Mem. Fac. Agr. Kagoshima Univ., **15**, 1-27, 1979

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

VII. Surface Area and Volume of Unhusked and Husked Grains

Tadao C. KATAYAMA
(Laboratory of Crop Science)

Received for Publication August 17, 1978

Introduction

Kato *et al.*[10] classified varieties of *Oryza sativa* L. into two subspecies, *japonica* and *indica*. Terao *et al.*[18] divided them into three major-groups, *i.e.*, *indica*, *japonica* and *javanica*. On the other hand, Ting[19] classified them into kêng and sên. Matsuo[14] reported on the morphological characters and their geographical relationships. However, the idea of dividing rice varieties seems to be swiftly losing its significance in accordance with the further performances of intensive works[1,4].

In order to confirm the classification of varieties, especially on Sikkimese rice, and to clarify the relationships between its strains and those belonging to the types of typical *indica* and *japonica*, diallel crosses were carried out, using 16 strains. Since the consideration using diallel crosses is superior to those using single cross for looking into combining ability, heterosis and cytoplasmic inheritance. Moreover, the system of genes controlling agronomically significant quantitative traits, such as plant height, has been studied through diallel analysis method[12]. So, diallel cross was employed in this experimental series. In the previous papers in this series, crossability, pollen and seed fertilities[4], heading date and growing period[5], some morphological characters of plant[6], morphological characters of unhusked[7] and husked[8] grains, comparison of unhusked and husked grains[9], and some relations among them were reported.

The ears of rice plant have an ability of net photosynthesis. Maximum rate of net photosynthesis per one exposed surface has been fixed as 1—2 mg CO_2/dm^2 (100 spikelets)/h[20]. Grain volume has been looked upon as an end product. Then, studies on surface and volume of grains were regarded as the important characters in view of strain differentiations. In the present report, surface areas and volumes of unhusked and husked grains, and some relations among them were mainly described. Conclusive survey of evolution and strain differentiations are to be published in the papers following hereafter.

Materials and Methods

Fourteen strains of Sikkimese rice varieties were picked out from 68 strains collected at Sikkim in 1959[11], and used in this experiment. In addition, one strain of *indica* and another one strain of *japonica* were used as the tester. They are listed up and classified in Table 1. Procedures of the cross and cultivation of the parental and hybrid plants were

minutely mentioned in the previous paper[4].

For ascertaining the practical values of unhusked and husked grains[7,8], the whole data referring to the six characters were illustrated by the average values in the whole seeds used in the respective strains and the hybrid combinations. In the present paper, six morphological characters were presented, *i.e.*, grain surface areas (= length × width) and grain volumes (= length × width × thickness) of unhusked and husked grains, area quotient and volume quotient (= ratio of value of husked to value of unhusked grains). To make clear the reciprocal relations, the correlation coefficient and linear regression of the respective characters of female parent upon male parent were calculated. Basing on the data obtained in the calculation, t-test was made from analyses of the variance for reciprocal cross combinations. Further, to make clear the relationships between the respective characters, correlation coefficient and linear regression of these two characters were calculated.

Results

PART I. Respective character

1. Area of unhusked grains

Parent: Areas of unhusked grains in the parental plants are shown in Table 1. The largest (29.36 mm²) was obtained in No.15, followed by No.5 (26.57 mm²). The smallest (20.74 mm²) was noted in No.16, followed by No.14 (22.28 mm²). Average and standard deviations through the whole strains were found to be 23.94 ± 2.07.

Hybrid: The values of area of unhusked grains among diallel crosses are shown in Table 2. A wide range was observed. Areas for individual seed level ranged from 33.03 mm² to 19.2 mm². In the combination level, the largest (31.72 mm²) was obtained in the combination, No 6 (♀) × No.15 (♂), followed by No.15 × No.14 (29.54 mm²) and No.9 × No.6

Table 1. Materials used in the diallel cross experiment, variety name, origin and six characters of unhusked and husked grains

Code No.	Strain	Origin	Variety	Unhusked		Husked		Quotient	
				Area (mm²)	Volume (mm³)	Area (mm²)	Volume (mm³)	Area	Volume
1	108	Formosa	*Indica*	23.26	46.99	14.51	24.52	0.62	0.52
2	563	Japan	*Japonica*	23.19	44.29	12.40	20.34	0.54	0.46
3	C7707	Sikkim	Addey	22.72	46.80	14.03	24.56	0.62	0.53
4	C7716	Sikkim	Lama	25.20	49.40	15.86	27.43	0.63	0.56
5	C7717	Sikkim	Lama	26.57	57.13	15.91	28.95	0.60	0.51
6	C7718	Sikkim	Tokmor Zo	26.36	51.67	15.45	26.88	0.59	0.52
7	C7719	Sikkim	Tokmor Zo	22.57	48.97	13.04	25.17	0.58	0.51
8	C7722	Sikkim	Addey	23.08	43.61	13.48	21.97	0.58	0.50
9	C7725	Sikkim	Addey	24.63	52.95	14.44	25.42	0.59	0.48
10	C7727	Sikkim	Addey	22.83	47.26	15.32	26.81	0.67	0.57
11	C7729	Sikkim	Addey	23.37	42.76	13.63	22.63	0.58	0.53
12	C7732	Sikkim	Tapachini	23.50	49.35	14.36	25.85	0.61	0.52
13	C7734	Sikkim	Fudangay	23.35	51.60	14.12	27.24	0.61	0.53
14	C7735	Sikkim	Fudangay	22.28	47.45	13.56	25.35	0.61	0.53
15	C7754	Sikkim	Champasari	29.36	61.37	17.20	30.10	0.59	0.49
16	C7757	Sikkim	Addey	20.74	42.11	12.70	21.97	0.61	0.52

Table 2. Area of unhusked grains of F_1 hybrids in mm^2

♂ \ ♀	Code No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		26.57	24.60	24.92	24.54	26.88	23.45	23.93	23.95	24.26	24.99	22.95	23.68	22.89	26.80	23.04
2	23.57		25.09	27.50	25.99	26.95	24.28	25.93	21.37	25.10	26.08	24.93	23.50	24.32	27.59	23.45
3	23.43	24.22		21.85	25.02	24.96	21.05	24.69	23.93	23.06	21.86	22.50	20.82	21.75	26.64	21.55
4	26.02	23.16	25.32		24.81	24.98	22.89	24.78	24.30	24.90	26.41	24.57	23.19	21.99	27.82	23.17
5	27.80	23.92	24.52	24.01		25.03	22.95	25.86	23.98	26.26	26.68	24.67	24.21	24.34	26.39	21.77
6	24.32	28.05	28.58	25.38	26.95		26.70	28.08	27.32	28.36	29.38	25.79	27.28	25.63	31.72	24.24
7	24.85	25.27	24.12	24.93	26.45	26.79		26.17	24.15	23.49	25.20	26.16	23.70	24.05	26.76	22.35
8	25.22	25.76	27.49	23.30	20.96	22.74	26.17		27.74	27.39	26.29	27.06	21.12	24.25	28.63	25.55
9	26.47	26.75	21.97	26.32	28.36	28.97	24.64	24.50		24.80	27.93	25.31	24.14	22.21	24.77	21.67
10	22.94	23.05	21.19	24.86	23.49	24.86	21.77	23.76	24.16		20.38	23.80	21.90	23.08	25.20	20.99
11	24.13	24.21	23.19	25.44	24.73	24.07	23.13	25.30	24.27	24.70		25.13	24.27	23.53	25.60	22.73
12	23.21	25.10	23.57	25.10	25.60	26.13	22.51	22.93	24.49	24.47	25.56		24.16	24.30	26.38	23.56
13	22.95	24.19	21.71	22.84	22.71	24.56	21.92	22.95	23.41	22.52	23.92	23.78		22.08	24.90	21.29
14	23.10	23.87	21.98	23.37	22.85	25.31	20.95	24.26	23.46	21.88	23.83	23.61	21.81		25.14	20.37
15	24.72	27.11	24.61	27.79	27.77	28.46	24.24	26.23	28.18	28.10	27.29	26.13	28.37	29.54		25.45
16	21.75	23.71	21.23	23.12	24.17	24.04	20.15	23.04	21.45	21.96	22.31	22.04	21.67	21.78	24.09	

Table 3. Averages and standard deviations of six characters in female and male parental levels; area (L × W), volume (L × W × T) of unhusked and husked grains, quotients of husked and unhusked grains

Code No.	Area in mm² (Unhusked)		Volume in mm³ (Unhusked)		Area in mm² (Husked)	
	Female	Male	Female	Male	Female	Male
1	24.50 ± 1.34	24.30 ± 1.59	51.04 ± 3.24	51.54 ± 5.98	14.36 ± 0.60	14.51 ± 0.91
2	25.04 ± 1.70	25.00 ± 1.54	53.91 ± 3.50	55.28 ± 6.01	14.58 ± 0.51	14.74 ± 0.61
3	23.16 ± 1.72	23.95 ± 2.19	49.51 ± 4.56	51.79 ± 7.57	14.04 ± 0.95	14.41 ± 0.91
4	24.56 ± 1.52	24.72 ± 1.68	49.56 ± 3.64	50.61 ± 5.19	15.46 ± 0.76	15.37 ± 0.80
5	24.83 ± 1.55	24.96 ± 1.99	51.58 ± 3.67	52.00 ± 7.06	15.57 ± 0.77	14.99 ± 0.73
6	27.19 ± 1.98	25.65 ± 1.70	60.73 ± 7.64	53.00 ± 6.69	15.90 ± 0.74	15.27 ± 0.78
7	24.96 ± 1.33	23.12 ± 1.86	57.84 ± 3.60	49.21 ± 6.77	13.90 ± 0.73	14.00 ± 0.89
8	25.31 ± 2.38	24.83 ± 1.45	56.36 ± 9.14	51.39 ± 5.85	14.72 ± 0.46	14.91 ± 0.77
9	25.25 ± 2.25	24.41 ± 1.97	59.54 ± 8.32	52.67 ± 5.90	14.75 ± 0.73	14.77 ± 0.86
10	23.03 ± 1.50	24.75 ± 2.06	47.93 ± 4.49	53.49 ± 5.74	14.60 ± 1.09	14.79 ± 1.06
11	24.30 ± 0.88	25.21 ± 2.41	47.88 ± 2.65	52.36 ± 8.37	14.62 ± 0.65	14.91 ± 1.31
12	24.47 ± 1.17	24.56 ± 1.44	50.21 ± 2.59	52.07 ± 6.22	15.06 ± 0.63	14.78 ± 0.79
13	23.05 ± 1.07	23.59 ± 2.10	47.45 ± 2.86	50.42 ± 6.05	14.38 ± 0.70	14.22 ± 0.83
14	23.05 ± 1.43	23.72 ± 2.00	47.99 ± 4.05	51.45 ± 5.11	14.02 ± 0.82	14.44 ± 0.89
15	26.93 ± 1.62	26.56 ± 1.90	54.44 ± 3.83	56.80 ± 6.94	15.79 ± 0.61	15.56 ± 0.81
16	22.43 ± 1.21	22.75 ± 1.54	45.72 ± 2.59	47.60 ± 5.10	13.85 ± 0.64	13.91 ± 0.74
Whole	24.50 ± 2.02		51.98 ± 6.48		14.72 ± 0.95	

