GEOGRAPHICAL DISTRIBUTIONS AND PREDOMINANT RACES OF PYRICULARIA ORYZAE

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Several countries other than Japan, U.S.A. and Taiwan have carried out studies on the pathogenic races of the rice blast fungus since the symposium on the rice blast disease held at the International Rice Research Institute (IRRI) in 1963.

It will be useful to the study of horizontal resistance to the disease of rice to take a view of geographical distribution of pathogenio and predominant races in certain countries from the data which have been reported.

I. Geographical distribution of the pathogenic races

According to the paper, "Pathogenic races of Pyricularia oryzae Cav. in Asian and some other countries" by S. Matsumoto et al., nearly two hundred specimens of diseased plants in thirteen countries were tested on their pathogenic races at the National Institute of Agricultural Sciences of Japan from 1962 to 1966. At the same time, workers at the Japan-United States Cooperative Blast Project conducted inoculation tests of the isolates which had been exchanged between both countries. (Figure 1 and Table 1).

From the results of these tests, four geographical areas are distinguishable on the basis of race distribution: 1) Japanese, 2) Philippine, 3) Indian and 4) American. The races found in each of these areas have some pathogenic characteristics while showing differences from each other. The common characteristics in the pathogenicity of the races in each area are summarized below:

1) Races found in the Japanese area

Major races encountered in Korea and Taiwan belong to those characterized in Japan, namely, Japanese race N-1, N-2, N-3, N-4 and N-5. They are pathogenic to all varieties of Japonica type, i.e., Homarenishiki, Ginga, Norin 20, Norin 22 and Caloro, but are nonpathogenic to the majority of Indica type varieties, i.e., Tetep, Tadukan, Usen, NP-125, Raminad Str. 3 and Wag wag. Many varieties of Japonica type are cultivated widely in this area.

2) Races found in the Philippine area

Most major races found in the Philippines, Vietnam, Cambodia and Thailand and to some extent in Taiwan and Indonesia are identical to or closely resemble some of the US races 5, 6 and 11. As shown in Table 1, they show similar reaction patterns onthe Japanese differential varieties, with susceptible reaction on only two or three varieties, namely, Usen, Ishikarishiroke and Aichiasahi. They are characterized by: a) nonpathogenicity to all varieties of Japonica type except Aichiasahi and Caloro, thus indicating a striking contrast to the reaction observed with races in the Japanese area, and b) nonpathogenicity to the so-called Chinese type varieties, i.e., Chokoto, Yakeiko, Kanto 51, C.I. 5309 and Dular, also indicating a striking contrast to the reaction of races in the Indian area. Among the varieties of Indica type, these races are all pathogenic to Usen, and some of them are pathogenic to Raminad Str. 3 and Wag wag.

3) Races found in the Indian area

Major races found in India, Ceylon and West Pakistan, and some races in Indonesia, are identical or show close similarity to the US race 8 or 9. As shown in Table 1, all the major races in this area are nonpathogenic to most of the varieties of Japonica type, and in this respect are similar to the races in the Philippine area. However, they are pathogenic to most varieties of the Chinese type such as Chokoto, Yakeiko, Kanto 51, C.I. 5309 and Dular, thus indicating a striking contrast to the reaction of the races in the Philippine area. They also differ in that they are pathogenic to NP-125, which is resistant to most isolates from other areas.

4) Races found in the American area

According to the results reported by United States workers, the most prevalent races were US race 3 and 6 followed by US race 16.

G. E. Galvez reported that US race 6, which corresponded to ID-13, was the most prevalent one in Colombia, which was followed by the races II-1, IB-7, IA-1 and IB-38 in the proposed international race number by IRRI. Of these, the race II-1 showed pathogenic reactions to Aichiasahi and Bluebonnet 50, which were used as supplemental varieties in contrast with the isolates quoted in previous papers which were suspected as cultural variants or other species of Pyricularia. On the other hand, the races with a distinct pathogenicity to Zenith were collected from most of this area, namely U. S. A., Mexico, El Salvador, Nicaragua, Costa Rica, Colombia, Venezuela and Brazil, and the wider distribution of these kinds of races could be shown to be characteristic of this area. Zenith and Gulfrose are cultivated in this area.

