PHYLOGENETIC DIFFERENTIATION OF THE CULTIVATED RICE PLANT

I. Varietal variations of various characters.

By

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Introduction

The rice plant, distributing from tropical to temperate regions, has been once believed to be composed of two subspecies, Indica and Japonica (9) (or Shen and Kêng in China), and comparative studies of varieties have been carried out on the ground of this classification. Terao and Mizushima (38, 39) pointed out, however, that the interrelation of varieties in hybrid sterility was too complicated to establish these two subspecies, while three or several variety-groups were detectable indistinctly. On the other hand, Matsuo (18) stated, after observing geographical variation of various characters, that the varieties of rice plant were to be divided into three types, A, B, and C. The present problem, how to classify the rice plant, seems to be of some interest for every-body who are concerned with the breeding of the rice plant; this may be due to the respect that an understanding of the genetical construction of rice plant through the study of the present problem is of essential importance for laying a foundation of the breeding.

In order to throw a light on this problem, the authors have dealt with varietal variations of various morphological, physiological, and ecological characters, intervarietal hybrid sterility, intervarietal genic differences, and other respects in a series of studies. Among these works, some observations on the variation of several characters among the varieties of various districts of Eastern Asia will be repoted in the present paper.

Variations of diverse kinds of characters are found among the varieties of rice plant. When numerous varieties were observed with regard to various characters, how to arrange the results of observation would be in itself a subject for consideration. And this may be considered according to a general conception of evolution as follows: A number of genic changes being existent in a species of living thing, an enormous number of gene combinations among them would be possible. A part of them may be inviable and may not be realized, but the rest, adaptable to some extent, will still give rise to an astronomical figure in number. Therefore, in the field of possible gene combinations only a part will be realized to form existent varieties. (If all were existed, cross breeding would lose its reason.) Whereas, if the gene combinations occupied by existent varieties were of such a nature as picked out randomly from the

field of possible combinations and had no relation inter se, no phylogenetical differentiation would be traceable in that population of varieties. In such a case, regarding to phenotypes, varietal variations of the characters as influenced by a number of genes all would be of continuous shape, and various character combinations all would be existent in essentially equal frequencies.

However, the above mentioned situation may not be the usual case. Several intra-similar and inter-dissimilar groups may be formed within a species on account of the development of mutually isolated populations and other factors exerting influence on them, and thus definite kinds of gene combinations may be raised in frequency. In the phenotype, there might be expected such phenomena as discontinuous intervarietal variations in characters as influenced by a number of genes and a definite tendency in character combinations.

Though the genic changes underlying among various varieties may be too difficult to analyse thoroughly, it will be conceivable, according to the above mentioned considerations, that observations of various characters with reference to the discontinuity of varietal variation and the tendency of character combination will lead to a speculation of phylogenetical differentiation in the genotype.

The results of observations in the present study were arranged along the above mentioned line; and came to such a conclusion that the varieties of rice plant are differentiated in the direction of two variety-groups. The two variety-groups were named "Continental" and "Insular" with a view to express their geographical distribution. Insular variety-group seemed to be divided further into two minor groups which were named as "Tropical" and "Temperate".

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Materials

Varieties of the rice plant about eight hundred in total number were collected from 1941 to 1943 from various districts of Eastern Asia, i. e. Formosa, Indochina, Siam, India, Chinese Continent, Hai-Nan Island, Philippine, Celebes, Indonesia (Sunda Islands), and Japan. A greater part of Formosan varieties and some part of Japanese ones were spared by the Agricultural Research Institute of the Government of Formosa, the other part of Japanese varieties were spared by the Ohara Institute for Agricultural Research (Kurashiki, Japan), and Indian varieties were spared either by Plant Breeding Institute of the former Taihoku Imperial University or by the Coimbatore Agricultural Experimental Station, India. Varieties of other districts were collected at different opportunities

from agricultural institutions or farmers of respective districts. For the convenience of designating each of these varieties, they were numbered, and the numbers were used instead of the local names.

These varieties were inbred repeatedly in an experimental garden on a certain system which was essentially equal to pedigree selection, but was aimed only to gain pure lines and without a definite direction of selection. Some one hundred and twenty varieties were selected nearly randomly from the whole varieties and determined as "representative varieties". A major part of the preserved varieties or these "representative varieties" were used for the observation of various characters.

There were prepared, as the materials of observation, fully enriched seeds selected from those harvested at proper stages and stored in a desiccator with calsium chloride. The method of observation of each character will be described in the paragraphs of observation results.

It was generally attended to avoid any pre-conception such as Indica and Japonica types.

Observation Results

(1) Phenol Reaction

Varietal difference in phenol reaction of the glumes of rice seed was pointed out first by Kondo and Kasahara (14) and Kuwatuska (16). Since then, it has been believed that so-called Indica type shows a positive reaction while Japonica type does not (36). The authors observed the phenol reaction of almost all of the preserved varieties by the following method: to soak ten seeds of each variety in 1.5% phenol solution for two to three hours, then dry them gradually over a night, and observe the coloration being whether positive (plus) or negative (minus) and, if positive, the depth of color. (By this method, a same sample always showed a same reaction; changing the concentration of phenol solution or the time of soaking, the depth of color in positively reacting varieties changed, but the change between positive and negative was never seen.)

Table 1. Varietal variation of phenol reaction.

Districts	Reaction +				Reaction −	Total num. of vars.
	Deep brown	Sepia	Light brown	in total		
Indochina	21	31	7	59	8	67
India & Siam	23	25	13	61	6	67
Formosa (plain part)	29	24	7	60	2 *	62
South China	1	23	11	35	8	43
West China	2	17	2	21	3	24
Central China	3	18	3	24	24	48
North China	—	1	1	2	7	9
Formosa (mountain part)	—	9	11	20	41	61

Hai-Nan Island	—	7	7	14	18	32
Philippine	24	15	7	46	24	70
Celebes	13	17	5	35	40	75
Sunda Islands	6	14	6	26	43	69
Japan (lowland vars.)	—	—	—	—	36	36
Japan (upland vars.)	1	14	—	15	7	22
Total	123	215	80	418	267	635

* Horai varieties

The frequency of varieties showing positive and negative reactions among the varieties of various districts is given in Table 1. Varieties showing positive reaction were predominant in Indochina, India, Southern China and Formosa (native varieties of plain part); while, varieties showing negative reaction were in Sunda Islands, Celebes, Philippine, Hai-Nan Island, Mountain part of Formosa and Northern China, and lowland varieties of Japan all were of negative reaction. It may be said in short words that the varieties showing positive and negative reactions distribute mainly over the continent of Eastern Asia and the islands of western Pacific respectively.

As regards the inheritance of phenol reaction, Morinaga et al (21) have demonstrated that the positive reaction is a single dominant over the negative reaction. Having examined its genetical behavior with a relatively large number of hybrids, the authors also came to the same conclusion without any exception, and recognized further that the segregation ratio was affected little by intervarietal hybrid sterility. Some example of the segregation is given in Table 2, but the details will be reported in another paper.

Table 2. Examples of segregation ratio of phenol reaction in F_2s.

Crosses	Obs. +	Num. −	Exp. +	Num. −	X^2	% of normal pollen (F_1)
1 × 325	127	38	123.75	41.25	0.330	85
1 × 521	101	28	96.75	32.25	0.743	58
1 × 703	127	42	126.75	42.25	0.002	89
108 × 325	136	42	133.5	44.5	0.187	95
108 × 703	110	38	111.0	37.0	0.036	62
108 × 647	98	32	97.5	32.5	0.010	87
219 × 108	80	29	81.75	27.25	0.112	65
414 × 219	188	63	188.25	62.75	0.013	63
414 × 325	167	59	169.5	56.5	0.147	66
521 × 1	93	30	92.25	30.75	0.024	58

As regards the physiological cause of phenol reaction, no more has been known than a speculation of some enzyme taking part in the reaction (11); at any rate, it seems difficult to assume that this character has some important rôle physiologically

or ecologically. It was found, however, that the varieties showing positive and negative reactions were different in various characters. This would be, as discussed later, due to the preponderance of definite character combinations among the varieties. For the sake of expressing this tendency, the relation of phenol reaction to the variation of each character was observed as given below.

(2) The degree of destruction of endosperm by caustic potash

Kondo and Kasahara (12,13) pointed out that the degree of destruction of rice endosperm in ca. 2% solution of caustic potash (KOH) was proportional to the quantity of the drug absorbed, and heavily destructed rice was generally viscous and nice in taste. In the present study, a larger part of the preserved varieties were observed on this character by the following method: Ten grains were cut transversally at the middle part and were soaked in 1.8% or 2.1% solution of KOH for twenty-four hours at the room temperature, 27°-30°C. The degrees of destruction were graded as the following seven classes on which index-numbers, 0-6, were set respectively: (0) unchanged, (1) cut surface being swelled, (2) cut surface being destructed and the whole endosperm being swelled, (3) endosperm being destructed to show irregular shape, (4) destructed as if a piece of cotton, (5) dissolved and semi-transparent, and (6) nearly transparent. The degree of destruction of a variety was given by the average of the index-numbers on ten grains.

