters showed homogeneous combinations in 39/48 cases, *i.e.*, 81.3% of them. On the other hand, set of W characters showed those only in 30/48 cases, *i.e.*, 62.5% of them. In detail, ++, +−, +=, −+, −−, −=, =+, =− and == combinations were counted as 118 cases (41.0% of them, 19.67±4.37), 19 (6.6%, 3.17±1.94), 13 (4.5%, 2.17±0.75), 24 (8.3%, 4.00±1.79), 86 (29.9%, 14.33±5.47), 9 (3.1%, 1.50±1.38), 7 (2.4%, 1.17±1.47), 6 (2.1%, 1.00±1.10) and 6 (2.1%, 1.00 ±1.27), respectively. In the total, 210/288 cases (=72.9%) showed homogeneous combinations. Average and its standard deviations through the whole sets were found to be 35.00±3.10.

In Table 8, combination status in strain level are shown. One (strain No. 2), 1 (No. 3), 2 (Nos. 4, 11), 2 (Nos. 5, 10), 2 (Nos. 8, 13), 2 (Nos. 1, 16), 2 (Nos. 7, 15), 1 (No. 14), 1 (No. 6) and 2 (Nos. 9, 12) showed homogeneous combinations in 32, 31, 30, 28, 27, 26, 25, 23, 21 and 20 characters, respectively. Average and its standard deviations through the whole characters were found to be 26.19±3.75. It was noticeable that strain No. 2 showed homogeneous combinations in 32/33 characters, *i.e.*, 97.0% of them.

Discussion

Basing on the results obtained in the present experiments, the following problems are to be discussed here.

1. The diallel cross of the preliminarily selected plant materials is rarely used in the practical breeding. For a final testing of the limited number of selected plants which is to be carried out with the aim of forming the basis of a new synthetic varieties or a hybrid, however, the diallel method is very useful not only in agricultural meanings[3,8], but also in chemical components[1,21] or other purposes[4]. Haymann[5] stated that at least ten parents should be used for a reasonably accurate estimation of the components of variation. This method is also convenient for the testing of species or strain differentiations.

2. Length, width and other characters on grain and plant morphology were already reported[8-14]. Moreover, comparisons of the differences between the maximum and the minimum values found in several characters, were recognized as useful procedure[15]. In addition to these characters, comparison of significant relationships mentioned in the present paper were considered to be useful indices in the testing of the strain relationships. This method is noticed as a new method in these experimental statuses.

3. It has been reported that the reciprocal hybrids are not significantly different[17]. On the other hand, remarkable differences in the reciprocal hybrids were reproted[25], and a considerable amount of cytoplasmic inheritance was held[23]. In the present experiment, 6 among 204 character-combinations showed negative values (Table 2). Though strain No. 8 (Addey variety) showed negatively significant relations in 3 characters (Nos. 30, 31, 32), no remarkable significant differences were generally shown. Then, it was concluded that reciprocal differences suggested no considerable cytoplasmic inheritance in these experiments.

4. Concerning the corresponding characters, *i.e.*, 6 sets of grain morphology, L and L/W showed significances in 85.3% throughout the whole combinations. It was noticeable that combinations, which were composed by L in one or both hands, showed high significant relationships, and they may be said to have a status stabler than those of the remaining 4 sets in view of the genetic background[14].

5. Concerning the reciprocal relations corresponding to grain characters, the characters of

unhusked (character Nos. 13–18) and husked (Nos. 20–25) grains showed significant relations through the whole components (=6), while the characters of comparison (Nos. 27–32) showed no significance at all. It was concluded that the former two columns as well as the latter one might be said to be suitable and unsuitable indices, respectively, for the comparison of strain- or variety-differentiations. In these statuses, it was conspicuous that strain No. 8 showed significant correlations in character No. 27. This phenomenon proposed an interesting problem concerning the strain differentiations.

6. From the data shown in Table 3, character No. 6 (=growing period) showed high significances through the whole relations (=6). This character is controlled by photoperiodic characteristics in view of the genetic background. It might be said that it was looked upon of as having a stable status through the whole characters used in these experimental series.