Code No.	Volume in mm³ (Husked)		Quotient (Area)		Quotient (Volume)	
	Female	Male	Female	Male	Female	Male
1	25.64 ± 1.66	26.20 ± 1.77	0.59 ± 0.02	0.60 ± 0.04	0.50 ± 0.02	0.51 ± 0.06
2	27.23 ± 1.07	27.75 ± 1.40	0.59 ± 0.03	0.59 ± 0.03	0.51 ± 0.04	0.51 ± 0.06
3	25.96 ± 1.74	26.51 ± 2.00	0.61 ± 0.03	0.61 ± 0.04	0.53 ± 0.04	0.52 ± 0.05
4	27.14 ± 1.69	27.50 ± 1.41	0.63 ± 0.02	0.63 ± 0.02	0.55 ± 0.03	0.55 ± 0.04
5	27.87 ± 1.30	26.52 ± 1.68	0.63 ± 0.02	0.60 ± 0.03	0.54 ± 0.03	0.52 ± 0.05
6	28.34 ± 1.47	27.33 ± 1.82	0.59 ± 0.04	0.60 ± 0.04	0.48 ± 0.05	0.52 ± 0.05
7	25.54 ± 1.46	25.48 ± 2.35	0.56 ± 0.02	0.61 ± 0.04	0.45 ± 0.03	0.52 ± 0.05
8	25.96 ± 1.15	26.43 ± 1.40	0.59 ± 0.05	0.60 ± 0.03	0.48 ± 0.08	0.52 ± 0.05
9	27.95 ± 1.61	27.13 ± 1.97	0.59 ± 0.04	0.61 ± 0.03	0.48 ± 0.06	0.52 ± 0.05
10	26.65 ± 2.71	26.82 ± 1.90	0.63 ± 0.02	0.60 ± 0.03	0.56 ± 0.02	0.51 ± 0.05
11	25.41 ± 1.54	26.06 ± 2.56	0.61 ± 0.03	0.59 ± 0.03	0.53 ± 0.02	0.51 ± 0.05
12	27.08 ± 1.43	26.57 ± 1.64	0.62 ± 0.02	0.60 ± 0.04	0.54 ± 0.03	0.52 ± 0.05
13	26.25 ± 1.85	26.23 ± 1.38	0.63 ± 0.02	0.61 ± 0.04	0.55 ± 0.02	0.53 ± 0.05
14	25.71 ± 2.38	26.93 ± 2.08	0.61 ± 0.02	0.61 ± 0.04	0.54 ± 0.02	0.53 ± 0.05
15	27.87 ± 1.33	27.73 ± 1.23	0.59 ± 0.03	0.59 ± 0.03	0.51 ± 0.04	0.49 ± 0.05
16	25.47 ± 1.32	24.90 ± 1.32	0.62 ± 0.01	0.61 ± 0.03	0.56 ± 0.01	0.53 ± 0.04
Whole	26.63 ± 1.88		0.60 ± 0.03		0.52 ± 0.05	

(28.97 mm²). The smallest (20.15 mm²) was noted in the combination, No.16 × No.7, followed by No.14 × No.16 (20.37 mm²) and No.10 × No.11 (20.38 mm²). The differences in the area were confirmed to be very large in accordance with the varieties in the respective combination-sets.

In Table 3, the average value and the standard deviations in the area through the whole combinations are shown. Each figure used in the table shows average and standard deviations in each parent when the strain was used as female and male parents, including 15 combinations each. In other words, the data ranked in the female row in Table 3 were horizontally calculated at the figures shown in Table 2, and the data ranked in the male

Table 4. Correlation coefficient and linear regression of three characters of female parent (Y) on male parent (X); area of unhusked grains, volume of unhusked grains and area of husked grains. O points: 26.3 mm^2, 55.0 mm^3 and 14.6 mm^2 in 1st, 2nd and 3rd characters, respectively, in both female and male parents

Code No.	Area (Unhusked)			Volume (Unhusked)			Area (Husked)		
	Correlation coefficient	d.f.	Linear regression	Correlation coefficient	d.f.	Linear regression	Correlation coefficient	d.f.	Linear regression
1	0.2167	13	—	−0.2248	13	—	0.4351	13	—
2	0.0123	13	—	−0.2433	13	—	0.4678	13	—
3	0.6037*	13	Y = 0.462X − 4.239	0.5428*	13	Y = 0.332X − 2.291	0.8227***	13	Y = 0.754X − 0.998
4	0.3712	13	—	0.5716*	13	Y = 0.400X − 1.840	0.6656**	13	Y = 0.613X + 1.217
5	−0.1064	13	—	−0.3107	13	—	0.1576	13	—
6	0.1519	13	—	0.1670	13	—	0.3656	13	—
7	0.7307**	13	Y = 0.518X + 0.646	0.5274*	13	Y = 0.212X + 2.084	0.8214***	13	Y = 0.662X − 0.897
8	−0.0870	13	—	−0.0924	13	—	−0.0041	13	—
9	0.1565	13	—	0.2148	13	—	0.4413	13	—
10	0.4197	13	—	0.2686	13	—	0.6457**	13	Y = 0.686X − 0.303
11	0.3594	13	—	0.2149	13	—	0.1873	13	—
12	0.2074	13	—	−0.1181	13	—	0.7814***	13	Y = 0.616X + 1.199
13	0.8800***	13	Y = 0.511X − 3.742	0.6014*	13	Y = 0.284X − 3.118	0.7139**	13	Y = 0.661X − 0.028
14	0.6437**	13	Y = 0.466X − 4.203	0.1949	13	—	0.7983***	13	Y = 0.783X − 1.420
15	−0.0046	13	—	−0.1264	13	—	0.7416**	13	Y = 0.555X + 2.380
16	0.5710*	13	Y = 0.457X − 4.334	0.0061	13	—	0.7380**	13	Y = 0.663X − 0.874
Whole	0.4182***	118	Y = 0.427X − 1.693	0.1547	118	—	0.6625***	118	Y = 0.638X + 1.136

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

row in Table 3 were longitudinally calculated at the figures in Table 2, respectively. In view of the female parent, the highest value (27.19 mm^2) in the parental average was obtained in No.6, followed by No.15 (26.93 mm^2). The lowest (22.43 mm^2) in the parental average was noted in No.16, followed by Nos.13 and 14 (23.05 mm^2). The differences of the area in the parental level were ascertained to be large in accordance with each parent. The relation between the values of average and standard deviations was not recognized clearly. In view of the male parent, the highest value (26.56 mm^2) in the parental average was obtained in No.15, followed by No.6 (25.65 mm^2). The lowest value (22.75 mm^2) in the parental average was also noted in No.16, followed by No.7 (23.12 mm^2). The relation between the values of average and standard deviations was not recognized clearly, either. The average and its standard deviations in the whole combinations were 24.50 ± 2.02.

To make clear the area in view of reciprocal combinations, correlation coefficient and linear regression of area of female parent on male parent in the same strain were calculated and are shown in Table 4. Basing on the data in this calculation, t-test was made from analyses of variance for reciprocal cross combinations. From this table, the following facts were ascertained. One, 2, 2 and 11 strains showed significances at 0.1%, 1%, 5% levels and no significance even at 5% level, respectively. Through the whole strains, correlation coefficient was + 0.4182 to the degree of freedom of 118, which was obviously significant at 0.1% level. Generally speaking, the larger was the area noted at the time when strain was used as female parent, the larger was it noted at the time when strain was used as male parent. It was concluded that the reciprocal differences in this study suggested no considerable cytoplasmic influence on the area.

The differences (mm^2) between the maximum and the minimum values of area for each parent, in view of the female parent, were as follows in the order from No.1 to No.16; 3.99, 6.49, 5.82, 5.83, 6.03, 7.48, 4.64, 7.67, 7.30, 4.82, 2.87, 3.87, 3.61, 4.94, 5.30 and 4.02, respectively. The average and its standard deviations were 5.29 ± 1.46. The strain showing large value in this respect had a remarkable difference in the area, which was found in the combinations with 15 alien parents, at the time when it was used as female parent and alien strains were used as male parents, respectively. In an extreme case, the areas were 28.63 mm^2 and 20.96 mm^2 in No.8 × No.15 and No.8 × No.5, respectively. In other words, No.8 showed affinities remarkably different from each strain, at the time when No.8 was used as female parent. The strain showing small value in this respect had a few differences in area, which was found in the combinations with 15 alien parents, at the time when the strain was used as female parent and alien strains were used as male parents. In an extreme case, the areas were 25.60 mm^2 and 22.73 mm^2 in No.11 × No.15 and No.11 × No.16, respectively. In other words, No.11 showed affinities nearly similar to each strain, at the time when No.11 was used as female parent. Those in view of the male parent were as follows in the same order; 6.05, 5.00, 7.39, 5.94, 7.40, 6.23, 6.55, 5.15, 6.81, 6.40, 7.55, 5.02, 7.55, 7.79, 7.63 and 5.18, respectively. Those average and its standard deviations were 6.48 ± 1.02. The strain showing large value in this respect had a remarkable difference in area, which was found in the combinations with 15 alien parents, at the time when the strain was used as male parent and alien strains were used as female parents, respectively. In an extreme case, the areas were 29.54 mm^2 and 21.75 mm^2 in No.15 × No.14 and No.3 × No.14, respectively. The former value was nearly the largest through the whole combinations (= 240). In other words, No.14 showed affinities remarkably different from each strain, at the time when it was used as male parent. The strain showing small value in this respect had a few dif-

ferences in area, which was found in the combinations with 15 alien parents, at the time when the strain was used as male parent and alien strains were used as female parents. In an extreme case, the areas were 28.05 mm^2 and 23.05 mm^2 in No.6 × No.2 and No.10 × No.2, respectively. In other words, No.2 showed affinities relatively similar to each strain, at the time when it was used as male parent. In reciprocal views, correlation coefficient between these was −0.2178, showing no significance even at 5% level.