Variation of the degree of destruction among the varieties of various districts is given in Table 3. The variation seemed to be continuous; the varieties positive in phenol reaction were slight in the degree of destruction generally, while those of negative reaction varied on a wide range. The geographical variation was somewhat similar in the tendency to that of phenol reaction; the varieties as destructed heavily by caustic potash were found mostly in the temperate regions, such as Japan and Northern China, and partially in Celebes, Sunda Islands and other district.

Table 3. Variatal variation of the degree of destruction of endosperm in alkali-test.

Districts	Degree of destruction ※							Total num. of vars.
	0	1	2	3	4	5	6	
Indochina	—	15	37	15	2	1	—	70
India & Siam	—	27	18	6	—	1	—	54
Formosa (plain part)	—	35	8	6 *	—	2 *	—	51
South China	—	27	9	2	3	—	—	43
West China	—	5	18	1	—	—	—	24
Central China	—	15	16	4	7	5	—	47
North China	—	3	—	1	5	1	—	10
Formosa (mountain part)	1	10	2	28	9	3	—	53
Hai-Nan Island	—	6	8	8	4	—	—	26
Philippine	—	51	13	6	1	2	—	73
Celebes	—	22	29	6	4	10	2	73

Sunda Islands	—	30	13	5	4	—	—	57
Japan (lowland vars.)	—	—	—	10	17	9	—	36
Japan (upland vars.)	—	—	1	2	13	6	—	22
Vars. of phenol reaction +	—	198	128	43	17	8	—	394
Vars. of phenol reaction −	1	52	49	57	52	33	2	245
Total	1	250	177	100	69	40	2	639

* Horai Varieties

※ Explanation in text

The genetical behavior of this character is unknown, whereas it was found, in the second and third generations of the hybrids between the varieties showing slight destuction and those showing heavy destruction, that a major part of the segregates was intermediate in the degree of destruction. Considering from this point, this character is likely to be affected by a number of genes.

(3) Pottasium chlorate resistance

The resistance of plants to pottasium chlorate ($KC10_3$) is different with species or variety. Yamasaki (42,43), having studied its variation among Japanese rice varieties, demonstrated such a relation that the varieties resistant to $KC10_3$ tended to be resistant to drought. The present study pointed out, however, as given below, that the varieties resistant to $KC10_3$ (corresponding seemingly to so-called Japonica type) were not resistant to the lack of available water in soil.

Table 4. (a) Relation between the concentration of $KClO_3$ and the degree of injury.

Days after treatment / Conc. in %	60 (R. T. S. 23)			421 (P. T. B. 8)			504 (Taichung no. 65)			563 (Kinoshita mochi)		
	3	5	7	3	5	7	3	5	7	3	5	7
0.0125	0	0.5	0.6	0	0	0.1	—	—	—	—	—	—
0.025	0.4	0.8	0.9	0.2	0.6	0.7	—	—	—	—	—	—
0.05	0.4	1.0	1.7	0.2	0.5	0.8	—	—	—	—	—	—
0.1	0.5	1.2	1.8	0.6	1.0	1.4	0	0.3	0.6	—	—	—
0.2	1.0	1.8	2.1	0.7	1.1	1.5	0.1	0.5	0.6	—	—	—
0.5	—	—	—	—	—	—	0.1	0.4	0.7	0	0.3	0.3
1.0	—	—	—	—	—	—	0.5	0.7	0.8	0.2	0.6	0.7
2.0	—	—	—	—	—	—	0.6	0.7	0.8	0.1	0.6	0.6
4.0	—	—	—	—	—	—	1.7	2.4	2.6	0.9	1.7	2.0

(b) Relation between the number of days from water soaking of seeds to the treatment and the degree of injury.

Days	60 0.05 %	421 0.2 %	504 1 %	563 4 %
1	0	0	0	0
2	0.7	0	0.2	0
3	1.7	1.8	0.7	1.0
4	1.7	1.3	0.8	1.6
5	1.7	1.9	0.8	1.7
6	1.9	1.4	0.5	1.2
7	1.6	1.5	0.9	1.7

Index-numbers of the degree of injury:

0 ·· without visible injury,

1 ·· growth being delayed and contaminated partially,

2 ·· growth being inhibited and contaminated wholly,

3 ·· killed and rotted.

(c) Relation between the length of treatment and the degree of injury.

Hours	60 0.1%	421 0.1%	504 2.0%	563 2.0%
1	0.1	0	0.3	0
4	1.3	0	0.4	0.2
7	2.0	0.5	—	0.1
24	2.5	1.1	0.8	0.4
48	2.5	2.7	—	0.5
72	—	—	2.5	—

Varieties:

60 ·· R. T. S. 23 (Indochina)　　421 ·· P. T. B. 8 (India)

504 ·· Taichung no. 65 (Formosa)　　563 ·· Kinoshita-mochi (Japan)

A larger part of the preserved varieties were observed on this character. At first, with a view to find out a proper method of observation, several preliminary experiments were carried out with reference to the expression of resistance in seedlings. And it was found that (1) the injury of pottasium chlorate such as the inhibition of growth and contamination appeared gradually after the treatment with the lapse of time, (2) a definite degree of injury inherent to variety showed itself when the seedlings were treated on the fourth or later days after the water soaking of seed, for every varieties being resistant at the early stage of germination, and (3) the degree of injury advanced with the multiplication of the concentration as well as the prolongation of the treatment (vide Table 4). On the ground of these results, the method for observing many varieties was fixed as follows: Seeds were germinated for four days at 30°C, and the seedlings possessing coleoptiles of 0.5-1cm in length were selected. They were divided into four parts of ten plants in each, then soaked respectively in 0.05%, 0.2%, 1%, or 4% solution of $KClO_3$ for twenty-four hours, and after washed with water, they were kept again in petri-dishes for seven days at 30°C. The degree of injury was observed on the third, fifth, and seventh days after the treatment, and graded as the following four classes: (0) no visible injury, (1) partially or slightly contaminated and the growth being delayed, (2) contaminated wholly and the growth being inhibited, aud (3) killed and rotted. The degree of injury of a lot was shown by the average of index-numbers of the ten seedlings tested. Further, assuming the degree of injury to be proportional to the logarithm of concentration within a certain limit, the resistance of a variety was represenetd by the logarithm of concentration of pottasium chlorate solution necessary for giving rise to a definite degree of injury, 1.5 in the index-number given above.

Table 5. Varietal variation of pottasium chlorate resistance.

Districts	Conc. of $KClO_3$ for 1.5 degree of injury in logarithm								Total num. of vars.
	—3.67	—3.33	—3.00	—2.67	—2.33	—2.00	—1.67	—1.33	
Indochina	3	17	10	3	1	1	—	1	36
India & Siam	2	9	5	6	4	3	2	—	31
Formosa (plain part)	7	30	3	2	—	1*	—	—	43
South China	4	12	6	2	—	6	2	3	35
West China	1	12	2	—	2	—	1	3	21
Central China	—	12	6	7	2	4	2	14	47
North China	—	1	—	—	1	—	—	5	7
Formosa (mountain part)	—	1	3	2	2	—	5	2	15
Hai-Nan Island	—	1	—	—	1	1	13	5	21
Philippine	—	7	5	6	7	2	10	6	43
Celebes	—	3	6	4	3	5	10	3	34
Sunda Islands	—	6	2	—	—	1	13	15	37
Japan (lowland vars)	—	—	—	—	—	1	4	17	22
Japan (upland vars.)	—	—	—	—	—	—	8	6	14
Vars. of phenol +	11	102	39	29	18	20	12	8	239
reaction —	1	6	7	4	4	7	56	70	155
Totals	12	108	46	33	22	27	68	78	394

* Horai varieties

Variation of pottasium chlorate resistance among the varieties of various districts is given in Table 5. It will be seen in Table 5 that the varieties are to be divided into two groups, resistant and non-resistant, as intermediate varieties being relatively few. Thus, varietal variation of this character seemed to be of discontinuous nature. The varieties positive in phenol reaction were mostly resistant to pottasium chlorate, and vise versa. Accordingly, geographical variation of this character was similar in the tendency to that of phenol reaction; resistant varieties were predominant in the continent of Eastern Asia, while non-resistant ones were in the island of western Pacific.

