PHYLOGENETIC DIFFERENTIATION OF THE CULTIVATED RICE PLANT

II. Intervarietal Hybrid Sterility

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Introduction

Intervarietal hybrid sterility in the rice plant, which has been familiar with rice breeders in Formosa from the earliest time, has arisen the interest of agronomists since Kato (1) dealt with it as a basis of his Japonica-Indica classification. And it has been once believed that the sterility shows itself in the hybrid between Japonica and Indica types, but does not witnin a same type.

However, a scepticism about this conception was put forward by Terao and Mizushima (7, 8), demonstrating the intricacy of mutual relations of varieties in this hybrid sterility. While they suggested several inter-sterile variety groups, Mizushima (3, 4) pointed out lately, after observing the hybrids of several dozens of varieties of Japan, Java and America with definite analysing varieties, that the reaction type (which analysing variety and a given variety show sterility in their hybrid) varied among the varieties continuously.

On the other hand, the author pointed out in the preceding paper(5), on the ground of discontinous variation of various characters and a definite tendency in their combinations, that rice varieties were to be divided into Continental and Insular variety groups, and the Insular group further into two minor groups, named as Tropical and Temperate.

As a continuation of this foregoing work, variation of the reaction type of hybrid sterility was investigated by using definite analysing varieties, and was compared with the differentiation of variety groups. The present paper is a report of those results. The method of investigation was as a rule similar with Mr. Mizushima's method, however, a somewhat different conclusion was reached, probably owing to the difference in the materials as well as in the method of arranging observation results. Namely, the reaction types of various varieties were fo und to be classified into two main groups, I and II, corresponding respectively to Continental and Insular variety groups. In addition to these, some foundamental nature of this hybrid sterility as observed in parallel with the differentiation of reaction types will be mentioned in the present paper.

The present study was carried out in the Taiwan Provincial College of Agriculture from 1944 to 1950. The author express his hearty thanks to the college authorities for their kind support, and also to the staffs of the laboratory for their enthusiastic cooperation.

Materials and Methods

Some one hundred and twenty varieties taken out nearly randomly from diverse varieties of Eastern Asia were used as the materials. Before using in the present study, they were inbred repeatedly for two to several generations. Other detailed explanations of these varieties will be omitted here, as they are same to those used in the preceding study.

Seven varieties were picked out from them as the analysing varieties. Name and some characters of these analysing varieties are given in Table 1. They were chosen as representatives of the varieties of India, Indochina, Formosa, Celebes, Philippine, and Japan; additionally, a glutinous variety having glumes of dark color, 563, was partly for the purpose of gene analyses.

Table 1. Name, origin and some characters of analysing varieties.

No. or vara.	Name	Origin	Varielal group	Color Ap.	St.	Response to day length
*1	70a som cau	Indochina	Continental	—	—	sensible
108	Peh-ku	Formosa	〃	—	—	insensible
219	Garumbalay	Philippine	Insular (tropical)	+	—	〃
414	P. T. B. 10	India	Continental	—	—	sensible
521	Kisshin	Japan	Insular (temperate)	—	—	〃
563	Kinoshita-mochi	〃	〃	+	±	insensible
617	Padi ase banda	Celebes	〃	—	—	〃

Each of these seven varieties were pollinated with the pollen from the above mentioned 120 varieties respectively, and F_1 hybrids about 800 in total number were obtained. These F_1s, two or three plants per cross, were cultured together with maternal and paternal varieties in the paddy field.

For measuring the hybrid sterility, the percentage of normal pollen was observed by the following method: To take 5-10 florets of one day before the openning, smear the anther and stain with iodine pottasium iodide solution, and observe under the microscope more than 1,000 pollen grains.

These observations were continued from 1945 to 1950; a same material was observed repeatedly when low temperatures below 23°C or a typhoon occured during two weeks before the heading.

Table 2. Tests of the difference between lines of a same variety in the percentage of normal pollen.