To make clear the relations between Sikkimese rice and two testers, the differences in area at the time when two testers were crossed with Sikkimese rice, and the reciprocals were calculated. In view of the female parent, the differences (mm^2) in area for *indica* (No.1) and *japonica* (No.2) were as follows in the order from No.3 to No.16, provided that the calculation was made only by the absolute value; 0.79, 2.84, 3.88, 3.73, 0.38, 0.54, 0.28, 0.11, 0.08, 1.89, 1.24, 0.77, 2.39 and 1.96, respectively. It may be noted that the values were peculiarly large in Nos.5 and 6. The strain showing large value in this respect had a remarkable difference in area, which was found in the combinations with two testers, at the time when the strain was used as female parent and the testers were used as male parents. In an extreme case, the areas were 27.80 mm^2 and 23.92 mm^2 in No.5 × No.1 and No.5 × No.2, respectively. In other words, No.5 showed affinities remarkably different from each tester, at the time when No.5 was used as female parent. The strain showing small value in this respect had a few differences in area, which was found in the combinations with two testers, at the time when the strain was used as female parent and the testers were used as male parents. In an extreme case, the areas were 24.13 mm^2 and 24.21 mm^2 in No.11 × No.1 and No.11 × No.2, respectively. In other words, No.11 showed affinities quite similar to each tester, at the time when No.11 was used as female parent. Average and its standard deviations in the whole Sikkimese rice were 1.49 ± 1.31. In view of the male parent, the differences in the area for *indica* and *japonica* were as follows in the same order; 0.49, 2.58, 1.45, 0.07, 0.83, 2.00, 2.58, 0.84, 1.09, 1.98, 0.18, 1.43, 0.79 and 0.41, respectively. It may be noted that the values were peculiarly large in Nos. 4 and 9. The strain showing large value in this respect had a remarkable difference in area, which was found in the combinations with two testers, at the time when the strain was used as male parent and the testers were used as female parents. In an extreme case, the areas were 24.92 mm^2 and 27.50 mm^2 in No.1 × No.4 and No.2 × No.4, respectively. In other words, No.4 showed affinities remarkably different from each tester, at the time when No.4 was used as male parent. The strain showing small value in this respect had a few differences in area, which was found in the combinations with two testers, at the time when the strain was used as male parent and the testers were used as female parents. In an extreme case, the areas were 26.88 mm^2 and 26.95 mm^2 in No.1 × No.6 and No.2 × No.6, respectively. In other words, No.6 showed affinities quite similar to each tester, at the time when the strain was used as male parent. Average and its standard deviations in the whole Sikkimese rice were 1.19 ± 0.84. In reciprocal views, correlation coefficient between these was −0.0727, showing no significance even at 5% level.

2. Volume of unhusked grains

Parent: Volumes of unhusked grains in the parental plants are shown in Table 1. The largest (61.37 mm^3) was obtained in No.15, which was the same as the area, followed by No.5 (57.13 mm^3), which was also the same as the area. The smallest (42.11 mm^3) was noted in No.16, which was the same as the area, followed by No.11 (42.76 mm^3). Average and standard deviations in the whole strains were found to be 48.98 ± 5.17.

Hybrid: The values of volume of unhusked grains among diallel crosses are shown in

Table 5. Volume of unhusked grains of F_1 hybrids in mm³

♀ \ ♂ Code No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		57.13	53.14	52.58	49.57	55.37	49.71	47.38	50.06	53.13	48.48	44.75	51.15	50.13	54.14	48.85
2	49.26		58.71	56.10	52.24	57.13	50.26	53.68	46.80	55.97	53.99	54.85	51.94	53.50	59.87	54.40
3	50.61	54.98		47.20	55.29	54.66	46.52	51.60	51.93	48.89	43.28	45.68	43.31	49.16	56.21	43.32
4	52.30	49.10	52.67		49.62	50.46	46.47	48.57	52.25	51.54	51.24	48.16	47.54	42.66	57.03	43.79
5	58.94	48.56	50.51	49.46		50.56	48.88	53.53	49.64	55.15	53.09	49.83	51.57	52.82	57.00	44.19
6	47.42	62.83	68.31	51.27	63.06		61.94	64.02	64.20	65.51	64.05	52.61	62.74	61.77	73.91	47.27
7	58.40	57.36	58.61	49.86	60.31	61.89		59.41	59.65	54.26	56.95	62.52	55.93	54.83	63.15	54.42
8	57.50	63.37	63.23	44.97	40.03	42.30	59.14		63.53	62.18	58.10	64.94	43.51	56.26	68.14	58.25
9	65.38	69.82	45.70	64.22	67.21	69.82	60.86	59.29		57.54	67.03	60.24	59.63	51.75	51.03	43.56
10	47.26	51.40	44.08	51.21	50.27	50.71	47.02	48.00	51.94		37.09	49.50	44.68	53.55	50.90	41.35
11	48.50	49.87	41.97	50.12	48.72	46.21	46.26	47.56	47.08	50.39		51.01	48.06	45.65	51.97	44.78
12	46.42	54.47	50.44	49.20	49.66	52.52	47.72	46.09	49.96	51.63	50.61		49.05	52.00	54.87	48.53
13	51.87	51.53	44.94	44.08	47.01	48.87	45.59	45.21	49.63	46.62	46.88	48.99		44.60	52.04	43.86
14	48.28	52.28	49.68	46.74	45.02	50.87	37.50	47.06	52.55	48.14	47.66	51.71	44.71		52.79	44.81
15	47.71	54.76	50.20	56.14	53.60	56.07	48.97	54.30	56.64	57.32	63.04	52.00	56.74	56.42		52.68
16	43.28	51.69	44.58	46.01	48.34	47.60	41.31	45.16	44.19	44.14	43.95	44.30	45.72	46.61	48.90	

Table 5. A wide range was observed. Volumes for individual seed level ranged from 74.2 mm^3 to 35.1 mm^3. In the combination level, the largest (73.91 mm^3) was obtained in the combination, No.6 × No.15, which was the same as the area, followed by No.9 × No.2 and No.9 × No.6 (69.82 mm^3). The smallest (37.09 mm^3) was noted in the combination, No.10 × No.11, followed by No.14 × No.7 (37.50 mm^3) and No.16 × No.7 (41.31 mm^3). The differences in the volume were confirmed to be very large in accordance with the varieties in the respective combination-sets.

In Table 3, the average value and the standard deviations in the volume in the whole combinations are shown. In view of the female parent, the highest value (60.73 mm^3) in the parental average was obtained in No. 6, which was the same as the area, followed by No.9 (59.54 mm^3). The lowest (45.72 mm^3) in the parental average was noted in No.16, which was the same as the area, followed by No.13 (47.45 mm^3). The differences of the volume in the parental level were ascertained to be large in accordance with each parent. The relation between the values of average and standard deviations was not recognized clearly. In view of the male parent, the highest value (56.80 mm^3) in the parental average was obtained in No.15, which was the same as the area, followed by No.2 (55.28 mm^3). The lowest value (47.60 mm^3) in the parental average was also noted in No.16, which was the same as the area, followed by No.7 (49.21 mm^3). The relation between values of average and standard deviations was not recognized clearly, either. The average value and its standard deviations in the whole combinations were 51.98 ± 6.48.

To make clear the volume in view of reciprocal combinations, correlation coefficient and linear regression of volume of female parent on male parent in the same strain were calculated and are shown in Table 4. Four strains showed significances at 5% level, but the remaining 12 strains showed no significance even at 5% level, respectively. Through the whole strains, correlation coefficient was + 0.1547 to the degree of freedom of 118, which meant no significance even at 5% level. It was concluded that the reciprocal differences in this study suggested no considerable cytoplasmic influence on the volume.

The differences (mm^3) between the maximum and the minimum values of volume for each parent, in view of the female parent, were as follows in the order from No.1 to No.16; 12.38, 13.07, 12.90, 14.37, 14.75, 26.64, 13.29, 28.11, 26.26, 16.46, 10.00, 7.78, 8.18, 15.29, 15.33 and 10.38, respectively. The average and its standard deviations were 15.32 ± 6.32. Those in view of the male parent were as follows in the same order; 15.66, 21.26, 26.34, 20.14, 23.03, 27.52, 24.44, 18.86, 20.01, 21.37, 29.94, 20.63, 19.43, 19.11, 25.01 and 16.90, respectively. Those average and its standard deviations were 21.85 ± 3.91. In reciprocal views, correlation coefficient between these was + 0.0190, showing no significance even at 5% level.

To make clear the relations between Sikkimese rice and two testers, the differences in volume at the time when two testers were crossed with Sikkimese rice, and the reciprocals were calculated. In view of the female parent, the differences (mm^3) in volume for *indica* (No.1) and *japonica* (No.2) were as follows in the order from No.3 to No.16, provided that the calculation was made only by the absolute value; 4.37, 3.20, 10.38, 15.41, 1.04, 5.87, 4.44, 4.14, 1.37, 8.05, 0.34, 4.00, 7.05 and 8.41, respectively. It may be noted that the value was peculiarly large in No.6. Average and its standard deviations in the whole Sikkimese rice were 5.58 ± 4.07. In view of the male parent, the differences in the volume for *indica* and *japonica* were as follows in the same order; 5.57, 3.52, 2.67, 1.76, 0.55, 6.30, 3.26, 2.84, 5.51, 10.10, 0.79, 3.37, 5.73 and 5.55, respectively. It may be noted that the value was peculiarly large in No.12. Average and its standard deviations in the whole Sikkimese rice were

Table 6. Area of husked grains of F_1 hybrids in mm²

♂ \ ♀	Code No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		14.84	14.58	14.80	14.66	15.18	14.01	13.93	14.79	14.63	14.28	13.26	13.74	14.06	15.16	13.41
2	14.61		14.44	15.40	14.93	15.10	13.94	14.14	14.19	14.35	15.61	14.56	14.05	14.57	14.81	14.02
3	12.30	14.22		13.84	14.60	15.84	13.40	14.71	14.12	13.39	14.04	14.79	13.15	13.36	15.56	13.28
4	15.04	15.15	15.48		14.98	15.85	14.50	16.15	15.46	16.09	16.72	15.40	14.93	14.53	16.91	14.63
5	16.10	15.60	14.85	15.92		15.38	15.29	16.60	14.87	15.62	16.67	15.82	15.34	14.93	16.67	13.90
6	15.37	15.49	16.05	16.43	14.74		15.25	15.73	16.22	16.65	16.97	16.38	15.31	15.44	17.31	15.21
7	13.57	13.85	13.38	14.93	15.37	14.21		14.41	13.74	13.32	13.67	14.28	13.07	12.94	14.66	13.03
8	14.38	14.49	14.81	15.22	13.91	14.77	14.64		15.53	15.23	14.71	14.72	14.61	14.23	15.33	14.14
9	14.81	14.90	14.06	15.54	15.87	15.87	13.90	14.50		13.85	15.76	14.35	14.19	14.53	15.04	14.01
10	14.89	14.33	13.49	15.99	15.51	16.22	13.60	15.18	15.64		12.62	14.60	13.87	14.51	15.42	13.05
11	14.53	14.42	13.75	15.99	14.76	13.56	14.46	15.01	14.16	15.48		14.78	14.36	14.70	15.31	13.96
12	14.18	14.64	14.89	15.70	16.09	15.40	14.41	14.45	15.11	14.99	15.15		14.44	15.83	16.00	14.55
13	14.87	14.94	13.73	14.52	14.20	15.54	13.45	14.93	14.40	14.30	13.96	14.65		13.43	15.44	13.40
14	14.02	14.13	13.60	14.57	14.22	15.06	11.96	14.77	14.05	14.11	14.26	14.59	13.21		14.87	12.89
15	15.34	15.99	15.86	16.84	16.42	16.55	14.45	15.15	15.94	16.17	15.75	15.69	15.62	15.95		15.17
16	13.66	14.16	13.22	14.82	14.52	14.55	12.69	13.98	13.32	13.69	13.49	13.80	13.39	13.53	14.93	

Code No.