Table 6. Segregation of the degree of injury caused by $KClO_3$ (0.2%) among F_3 strains.

Crosses	Degree of injury					Total num. of strains
	0	0.5	1.0	1.5	2.0	
108 × 504	44	287	302	142	21	796
108 × 564	36	79	64	16	2	197

The degree of injury in parental varieties:
108 (Feh-ku)··2.5 504 (Taichung 65)··1.2 564 (Nakamura)··0.2

Though it may be difficult to work out the genetical behavior of pottasium chlorate

resistance, this character seems to be influenced by a number of genetical factors, as in F_2 hybrids between resistant and non-resistant varieties, most plants have been intermediate or relatively resistant. Table 6 gives examples of such a segregation.

(4) Low temperature resistance

Varietal variation of low temperature resistance has been dealt with by some workers in connection with drought resistance (1, 23, 40). Besides, it is well known in Formosa that Horai or Japanese varieties are more resistant than the native ones. In the present study, low temperature resistance of the varieties of various districts were observed by means of the treatment of seedlings in a refrigerator. It was found as a result of some preliminary experiment that (1) the injury of low temperature such as the delay of growth and contamination appeared after the treament gradually with the lapse of time, (2) the treatment beginning on the third or later days after the water soaking of seed (at. 30°C) showed varietal difference in the degree of injury, and (3) the length of time of treatment little affected the degree of injury (vide Table 7).

Table 7. Relation of the number of days from water soaking of seeds to low temperature treatment (1) and the length of treatment (2) to the degree of injury.

Length(2) / Days from soak (1) \ of treat.	1 day				2 days				4 days				6 days			
	28	101	563	638	28	101	563	638	28	101	563	638	28	101	563	638
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0.5	0.5	0	0	1.0	1.0	0	0
3	0.3	0.5	0	0	0.5	1.0	0	0	1.0	1.0	0	0	1.0	1.0	0	0
4	0	1.0	0	0	1.0	1.0	0	0	1.0	1.0	0.5	0.5	1.0	1.0	0.5	0.5
5	0	0	0	0	0.5	1.0	0.5	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

The degree of injury:
0··no visible injury
0.5··growth being delayed and contaminated
1.0··killed and rotted

Varieties:
28··241 l'n chim (Indochina)
101··u-kuh-tsing-you (Formosa)
563··Kinoshita-mochi (Japan)
638··poenoet hitam (Sunda Islands)

Thus, for the observation of each variety, seeds were germinated at 30°C for three or four days, and twenty seedlings possessing coleoptiles of about 1 cm in length were put in a petri-dish, and were kept in a low temperature thermostat regulated at ca. 1°C (never freeze) for one, three or five days. To avoid ununiformity of temperature, petri-dishes were rearranged at least once a day. The degree of injury was observed on the third aud fifth days after the treatment, and was graded as the three classes, (0) no visible injury, (0.5) the growth being delayed and contaminated, and (1) killed and rotted. The degree of injury of a lot was shown by the average of index-numbers of the twenty seedlings. As the treatment of one, three and five days all showed similar results, the low temperature resistance of a variety was represented by the average of the results of these three kinds of treatments.

Variation of low temperature resistance among the varieties of various districts is

given in Table 8. The varieties seemed to be divided into two groups, resistant and non-resistant, as intermediate varieties being relatively few. The varieties negative in phenol reaction tended to be more resistant than the positive varieties. Then, the geographical variation of this character was similar in the tendency to the cases of phenol reaction and pottasium chlorate resistance; resistant varieties were predominant in Eastern Asiatic continent, while non-resistant ones were in the islands of western Pacific. Though the varieties of higher latitudal regions seemed in general to be slightly more resistant against low temperature than those of lower latitudal regions, it would be an interesting fact that highly resistant varieties were not few in tropical regions.

Table 8. Varietal variation of low temperature resistance (the degree of injury by low temperature treatment).

Districts	Degree of injury					Total num. of vars.
	0	0.2	0.4	0.6	0.8	
Indochina	—	1	2	6	5	14
India & Siam	—	2	2	6	8	18
Formosa (plain part)	—	2*	—	9	5	16
South China	1	3	3	1	5	13
West & Central China	3	—	4	4	1	12
North China	4	—	1	—	1	6
Formosa (mountain part)	6	—	—	2	—	8
Hai-Nan Island	1	3	—	1	—	5
Philippine	2	5	1	4	4	16
Celebes	3	3	4	3	—	13
Sunda Islands	3	4	2	1	1	11
Japan (lowland vars.)	8	2	1	—	—	11
Japan(upland vars.)	2	4	1	1	—	8
Vars. of phenol +	3	9	12	30	25	79
reaction —	29	21	9	8	5	72
Toals	32	30	21	38	30	151

* Horai varieties

In Formosa, growing the seedlings of various varieties in winter as the first crop, the death of definite varieties by cold injury will be experience frequently. The frequency of death in winter, observed otherwise, was found to agree well with the degree of injury by the low temperature treatment.

Considering from the appearance of varietal variation, low temperature resistance seems to be influenced by several genetical factors, though the inheritance has not been studied yet.

(5) Drought resistance

Drought resistance may imply in plant physiology the ability of a individual plant

or a cell to survive under the condition of water absorbtion being impossile (44). On the other hand, drought resistance may be often expressed in agronomy in terms of the growth or yield under insufficient water supply, and thus the stage of growth, the depth of root system and other ecological characters, in addition to physiological drought resistance, may take part in it. It may be due to the confusion of different senses of the same word that the essential nature of drought resistance in the rice plant has not yet been understood thoroughly in spite of numerous studies on it.

Drought resistance in the present study was examined by so-called Mimosa method (37). It means thus the ability of a plant to survive without available water in soil and to recover after watering. Twenty seedlings of rice and one plant of Mimosa pudica were planted in a pot of 25 cm in diameter, and grown with proper care. When the rice plants stretched from five to seven leaves and the root of Mimosa developped fully, watering was stopped. Then, observing the stimulated movement of Mimosa everyday, the time of suspension of movement by drying was determined, and after five or six days the pot was watered fully. The number of days of treatment, five or six days, was determined by a preliminary test. The percentage of survival and the degree of drought injury were observed two days and four days after the watering. The degree of injury was graded as the five classes, (0) without visible injury, (1) one or two lower leaves being dead, (2) a half of leaves being dead, (3) only one or two upper leaves surviving, and (4) dead wholly. The index-numbers of the twenty plants were averaged on each variety. The varieties of various districts were tested three times in different seasons.

Table 9. Varietal variation of drought resistance (measured by Mimosa method).

Districts	Degree of injury							% of survival					Total num. of vars.
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	20	40	60	80	100	
Indochina	—	1	6	2	—	—	—	—	—	—	1	8	9
India & Siam	—	5	4	3	—	2	—	—	—	3	4	7	14
Formosa (plain part)	2	7	2	1	—	1*	—	—	1*	—	2	10	13
South China	—	5	5	1	1	1	—	—	—	2	3	8	13
Central China	2	2	3	2	1	—	—	—	—	1	2	7	10
North China	—	1	1	—	1	2	—	—	2	—	1	2	5
Formosa(mountain part)	—	1	2	2	—	1	—	—	—	1	3	2	6
Hai-Nan Islands	—	1	—	1	2	1	—	—	—	3	1	1	5
Philippine	—	2	—	1	5	4	1	2	1	7	1	2	13
Celebes	—	2	—	2	3	1	—	—	1	3	2	2	8
Sunda Islands	—	—	2	2	2	5	—	—	5	4	1	1	11
Japan (lowland vars.)	—	—	—	1	1	5	—	—	2	4	1	—	7
Japan (upland vars.)	—	—	—	—	1	2	1	2	1	1	—	—	4
Vars. of Phenol +	3	25	20	9	2	3	1	2	—	5	14	42	63
reaction —	1	2	5	9	15	22	1	2	13	24	8	8	55
Totals	4	27	25	18	17	25	2	4	13	29	22	50	118

Explanation of the degree of injury is in text.

* Horai varieties.

Variations of the degree of injury and the percentage of survival among the varieties are given in Table 9. The varietal variation seemed to be discontinuous to some extent, as intermediate varieties being relatively few. Among the varieties positive in phenol reaction, those resistant to drought were relatively large in number, and vice versa. Then, the geographical variation showed similar tendency to the cases of phenol reaction and other above mentioned characters; resistant varieties were predominant in Eastern Asiatic continent, while non-resistant ones were in the islands of western Pacific. These tendencies were found similarly in the degree of drought injury as well as in the percentage of survival, and these two characters were found to be correlated intimately inter se ($r=0.87$). Therefore, these two characters seem to be different expressions of an essentially same property.