Lines Maternal	Paternal	1 x 219 (i)	(ii)	219 x 108 (i)	(ii)	219 x 414 (i)	(ii)	563 x 108 (i)	(ii)	563 x 219 (i)	(ii)
I	I	75	79	70	78	61	64	23	28	89	82
I	II	79	74	66	68	59	52	34	36	88	86
II	I	70	87	52	67	50	55	43	36	84	80
II	II	88	77	61	64	51	58	38	34	71	88

I, II. No. of lines in a same variety,
(i), (ii). No. of plants in a same cross.

Crosses		1 × 219		219 × 108		219 × 414		563 × 108		563 × 219	
Source of variation	D. F.	S. S.	M. S.	S. S.	M. S.	S. S.	M. S.	S. S.	M. S.	S. S.	M. S.
Total	7	270		289		179		262		248	
Lines	3	44	14.7	165	55.0	113	37.7	215	71.7	69	23.0
Maternal	1	28	28.0	136	136.0	60	60.0	112	112.0	60	60.0
Paternal	1	6	6.0	1	1.0	12	12.0	18	18.0	1	1.0
Interaction	1	10	10.0	28	28.0	41	41.0	85	85.0	8	8.0
Remainder	4	226	56.5	124	31.0	66	15.5	247	61.7	179	44.8

Remarks : D. F.:Degree of freedom, S. S.: Sum of squares,
M. S.: Mean square.

Analysis of variance as the whole.

Variation due to	D. F.	S. S.	M. S.	F (remarks)
Among crosses	4	12434	3109	87.2 (beyond 1%level)
Within crosses	35	1248	35.7	
Total	39	13682		

In 1949, seeds of several analysing varieties produced in different years were examined as to whether different seeds (or lines) of a same variety would give an identical reaction or not. And it was recognized, as seen in Table 2, that the varieties were pure enough to be free from significant differences between different lines of a same variety. In other few varieties, however, different results were found between crosses of a same parental combination, probably owing to the impurity of materials. Nevertheless, this seemed not to be so fatal as to disturb the interpretation of observation results.

Observation Results

(1) A general aspect of the hybid sterility.

Hybrid plants were generally vigorous in growth, and showed no deterioration in the sexual organs. And it was confirmed that the behavior of chromosomes was completely regular in the meiosis of a sterile hybrid. However, a sterile hybrid showed diverse kinds of abortive pollen grains, and they were found to originate from the degeneration of microspores during the course of development. Some observations on the development of microspore and embryosac will be reported in another paper.

Under the microscope, pollen grains were distinguished into three classes: (A) normal pollen, showing regular diameter and starchy content, (B) anormal or underdevelopped pollen, diameter being smaller and containing insufficient starch, and (C) inert or empty pollen, irregular in shape and without any content, but having a micropyre and two layers of envelopping membran.

It was found further, by comparing the plants of a same cross in different seasons,

that the percentage of normal pollen was affected little by outer conditions, while the percentage of fertile grain fluctuated on a wider range. The correlation between normal pollen percentage and fertile grain percentage is given in Table 3. The latter was in a greater part of hybrids similar with or lower than the former. The difference between these two kinds of percentages may be mainly due to the modification of the latter, but may possibly be due to, in a few cases, the difference between normal pollen percentage and normal embryosac percentage, as pointed out by Terao and Mizushima(7).

Table 3. Correlation between normal pollen percentage and fertile grain percentage.

% of normal Pollen	% of fertile grain 95	85	75	65	55	45	35	25	15	5	Totals
95	11	29	25	12	9	7	2				95
85	3	14	14	10	14	14	6	1	3	1	80
75	2	4	8	9	17	14	9	6	3	2	74
65		5	7	7	13	16	10	9	1		68
55		1	1	2	13	14	8	10	3		52
45					1	7	7	5	7	2	29
35		1	1		1			3	10	3	19
25						2		3	3	1	9
15								1	1	2	4
5									1	2	3
Totals	16	54	56	40	68	74	42	38	32	13	433

(2) Hybrid sterility among analysing varieties and the comparison of reciprocal crosses.