Among areas not included in the above, isolates from Hong Kong did not show different patterns to Philippine isolates but did show distinct pathogenicity to Dular, which is nonpathogenic to almost all the Philippine races. It is suspected that the isolates from Hong Kong indicate characteristics of isolates of mainland China, especially southern China, because their pathogenicity differs from those of neighboring countries such as Taiwan, the Philippines and Vietnam.

Isolates from Guinea in West Africa were similar to Indian races and showed a wider spectrum of reaction on the differential varieties. However, it would be better to omit them from the grouping, because tested isolates were few, and no further information is available on the races of this area.

Isolates from Hungary, Egypt and Australia showed only narrower spectrums of reaction on the differential varieties, and tested isolates were too few to group them into areas.

II. Predominant races in several countries

Research on predominant or common races of the fungus suggests the global distribution of the races. Predominant races in a certain country can be presumed from the existing data, though the data do not always aim at systematic sampling to know the actual distribution of the races.

The frequency of races differentiated in Japan in 1961 (Table 2) did not result from systematic sampling during the year-long study throughout the country. Japanese race N-2 was the most prevalent race, followed by race N-1. Because the full-scale breakdown of resistance of so-called Chinese type varieties started two or three years later, C-1 and C-2 were collected in only limited areas in 1961.

Results of last year's isolates (Table 2) were insufficient because data of four prefectural experimental stations were simply accumulated without any statistical consideration. Considerable numbers of N-2 and N-1 were collected throughout other countries, though there was some increase or decrease in limited areas. C-8 increased strikingly in number and over a large area from one isolate in 1961 to 220 in 1970, while none of C-2 was collected; C-1 still had considerable numbers but did not show as wide distributions as C-8. The increase of C group races can be explained by the increase in cultivation of the varieties which were originated from so-called Chinese type varieties, though there is inadequate explanation for the striking increase of C-8, which overwhelms other races. It is interesting that predominant races in T, C, and N groups, which are T-2, C-8, and N-2, respectively, show the same reaction on the N-group differentials in Japanese differential varieties compared with those of other races.

M. Yamada, who studied systematic sampling of the pathogenic races of the fungus, pointed out the pathogenic strength of C-8 as the reason for dominating other races. Though inexact, "pathogenic strength" means aggressiveness or horizontal pathogenicity, which is quantitative as well as horizontal resistance.

As the composition of pathogenic races in Japan is simpler than those in other countries such as the Philippines, a relationship between the predominant races and the races which were derived from them appears clearer in Japan than the other countries. From the viewpoint of the pathogenic gene, serial changing of the major races in Japan might be explained as follows:

N-2, which corresponds to international race IH-1, turns into N-1 by obtaining pathogenic gene from Ishikarishiroke, which is named $Av\text{-}i^{+}$ by Kiyosawa, and those two races, N-2 and N-1, turn into C-8 and C-1 respectively by obtaining pathogenic gene, $Av\text{-}k^{+}$, from Kanto 51.

Table 3 shows the unpublished results of my work in Ceylon from 1967 to 1969. In addition to the set of international differential varieties, seven important varieties in Ceylon at the time were tested as supplemental varieties, which divided the international races into subraces.

From the result, the races corresponding to international races IE-1, ID-13 and IC-17, occupied major parts of Ceylonese races. Among them there seems to be serial passages of changing from one subrace to another by the addition of pathogenicity to a certain variety. For example, IE-1 group appears to be varied from subrace No. 26 to No. 22 one after another by the addition of pathogenicity to Aichiasahi, Podiwee a-8, H-4, and IR-8-68, successively. IE-1 and IC-17 seem predominant races because of their frequencies. However, ID-13 is still doubtful, because it did not include the subrace pathogenic to H-4, which at that time was the most widely distributed variety.