According to the appearance of varietal variation, drought resistance seems to be influenced by a number of genetical factors, though the inheritance being unknown.

(6) The number of days of germination

It is well known that the speed of germination differs with the temperature and other conditions as well as the age of seed, and these matters being constant, varietal difference shows itself clearly (5, 17, 26, 32, 35). In the present study, germination tests were carried out on a greater part of the preserved varieties. Fully after-ripened seeds which had been kept in desiccators for three to six monthes after harvest and

Table 10. Varietal variation of the days of 50% germination at 30°C.

Disiricts	Num. of days					Total num. of vars.
	1.5	2.0	2.5	3.0	3.5	
Indochina	19	2	1	—	—	22
India & Siam	15	6	6	—	1	28
Formosa (plain part)	38	1	1*	—	—	40
South China	23	8	4	2	—	37
West China	17	3	2	—	—	22
Central China	21	6	14	4	2	47
North China	1	—	5	1	—	7
Formosa(mountain part)	7	1	4	1	2	15
Hai-Nan Island	1	2	15	2	—	20
Philippine	7	5	10	2	—	24
Celeces	5	3	8	2	—	18
Sunda Isladns	1	5	23	2	—	31
Japan (lowland vars.)	3	4	15	—	—	22
Japan (upland vars.)	5	6	2	1	—	14
Vars. of phenol	153	28	21	1	—	203
reaction	20	24	90	16	5	155
Totals	173	52	111	17	5	358

* Horai varieties

more than 95% in germinating capacity were used. One lot of fifty sterilized seeds was bedded on a moistened blotting paper layed in a petri-dish, and was put in an incubator regulated at 30°C. Observing the germination everyday, the number of days necessary for the germination of 50% of seeds was calculated. Such germination tests were repeated twice in different years on each variety.

Variation of the days of fifty percents germination among the varieties of various districts is given in Table 10. The varietal variation seemed somewhat to be of discontinuous nature, and two varietal groups, fast and slow in germination seemed to be distinguishable. Varieties positive in phenol reaction were mostly faster in germination than negative ones. In geographical variation, a tendency similar to the cases of phenol reaction and other characters was pointed out.

These phenomena were recognizable more evidently when the temperature was lower than 30°C. Those results will be reported in another paper. According to the appearance of varietal variation, a number of genetical factors seems to be concerned in the varietal difference of germinating speed.

(7) The number of days of maturation of endosperm

The number of days from the opening of flower to the maturation of seeds differs with variety. It is well known in Formosa that the native varieties are faster in the maturation of seed than Horai or Japanese varieties. In the present study, the number of days from the heading to the hardening of endosperm was investigated on the varieties of various districts. Taking ten ears per variety, the dates of heading and

Table 11. Varietal variation of the speed of maturation of endosperm (number of days from heading to the hardening of endosperm).

Districts	Num. of days								Total num. of vars.
	10	11	12	13	14	15	16	17	
Indochina	—	5	3	—	—	—	—	—	8
India & Siam	1	8	2	1	1	—	—	—	13
Formosa (plain part)	1	8	2	—	—	1*	—	—	12
Chinese Continent	2	10	7	3	1	2	—	2	27
Formosa (mountain part)	—	—	4	2	—	—	—	—	6
Hai-Nan Island	—	1	—	—	1	3	—	—	5
Philippine	—	—	1	3	2	—	—	—	11
Celebos	—	1	2	3	2	—	—	—	8
Sunda Islands	—	—	2	7	2	—	—	—	11
Japan	—	—	1	4	2	2	2	—	11
Vars. of phenol +	4	29	16	5	1	1	—	—	58
reaction —	—	4	6	23	10	7	2	2	54
Totals	4	33	24	28	11	8	2	2	112

* Horai varieties

the hardening of grains in the upper part of ear were observed, and the days from heading to hardening of those ten ears were averaged. The number of days of maturation was found to be smaller at higher temperature and under fine weather, whereas during the period of observing a larger part of the varieties, that was from early May to early June, 1948, it was fine almost everyday and the temperature of daily average was approximately between 25° and 27°C.

Variation of the speed of endosperm maturation among the varieties of various districts is given in Table 11. Though the variation seemed nearly continuous, the varieties positive in phenol reaction were mostly faster in endosperm maturation than the negative ones, and the geographical variation seemed to have a tendency similar to the cases of phenol reaction and other characters.

According to the appearance of varietal variation, a number of genetical factors seems to be concerned in this character in the same way as in the other characters mentioned above. This character was found to be correlated intimately with the days of germination (vide Table 21). These two characters may possibly be influenced by same genetical factors.

(8) Shedding of grain

Shedding is due to the development of separating layer at the basal part of grain (41), and it seems to become easier with the lapse of days after the formation of grain as well as with the fall of temperature during maturation. In the present study, ears

Table 12. Varietal variation of the weight of grain shedding

Districts	Weight in gr.										Total num. of vars.
	25	50	75	100	125	150	175	200	225	250	
Indochina	—	3	5	6	1	—	—	—	—	—	15
India & Siam	1	3	7	3	1	—	—	—	—	—	15
Formosa (Plain part)	—	1	13	8	—	1*	—	—	—	—	23
South China	—	4	3	5	—	1	—	—	—	—	13
Central China	—	2	2	3	1	1	—	—	—	—	9
North China	—	—	4	—	—	—	—	1	—	—	5
Formosa(mountain part)	—	—	1	3	1	3	2	—	—	—	10
Hai-Nan Island	—	—	—	1	1	1	—	1	—	1	5
Philippine	—	8	10	3	3	2	1	—	1	—	28
Celebes	—	1	2	6	3	5	1	1	—	—	19
Sunda Islands	—	—	—	—	—	3	2	2	4	1	12
Japan (lowlana vars.)	—	—	4	1	1	2	5	—	—	—	13
Japan (upiand vars.)	—	—	1	4	6	2	—	—	—	—	13
Vars. of phenol +	1	18	41	32	10	3	1	—	—	—	106
reaction —	—	4	11	11	8	18	10	5	5	2	74
Totals	1	22	52	43	18	21	11	5	5	2	180

* Horai varieties

of the varieties of various districts, matured in high temperature period, harvested at proper stages, and preserved indoors for less than one month, were used, and the weight of shedding of single grain was measured by using Yamasaki's shedding-meter on more than fifty grains per variety. Measurements were repeated three times in 1944, 1945, and 1949, and the results were averaged.

Varietal variation of the weight of shedding is given in Table 12. This character, varying on a wide range among the varieties, did not showed a clear discontinuity of variation. However, most of the varieties positive in phenol reaction were shed easily, and those negative in phenol reaction varied on a wider range. The geographical variation was similar in the tendency somewhat to the cases of phenol reaction and other characters; the varieties hard to be shed were found mostly in Japan, Formosa (Horai and the native varieties of mountain part), Philippine, Celebes and Sunda Islands.

According to Izumi (7), Onodera (28), Ramiah (30) and others, shedding is determined at least by several kinds of genetical factors.

(9) The length of awn

Presence or absence and the length of awn differ to a considerable extent with the outer conditions (4, 5). Varieties of various districts were grown in nine different seasons at the interval of one to two monthes (the details will be reported in another paper), and the length of awn in different seasons was measured. All grains of five ears per variety were measured at one time of growing, regarding awnless grains as zero. And it was found, as given in Table 13, that the awn became longer in the period of high temperature. Then, the length of awn of a variety was shown by the average of results in different seasons.

Table 13. An example of seasonal variation of the length of awn.
Variety: 647 (Padi ase banda, Celebes), insensible to day length.

No. of sowing	I	II	III	IV	V	VI	VII	VIII	Average
Date of heading	17/10	16/4	15/5	8/6	24/7	14/8	16/9	15/10	
Length of awn in mm.	33.0 *± 6.24	19.4 ± 10.2	38.0 ± 12.6	39.3 ± 14.0	39.3 ± 13.5	44.7 ± 13.5	41.8 ± 12.8	39.3 ± 10.0	35.6

* standard deviation of a single determination

Varietal variation of the length of awn is given in Table 14. As most of the varieties being either awnless or more than 20 mm in length and intermediate varieties being rare, two varietal groups, awnless and awned, were distinguishable clearly. Awned varieties were mostly negative in phenol reaction, and awnless varieties were either positive or negative in phenol reaction. The geographical variation was similar in the tendency to the cases of phenol reaction and other characters.

With regard to the inheritance of awnedness, a number of works (8, 15, 25, 33) has demonstrated that the length of awn is controlled by the interaction of several multiple

factors and in some cases by inhibitory factors in addition. The authors also arrived at a similar conclusion; those data will be reported at another opportunity.

Tabe 14. Varietal variation of the length of awn.