4.11 ± 2.54. In reciprocal views, correlation coefficient between these was −0.5663, showing significance at 5% level. It means that the larger was the differences at the time when the strains were used as female parent, the smaller was it noted at the time when they were used as male parent ($Y = -0.926X - 2.778$).

3. Area of husked grains

Parent: Areas of husked grains in the parental plants are shown in Table 1. The largest (17.20 mm²) was obtained in No.15, followed by No.5 (15.91 mm²), both of which were the same as area and volume of unhusked grains. The smallest (12.40 mm²) was noted in No.2, followed by No.16 (12.70 mm²). Average and standard deviations in the whole strains were found to be 14.38 ± 1.30.

Hybrid: The values of area of husked grains among diallel crosses are shown in Table 6. A wide range was observed. Areas for the individual seed level ranged from 19.4 mm² to 9.7 mm². In the combination level, the largest (17.31 mm²) was obtained in the combination, No.6 × No.15,which was the same as the area and volume of unhusked grains, followed by No.6 × No.11 (16.97 mm²) and No.4 × No.15 (16.91 mm²). The smallest (11.96 mm²) was noted in the combination, No.14 × No.7, followed by No.3 × No.1 (12.30 mm²) and No.10 × No.11 (12.62 mm²). The differences in the area were confirmed to be very large in accordance with the varieties in the respective combination-sets.

In Table 3, the average value and the standard deviations in the area through the whole combinations are shown. In view of the female parent, the highest value (15.90 mm²) in the parental average was obtained in No.6, which was the same as the area and volume of unhusked grains, followed by No.15 (15.79 mm²). The lowest value (13.85 mm²) in the parental average was noted in No.16, which was also the same as the area and volume of unhusked grains, followed by No.7 (13.90 mm²). The differences of the area in the parental level were ascertained to be large in accordance with each parent. The relation between the values of average and standard deviations was not recognized clearly. In view of the male parent, the highest value (15.56 mm²) in the parental average was obtained in No.15, which was the same as the area and volume of unhusked grains, followed by No.4 (15.37 mm²). The lowest value (13.91 mm²) in the parental average was also noted in No.16, followed by No.7 (14.00 mm²). The relation between values of average and standard deviations was not recognized clearly, either. The average value and its standard deviations through the whole combinations were 14.72 ± 0.95.

To make clear the area in view of reciprocal combinations, correlation coefficient and linear regression of area of female parent on male parent in the same strain were calculated and are shown in Table 4. Four, 5 and 7 strains showed significances at 0.1%, 1% levels and no significance even at 5% level, respectively. In the whole strains, correlation coefficient was +0.6625 to the degree of freedom of 118, which is obviously significant at 0.1% level. Generally speaking, the larger was the area noted at the time when strain was used as female parent, the larger was it noted at the time when strain was used as male parent. It was concluded that the reciprocal differences in this study suggested no considerable cytoplasmic influence on the area.

The differences (mm²) between the maximum and the minimum values of area for each parent, in view of the female parent, were as follows in the order from No.1 to No.16; 1.92, 1.67, 3.54, 2.41, 2.77, 2.60, 2.43, 1.68, 2.02, 3.60, 1.91, 2.24, 2.14, 3.13, 2.39 and 2.24, respectively. The average and its standard deviations were 2.42 ± 0.59. Those in view of the male parent were as follows in the same order; 3.80, 2.14, 2.83, 3.00, 2.51, 2.99, 3.33, 2.67, 2.90, 3.33, 4.35,

3.12, 2.55, 3.01, 2.65 and 2.32, respectively. It may be noted that the value was peculiarly large in No.11. Average and its standard deviations in the whole Sikkimese rice were 2.97 ±0.55. In reciprocal views, correlation coefficient between these was +0.1985, showing no significance even at 5% level.

To make clear the relations between Sikkimese rice and two testers, the differences in area at the time when two testers were crossed with Sikkimese rice, and the reciprocals were calculated. In view of the female parent, the differences (mm^2) in area for *indica* (No.1) and *japonica* (No.2) were as follows in the order from No.3 to No.16, provided that the calculation was made only by the absolute value; 1.92, 0.11, 0.50, 0.13, 0.28, 0.11, 0.09, 0.56, 0.11, 0.46, 0.07, 0.11, 0.65 and 0.50, respectively. It may be noted that the value was peculiarly large in No.3. Average and its standard deviations in the whole Sikkimese rice were 0.40 ± 0.48. In view of the male parent, the differences in the area for *indica* and *japonica* were as follows in the same order; 0.14, 0.60, 0.27, 0.08, 0.07, 0.21, 0.60, 0.28, 1.33, 1.30, 0.31, 0.51, 0.35 and 0.61, respectively. Average and its standard deviations in the whole Sikkimese rice were 0.48 ± 0.40. In reciprocal views, correlation coefficient between these was −0.2918, showing no significance even at 5% level.

4. Volume of husked grains

Parent: Volumes of husked grains in the parental plants are shown in Table 1. The largest (30.10 mm^3) was obtained in No.15, which was the same as the former three characters, followed by No.5 (28.95 mm^3), which was also the same as the former three characters. The smallest (20.34 mm^3) was noted in No.2, which was the same as the area, followed by Nos. 8 and 16 (21.97 mm^3). Average and standard deviations in the whole strains were found to be 25.32 ± 2.64.

Hybrid: The values of volume of husked grains among diallel crosses are shown in Table 7. A wide range was observed. Volumes for individual seed level ranged from 33.0 mm^3 to 16.9 mm^3. In the combination level, the largest (31.03 mm^3) was obtained in the combination, No.12 × No.14, followed by No.6 × No.15 (30.47 mm^3). The smallest (18.42 mm^3) was noted in the combination, No.14 × No.7, followed by No.10 × No.11 (20.44 mm^3) and No.10 × No.16 (22.06 mm^3). The differences in the volume were confirmed to be very large in accordance with the varieties in the respective combination-sets.

In Table 3, the average value and the standard deviations in the volume in the whole combinations are shown. In view of the female parent, the highest value (28.34 mm^3) in the parental average was obtained in No.6, which was the same as the former three characters, followed by No.9 (27.95 mm^3), which was the same as the volume of unhusked grains. The lowest value (25.41 mm^3) in the parental average was noted in No.11, followed by No.16 (25.47 mm^3). The differences of the volume in the parental level were ascertained to be large in accordance with each parent. The relation between the values of average and standard deviations was not recognized clearly. In view of the male parent, the highest value (27.75 mm^3) in the parental average was obtained in No.2, followed by No.15 (27.73 mm^3). The lowest value (24.90 mm^3) in the parental average was noted in No.16, which was the same as the former three characters, followed by No.7 (25.48 mm^3). The relation between values of average and standard deviations was not recognized clearly, either. The average value and its standard deviations in the whole combinations were 26.63 ± 1.88.

To make clear the volume in view of reciprocal combinations, correlation coefficient and linear regression of volume of female parent on male parent in the same strain were calculated and are shown in Table 8. One, 5 and 10 strains showed significances at 1%, 5%

Table 7. Volume of husked grains of F_1 hybrids in mm^3

♀ \ ♂	Code No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Code No.	1		28.20	27.70	26.34	25.07	26.72	26.20	24.38	22.93	27.07	24.99	22.28	25.42	26.15	26.68	24.41
	2	28.05		28.88	27.57	25.53	27.63	25.37	25.59	28.24	28.27	27.79	27.52	27.12	27.25	26.36	27.20
	3	22.76	27.59		26.16	26.86	28.83	26.40	26.48	25.98	23.30	25.13	27.36	25.38	26.32	27.54	23.24
	4	26.17	28.48	27.55		25.17	28.53	25.38	28.10	28.91	28.80	29.09	25.56	26.73	24.99	29.09	24.58
	5	27.53	27.14	26.73	28.34		27.22	28.13	29.55	26.92	28.27	29.34	27.59	28.38	28.22	30.01	24.74
	6	26.13	27.42	29.05	29.25	26.83		27.76	27.21	30.17	30.14	29.19	29.32	27.41	28.72	30.47	26.01
	7	24.97	25.62	25.69	27.32	27.82	26.29		25.07	26.24	23.84	23.65	27.42	24.31	23.42	27.12	24.37
	8	24.46	25.21	25.92	26.33	23.65	25.40	25.33		27.64	27.41	25.45	26.50	27.18	26.18	27.44	25.31
	9	28.14	30.10	26.29	29.68	29.84	30.31	26.97	27.70		25.35	28.37	26.12	27.95	29.21	27.07	26.20
	10	27.25	28.66	24.15	28.78	28.38	30.17	26.79	26.57	28.47		20.44	26.13	25.24	29.17	27.45	22.06
	11	25.43	26.24	22.14	28.62	25.72	23.32	25.45	24.77	24.50	26.63		26.01	25.56	26.17	26.64	24.01
	12	24.82	27.23	27.40	26.85	28.00	27.72	27.09	25.72	27.35	26.83	26.51		25.70	31.03	28.00	25.90
	13	29.74	28.98	25.13	25.27	25.56	27.51	24.75	26.58	27.79	26.46	24.01	25.93		23.77	28.10	24.12
	14	25.80	27.55	26.52	25.79	25.03	26.20	18.42	26.14	28.24	26.81	25.38	28.16	23.51		27.21	24.88
	15	26.85	29.90	29.66	29.30	28.41	28.14	25.14	27.42	29.01	28.46	27.88	27.61	27.49	26.32		26.40
	16	24.86	27.90	24.85	26.82	25.85	25.90	22.97	25.16	24.51	24.64	23.74	24.98	26.11	27.06	26.73	

Table 8. Correlation coefficient and linear regression of three characters of female parent (Y) on male parent (X); volume of husked grains, quotient of area and quotient of volume. O points; 24.3 mm³, 60.5% and 50.5% in 1st, 2nd and 3rd characters, respectively, in both female and male parents