The percentages of normal pollen in mutual hybrids between the above mentioned analysing varieties are given in Table 4. While the hybrids between 1 and 108, 219 and 647, and, 521 and 563 were free from sterility, other crosses all showed sterility, and their normal pollen percentages were different with the combination of varieties.

At the same time, it will be recognized in Table 4, that reciprocal crosses are essentially equal to each other in normal pollen percentage.

Table 4. Normal pollen percentages in reciprocal crosses between analysing varieties.

Crosses	% of pollen (A)	(B)	(C)	Croases	% of pollan (A)	(B)	(C)
1 x 108	97.2	1.8	1.0	108 x 1	98.1	0.4	1.5
1 x 219	70.9	12.9	16.2	219 x 1	68.5	20.7	10.8
1 x 414	55.9	13.3	30.8	414 x 1	59.1	27.7	13.2
1 x 521	78.5	18.4	3.1	521 x 1	78.0	18.9	3.1
1 x 563	57.6	40.1	2.3	563 x 1	54.2	42.8	3.0

1	x	647	86.1	9.6	4.3	647	x	1	86.2	11.6	2.2
108	x	216	71.5	13.0	15.5	219	x	108	65.0	19.0	16.0
108	x	414	76.7	0.6	22.7	414	x	108	74.8	5.3	19.9
108	x	521	26.6	63.2	10.2	521	x	108	26.5	65.4	8.9
108	x	563	29.0	58.0	13.0	563	x	108	34.0	49.0	17.0
108	x	647	83.9	10.8	5.3	647	x	108	85.8	11.6	2.6
219	x	414	60.9	7.5	31.6	414	x	219	62.7	3.3	34.0
219	x	521	73.4	20.2	6.1	521	x	219	79.5	17.2	3.3
219	x	563	72.1	26.2	1.7	563	x	219	68.9	26.8	4.3
219	x	647	98.6	0.7	0.7	647	x	219	97.5	0.7	1.8
414	x	521	44.0	21.8	34.2	521	x	414	46.0	21.1	32.9
414	x	563	67.1	27.3	5.6	563	x	414	66.7	27.7	5.6
414	x	647	71.5	1.3	27.2	647	x	414	73.4	2.0	24.6
521	x	563	88.3	9.1	2.6	563	x	521	93.9	3.1	3.0
521	x	647	77.8	19.5	2.7	647	x	521	75.0	20.5	4.5
563	x	647	86.5	12.8	0.7	647	x	563	86.1	13.8	0.1

(A): normal pollen, (B): underdevelopped pollen,

(C): inert pollen; detailed explanation in text.

(3) Variation of normal pollen percentage among various hybrids.

Table 5. Variation of the percentage of normal pollen.

Anal. Vars.	100	95	90	85	80	75	70	65	60	55	50	45	40	30	20	10	0	Totals
1	11	28	20	10	11	7	7	5	7	4	3		3	1	1			118
100	10	25	9	20	13	7	7	5	3	3	6	4	2	2				116
219	17	16	10	17	12	6	10	6	4	3	4	3	3	1		1	1	114
414	5	3	2	4	9	6	12	15	15	14	13	9	5	3				115
521	3	17	8	8	11	9	5	14	7	4	8	5	13	3	4			119
563	6	11	16	12	8	7	5	4	10	6	7	4	7	8	2	2		115
647	10	26	18	15	14	7	9	5	5	5	1	1	2					118
Totals	62	126	83	86	78	49	55	54	52	39	42	26	35	17	7	3	1	815

Variation of normal pollen percentage among the hybrids between each of the analysing varieties and respective varieties is given in Table 5. Normal pollen percentage ranged roughly speaking from 100% to 0%, and relatively high percentages were larger in number. And they seemed to be grouped into several classes, such as 100%-90%, 85%-75%, 70%-55%, 55%-40% and so on.

Variation of the percentage of inert pollen among various hybrids was, as given in Table 6, seemingly continuous, and hybrids showing high percentages of inert pollen were relatively few with the exception of the hybrids with 414.

Table 6. Variation of the percentage of inert pollen.