Districts	Length in mm. (mid-points of log. class interval) 1.3	2.0	3.2	5.0	8.0	12.6	20.0	31.5	50.0		Total num. of vars.
Indochina	8	1	—	—	—	—	—	—	—	—	9
India & Siam	13	—	—	—	—	1	—	1	—	—	15
Formosa (plain part)	13	—	—	—	—	—	—	—	—	—	13
South China	11	—	—	—	1	—	—	—	1	—	13
Central China	7	1	—	—	—	—	—	1	—	—	9
North China	3	—	—	—	—	—	—	—	2	—	5
Formosa (mountain part)	5	—	—	—	—	—	—	—	1	—	6
Hai-Nan Island	4	—	—	—	—	—	—	—	1	—	5
Philippine	12	—	—	1	—	—	—	—	—	—	13
Celebes	3	—	—	—	—	—	—	—	5	—	8
Sunda Islands	2	—	—	—	—	1	—	1	6	1	11
Japan (lowland vars.)	4	—	—	1	—	—	1	—	1	—	7
Japan (upland vars.)	—	—	—	2	—	—	—	2	—	—	4
Vars. of phenol +	55	1	—	2	—	1	—	2	1	—	62
reaction −	30	1	—	2	1	1	1	3	16	1	56
Totals	85	2	—	4	1	2	1	5	17	1	118

(10) The length of glume hair

Numerous hairs of singular cell grow on the surface of inner and outer glumes, and are longer and denser at the apical part of glumes. The length of hairs at the apical part were measured on various varieties by using a low power microscope. More than fifty hairs of three grains per variety were measured.

Table 15. Varietal variation of the length of glume hair.

Districts	Length in micra 0	100	200	300	400	500	600	700	800	900	1mm or more	Total num. of vars.
Indochina	—	—	5	5	3	—	—	—	—	—	—	13
India & Siam	—	—	9	5	—	1	2	—	—	—	—	17
Formosa (plain part)	—	—	2	10	2*	—	—	—	1	—	—	15
South China	—	—	5	2	—	1	—	1	—	—	—	9
Central China	—	—	5	—	—	1	1	—	—	—	—	7
North China	—	—	—	1	—	—	—	2	2	—	—	5
Formosa (mountain part)	—	—	1	1	1	1	1	1	—	—	1	7
Hai-Nan Islands	1	—	—	1	—	1	2	—	—	—	—	5
Philippine	5	—	1	3	3	1	1	—	—	—	—	14
Celebes	—	—	2	4	1	3	1	—	—	—	—	11
Sunda Islands	—	—	—	—	1	1	5	—	1	1	1	10
Japan (lowland vars.)	—	—	—	—	2	3	1	1	—	—	—	7
Japan (upland vars.)	—	—	—	3	1	—	—	—	—	—	—	4
Vars. of phenol +	—	—	23	31	5	2	2	—	1	—	—	63
reaction −	6	—	6	4	9	11	12	5	3	1	2	59
Totals	6	—	30	35	14	13	14	5	4	1	2	124

* Horai varieties

Varietal variation of the length of hair is given in Table 15. It was seemingly continuous, whereas the varieties positive in phenol reaction tended to be shorter in the length, and the varieties negative in phenol reaction showed a wider range of variation. The tendency of geographical variation were somewhat similar to the cases of phenol reaction and other characters.

A variety of Sunda Islands (344 : Betong) was found to be as long as exceeding 1.8mm. On the other hand, a few varieties of Philippine and Hai-Nan Island were hairless. This hairless was found to be expressed by two recessive genes, while the length of hair in ordinary haired varieties seemed to be influenced by a number of multiple factors. Examples of the segregation are given in Table 16. An intimate

Table 16. Some examples of segregation of the length of glume hair in F2s.

Crosses	Length of hair in micra							Total
(Length in parents)	200	300	400	500	600	700	800	num.
108 × 703 (262) (685)	1	15	54	37	12	2	1	122

	Obs: Num.		Exp. Num. Haired Hairless (15 : 1)		X^2
	Haired	Hairless			
219 × 103 (0) (262)	103	4	100.3	6.7	1.16
219 × 421 (0) (247)	74	4	73.1	4.9	0.21
647 × 219 (475) (0)	162	13	164.1	10.9	0.43

intervarietal correlation was pointed out between the length of hair and the length of awn in awned varieties ($r=0.79$). These two characters may be supposed to be influenced by same genetical factors.

(11) Length-width ratio of unhulled rice

Length-width ratio of hulled rice has been observed by a number of workers (2,10, etc.) as a character available for the practical classification of varieties, and its geographical variation was investigated by Negamatsu (24). As the shape of hulled rice being dependent upon the shape of hull, the shape of unhulled rice, observed in the present study, will be a character same to the shape of hulled rice. Almost all preserved varieties were observed on the length and the width of unhulled grain. Ten fully enriched grains per variety were measured by using a calipers.

Varietal variation of the ratio is given in Table 17. The ratio ranged, roughly speaking, from two to four among varieties, while a greater part of the varieties was between 2.4 and 3.0. The varietal variation seemed to be continuous. Unlike the cases of other characters mentioned above, varieties positive in phenol reaction and negative ones were similar in the mode of varietal variation. Accordingly, the geographical variation of this character was also different from the cases of phenol reaction and other

Table 17. Varietal variation of the length-width ratio of unhulled rice.

Districts	Length-width ratio													Total num. vars.
	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	
Indochina	—	—	1	1	3	13	25	16	8	4	—	4	1	76
India & Siam	—	—	5	3	21	11	11	2	3	4	1	2	1	69
Philippine	—	—	1	6	14	14	15	13	3	1	3	3	1	74
Celebes	—	4	2	3	17	21	11	6	3	3	4	—	—	74
Sunda Islands	1	4	4	9	9	16	11	7	2	3	2	—	—	68
Hai-Nan Island	—	2	1	7	9	7	1	2	1	1	—	—	—	31
South China	—	—	4	4	13	11	5	5	—	1	—	—	1	44
Central China	—	5	10	5	11	12	5	—	—	—	—	—	—	48
West China	—	—	2	2	3	11	6	—	—	—	—	—	—	24
North Cnina	—	—	3	—	1	3	2	—	—	—	—	—	—	9
Formosa (plain part)	1	4*	4*	23	21	7	2	—	—	—	—	—	—	62
Formosa(mountain part)	—	3	19	14	17	6	1	1	—	—	—	—	—	61
Japan (lowland vars.)	1	12	7	4	1	—	—	—	—	—	—	—	—	25
Japan (upland vars.)	—	2	8	7	4	—	—	—	—	—	—	—	—	21
Vars. of phenol +	3	22	31	55	101	92	73	35	14	12	7	8	2	455
reaetion −	—	14	40	38	43	40	22	17	6	5	3	1	2	231
Totals	3	36	71	93	144	132	95	52	20	17	10	9	4	686

* Horai varieties

characters; the varieties of higher latitudal regions were small uniformly in the ratio, while those of lower latitudal regions varied on a wider range. These respects agree well with Mr. Nagamatsu's result.

Table 18. Varietal variation of the width of unhulled rice.

Phenol reaction	2.1 mm	2.4	2.7	3.0	3.3	3.6	3.9	Total num. of vars.
+	—	33	105	178	86	26	4	432
−	2	13	27	67	83	59	15	266
Totals	2	46	132	245	169	85	19	698

Varietal variation of the length of unhulled rice was similar to that of the length-width ratio. With regard to the width of unhulled rice, the varieties positive in phenol reaction were found generally to be smaller than the negative ones (vide Table 18).

It has been pointed out by a number of works (19, 20, etc.) that several multiple factors exert influence on the size and shape of rice grain.

(12) The length of first and second internodes

Hamada (3) pointed out that the length of first internode, viz. so-called mesocotyl,

grown without light, was longer in Indica type than in Japonica type. Okura and Miyata (27) and Mizushima (22) showed, however, that varietal variation of the length of mesocotyl was of continuous nature and did hardly prove the distinction of the two types. Dr. T. Shibuya and one of the present authors (34), dealing also with the variation of this character, came to such a conclusion: The length of organs of rice seedling varys with the temperature and the moisture content of culture media, and while the varietal variations as a whole are continuous, the varieties of higher latitudal regions tend to be relatively short in the length of first and second internodes, and those of lower latitudal regions vary on a wider range.

As the materials used in this work being same to those of the present study, then adding the data obtained later, varietal variations of the length of first and second internodes were investigated again. The results were, as given in Tables 19 and 20, similar to those mentioned above; The varieties positive in phenol reaction and those negative were not different in the range of varietal variation. The length of first internode and that of second internode did not showed a signifcant intervarietal correlation inter se (r=0.133).