Code No.	Volume (Husked)			Quotient (Area)			Quotient (Volume)		
	Correlation coefficient	d.f.	Linear regression	Correlation coefficient	d.f.	Linear regression	Correlation coefficient	d.f.	Linear regression
1	−0.0182	13	—	−0.4026	13	—	−0.2171	13	—
2	0.3821	13	—	−0.0067	13	—	−0.2579	13	—
3	0.5439*	13	Y = 0.478X + 0.847	0.0601	13	—	−0.0627	13	—
4	0.5857	13	Y = 0.705X + 0.981	0.1599	13	—	0.2474	13	—
5	0.0044	13	—	−0.0622	13	—	−0.1227	13	—
6	0.4603	13	—	0.0637	13	—	0.0053	13	—
7	0.5070	13	—	0.4395	13	—	0.3144	13	—
8	0.2164*	13	—	0.4155	13	—	0.2569	13	—
9	0.5797*	13	Y = 0.733X + 2.549	−0.1771	13	—	0.1181	13	—
10	0.5440*	13	Y = 0.767X + 0.763	−0.1665	13	—	0.0116	13	—
11	0.0757	13	—	0.5312*	13	Y = 0.550X + 0.820	−0.3651	13	—
12	0.6839**	13	Y = 0.862X + 1.315	0.0309	13	—	−0.2419	13	—
13	0.4912	13	—	0.4556	13	—	0.3631	13	—
14	0.6342*	13	Y = 0.975X − 1.300	0.7895***	13	Y = 0.341X − 0.067	0.6379*	13	Y = 0.259X + 2.267
15	0.0983	13	—	−0.1453	13	—	−0.1872	13	—
16	0.2536	13	—	−0.0046	13	—	0.0874	13	—
Whole	0.4479***	118	Y = 0.452X + 2.162	0.1542	118	—	0.0881	118	—

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

Table 9. Ratio of area of husked grains to area of unhusked grains in F_1 hybrids

♂ \ ♀	Code No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		0.56	0.59	0.59	0.60	0.57	0.60	0.58	0.62	0.60	0.57	0.58	0.58	0.61	0.57	0.58
2	0.62		0.58	0.60	0.57	0.56	0.57	0.55	0.66	0.57	0.60	0.58	0.60	0.60	0.54	0.60
3	0.53	0.59		0.63	0.58	0.64	0.64	0.60	0.59	0.58	0.64	0.66	0.63	0.61	0.58	0.62
4	0.58	0.65	0.61		0.60	0.64	0.63	0.65	0.64	0.65	0.63	0.63	0.64	0.66	0.61	0.63
5	0.58	0.65	0.61	0.66		0.61	0.67	0.64	0.62	0.60	0.63	0.64	0.63	0.61	0.63	0.64
6	0.63	0.55	0.56	0.65	0.55		0.57	0.56	0.59	0.59	0.58	0.64	0.56	0.60	0.55	0.63
7	0.55	0.55	0.56	0.60	0.58	0.53		0.56	0.57	0.57	0.54	0.55	0.55	0.54	0.55	0.58
8	0.57	0.56	0.54	0.65	0.66	0.65	0.56		0.60	0.56	0.56	0.54	0.69	0.59	0.54	0.55
9	0.56	0.56	0.64	0.59	0.56	0.55	0.56	0.59		0.56	0.56	0.57	0.59	0.65	0.61	0.65
10	0.65	0.62	0.64	0.64	0.66	0.65	0.63	0.64	0.65		0.62	0.61	0.63	0.63	0.61	0.62
11	0.60	0.60	0.69	0.63	0.60	0.56	0.63	0.59	0.58	0.63		0.59	0.59	0.63	0.60	0.61
12	0.61	0.58	0.63	0.63	0.63	0.59	0.64	0.63	0.62	0.61	0.59		0.60	0.65	0.61	0.62
13	0.65	0.62	0.63	0.64	0.63	0.63	0.61	0.65	0.62	0.64	0.58	0.61		0.61	0.62	0.63
14	0.61	0.59	0.62	0.62	0.62	0.60	0.57	0.61	0.60	0.65	0.60	0.62	0.61		0.59	0.63
15	0.62	0.59	0.65	0.61	0.59	0.58	0.60	0.58	0.57	0.58	0.58	0.60	0.55	0.54		0.60
16	0.63	0.60	0.62	0.64	0.60	0.61	0.63	0.61	0.62	0.62	0.61	0.63	0.62	0.62	0.62	

Code No.

levels and no significance even at 5% level, respectively. In the whole strains, correlation coefficient was +0.4479 to the degree of freedom of 118, which is obviously significant at 0.1% level. Generally speaking, the larger was the volume noted at the time when strain was used as female parent, the larger was it noted at the time when strain was used as male parent. It was concluded that the reciprocal differences in this study suggested no considerable cytoplasmic influence on the volume.

The differences (mm^3) between the maximum and the minimum values of volume for each parent, in view of the female parent, were as follows in the order from No.1 to No.16; 5.92, 3.52, 6.07, 4.51, 5.27, 4.46, 4.40, 3.99, 4.76, 8.11, 6.48, 6.21, 5.97, 9.82, 4.76 and 4.93, respectively. The average and its standard deviations were 5.57 ± 1.60. Those in view of the male parent were as follows in the same order; 6.98, 4.89, 7.52, 4.41, 6.19, 6.75, 9.71, 5.17, 7.24, 6.84, 8.75, 7.04, 4.87, 7.61, 4.11 and 5.14, respectively. Those average and its standard deviations were 6.45 ± 1.59. In reciprocal views, correlation coefficient between these was +0.2701, showing no significance even at 5% level.

To make clear the relations between Sikkimese rice and two testers, the differences in volume at the time when two testers were crossed with Sikkimese rice, and the reciprocals were calculated. In view of the female parent, the differences (mm^3) in volume for *indica* (No.1) and *japonica* (No.2) were as follows in the order from No.3 to No.16, provided that the calculation was made only by the absolute value; 4.83, 2.31, 0.39, 1.29, 0.65, 0.75, 1.96, 1.41, 0.81, 2.41, 0.76, 1.75, 3.05 and 3.04, respectively. It may be noted that the value was peculiarly large in No.3. Average and its standard deviations in the whole Sikkimese rice were 1.82 ± 1.24. In view of the male parent, the differences in the volume for *indica* and *japonica* were as follows in the same order; 1.18, 1.23, 0.46, 0.91, 0.83, 1.21, 5.31, 1.20, 2.80, 5.24, 1.70, 1.10, 0.32 and 2.79, respectively. It may be noted that the value was peculiarly large in No.9. Average and its standard deviations in the whole Sikkimese rice were 1.88 ± 1.61. In reciprocal views, correlation coefficient between these was +0.3200, showing no significance even at 5% level.

5. Ratio of area of husked grains to area of unhusked grains

Parent: Ratios of area of husked grains to area of unhusked grains (abbreviated as "the ratio") in the parental plants are shown in Table 1. The largest (0.67) was obtained in No.10, followed by No.4 (0.63). The smallest (0.54) was noted in No.2, which was the same as area and volume of husked grains, followed by Nos. 7, 8 and 11 (0.58). Average and standard deviations in the whole strains were found to be 0.60 ± 0.03.

Hybrid: The values of the ratio among diallel crosses are shown in Table 9. The ratios for individual seed level ranged from 0.72 to 0.50. In the combination level, the largest (0.69) was obtained in the combinations, No.8 × No.13 and No.11 × No.3, followed by No.5 × No.7 (0.67). The smallest (0.53) was noted in the combinations, No.3 × No.1 and No.7 × No.6.

In Table 3, the average value and the standard deviations in the ratio in the whole combinations are shown. In view of the female parent, the highest value (0.63) in the parental average was obtained in Nos.4, 5, 10 and 13. The lowest value (0.56) in the parental average was noted in No.7. The relation between the values of average and standard deviations was not recognized clearly. In view of the male parent, the highest value (0.63) in the parental average was obtained in No.4. The lowest value (0.59) in the parental average was noted in Nos.2, 11 and 15. The relation between values of average and standard deviations was not recognized clearly, either. The average value and its standard deviations through the whole

combinations were 0.60 ± 0.03, which was the same as it of parental plants.

To make clear the ratio in view of reciprocal combinations, correlation coefficient and linear regression of the ratio of female parent on male parent in the same strain were calculated and are shown in Table 8. One and 1 strain showed significances at 0.1% and 5% levels, but the remaining 14 strains showed no significance even at 5% level. In the whole strains, correlation coefficient was +0.1542 to the degree of freedom of 118, which meant no significance even at 5% level. It was concluded that the reciprocal differences in this study suggested no considerable cytoplasmic influence on the ratio.

The differences between the maximum and the minimum values of the ratio for each parent, in view of the female parent, were as follows in the order from No.1 to No.16; 0.06, 0.12, 0.13, 0.08, 0.09, 0.10, 0.07, 0.15, 0.10, 0.05, 0.13, 0.07, 0.07, 0.08, 0.11 and 0.04, respectively. The average and its standard deviations were 0.09 ± 0.03. Those in view of the male parent were as follows in the same order; 0.12, 0.10, 0.15, 0.07, 0.08, 0.12, 0.11, 0.10, 0.09, 0.09, 0.10, 0.12, 0.14, 0.12, 0.09 and 0.10, respectively. Those average and its standard deviations were 0.11 ± 0.02. In reciprocal views, correlation coefficient between these was +0.0338, showing no significance even at 5% level.

To make clear the relations between Sikkimese rice and two testers, the differences in the ratio at the time when two testers were crossed with Sikkimese rice, and the reciprocals were calculated. In view of the female parent, the differences in the ratio for *indica* (No.1) and *japonica* (No.2) were as follows in the order from No.3 to No.16, provided that the calculation was made only by the absolute value; 0.06, 0.07, 0.07, 0.08, 0.00, 0.01, 0.00, 0.03, 0.00, 0.03, 0.03, 0.02, 0.03 and 0.03, respectively. Average and its standard deviations in the whole Sikkimese rice were 0.03 ± 0.03. In view of the male parent, the differences in the ratio for *indica* and *japonica* were as follows in the same order; 0.01, 0.01, 0.03, 0.01, 0.03, 0.03, 0.04, 0.03, 0.03, 0.00, 0.02, 0.01, 0.03 and 0.02, respectively. Average and its standard deviations in the whole Sikkimese rice were 0.02 ± 0.01. In reciprocal views, correlation coefficient between these was −0.4905, showing no significance even at 5% level.

6. Ratio of volume of husked grains to volume of unhusked grains

Parent: Ratios of volume of husked grains to volume of unhusked grains (abbreviated as "the ratio") in the parental plants are shown in Table 1. The largest (0.57) was obtained in No.10, followed by No.4 (0.56), both of which were the same as the former ratio. The smallest (0.46) was noted in No.2, which was the same as area and volume of husked grains and of the former ratio, followed by No.15 (0.49). Average and standard deviations in the whole strains were found to be 0.52 ± 0.03.