Anal. Vars	0	5	10	15	20	25	30	35	40	45	50	60	100	Totals
1	31	40	26	6	6	3	2		2	1		1		118
108	28	53	17	13	2	2			1					116
219	42	31	14	12	6	3	2			3			1	114
414	8	7	21	18	18	11	10	11	8	2	1			115
521	28	61	19	6	2	2		1						119
563	26	44	20	8	9	3	3				2			115
647	31	59	15	2	2	3	1	2	2			1		118
Totals	194	295	131	66	45	27	18	14	13	6	3	2	1	815

Table 7. Correlation between normal pollen percentage (A) and inert pollen percentage (C).

C \ A	100	95	90	85	80	75	70	65	60	55	50	45	40	30	20	10	0	Totals
0	62	62	21	13	10	7	8	4	2	1	2	1	1					194
5		64	47	43	35	18	13	21	17	12	12	4	5	2	2			295
10			15	22	15	12	15	10	9	8	7	5	10	2	1			131
15				8	12	5	6	8	10	3	2	2	3	5	1	1		66
20					6	5	5	3	4	3	5	3	7	2	1	1		45
25						2	7	2	3	3	2	1	3	2	1	1		27
30							1	3	2	3	4	1	2	2				18
35								3	3	1	1	6						14
40									2	5	4	1	1					13
45											2		2	2				6
50											1	2						3
60													1		1			2
100																	1	1
Totals	62	126	83	86	78	49	55	54	52	39	42	26	35	17	7	3	1	815

Between normal pollen percentage and inert pollen percentage such a correlation as shown in Table 7 was found: The proportion of inert pollen (C) to under-developped pollen (B) was found to be different with the cross, even though normal pollen percentage being the same. Therefore, how to express the abnormality of pollen may be a problem. In the present study, the hybrids of more than 87.5% in normal pollen percentage were regarded conveniently as free from sterility, and those of less than 87.5% were divided into several classes in accordance with the relation of normal pollen percentage and inert pollen percentage. (vide Table 11)

Certain crosses between the analysing varieties, 1×108, 219×647, and 521×563, did

not show hybrid sterility as mentioned above. Whereas, there was found a number of such varieties as showing sterility in the hybrid with one of these analysing varieties, but not with the other. In other words, among three varieties, A, B, and C, A×B and B×C are free from sterility, while B×C is sterile. Having taken out such cases from the whole of the crosses observed in the present work, numerous cases as listed in Table 8 were found. In these cases, the percentage of normal pollen in A×C varied roughly speaking from 85% to 45%, and percentages round 70% were large in number. This phenomenon is found also in the results of Terao and Mizushima (7), and seems to be a characteristic of the intervarietal hybrid sterility in rice plant.

Table 8. List of varieties as giving fertile hybrid with one and sterile hybrid with the other of two analysing varieties which are fertile with each other (A×B and B×C are fertile, but A×C is sterile).

No.	Variety A	Variety B	Variety C (Nos. of varieties)	Num. of vars.
(1)	1	108	315, 325, 419, 440, 644, 716, and 721	7
(2)	108	1	109, 111, 221, 244, 417, 504, 546. 624. 655, 703, 706 710, 715, 734; 739, 757, 833, 871, and 1098	19
(3)	219	647	2, 51, 104, 115, 427, 445, 451, 538, 552, 566, 571, 701, 719, and 1091	14
(4)	647	219	220, 318, 321, 546, 708, 766, and 777	7
(5)	521	563	25, 33, 104, 115, 143, 259, 272, 325, 451, 501, 538, 644, 707, 712, 736, and 868	16
(6)	563	521	244, 319, 336, 655, and 757	5

(4) Differentiation of the reaction type of hybrid sterility among the varietieties of Eastern Asia.

The reaction type of hybrid sterility of a given variety will be represented to some extent by whether the variety would show sterility or not in the hybrids with definite analysing varieties respectively. Thus, denoting a hybrid of more than 87.5% in normal pollen percentage by a plus sign, and less than 87.5% by a minus sign, the reaction type of the variety will be represented by a combination of seven plus or minus signs. By using this method, to distinguish different reaction types $2^7=128$ in total number will be possible.