7. From the data shown in Tables 4 and 5, the followings were ascertained. In the respective strain levels, 480/752 combinations, *i.e.*, 63.8% of them, showed significances. The total significances in the respective groups were counted as follows; ① affinity (character Nos. 2·3～3·4) ··· 27.1% (=13/48), ② morphological characters (7·8～11·12) ··· 50.4% (=121/240), ③ grain morphology of the unhusked grains (13·14～17·18) ··· 58.3% (=56/96), ④ those of the husked grains (20·21～24·25) ··· 63.5% (=61/96), ⑤ quotients of them (27·28～31·32) ··· 62.5% (=60/96), ⑥ comparison of them (13·20～18·25) ··· 99.0% (=95/96), ⑦ relations between area and volume (33·34～37·38) ··· 92.5% (=74/80). They may be divided into three groups in view of the significant relations, *i.e.*, the high, the middle and the low relation-groups. The 6th and 7th ones belonged to the high group, the 2nd, 3rd, 4th and 5th ones belonged to the middle group, and the 1st one belonged to the low group, respectively. It was concluded that the 6th and 7th groups, and the 1st group might be said to be the stable or the unstable status in view of the genetic background, respectively.

8. The superiority of F_1 hybrids was estimated on the basis of heterosis, which was illustrated by the mean increasing of F_1 hybrids over the mid-parental value of plants as might be seen in tobacco[18], grain sorghum[26], wheat[1] and rice[19]. In this connection, comparisons of parents and strain-averages were made (Tables 7 and 8). Character Nos. 7, 8, 9, 10 and 12 showed ++ marks in the most strains. In other words, agronomical characters showed a significant heterosis or a super dominance in disregard of the varietal status. This phenomenon proposed a problem of great interest concerning the strain differentiations. On the other hand, character Nos. 3 and 4 showed −− marks in the most strains. In other words, affinity showed significant hybrid weakness in disregard of varietal status. These phenomena may duely be attributed to the environmental conditions.

In the total, +, − and = marks were recorded as 57.8% (=610/1,056), 35.9% (=379/1,056) and 6.3% (=67/1,056), respectively. In conclusion, heterosis may be said to be remarkable to some extent in these viewpoints.

Summary

Succeeding to the previous papers, diallel cross experiments were carried out, using 14 strains of Sikkimese rice varieties and one type of *indica* and another type of *japonica*. The main results obtained during this study were summarized as follows:

1. In the reciprocal relations of 34 characters, the whole strain levels and the respective strain level showed significant relations in 64.7% (=22/34 cases) and 37.5% (=204/544 cases), respec-

tively. In the 6 sets of grain morphology, L and L/W characters showed significances in 85.3% of them. Concerning the corresponding character-sets, these 2 sets might be looked upon as the indices more stable and suitable than the remaining 4 sets. In the stricter sense, character-sets of the unhusked and husked grains showed significant relations through the whole components, but in comparison it showed no significance at all. So, it was concluded that the former two sets might be regarded as the stable and suitable indices in analyzing strain- or variety-differentiations.

2. In the two respective characters of 47 combinations, the whole strain levels and the respective strain level showed significant relationships in 85.1% (=40/47 combinations) and 63.8% (=480/752 combinations), respectively. In the 6 sets of grain morphology, L/W vs. L/T and W vs. T showed significances in 100.0% and 95.8% of them, respectively. Concerning the corresponding character-sets, these 2 sets might be regarded as the indices more stable and suitable than the remaining 4 sets.

3. In comparison of the values found in the parents and the respective strain averages, the superiorities of hybrids, *i.e.*, heteroses, were recognized in 57.8% (=610/1,056 cases). Accordingly, it was concluded that a considerable heterosis might be existing to some extents. The homogeneous combinations, which were illustrated by values obtained in comparison of the female case and the parental case, and the male case and the parental case, were recorded as $++$, $--$ and $==$. The remaining 6 combinations were designated as heterogeneous ones. The former ones were found in 79.4% (=419/529 combinations).

Character Nos. 7, 8, 9, 10, 12, and Nos. 3, 4 showed $++$ marks and $--$ marks in the most strains, respectively. These phenomena proposed quite interesting problems concerning the strain differentiations and breeding programs.

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