Hybrid: The values of the ratio among diallel crosses are shown in Table 10. The ratios for individual seed level ranged from 0.67 to 0.37. In the combination level, the largest (0.63) was obtained in the combination, No.8 × No.13, which was the same as the former ratio, followed by No.3 × No.12, No.8 × No.6, No.9 × No.16, No.10 × No.6 and No.12 × No.14 (0.60). The smallest (0.40) was noted in the combinations, No.8 × No.2 and No.8 × No.15, followed by No.6 × No.15, No.8 × No.3 and No.8 × No.12 (0.41).

In Table 3, the average value and the standard deviations in the ratio in the whole combinations are shown. In view of the female parent, the highest value (0.56) in the parental average was obtained in Nos.10 and 16. The lowest value (0.45) in the parental average was noted in No.7, which was the same as the former ratio. The relation between the values of average and standard deviations was not recognized clearly. In view of the male parent, the highest value (0.55) in the parental average was obtained in No.4, which was the same

Table 10. Ratio of volume of husked grains to volume of unhusked grains in F_1 hybrids

♀ \ ♂	Code No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Code No.	1		0.49	0.52	0.50	0.51	0.48	0.53	0.52	0.46	0.51	0.52	0.50	0.50	0.52	0.49	0.50
	2	0.57		0.49	0.49	0.49	0.48	0.51	0.48	0.60	0.51	0.52	0.50	0.52	0.51	0.44	0.50
	3	0.45	0.50		0.55	0.49	0.53	0.57	0.51	0.50	0.48	0.58	0.60	0.59	0.54	0.49	0.54
	4	0.50	0.58	0.52		0.51	0.57	0.55	0.58	0.55	0.56	0.57	0.53	0.56	0.59	0.51	0.56
	5	0.47	0.56	0.53	0.57		0.54	0.58	0.55	0.54	0.51	0.55	0.55	0.55	0.53	0.53	0.56
	6	0.55	0.44	0.43	0.57	0.43		0.45	0.43	0.47	0.46	0.46	0.56	0.44	0.47	0.41	0.55
	7	0.43	0.45	0.44	0.55	0.46	0.43		0.42	0.44	0.44	0.42	0.44	0.44	0.43	0.43	0.45
	8	0.43	0.40	0.41	0.59	0.59	0.60	0.43		0.44	0.44	0.44	0.41	0.63	0.47	0.40	0.44
	9	0.43	0.43	0.58	0.46	0.44	0.43	0.44	0.47		0.44	0.42	0.43	0.47	0.56	0.53	0.60
	10	0.58	0.56	0.55	0.56	0.57	0.60	0.57	0.55	0.55		0.55	0.53	0.57	0.55	0.54	0.53
	11	0.52	0.53	0.53	0.57	0.53	0.51	0.55	0.52	0.52	0.53		0.51	0.53	0.57	0.51	0.54
	12	0.54	0.50	0.54	0.55	0.53	0.53	0.57	0.56	0.55	0.52	0.52		0.52	0.60	0.51	0.53
	13	0.57	0.56	0.56	0.57	0.54	0.56	0.54	0.59	0.56	0.57	0.51	0.53		0.53	0.54	0.55
	14	0.53	0.53	0.53	0.55	0.56	0.52	0.49	0.56	0.54	0.56	0.53	0.55	0.53		0.52	0.56
	15	0.56	0.55	0.59	0.52	0.53	0.50	0.51	0.51	0.51	0.50	0.44	0.53	0.49	0.47		0.50
	16	0.57	0.54	0.56	0.58	0.54	0.54	0.56	0.56	0.56	0.56	0.54	0.56	0.57	0.58	0.55	

as the former ratio. The lowest value (0.49) in the parental average was noted in No.15. The relation between values of average and standard deviations was not recognized clearly, either. The average value and its standard deviations in the whole combinations were 0.52 ± 0.05.

To make clear the ratio in view of reciprocal combinations, correlation coefficient and linear regression of the ratio of female parent on male parent in the same strain were calculated and are shown in Table 8. Only 1 strain showed significance at 5% level, but the remaining 15 strains showed no significance even at 5% level. In the whole strains, correlation coefficient was +0.0881 to the degree of freedom of 118, which meant no significance even at 5% level. It was concluded that the reciprocal differences in this study suggested no considerable cytoplasmic influence on the ratio.

The differences between the maximum and the minimum values of the ratio for each parent, in view of the female parent, were as follows in the order from No.1 to No.16; 0.07, 0.16, 0.15, 0.09, 0.11, 0.15, 0.13, 0.23, 0.18, 0.07, 0.06, 0.10, 0.08, 0.07, 0.15 and 0.04, respectively. It may be noted that the value was peculiarly large in No.8. The average and its standard deviations were 0.12 ± 0.05. Those in view of the male parent were as follows in the same order; 0.15, 0.18, 0.18, 0.13, 0.16, 0.17, 0.15, 0.17, 0.16, 0.13, 0.16, 0.15, 0.19, 0.17, 0.15 and 0.16, respectively. Those average and its standard deviations were 0.16 ± 0.02. In reciprocal views, correlation coefficient between these was +0.1470, showing no significance even at 5% level.

To make clear the relation between Sikkimese rice and two testers, the differences in the ratio at the time when two testers were crossed with Sikkimese rice, and the reciprocals were calculated. In view of the female parent, the differences in the ratio for *indica* (No.1) and *japonica* (No.2) were as follows in the order from No.3 to No.16, provided that the calculation was made only by the absolute value; 0.05, 0.08, 0.09, 0.11, 0.02, 0.03, 0.00, 0.02, 0.01, 0.04, 0.01, 0.00, 0.01 and 0.03, respectively. Average and its standard deviations

Table 11. Volume of unhusked grains of the parental plants in relation to area of unhusked grain

Area (mm^2)	Volume (mm^3)															
	62.0 ≀ 61.1	·	58.0 ≀ 57.1	·	53.0 ≀ 52.1	52.0 ≀ 51.1	51.0 ≀ 50.1	50.0 ≀ 49.1	49.0 ≀ 48.1	48.0 ≀ 47.1	47.0 ≀ 46.1	46.0 ≀ 45.1	45.0 ≀ 44.1	44.0 ≀ 43.1	43.0 ≀ 42.1	Total
29.5 ~ 29.1	1															1
·																·
27.0 ~ 26.6			1													1
26.5 ~ 26.1						1										1
26.0 ~ 25.6																0
25.5 ~ 25.1								1								1
25.0 ~ 24.6					1											1
·																·
23.5 ~ 23.1						1		1			1		1	1	1	6
23.0 ~ 22.6									1	1	1					3
22.5 ~ 22.1										1						1
·																·
21.0 ~ 19.6															1	1
Total	1	·	1	·	1	2	0	2	1	2	2	0	1	1	2	16

Figure used in the table shows the number of strains.
r = +0.8950*** (d.f. = 14), significant at 0.1% level.

Table 12. Correlation coefficient and linear regression of three characters; I–volume of unhusked grain (Y, O point = 55.0 mm³) on area of unhusked grain (X, O point = 26.3 mm²), II–volume of husked grain (Y, O point = 24.3 mm³) on area of husked grain (X, O point = 14.6 mm²), III–area of husked grain (Y, O point = 14.6 mm²) on area of unhusked grain (X, O point = 26.3 mm²)

	I			II			III		
Code No.	Correlation coefficient	d.f.	Linear regression	Correlation coefficient	d.f.	Linear regression	Correlation coefficient	d.f.	Linear regression
1	0.8133***	28	Y = 1.478X + 0.577	0.5870***	28	Y = 0.536X − 1.829	0.6217***	28	Y = 0.702X − 3.439
2	0.6383***	28	Y = 0.861X − 2.237	0.3085	28	—	0.5790***	28	Y = 1.008X − 2.736
3	0.8539***	28	Y = 1.042X − 3.409	0.8023***	28	Y = 0.788X − 3.571	0.7294***	28	Y = 0.899X − 4.228
4	0.7809***	28	Y = 0.753X − 1.551	0.8000***	28	Y = 0.980X − 1.902	0.7672***	28	Y = 0.933X − 5.975
5	0.8366***	28	Y = 1.064X − 1.131	0.8581***	28	Y = 0.804X − 1.459	0.7083***	28	Y = 0.934X − 5.075
6	0.9219***	28	Y = 0.907X − 0.577	0.8471***	28	Y = 0.781X − 1.082	0.5596**	28	Y = 0.848X − 2.601
7	0.8688***	28	Y = 0.932X − 3.685	0.8204***	28	Y = 0.679X − 3.280	0.6037***	28	Y = 0.837X − 2.759
8	0.9017***	28	Y = 0.893X − 1.924	0.7706***	28	Y = 0.699X − 1.404	0.4763**	28	Y = 0.907X − 3.682
9	0.8367***	28	Y = 0.890X − 3.382	0.5988***	28	Y = 0.501X − 2.105	0.5591**	28	Y = 0.893X − 3.271
10	0.9197***	28	Y = 1.236X − 2.122	0.8420***	28	Y = 0.751X − 2.512	0.7610***	28	Y = 0.817X − 5.048
11	0.9082***	28	Y = 0.991X − 0.556	0.9465***	28	Y = 0.936X − 1.479	0.8464***	28	Y = 0.943X − 3.886
12	0.8880***	28	Y = 1.505X + 1.543	0.7059***	28	Y = 0.650X − 1.720	0.4419*	28	Y = 0.493X − 3.975
13	0.8256***	28	Y = 1.059X − 2.450	0.7362***	28	Y = 0.711X − 3.446	0.9039***	28	Y = 0.909X − 5.082
14	0.7138***	28	Y = 1.032X − 3.049	0.6223***	28	Y = 0.425X − 2.470	0.7696***	28	Y = 0.950X − 4.780
15	0.7464***	28	Y = 0.850X + 0.888	0.8440***	28	Y = 0.469X + 1.710	0.6573***	28	Y = 0.981X − 2.662
16	0.8188***	28	Y = 0.922X − 4.456	0.6307***	28	Y = 0.636X − 3.179	0.9120***	28	Y = 1.142X − 4.678
Whole	0.8935***	238	Y = 1.167X − 1.828	0.8036***	238	Y = 0.868X − 2.895	0.7427***	238	Y = 0.921X − 4.026

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

Table 13. Volume of unhusked grains of the F_1 hybrids in relation to area of unhusked grains