Having investigated the frequency of each of possible reaction types found actually among the used varieties, thirty-one kinds as given in Table 9 were found out.

Table 9. List of the reaction types found among the used varieties.

No.	1	108	219	414	521	563	647	Num. of vars.	No.	1	108	219	414	521	563	647	Num. of vars.
1	+	+	−	+	−	+	+	1	17	−	+	+	−	−	+	+	2
2	+	+	−	+	−	−	+	2	18	+	−	+	−	+	−	+	3
3	+	+	−	+	−	−	−	4	19	−	−	+	−	−	+	+	4
4	+	−	−	+	−	−	−	1	20	+	−	+	−	−	−	+	3
5	−	−	−	+	−	−	−	1	21	−	−	+	−	−	−	+	12
6	+	+	+	−	−	+	+	1	22	−	−	+	−	−	−	−	5
7	+	+	−	−	−	+	+	2	23	+	−	+	−	+	+	−	1
8	+	+	+	−	−	−	+	3	24	−	−	−	−	+	+	+	4
9	+	+	−	−	−	−	+	4	25	−	−	+	−	+	+	−	1
10	+	+	−	−	−	+	−	4	26	+	−	−	−	+	+	−	1
11	+	+	−	−	−	−	−	20	27	−	−	−	−	+	+	−	5
12	+	−	−	−	−	−	−	7	28	−	−	−	−	−	+	+	1
13	−	+	−	−	−	−	−	4	29	−	−	−	−	−	+	−	1
14	−	+	+	−	+	+	+	1	30	−	−	−	−	+	−	−	2
15	+	−	+	−	+	+	+	3	31	−	−	−	−	−	−	−	7
16	−	−	+	−	+	+	+	6									

These reaction types were placed in order in conformity with the number and position of plus or minus signs, and any two reaction types same to each other excepting one sign were connected by drawing a line. In other words, these reaction types were arranged in the order of their mutual similarity. And the result as given in Table 10 was obtained.

It will be seen in Table 10 that the reaction types of the used varieties are to be classified into two main groups, I and II, and each group is divided again, though a little less clearly, into two minor groups, a and b. However, a part of them in group II, as seemingly belonging to both of IIa and IIb, was grouped to be IIab. And a few varieties gave sterile hybrids with every analysing varieties, resulting a reaction type as consisting of seven minus signs. They could not be connected with any of the groups, and remained as "indistinct group".

The characteristics of these reaction type groups as shown by the pollen sterility in hybrids with respective analysing varietes are summarized in Table 11. Varieties belonging to group Ia all gave fertile hybrids with 414, and showed different percentages of normal pollen with other analysing vareties, expressing relatively high percentages of inert pollen. A greater part of varieties belonging to Ib group gave fertile hybrids with 1 and 108, and showed high percentages of inert pollen with 414. IIab produced fertile hybrids with 219, 521, 563, and 647. IIa were consisted of such varieties as producing fertile hybrids with 219 and 647, and IIb with 521 and 563.

Table 10. Reaction types of hybrid sterility arranged in comformity with their mutual similarity