Table 19. Varietal variation of the length of first internode.

Districts	Length in mm. (Mid-points of logarithmic class interval)												Total num. of vars.
	1.26	2.0	3.16	5.0	8.0	12.6	20.0	31.6	50.0	80.0	126		
Indochina	1	—	4	10	18	7	12	7	1	1	1	1	62
India & Siam	2	2	1	2	3	—	1	6	10	4	5	8	44
Formosa (plain part)	—	—	3	6	5	2	10*	6	8	9	1	4	54
South china	1	—	3	1	2	—	—	1	5	3	2	—	18
Central China	2	1	1	—	2	—	1	2	1	—	—	—	10
North China	2	—	—	1	—	1	1	1	—	—	—	—	6
Formosa(mountain part)	—	—	—	—	1	—	2	2	1	3	4	—	13
Hai-Nan Island	—	—	—	—	—	1	4	5	3	5	2	—	20
Philippine	—	—	—	—	—	3	5	8	22	14	18	2	72
Celebes	—	—	—	—	1	6	5	8	10	5	1	—	36
Sunda Island	1	—	1	—	1	1	5	10	11	8	4	—	42
Japan lowland vars.)	—	—	—	3	5	12	7	4	2	—	—	—	33
Japan (upland vars.)	—	—	—	1	1	3	5	6	5	1	—	—	22
Vars. of phenol +	6	2	10	20	25	18	36	37	47	31	32	15	279
reaction —	3	1	3	4	14	17	22	29	32	22	6	—	153
Totals	9	3	13	24	39	35	58	66	79	53	38	15	432

* Horai varieties

The extent of elongation of these organs may presumably depend upon the quantity and distribution of growth hormones produced in the inner part of plant and may be controlled by numerous genetical factors.

Table 20. Varietal variation of the length of second internode.

Districts	Length in mm (mid-points of log. class intereals) 1.26	2.0	3.16	5.0	8.0	12.6	20.0	31.6	50.0		Total num. of vars.
Indochina	—	2	—	1	1	15	25	17	—	1	62
India & Siam	3	—	1	1	3	5	11	14	4	—	42
Formosa (plain part)	3*	—	—	1	1	1	16	26	5	—	53
South China	4	—	—	—	1	—	2	7	4	—	18
Central China	6	—	—	—	—	1	—	1	2	—	10
North China	4	—	—	1	—	—	—	1	—	—	6
Formosa(mountain part)	—	—	—	—	1	3	4	4	1	—	13
Hai-Nan Island	1	—	—	—	2	2	7	8	—	—	20
Philippine	10	3	2	9	11	13	9	11	2	—	70
Celebes	—	—	—	—	2	3	7	6	13	5	36
Sunda Islands	1	—	1	—	3	3	15	14	5	—	42
Japan (lowlard vars.)	27	1	1	2	1	—	—	—	—	—	32
Japan (upland vars,)	17	1	—	—	2	2	—	—	—	—	22
Vars. of phenol +	25	5	3	7	16	33	62	86	33	5	275
reaction —	51	2	2	8	12	15	34	23	3	1	151
Totals	76	7	5	15	28	48	96	109	36	6	426

*Horai varieties

(13) Intervarietal correlations among the above mentioned characters.

Table 21. Intervarietal correlations among various characters (correlation coefficients).

	(2) Destruction of endosperm by KOH	(3) $KClO_3$ resist.	(4) Low temp. resist.	(5) Drought resist.	(6) Days of germi.	(7) Days of maturation	(8) Weight of shedding	(9) Length of awn	(10) Length of hair	(11) Length-width ratio of rice
(3) $KClO_3$ resist.	0.541 **									
(4) Low temp. resist.	0.579 **	0.592 **								
(5) Drought resist.	−0.521 **	−0.748 **	−0.544 **							
(6) Days of germi.	0.295 **	0.757 **	0.648 **	−0.655 **						
(7) Days of maturation	0.562 **	0.735 **	0.668 **	−0.653 **	0.556 **					
(8) Weight of shedding	0.398 **	0.599 **	0.541 **	−0.498 **	0.477 **	0.466 **				
(9) Length of awn	0.449 **	0.517 **	0.420 **	−0.474 **	0.406 **	0.358 **	0.515 **			
(10) Length of hair	0.508 **	0.677 **	0.642 **	−0.515 **	0.578 **	0.624 **	0.506 **	0.787(1) **		
(11) Length-width ratio of rice	−0.319 **	−0.284 **	−0.348 **	0.154	−0.223 *	−0.306 **	−0.115	−0.196 *	−0.194 *	
(12) Length of 1st internode	−0.262 **	−0.050	−0.176	0.047	−0.042	−0.262 **	0.077	−0.057	−0.136	0.206 *

** beyond 1% level, * between 1% and 5% levels.

(1) regarding to awned varieties only.

The propensity of correlation among the varietal variations of various characters mentioned above was in terms of correlation coefficient as given in Table 21. It may be seen in Table 21 that correlations are conspicuous among such characters as showing difference of a definite tendency between the varieties positive in phenol reaction and the negative ones, and also showing geographical variation similar in the tendency to that of phenol reaction. Particularly, the characters which showed discontinuity of variation, such as pottasium chlorate resistance, low temperature resistance, drought resistance and others, were correlated intimately inter se. These correlations will be, as being presumable from the fact that the varieties positive in phenol reaction and the negative ones have been contrary to each other in various characters, due to the preponderance of varieties possessing definite kinds of charcter combination. Therefore, the

Table 22. Examples of abnormal distribution of frequency in correlation tables.

(a) Correation between the length of awn and pottasium chlorate resistance.

Length of awn in mm (mid-points of logarithmic class intervals)	Conc. of $KClO_3$ in log. (vide Table 5)								Total
	− 3.67	− 3.33	− 3.00	− 2.67	− 2.66	− 2.00	− 1.67	− 1.33	
1.3	3	29	14	5	3	3	16	10	83
2.0	—	1	1	—	—	—	—	1	3
3.2	—	—	—	—	—	—	2	2	4
5.0	—	—	1	—	—	—	—	—	1
8.0	—	—	—	1	—	—	—	1	2
12.6	—	—	—	—	—	—	—	1	1
20.0	—	—	—	—	—	—	1	3	4
31.6	—	—	—	—	—	—	8	8	16
50.0	—	—	—	—	—	—	1	—	1
Total	3	30	16	6	3	3	28	26	115

(b) Correlation between the weight of grain shedding and pottasium chlorate resistance.

Weight of shedding in gr	Conc. of $KClO_3$ in log.								Total
	− 3.67	− 3.33	− 3.00	− 2.67	− 2.33	− 2.00	− 1.67	− 1.33	
25	—	1	—	—	—	—	—	—	1
50	1	8	5	2	1	1	1	—	19
75	4	12	12	4	4	2	5	6	49
100	—	20	2	5	3	2	5	5	42
125	—	3	1	—	—	—	8	6	18
150	—	—	1	—	—	1	12	7	21
175	—	—	—	—	—	—	6	5	11
200	—	—	—	—	—	—	2	3	5
225	—	—	—	—	—	—	1	4	5
250	—	—	—	—	—	—	1	—	1
Total	5	44	21	11	8	6	41	36	172

correlation coefficients will serve as a measure of preponderancy of definite character combinations.

It should be admitted, however, that the frequency distribution in the correlation tables were not always normal. Especially, concerning several characters showing complete discontinuity of varietal variation, peculiar shapes of frequency distribution, as given in Table 22, were found. In such cases, correlation coefficients may not evaluate the propensity of correlation correctly. Nevertheless, it may be recognizable in these correlation tables that definite character combinations are preponderant and thus the used varieties are to be divided into two groups.

(14) Frequency of varieties possessing various kinds of character combinations.

Varietal variations have been found to be discontinuous in the following five characters: phenol reaction, pottasium chlorate resistance, low emperature resistance, drought resistance, and the length of awn. Therefore, in regard to each of these characters, the used varieties may be divided into two groups and the characteristics of a given variety may be represented by a simple word, positive or negative, or, plus or minus. Thus, with regard to these five characters, denoting each character by one sign, plus or minus, a variety may be symbolized by a combination of five signs. Posssible combinations of five signs will be $2^5=32$ in total number. If these 32 kinds of character combinations all were similar in frequency, the given population of varieties should be considered to be composed of random combinations of genic changes, and there would be no evidence of phylogenetical differentiation to be expected in it. However, it will be presumed without difficulty from the above mentioned facts that definite kinds of character combinations will preponderate among the used varieties.