Area (mm^2)	Volume (mm^3)																		Total
	74.0 ≀ 72.1	72.0 ≀ 70.1	70.0 ≀ 68.1	68.0 ≀ 66.1	66.0 ≀ 64.1	64.0 ≀ 62.1	62.0 ≀ 60.1	60.0 ≀ 58.1	58.0 ≀ 56.1	56.0 ≀ 54.1	54.0 ≀ 52.1	52.0 ≀ 50.1	50.0 ≀ 48.1	48.0 ≀ 46.1	46.0 ≀ 44.1	44.0 ≀ 42.1	42.0 ≀ 40.1	40.0 ≀ 38.1	38.0 ≀ 36.1	
32.0 ~ 31.6	1																		1
. .																			.
30.0 ~ 29.6									1										1
29.5 ~ 29.1					1														1
29.0 ~ 28.6			3																3
28.5 ~ 28.1				1	2	1			4										8
28.0 ~ 27.6				1		1		2	2		1								7
27.5 ~ 27.1					2	4			1	1									8
27.0 ~ 26.6			1			2	2		3	2	1								11
26.5 ~ 26.1					2	1	1	3	1	3	3	2							16
26.0 ~ 25.6						1	1	1			4	2	1						10
25.5 ~ 25.1							1	1	3	3	3	6	2	1					20
25.0 ~ 24.6							1	1	1	2	3	9	9	1					27
24.5 ~ 24.1								4	1	2	4	6	8	6					31
24.0 ~ 23.6										2	1	6	6	4	1				20
23.5 ~ 23.1										1	2	4	6	5	2	1	1		22
23.0 ~ 22.6												2	1	6	5	1			15
22.5 ~ 22.1										1		1			3	1			6
22.0 ~ 21.6													3	3	8	6			20
21.5 ~ 21.1														2	3	1			6
21.0 ~ 20.6																1	2	1	4
20.5 ~ 20.1															1	1		1	3
Total	1	0	4	2	7	10	6	12	17	17	22	38	36	28	23	12	3	0	2	240

Figure used in the table shows the number of combinations. $r = +0.8935^{***}$ (d.f. = 238), significant at 0.1% level.

in the whole Sikkimese rice were 0.04 ± 0.04. In view of the male parent, the differences in the ratio for *indica* and *japonica* were as follows in the same order; 0.03, 0.01, 0.02, 0.00, 0.02, 0.04, 0.04, 0.00, 0.00, 0.00, 0.02, 0.01, 0.05 and 0.00, respectively. Average and its standard deviations in the whole Sikkimese rice were 0.02 ± 0.02. In reciprocal views, correlation coefficient between these was −0.2585, showing no significance even at 5% level.

PART II. Relation between the respective two characters

1. Area and volume of unhusked grains

Parent: Correlation coefficient of volume (abbreviated as "U·V") on area (abbreviated as "U·A") in parental plants was +0.8950 to the degree of freedom of 14, which is obviously significant at 0.1% level (Table 11). Generally speaking, the larger was U·A, the larger was U·V. Linear regression of U·A on U·V was calculated as follows; $Y = 0.710X + 0.194$, where Y and X indicate U·V and U·A, respectively. This formula indicates that U·V becomes 0.710 mm^3 larger, by becoming 1 unit larger in U·A (0 points, 24.8 mm^2 in U·A and 51.5 mm^3 in U·V, respectively).

Hybrid: Correlation coefficients of U·V on U·A in the same strain were calculated and are shown in Table 12. The whole strains showed significances at 0.1% level. In the whole combinations, correlation coefficient was +0.8935 to the degree of freedom of 238, which is significant at 0.1% level (Table 13). Generally speaking, the larger was U·A, the larger was U·V, too.

2. Area and volume of husked grains

Parent: Correlation coefficient of volume (abbreviated as "H·V") on area (abbreviated as "H·A") in parental plants was +0.8822 to the degree of freedom of 14, which is obviously significant at 0.1% level. Generally speaking, the larger was H·A, the larger was H·V. Linear regression of H·A on H·V was calculated as follows; $Y = 1.072X - 1.692$, where Y and X indicate H·V and H·A, respectively. This formula indicates that H·V becomes 1.072 mm^3 larger, by becoming 1 unit larger in H·A (0 points, 14.7 mm^2 in H·A and 25.3 mm^3 in H·V, respectively).

Hybrid: Correlation coefficients of H·V on H·A in the same strain were calculated and are shown in Table 12. Fifteen strains showed significances at 0.1% level. but the remaining 1 strain showed no significance even at 5% level. In the whole combinations, correlation coefficient was +0.8036 to the degree of freedom of 238, which is significant at 0.1% level. Generally speaking, the larger was H·A, the larger was H·V, too.

3. Areas of unhusked and husked grains

Parent: Correlation coefficient of H·A on U·A in parental plants was +0.8408 to the degree of freedom of 14, which is obviously significant at 0.1% level. Generally speaking, the larger was U·A, the larger was H·A. Linear regression of U·A on H·A was calculated as follows; $Y = 0.537X - 0.752$, where Y and X indicate H·A and U·A, respectively. This formula indicates that H·A becomes 0.537 mm^2 larger, by becoming 1 unit larger in U·A (0 points, 24.8 mm^2 in U·A and 14.7 mm^2 in H·A, respectively).

Hybrid: Correlation coefficients of H·A on U·A in the same strain were calculated and are shown in Table 12. Twelve, 3 and 1 strains showed significances at 0.1%, 1% and 5% levels, respectively. In the whole combinations, correlation coefficient was +0.7427 to the degree of freedom of 238, which is obviously significant at 0.1% level. Generally speaking, the larger was U·A, the larger was H·A, too.

Table 14. Correlation coefficient and linear regression of two characters; IV – volume of husked grain (Y, O point = 24.3 mm³) on volume of unhusked grain (X, O point = 55.0 mm³), V – quotient of volume (Y, O point = 50.5%) on quotient of area (X, O point = 60.5%)

Code No.	IV			V		
	Correlation coefficient	d.f.	Linear regression	Correlation coefficient	d.f.	Linear regression
1	0.3527	28	—	0.7503***	28	Y = 0.511X − 1.615
2	0.1034	28	—	0.9686***	28	Y = 0.716X − 1.933
3	0.5049**	28	Y = 0.437X − 3.493	0.8753***	28	Y = 0.651X − 0.901
4	0.6763***	28	Y = 0.595X − 5.263	0.8901***	28	Y = 0.600X − 0.440
5	0.4742**	28	Y = 0.474X − 3.708	0.9210***	28	Y = 0.745X − 0.866
6	0.5968***	28	Y = 0.500X − 1.974	0.9158***	28	Y = 0.588X − 1.027
7	0.4600*	28	Y = 0.499X − 1.748	0.9369***	28	Y = 0.603X − 1.132
8	0.2964	28	—	0.9285***	28	Y = 0.554X − 0.784
9	0.5845***	28	Y = 0.749X − 3.603	0.7671***	28	Y = 0.428X − 0.791
10	0.6346***	28	Y = 0.474X − 4.110	0.9017***	28	Y = 0.615X − 0.633
11	0.6943***	28	Y = 0.664X − 3.994	0.7501***	28	Y = 0.531X − 1.358
12	0.3027	28	—	0.9273***	28	Y = 0.629X − 1.102
13	0.4530*	28	Y = 0.422X − 4.507	0.9233***	28	Y = 0.677X − 1.531
14	0.6383***	28	Y = 0.408X − 3.979	0.8540***	28	Y = 0.624X − 1.447
15	0.3486	28	—	0.7225***	28	Y = 0.539X − 1.759
16	0.5991***	28	Y = 0.560X − 4.954	0.8878***	28	Y = 0.516X − 1.119
Whole	0.5240***	238	Y = 0.535X − 3.576	0.8299***	238	Y = 0.549X + 0.229

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

4. Volumes of unhusked and husked grains

Parent: Correlation coefficient of H·V on U·V in parental plants was +0.8826 to the degree of freedom of 14, which is obviously significant at 0.1% level. Generally speaking, the larger was U·V, the larger was H·V. Linear regression of U·V on H·V was calculated as follows; Y = 0.863X − 2.617, where Y and X indicate H·V and U·V, respectively. This formula indicates that H·V becomes 0.863 mm³ larger, by becoming 1 unit larger in U·V (0 points, 51.5 mm³ in U·V and 25.3 mm³ in H·V, respectively).

Hybrid: Correlation coefficients of H·V on U·V in the same strain were calculated and are shown in Table 14. Seven, 2 and 2 strains showed significances at 0.1%, 1% and 5% levels, respectively, but the remaining 5 strains showed no significance even at 5% level. In the whole combinations, correlation coefficient was +0.5240 to the degree of freedom of 238, which is significant at 0.1% level. Generally speaking, the larger was U·V, the larger was H·V, too.

5. Ratios of volume and area

Parent: Correlation coefficient of ratio of volume (abbreviated as "R·V") on ratio of area (abbreviated as "R·A") in parental plants was +0.8714 to the degree of freedom of 14, which is obviously significant at 0.1% level. Generally speaking, the larger was R·A, the larger was R·V. Linear regression of R·V on R·A was calculated as follows; Y = 0.908X − 0.493, where Y and X indicate R·V and R·A, respectively. This formula indicates that R·V becomes 0.908 larger, by becoming 1 unit larger in R·A (0 points, 0.60 in R·A and 0.51 in R·V, respectively).

Hybrid: Correlation coefficients of R·V on R·A in the same strain were calculated and are shown in Table 14. The whole strains showed significances at 0.1% level. In the whole combinations, correlation coefficient was +0.8299 to the degree of freedom of 238, which is

obviously significant at 0.1% level. Generally speaking, the larger was R·A, the larger was R·V, too.

Discussion

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

1. Length, width, thickness, ratios of length to width, of length to thickness, of width to thickness, and mutual relations were already reported in view of grain morphology[7-9]. From these data, several characteristics were noted concerning strain or variety differentiations. Moreover, in addition to these characters mentioned above, surface areas and volumes of unhusked and husked grains were applied for investigation of grain morphology in rice and some legumes[13], and some noteworthy meanings were shown. So, these characters were employed here.

2. The average values of hybrid in the parental level were sometimes larger than those of the respective parent for several characters (Tables 1 and 3). On the other hand, in view of the standard deviations, it did not necessarily follow that the values of the parental level were larger than those of the respective parent. At this point, some considerations on hybrid vigor or heterosis may as well be borne in mind. Richharia *et al.*[16] found substantial heterosis in height and tillering of F_1 hybrids of rice by comparing them with mid-parental values. Typical varietal representatives of the two distantly related variety-groups of rice in combination are expected to show considerable hybrid vigor. Superiority of F_1 hybrids was estimated on the basis of heterosis, which was illustrated by the mean increase of F_1 hybrids over the mid-parental value (MP) of parents[15], and on heterobeltiosis, which was illustrated by the mean increase of F_1 hybrids over the high parent (HP)[2,3]. The strains used in the present study may be included in this category. For example, in case of No.1 in view of area of unhusked grains, the average values in parental level were indicated to be 23.26 mm^2, 24.50 mm^2 and 24.30 mm^2 in pure line, averages for female and male parents, respectively (Tables 1 and 3). In combination level, the values were 23.26 mm^2, 23.19 mm^2, 26.57 mm^2 and 23.57 mm^2 in No.1, No.2, No.1 (♀) × No.2 (♂) and No.2 (♀) × No.1 (♂), respectively (Tables 1 and 2). These considerations were ascertained in the several characters calculated in the present experiment.