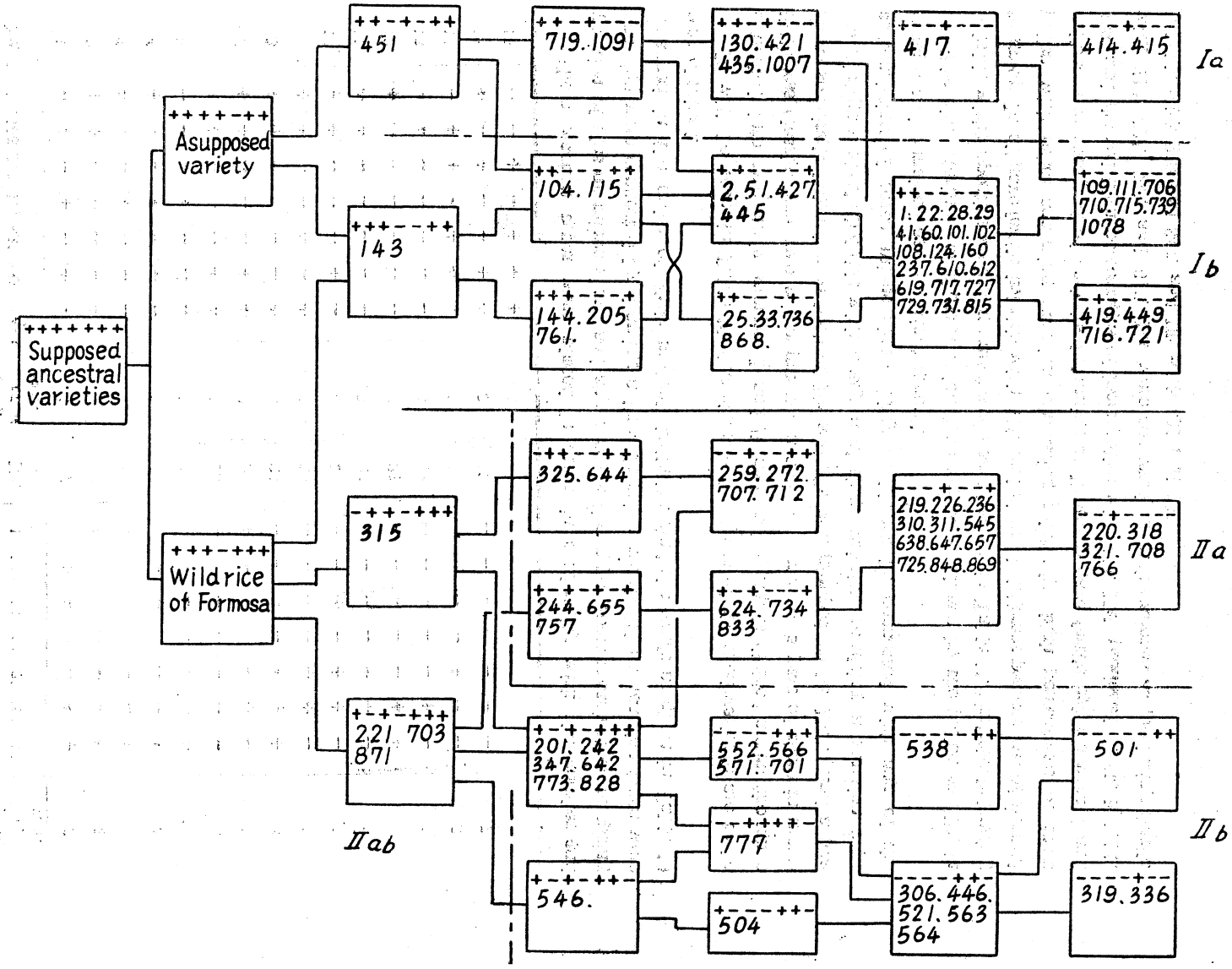


Table 11. Characteristics of pollen sterility of the reaction type groups.

Group Ia

	I	II	III	IV	V	VI
1	8			2		
108	7			3		
219		4	1	3	1	1
414	10					
521			6		4	
563	1	1	2	1	5	
647	3	3		4		

Group Ib

	I	II	III	IV	V	VI
1	41		1	3		
103	37	2	3	2	1	
218	4	9	7	18	7	
414		3	2	33	1	6
521		18	10		16	1
563	7	4	15	4	11	4
647	10	18	9	5	2	1

Group IIab

	I	II	III	IV	V	VI
1	3	2	2	1	2	
108	1	5	2	2		
219	10					
414			1	7		2
521	10					
563	10					
647	10					

Group IIa

	I	II	III	IV	V	VI
1	6	13	3	6	1	
108	2	15	7	3	1	1
219	29					
414		2	6	17		4
521	3	9	14		3	
563	6	13	7	1		2
647	24	3	2			

Group IIb

	I	II	III	IV	V	VI
1	2	3	6	4	1	
108		2	8		5	1
219	2	9	5			
414		2	5	5	2	2
521	14	1	1			
563	14	1			1	
647	5	6	5			

Remarks :

	Normal pollen (A)	Inart polleu (C)
I	Over87.5%	-
II	87.5-75.0	0-12.5
III	75.0-50.0	〃
IV	87.5-50.0	Over12.5
V	50.0- 0	0-25.0
VI	〃	Over25.0

(5) Geographical distribution of the reaction type groups and their relafion with Continental and Insular variety groups.