Having investigated the frequency of varieties possessing each of these 32 kinds of character combinations, the results given in Table 23 was obtained. It will be seen in Table 23 that such varieties are large in number as either belonging to combination no. 24, viz phenol reaction being plus (positive), pottasium chlorate resistance and low temperature resistance being minus (weak), drought resistance being plus (resistant), and the length of awn being minus (awnless), or belonging to combination no. 9 and no. 22 which are contrary to the above in every respects or except the length of awn. Thus, a majority of the used varieties can be divided into two variety-groups represented respectively by these two types of character combination. For the discrimination of these two variety-groups, use of pottasium chlorate resistance will be good, since it shows the most clear discontinuity of varietal variation.

Besides these two variety-groups, however, few varieties possessing other various kinds of character combinations will be found further in Table 23. Since particular care has been taken that diverse character combinations would not be resulted from the inaccuracy of observation, the existence of varieties as showing these extra character combinations seems to be without doubt. Then, we may come to such a conclusion that the varieties of rice plant are as a tenedency to be divided into two variety-groups, reserving some varieties which belong to neither of the two.

Table 23. Character combinations found among the used varieties and the frequency of varieties as showing each of those combinations.

Characters	no. of character combination															Total num. of vars.
	24	13	11	28	32	7	30	20	10	15	6	5	16	9	22	
Phenol reaction	+	+	+	−	−	−	−	−	−	+	+	+	+	−	−	
$KClO_3$ resist.	−	−	−	−	−	−	+	+	+	+	+	+	+	+	+	
Low temp. resist.	−	+	−	−	−	+	−	−	+	−	+	+	+	+	+	
Drought resist.	+	+	+	+	−	+	−	−	+	+	+	−	−	−	−	
Length of awn	−	−	+	−	−	+	−	+	−	−	−	+	−	+	−	
Indochina	10	2	−	1	−	−	−	−	−	−	−	−	−	−	−	13
India & Siam	9	1	1	1	−	−	1	−	−	2	−	−	−	−	1	16
Formosa (plain part)	15	−	−	−	−	−	−	−	−	−	−	−	−	−	1	16
South China	7	2	−	1	−	1	−	−	−	−	−	−	−	1	1	13
Central China	3	3	−	2	−	−	−	−	1	−	−	−	−	1	2	12
North China	1	1	−	−	−	−	−	−	−	−	−	−	−	2	2	6
Formosa(mountain part)	2	−	−	−	−	−	−	−	1	−	1	−	1	3	−	8
Hai-Nan Island	1	−	−	−	−	−	−	−	−	−	−	−	1	1	2	5
Philippine	3	−	−	−	1	−	1	−	−	−	−	−	−	1	8	14
Celebes	4	−	−	−	−	−	−	−	−	−	−	−	−	8	1	13
Sunda Islands	−	−	−	−	−	−	−	2	−	−	−	1	−	7	2	12
Japan (lowland vars.)	−	−	−	−	−	−	−	−	−	−	−	−	−	4	7	11
Japan (upland vars.)	−	−	−	−	−	−	−	−	−	−	−	4	2	2	−	8
Totals	55	9	1	5	1	1	2	2	2	2	1	5	4	30	27	147
Variety-groups	Continental				(Indistinct)							Insular				

Fifteen kinds of character combinations were found actually.

It will be recognizable, further, looking over the geographical distribution of various character combinations given in Table 23, that combination no. 24 distributes mainly over the continent of Eastern Asia, viz. China, Indochina, and India, while combinations no. 9 and no. 22 distribute mainly over the islands of Western Pacific, viz. Japan, Formosa (Horai and the native varieties of mountain part), Philippine, Celebes and Sunda Islands, in addition to Northern China. It may be said, with proper qualifications, that these two different types of character combinations are corresponding to so-called Indica and Japonica types respectively, but it will be better for the sake of expressing the tendency of geographical distribution to name these variety-groups as "Continental" and "Insular" groups.

(15) Differention within Continental and Insular variety-groups.

The used varieties were divided into Continental and Insular variety-groups conveniently according to the resistance against pottasium chlorate. And intervarieral correlarions within each variety-group were investigated. The correlations are given

Table 24. Intervarietal correlations within "Continental" and "Insular" variety-groups.

Continental / Insular	(2) Destruc. of endo-sperm	(4) Low temp. resist.	(5) Drought resist.	(6) Days of germi.	(7) Days of matu-ration	(8) Weight of shed-ding	(9) Length of awn	(10) Length of hair	(11) Length width ratio of rice	(12) Length of 1st inter-node
(2) Destruction of endo-sperm by KOH		0.116	−0.119	0.173	0.096	0.128	0.102	0.250 *	0.237 *	−0.068
(4) Low temp. resistance	0.426 **		0.032	0.034	0.029	0.030	0.111	0.003	−0.177	−0.175
(5) Drought resistance	−0.036	−0.069		−0.218	−0.081	0.189	−0.110	0.061	−0.312 *	−0.077
(6) Days of germination	0.299	0.441 **	−0.224		0.117	−0.343 **	0.069	0.161	0.094	0.231
(7) Days of maturation	0.310 **	0.401 **	−0.259 *	0.268 *		0.302 *	—	0.286 *	0.019	0.105
(8) Weight of shedding	−0.162	0.057	−0.053	−0.042	−0.053		—	−0.045	−0.121	−0.001
(9) Length of awn	0.226	0.082	−0.152	0.335 **	—	—		—	—	—
(10) Length of hair	0.187	0.386 **	−0.138	0.299 *	0.137	0.120	—		−0.116	0.136
(11) Length-width ratio of rice	−0.500 **	−0.265 *	0.255 *	−0.131	−0.346 *	0.282 *	—	0.064		−0.064
(12) Length of 1st inte-rnode	−0.544 **	−0.245 *	0.144	−0.415 **	−0.529 **	0.259 *	—	−0.239	0.405 **	

** beyond 1% level, * between 1% and 5% levels.

in Table 24 in terms of correlation coefficient. Comparing Table 24 with Table 21 given above, there may be found frequently such a case that two characters which showed a marked correlation among the whole used varieties are no longer correlated within a same variety-group. It may be confirmed, accordingly, that the correlation of various characters among the whole varieties are due to the preponderance of the two types of character combinations as mentioned above.

According to Table 24, however, intervarietal correlations within Insular variety-group will be found among several characters, such as the degree of destruction of endosperm by caustic potash, the length-width ratio of unhulled rice, the length of first internode, and others. Insular group may be presumed, therefore, to possess a definite tendency of character combination within it. As these characters being continuous in intervarietal variation, these correlations may point only the direction of intervarietal differentitation, and to classify the varieties by them seems to be difficult. However, for the purpose of expressing the situation clearly, each of the above mentioned three characters was represented by the sign, plus or minus, dividing the range of variation into two parts at the middle point, and thus the characteristics of a variety was symbolized by a combination of three signs. In this case, eight kinds of character combinations will be possible in total; the frequency of varieties showing each of these eight kinds was as given in Table 25.

It may be seen in Table 25 that combination no. 5, viz. endosperm being destructed heavily by caustic potash, the length-width ratio of unhulled rice being small, and the first internode being short, and combination no. 4, that is contrary in each character, are markedly large in number. Therefore, it may be a proper way to express the

Table 25. Character combinations in "Insular" variety-group. and the frequency of varieties as showing each character combination.

Characters	(4)	(7)	(6)	(2)	(1)	(3)	(5)	Total num. of vars.
(2) Destruction of endosperm by KOH	−	−	−	+	+	+	+	
(11) Length-width ratio of unhulled rice	+	−	+	+	+	−	−	
(12) Length of 1st internode	+	+	−	−	+	+	−	
Sunda Islands	8	2	1	—	1	—	—	12
Celebes	1	1	1	1	2	2	1	9
Philippnie	7	3	—	—	—	1	—	11
India	—	—	1	—	—	—	—	1
Hai-Nan Island	—	1	—	1	1	—	1	4
Formosa	—	—	—	—	1	2	4	7
China	1	—	—	—	1	1	6	9
Japan (lowland vars.)	—	—	—	—	—	1	11	12
Japan (upland vars.)	—	—	1	—	1	2	2	6
Totals	17	7	4	2	7	9	25	71
Variety-groups	Tropical						Temperate	

Seven Kinds of character combinations were found actually.

direction of differentiation to divide Insular variety-group into two minor groups. The varieties belonging to combination no. 5 may be named as "Temperate Insular", as they are distributing mostly over the temperate regions such as Japan and Northern China. In contrast to this, the varieties belonging to other character combinations, distributing over tropical regions, may be named as "Tropical Insular" group.

Discussion

It is necessary for the study of phylogenetical differentiation, as mentioned in some paragraph of the introduction, to produce an evidence to speculate the frequency of gene combinations being higher in definite kinds than in others, i. e. the preponderance of definite gene combinations.