Table 4 shows the results of the race differentiation in India by S. Y. Padmanabhan et al. IC-17 was the most predominant race and IE-1 also showed a larger frequency in Ceylon. On the other hand, ID-1 and IA-number races which were infrequent in Ceylon were commonly distributed in India. Of these, most of the IA-number races from India showed pathogenicity to Dular and Kanto 51, while Philippine IA-number races are mostly nonpathogenic to both varieties. Generally speaking, India and Ceylon can be included in the same race composition group (pages 1-5), and the predominant races of both countries also can be the same or close to each other.

Table 5 was taken from the Annual Report of the International Rice Research Institute 1967, from which races possessing less than four isolates were omitted. IA-group races, especially IA-109, which adds the pathogenicity of Raminad Str. 3 to ID-13, occupied greater parts of the isolates tested. In the same report, the results of differentiation of Philippine races by Philippine differentials, together with the number of isolates, were also reported. It was impossible from the data of the Annual Report to directly relate international races to Philippine races, because corresponding tables were not available. Among the Philippine races, P 8, P 15, P 12, and P 30, respectively, showed larger frequencies and they were presumed to be derived from IA-109 or adjacent races from their reaction to Philippine differentials. From those results, IA-109 instead of ID-13 could be a predominant race. Unfortunately, the annual reports of following years at IRRI did not give cumulative numbers of isolates of reported races but only the number of isolates of new races in 1968 and the reaction patterns of newly discovered Philippine races. Therefore, the changing trend in frequencies of races could not be obtained although increases of races pathogenic to so-called Chinese varieties could be known.

Discussion

With the advance of the differentiation study of the races, many new races which were started with a limited numbers of specimens have been discovered in many countries. But in general view of geographical distribution of the races and their predominant race might not be influenced that much. If this is so, the following hypothesis arises: The actual process of obtaining pathogenicity from a new variety or a new resistant gene is still unknown. But it is presumed that a new pathogenic race to a new variety or a new resistant gene occurs from the predominant race at a certain place in that time. For instance, in Japan, the occurrences of C-3, C-8, T-2 and also races pathogenic to Fukunishiki, which has a resistant gene from Zenith, could be good examples of this case; and in Ceylon the races pathogenic to H-4 and IR-8-68 also could be presumed to be derived from predominant races at the time. Considering this hypothesis, it would be interesting to know the predominant races of a certain place by using differential varieties which include several indigenous varieties, and to check the race of the varieties on which it is desirable to have a special resistant gene grown in blast nurseries in all important rice-growing areas throughout the world.

The race of blast fungus corresponding to "race 0" of *Phytophthora infestants* has not yet been discovered, i.e., there may be no rice variety to be susceptible to all the isolates of *Pyricularia oryzae* in terms of vertical resistance. Caloro, Usen, P. Perumal and some other varieties showed susceptibility to the all isolates obtained from a certain country, but they still might not be susceptible to the all of those from other countries. In this regard, a special affinity of the predominant or common races in a certain place to the variety which is indigenous or widely cultivated in the same place could be one of the reasons. In this, evaluation of the resistance of the variety to the blast fungus should be stressed, especially where the variety which aims to be widely applied at every place has the possibility of being cultivated.

Table 1. Geographic distribution of the representative races of rice blast fungus