Geographical distribution of the above mentioned reaction type groups is given in Table 12. It will be seen in Table 12 that Group Ia is distributed over India and China Continent, Group IIb over India, Indochina, China and Formosa (native vars. of plain part), Groups IIa and IIab mainly. in Sunda Islands, Celebes, Philippine, Hai-Nan Island and Formosa (native vars. of mountain part) and Group IIb mainly in Japan. In shortwords, Group I will be found mainly in Asiatic Continent, and Group II in the islands of Western Pacific. Thus, a tendency analogous to the cases of various characters as mentioned in the preceding study is found, and an intimate relations will be inferred between the reaction types of hybrid sterility and Continental-Insular variety groups.

Table 13 gives the relation of the reaction type of hybrid sterility to the variety groups which were pointed out in the preceding study. Continental and Insular variety groups were found to be nearly equivalent to reaction type groups I and II respestively. And varieties belonging to Tropical Insular and Temperate Insular gronps were preponderant in Groups IIa and IIb respectively. It will be concluded, therefore, that the reactiontype groups of hybrid sterility are corresponding to Continental-Insnlar variety groups.

Table 12. Geographical distribution of the reaction type groups.

Districts	Reaction type groups Ia	Ib	IIa	IIab	IIb	Indistinct	Num. of varieties
Indochina		10					10
India & Siam	6	4			1	1	12
Formoss (plain part)	1	11			1		13
China Formosa (mountain part)	3	12	5	1	1	1	23
		2	3	2			7
Hai-Nan Island		1	2	1	1		5
Philippine		2	7	2		1	13
Cel,ebes		3	6	1			10
Sunda Islands			5	2	3	1	11
Japan (lowland vars.)			1		7		8
Jaqau (upland vars.)					2	3	5
Total	10	45	29	10	16	7	117

Table 13. Relation between the reaction type groups and Continental-Insular variety groups.

Variety groups	Reaction type groups Ia	Ib	IIa	IIab	IIb	Indistinct	Totals
Continental	10	42				2	54
Indistinct (Continental or Insular)		2	2	2	1	1	8
Insular (in total)			27	8	15	4	54
Tropical			20	5	5	3	33
Temperate			7	3	10	1	21
Totals	10	44	29	10	16	7	116

Discussion

Considerations on the genetical mechanism of intervarietal hybrid sterility in the rice plant will be mentioned in another paper, but some evidences on it will be in our hands now. It has been pointed out by Terao and Mizushima (7) and also by the author that the behavior of chromosomes is regular in the meiosis of a sterile hybrid. Therefore, the assortment of chromosomes must be numerically normal. Further, as no significant difference is found between reciprocal crosses, cytoplasmic differences seem to have no bearing on this hybrid sterility. And sterile gametes are produced in a proportion definite with the cross. It may be inferrable, therefore, that the gametes possessing a definite gene combination are degenerated. If it were necessary for the development of a gamete to possess at least one dominant allelomorph of duplicate factors X_1 and X_2, varietal cross $X_1x_2 \times x_1X_2$ would produce x_1x_2 gamete to be degenerated. Different percentages of normal pollen will be explainable by the duplicaton of such a

genetical mechanism. This assumption goes well in explaining the cases as among three varietics A, B, and C, A × B and B × C are fertile, while A × C is sterile. According to these thinkings, even if two given varieties did not show sterility in their mutual hybrid, they may not necessary be identical in the combination of gamete development factors. Nevertheless, the higher the sterility is, the larger will be the genic difference between the two parental varieties as a whole.