The above given observation results may present in this connection the following facts: (1) discontinuity of varietal variation, (2) definite tendency in intervarietal correlation, and (3) preponderance of definite kinds of character combinations. On the ground of these facts, some consideration will be presented on intervarietal phylogenetical differentiation of the rice plant.

First, discontinuity of varietal variation will be considered: It may be a natural consequence when the character in question is determined or at least influenced mainly by a single genic change. On the other hand, when a character was influenced by a

number of genes and various kinds of individuals were to be segregated in F_2 hybrid varying continuously among them, the discontinuity of varietal variation may be regarded as proving the preponderance of definite kinds of gene combination.

According to the observation results, discontinuities of varietal variation have been pointed out distinctly in the characters as follows: pottasium chlorate resistance, low temperature resistance, drought resistance and the length of awn, and also somehow less distinctly in several characters as the weight of grain shedding, the days of germination and others.

To work out the genetical behavior of these characters may be a difficult task, but it has been demonstrated or speculated from the appearance of varietal variation that a number of genes concerns in the varietal variations of these characters. It will be concluded, therefore, that definite kinds of gene combinations are preponderant among numerous genic changes as exerting influence on these characters.

Furthermore, since different genotypes often exhibit similar phenotypes, even if varietal variation was seemingly continuous, it would not be assured that the gene combinations concerned are represented at essentially equal opportunity. Therefore, in such characters as the length-width ratio of unhulled rice which has shown continuous varietal varietal variation, the gene combinations concerned may not necessary be existent without any restraint.

Secondly, intervarietal correlations may be attributable to either of the following two cases: (a) The two characters in correlation are different expressions of an essentially same physiological character (physiological correlation), and both are influenced by the same kinds of genic change. (b) Varieties possessing defininite kinds of gene combination are predonderant over others. Among various examples of correlation given in the present study, those between characters seemingly similar in nature, such as between the length of awn and the length of glume hair, may be or may not be due to the influence of same genetical factors. It is difficult, however, to suppose that various characters all are influenced by the same genetical factors. Fursther, having divided the used varieties into two variety-groups according to the resistance against pottassium chlorate, there has been found frequently such a case that intra-group correlatious are scarcely significant in spite of marked correlations among the whole varieties. In this case, the correlation among the whole varieties will interpret that the used varieties are differentiated in the direction of the two variety-groups which are different from each other in various characters but are comparatively uniform within each.

Thirdly, this situation will be proved more clearly by the results of observations on character combination. Namely, it has been pointed out in this connection that the varieties possessing genic constitutions which express the following two kinds of phenotypes are preponderant strikingly over others: phenol reaction +, pottasium chlorate resistance —, low temperature resistance —, drought resistance +, and awn —, or the phenotype contrary in each character.

Since the used varieties has been taken out without any preconception, it will be reasonable to think that the above mentioned considerations will outline the pattern of intervarietal differentiation of the rice plant. It can be said, in short words, on the ground of the results obtained from intervarietal variation, intervarietal correlation, and character combination, well coincident inter se, that two phylogenetically differentiated variety-groups are existent among the varieties of rice plant. As mentioned in the observation results, if a proper conditional clause were added to the conception of the former Indica-Japonica classification, these two variety-groups could be regarded as corresponding to Indica and Japonica types. However, for expressing the new way of thinking on which these variety-groups have been established and their peculiar geographical distribution, it would be better to name them as "Continental" and "Insular" variety-groups.

It should be kept in mind, on the other hand, that the varieties possessing character combinations as belonging to neither of these two variety-groups have been found. These varieties, occupying extraordinary sites in correlation tables, may be of such a nature in genotype as corresponding to some recombinations between the two variety-groups.

In order to outline the whole pattern of intervarietal phylogenetical differentiation, differentiation within variety-group must be considered further. According to the observation results, within a same variety-group, discontinuitinuity of varietal variation, definite tendencies in intervarietal correlation and character combination as those found among the whole varieties have not been pointed out in regard to a greater part of characters. Various gene combinations seem to exist within variety-groups with little restraint, and intra-group differentiation will not be developped fully. In respect to several characters, however, varietal variations on a wide range have been seen within variety-group.

Especially, such characters vary remarkably within Insular variety-group as the degree of destruction of endosperm by caustic potash, the length-width ratio of unhulled rice, the length of first internode and others, which have shown no significant difference in the mode of variation between Continental and Insular variety-groups. Though variation of these characters being continuous, it has been recongized on the ground of intervarietal correlation that the varieties possessing definite character combinations such as follows are large in number: the destruction of endosperm by caustic potash being heavy, the length-width ratio of unhulled rice being small, and the first internode being short, and the combination contrary in each character. Thus, Iusular variety-group seems to be divided into two minor groups, though the distinction is not so evident. The former character combination distributes mainly over the temperate regions, and the latter and other character combinations distribute mainly over the tropical regions. Therefore, a proper naming may be to call them as "Temperate Insular" and "Tropical Insular" groups.

Matsu-o (18) pointed out recently, from some observations on the combination of various morphological characters, that if the varieties of Japan, Java and India were

assumed to be the "representative types" of rice varieties, other various varieties would also be classified into these three types, and named them as A, B, and C types. His method is quite different from the authors' in his a priori fixation of "representative types", and the characters dealt with by him are also different from the authors', but so far as the ultimate result is concerned, "Continental", "Tropical Insular", and "Temperate Insular" variety-groups in the present study seems to be equivalent approximately to B, C, and A types of Mr. Matsuo respectively.

We understand little how phylogenetical differentiation of rice varieties would have developped. It will be considered as a general rule that phylogeny is due to the development of different genotypes between geographically isolated populations and the sexual isolation that follows. Intervarietal hybrid sterility which may result intervarietal sexual isolation will be dealt with in the second paper of this series of studies.

Summary

1. The aim of the present study is to gain informations as to whether definite kinds of genic constitutions would be preponderant or not among the varieties of rice plant and how the varieties are to be divided into groups. More than one hundred and twenty varieties picked out nearly randomly from numerous varieties of various districts of Eactern Asia were observed with respect to diverse characters, and on the ground of those results, discontinuity of varietal variation, intervarietal correlations and tendencies in character combination were investigated.

2. Besides phenol reaction which was found to be determined by a single genic change, the following several characters in which a number of genes would be concerned. i. e. pottasium chlorate resistance, low temperature resistance, drought resistance and the length of awn, showed discontinuous sppearances of varietal variation by which the varieties were to be divided into two groups. Varietal variations of the days of germination, and the weight of grain shedding seemed somewhat to be discontinuous. The degree of destruction of endosperm by caustic potash (alkali-test), the days of endosperm maturation, the length-width ratio of unhulled rice, the length of first and second internodes grown in a dark place, showed continuous appearance of varietal variation.

3. With regard to a greater part of these characters, except the length-width ratio of unhulled rice and length of the first and second internodes, the varieties positive in phenol reaction and the negative varieties showed characteristics contrary to each other. At the same time these characters were found to be correlated inter se.

4. With regard to each of the five characters which showed discontinuous appearance of varietal variation, i.e. phenol reaction, pottasium chlorate resistance, low temperature resistance, drought resistance, and the length of awn, the used varieties were divided into two groups, plus and minus; and thus the characteristics of a variety was represented by a combination of five signs. Then, the frequency of varieties possessing

respective kinds of character combination was investigated. Consequently, two definite kinds of character combination, namely, phenol reaction: plus, pottasium chlorate resistance and low temperature resistance: minus (weak), drought resistance: plus (hard), and awn: minus (awnless), and a character combination contrary in each to the above, were found to be preponderant among the used varieties.

5. Varieties possessing the former character combination (phenol reaction: plus, etc) were found mostly among the varieties of Asiatic Continent, viz. China, Indo-china and India, while varieties possessing the latter one were found to distribute mainly over the islands of Western Pacific, viz. Sunda Islands, Celebes, Philippine, Formosa (Horai and the native varieties of mountain part) and Japan, in addition to northern China.

6. It was considered, on the ground of various facts as mentioned above, that the varieties of rice plant were to be divided into two variety-groups which were different in various characters, reserving some indistinct varieties which would belong to neither of them. These two variety-groups were named, with a view to manifest the tendency of geographical distribution, as "Continental" and "Insular" variety-groups.

7. Within Insular group, intervarietal correlations were found among such characters as follows: the degree of destruction of endosperm by caustic potash, the length-width ratio of unhulled rice, the length of first internode, and others. Accordingly, varieties possessing definite kinds of character combination were found to be preponderant. It was considered, therefore, that Insular variety-group could be divided into two minor groups, though the distinction being not so evident. These minor groups were named as "Tropical Insular" and "Temperate Insular" variety-groups according to the tendency of geographical distribution.

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