On the other hand, values of both quotients of area and volume found in parental pure lines were always nearly similar to that of averages of hybrid combinations.

3. In comparison with the data obtained in female and male parents, the following facts were ascertained. Average values of practical values in the female parent were always nearly similar to that of the male parent. Average values of standard deviations in the female parent were also nearly similar to that of the male parent. The former pattern was quite similar to that of the previous papers, but the latter one was clearly different from that of the previous papers[7,8]. These discrepancies may not be fully explained at this time.

4. From the data of reciprocal relations it was clearly ascertained that some sets of combinations were always observed to have been deranged from the standard pattern and in exceptional regions concerning several characters. These tendencies were found in several combinations among the several characters, for example, No.3 × No.6, No.5 × No.8, No.6 × No.15 and others. The combinations, having No.6 in one or both parents, were especially slipped out. In the previous papers[7,8], some segregations found in the distribu-

tion of the values in view of reciprocal comparisons. But in the present experiment, the detection of such tendency was only slight, and not remarkable. These discrepancies may be partly due to the differences of gene actions attributable to the respective characters. Moreover, these findings propose an interesting problem for strain or variety specificities.

5. It has been reported that the reciprocal hybrids were not significantly different[12]. On the other hand, remarkable differences in reciprocal hybrids were reported, and considerable cytoplasmic inheritance was held[17].

In the present experiment, it may be noticeable that 1, 1, 3, 3, 2 and 6 strains showed significances in 5, 4, 3, 2, 1 and 0 characters, respectively (Tables 4 and 8). These characters may be used for hetero- or homozygosis in each strain. In the whole combinations, significant relations were found in 3 characters, *i.e.*, area of unhusked grain, area of husked grain and volume of husked grain. Although 25 negative correlations were found in the reciprocal comparisons, no significant difference was shown through the whole combinations. So, it was concluded that the reciprocal differences suggested no considerable cytoplasmic inheritance reported in this experiment.

6. Five relations between the respective two characters were analyzed, basing on correlation coefficient. In view of parental plants, the whole cases (=5) showed significances at 0.1% level. In view of the whole combinations, the whole cases showed also significances at 0.1% level. Eleven, 4 and 1 strain showed significant correlations in 5, 4 and 3 relations between the two characters, respectively (Tables 12 and 14). It was noticeable that 3 relations, *i.e.*, the one observable between volume of unhusked grain and area of unhusked grain, between area of husked grain and area of unhusked grain, and between quotient of volume and quotient of area, showed significances through the whole strains. Correlation coefficients found in parental plants were always stronger than those of hybrid combinations.

In comparison with the practical values of unhusked and husked grains, the parental plants through the whole cases and hybrid combinations in most cases showed significances. This means that strains used here are noted to be indication of a synchrony[8] to intra-plant variance with strains. However, correlations found in area were clearly stronger than those in volume. It meant that the area was of stable character in comparison with the volume, and the former was not affected by any environmental conditions. Moreover, correlation coefficients found in unhusked grains in both parental plant and hybrid plants were clearly stronger than those of husked grains. It meant that characters found in unhusked grains were more stable than those of husked grains.

7. The differences between the maximum and the minimum values of the six characters for each parent were, in case of the male parent, somewhat larger than that in case of the female parent without exception, which was likewise in case of the previous papers[7,8]. Such phenomena were also found in the standard deviations. This tendency was especially remarkable in quotient of grain volume. In other words, variation ranges found in male parent were clearly more extensive than those of female parent. On the other hand, the differences in the respective characters, at the time when two testers crossed with Sikkimese rice, were nearly similar in both male and female parents.

In reciprocal views, correlation coefficients between the female and male parents were not significant through all characters in the former, and in 5 characters in the latter. In the latter, it was noticeable that correlation coefficient was significant at 5% level in volume of unhusked grains. In variety specificity, however, no clear tendency was commonly

ascertained through the whole characters measured.

Summary

Succeeding to the previous papers, diallel cross experiments were made, using 14 strains of Sikkimese rice varieties and one type of *indica* and another type of *japonica*. In this report, the six morphological characters, *i.e.*, surface area and volume of unhusked and husked grains, area and volume quotients of husked grains to unhusked grains, and the mutual relationships were described. The main results obtained during this study were summarized as follows:

1. The areas of unhusked grains of parental plants and F_1 hybrids were 23.94 mm^2 and 24.50 mm^2 in average, respectively. In view of the reciprocal combinations, 5 strains showed positive significances. The volumes of unhusked grains of parental plants and F_1 hybrids were 48.98 mm^3 and 51.98 mm^3 in average, respectively. In view of the reciprocal combinations, 4 strains showed positive significances. The areas of husked grains of parental plants and F_1 hybrids were 14.38 mm^2 and 14.72 mm^2 in average, respectively. In view of the reciprocal combinations, 9 strains showed positive significances. The volumes of husked grains of parental plants and F_1 hybrids were 25.32 mm^3 and 26.63 mm^3 in average, respectively. In view of the reciprocal combinations, 6 strains showed positive significances. The quotients of area of parental plants and F_1 hybrids were both 0.60 in average. In view of the reciprocal combinations, 2 strains showed positive significances. The quotients of volume of parental plants and F_1 hybrids were both 0.52 in average. In view of the reciprocal combinations, 1 strain showed positive significance.

2. The differences of the respective characters in the parental and combination levels were ascertained to get larger in accordance with the varieties of each parent. In view of reciprocal comparisons through the whole characters, it was concluded that the reciprocal differences suggested no considerable cytoplasmic influence on the six characters measured here. Substantial heteroses and heterobeltioses in several cases of F_1 hybrids compared with mid-parental and high-parental values were ascertained.

3. Five relations between the respective two characters were analyzed and showed the following results. Both in view of parental plants and the whole cross combinations, the whole cases showed positive significances at 0.1% level.

References

1) Chang, T. T.: Present knowledge of rice genetics and cytogenetics. *Intn. Rice Res. Inst. Technical Bull.*, **1**, 1–96 (1964)
2) Chang, T. T., Li, C. C. and Tagumpay, O.: Genotypic correlations, heterosis, inbreeding depression and transgressive segregation of agronomic traits in a diallel cross of rice (*Oryza sativa* L.) cultivars. *Bot. Bull. Acad. Sinica*, **14**, 83–93 (1973)
3) Fonseca, S. and Patterson, F.: Hybrid vigor in a seven-parent diallel cross in common winter wheat (*Triticum aestivum* L.). *Crop Sci.*, **8**, 85–88 (1968)
4) Katayama, T. C.: Diallel cross experiment among Sikkimese varieties, indica and japonica testers of rice, *Oryza sativa* L. I. Crossability, pollen and seed fertilities. *Mem. Fac. Agr. Kagoshima Univ.*, **10**, 1–35 (1974)
5) Katayama, T. C.: Diallel cross experiment among Sikkimese varieties, indica and japonica testers of rice, *Oryza sativa* L. II. Heading date and growing period. *Jap. Jour. Trop. Agr.*, **18**, 67–73 (1975)

6) Katayama, T. C.: Diallel cross experiment among Sikkimese varieties, indica and japonica testers of rice, *Oryza sativa* L. III. Morphological characters. *Mem. Fac. Agr. Kagoshima Univ.*, **11**, 1–55 (1975)
7) Katayama, T. C.: Diallel cross experiment among Sikkimese varieties, indica and japonica testers of rice, *Oryza sativa* L. IV. Unhusked grains. *Mem. Fac. Agr. Kagoshima Univ.*, **12**, 1–39 (1976)
8) Katayama, T. C.: Diallel cross experiment among Sikkimese varieties, indica and japonica testers of rice, *Oryza sativa* L. V. Husked grains. *Mem. Fac. Agr. Kagoshima Univ.*, **13**, 1–34 (1977)
9) Katayama, T. C.: Diallel cross experiment among Sikkimese varieties, indica and japonica testers of rice, *Oryza sativa* L. VI. Comparison of unhusked with husked grains. *Mem. Fac. Agr. Kagoshima Univ.*, **14**, 1–31 (1978)
10) Kato, S., Kosaka, H., Hara, S., Maruyama, Y. and Takiguchi, Y.: On the affinity of the cultivated varieties of rice plants, *Oryza sativa* L. *Jour. Dep. Agr. Kyushu Imp. Univ.*, **2**(9), 241–276 (1930)
11) Kihara, H. and Nakao, S.: The rice plant in Sikkim. *Seiken Zihô*, **11**, 45–54 (1960)
12) Li, C. C. and Chang, T. T.: Diallel analysis of agronomic traits in rice (*Oryza sativa* L.). *Bot. Bull. Acad. Sinica*, **11**, 61–79 (1970)
13) Maeda, K.: Floral morphology and its application to the classification of the peanut cultivars, *Arachis hypogaea* L. (in Japanese with English Summary). *Mem. Fac. Agr. Kôchi Univ.*, **23**, 1–53 (1973)
14) Matsuo, T.: Genecological studies on the cultivated rice (in Japanese with English Summary). *Bull. Nat. Inst. Agr. Sci. Ser. D.*, **3**, 1–111 (1952)
15) Matzinger, D. F., Mann, T. J. and Cockerham, C. C.: Diallel crosses in *Nicotiana tabacum*. *Crop Sci.*, **2**, 383–386 (1962)
16) Richharia, R. H. and Misro, B.: The japonica × indica hybridization project in rice: an attempt for increased rice production. *J. Bio. Sci.*, **2**(2), 35–47 (1959)
17) Sampath, S. and Mohanty, H. K.: Cytology of semisterile rice hybrids. *Curr. Sci.*, **23**, 182–183 (1954)
18) Terao, H. and Mizushima, U.: On the affinity of rice varieties cultivated in East Asia and America (in Japanese). *Bull. Agr. Exp. Sta., Ministry Agr. & Commerce (Japan)*, **55**, 1–7 (1944)
19) Ting, Y.: Origination of the rice cultivation in China. *Agr. B. Sen Yatsen Univ. Ser. III*, **7**, 1–18 (1949)
20) Tsuno, Y., Sato, T., Miyamoto, H. and Harada, N.: Studies on CO_2 uptake and CO_2 evolution in each part of crop plants. II. Photosynthetic activity in the leaf sheath and ear of rice plant (in Japanese with English Summary). *Proc. Crop Sci. Soc. Japan*, **44**, 287–292 (1975)