Table 10 was obtained, as mentioned in the observation results, by arranging various reaction types in conformity with their mutual similarity. In this table, generally speaking, gene combinations alike one another are placed on a same line, and with more dominant genes being on the lefter side. It will be inferred, therefore, assuming genic changes to go from dominant to recessive, and thus the ancestral varieties to have been dominant for a larger part of factors, that the varieties locating on the lefter hand in Table 10 will be nearer some unknown ancestral varieties from which the present ones have originated. And thus, the classification of reaction type groups in this table will be regarded as a sketch of the pattern of phylogenetic differentiaton of rice varieties.

It was known that various reaction types were to be divided into two main groups and each group again into two minor groups, and the groups were corresponding respectively to Continental, Tropical Insular, and Temperate Insular variety groups which had been established in the preceding study after some variation studies on diverse characters. Therefore, intervarietal hybrid sterility seems to be available as a basis of the classification of Continental and Insular variety groups, and also as an agent to point the direction of varietal differentiation.

Mizushima pointed out recently, after examining the reaction types of various varieties of Japan, Java and America, that the varieties varied continuously from those showing normal fertility with a larger part of analysing varieties to those showing normal fertility only with one or two analysing varieties of Japan or India. The results of the present study seems to be somewhat different from this, however, a conclusion similar with his will be obtained also by arranging the present data by his method.

Further, Table 10 will lead us to some imagination on the nature of wild rice varieties ancestral to the present ones. Such wild varieties, possibly having dominant allelomorphs for a larger part of gamete development factors, may produce fertile hybrids with every varieties as the supposed one shown at the leftest side of Table 10. It will be an interesting fact in this connection that the wild rice of Formosa has given fertile hybrids with all of the analysing varieties except 414, although this may be partly due to the heterozygous nature of the wild rice. (As when normal pollen percentage was different among the hybrid plants with the wild rice, the highest one was taken to be the representive of that cross.) This wild rice is seemingly only a relic form inhabiting in several narrowly limited area which are scattered along a stream. Nevertheless, noteworthy variatiors of characters are found within the colonies. Although such a variation may be partly due to natural hybridization with cultivated varieties,

the richness of variation may probably be an important characteristic of the wild rice in itself. For the purpose of researching the ancestor of rice plant, it seems necessary to advance genetical studies on the populations of the wild rice.

Summary

1. From 120 rice varieties of various districts of Eastern Asia, seven varieties were taken out as the analysing varieties, and were crossed with each of the 120 varieties, and thus each variety was examined as to which analysing varieties would present sterility in the hybrid with the variety, or as to the reaction type.

2. The percentage of normal pollen, by which the degree of sterility was represented, was found to be different with the combination of parental varieties ; and there was no difference between reciprocal crosses.

3. There was found a number of such cases as among three varieties, A, B, and C, A x B and B x C were not sterile, while A x C was sterile.

4. When normal pollen percentage was more than 87.5%, the cross was regarded as free from sterility, and was denoted by one plus sign. Thus, the reaction type of a variety was represented by seven signs (+ or -), where each sign stood for whether the variety was fertile or sterile in the hybrid with each of the seven analysing varieties.

5. Among 128 ($=2^7$) kinds of possible reaction types, only 31 kinds were found actually among the used varieties. These reaction types were arranged in conformity to the number and kinds of analysing varieties showing sterility, i. e. in conformity to their mutual similarity. And it was pointed out that they were to be classified into two groups, I and II, and each group seemed to be divided again into two minor groups, a and b.

6. Group I was found to be equivalent to "Continental" variety group, which had been established in the preceding study. Group IIa and IIb seemed also to be corresponding to "Tropical Insular" and "Temperate Insular" variety groups respectively.

7. It was pointed out, after some speculations on the genetical mechanism of intervarietal hybrid sterility that the classification of reaction types by their mutual similarity as the above mentioned one would serve as a sketch of phylogenetic differentiation of rice varieties.

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Appendix.

Variety no.	Original districts.
1 — 60	Indochina
110—160	Formosa (plain part)
201—272	Philippine
306—347	Sunda Islands
414—451	India & Siam
501—571	Japan
610—657	Celebes
701—739	China Continent
1001—1098	China Continent
828—871	Formosa (mountain part)