Variety	Reaction of races																			
	a[2]	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
Zenith																		+	+	+
Rexoro	+	+				+	+	+				+	+	+	+	+	+	+	+	+
Lacrosse	+	+	+			+	+	+	+	+	+		+	+	+	+			+	+
Caloro	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+		+	+
Sha-tiao-tsao P	+	+		+		+	+	+	+	+			+	+	+	+	+		+	+
Sha-tiao-tsao S	+	+		+		+	+	+	+	+		+	+	+	+	+	+	+	+	+
C.I. 5309	+												+	+	+	+			+	+
Dular	+												+	+	+	+	+	+	+	+
NP-125																+	+		+	+
Raminad Str. 3							+			+										
Wag-wag							+			+							+			
Taichung 65	+		+	+	+	+	+							+	+	+	+		+	+
Tetep																			±	
Tadukan																			±	
Usen						+	+	+	+	+	+	+	+	+				+	+	+
Chokoto	+												+	+	+	+			+	
Yakeiko	+												+	+	+	+	+		+	?
Kanto 51	+												+	+	+	+	+		+	?
Ishikari-shiroke	+	+		+		+	+	+					+	+	+	+	+		+	+
Homare-nishiki	+	+	+															±	+	
Ginga	+	+	+	+	+													+	+	±
Norin 22	+	+	+	+	+													+	+	±
Aichi-asahi	+	+	+			+	+	+	+	+	+	+	+	+	+	+		+	+	+
Norin 20	+	+	+	+	+													+	+	+
Japan	x[1]	x	x	x	x															
Korea		x	x	x																
Taiwan		x		x	x	x	x													
Philippines						x	x					x								
Vietnam							x	x	x	x	x									
Thailand						x			x	x	x									
Cambodia						x								x						
Indonesia						x		x				x	x	x		x				
India													x		x	x	x			
West Pakistan																	x			
Ceylon							x								x		x			
U.S.A.																		x	x	
Brazil																				x

1) existence of race

2)

Reaction	Name of races	Reaction	Name of races	Reaction	Name of races
a	Japan C-1	h	ID- 13 (JU-2)	o	IE- 1 (JU-2)
b	Japan N-1	i	ID- 13 (JU-3)	p	IC- 17 (JU-2)
c	Japan N-2	j	IA-109 (JU-2)	q	IC- 17 (JU-1)
d	IG- 1 (JU-3)	k	ID- 15 (JU-1)	r	IB- 54
e	IH- 1 (JU-1)	l	ID- 14 (JU-1)	s	IB- 33
f	ID- 13 (JU-1)	m	ID- 1 (JU-1)	t	IB- ?
g	IA-109 (JU-1)	n	ID- 1 (JU-3)		

International race numbers are based on the proposed number by IRRI.

Table 2. Japanese races of rice blast fungus

	Group T			Group C									Group N					
	1	2	3	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6
Variety																		
Te-tep	±																	
Tadukan	±	±																
Usen	+	+	+															
Chokoto	+			+	±		+		+		+							
Yakeiko	+			+	±	+		+		+	+	+						
Kanto 51	+			+	+	+	+	+	+	+	+	+						
Ishikarishiroke	+		+	+	+		+	+	+			+	+				+	+
Homarenishiki	+	+	+	+	+		+	+		+	+		+	+				
Ginga	+	+	+	+	+	+	+	+		+	+	+	+	+		+	+	
Norin 22	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Aichiasahi	+	+	+	+	+		+	+	+	+	+		+	+	+			+
Norin 20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
No. of isolates* in 1961	1	1	3	52	30	0	1	1	9	10	1	2	51	113	6	14	3	6
No. of isolates** in 1970	0	33	0	129	0	17	0	0	0	0	220	0	137	220	20	2	3	0
International Race Group	IC 1	ID 15	ID 13	IE 1 or IF 1	IE 1	IF 3	IE 1	IE 1	IE 1	IF 3	IF 3	IF 1 ?	IG 1	IH 1	IH 1	IH 1	IG 1	?

International race numbers are based on the proposed number by IRRI.
(* Goto, K. et al. 1964, ** Aichi, Hokkaido, Nagano, and Ooita Agr.Exp. Sta. 1971)

Table 3. Pathogenic races of rice blast fungus in Ceylon (1967-1969)

Subrace / variety	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	0
1. Raminad str. 3	+	+																										
2. Zenith			±													±												
3. NP-125	+	+	+	+	+	+	+	+	+	+	+	+	+															
4. Usen			+	+	+									+	+	+	+	+	+	+	+							
5. Dular	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+							+	+	+	+	+		
6. Kanto 51	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+							+	+	+	+	+		
7. Sha-tiao-tsao S	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+	+	+	+	+	+	
8. Caloro	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+		+		+	+	+	+	+	+	
9. M-302			+	+		+																						
10. IR-8-68			±				+	+						+								+						
11. H-4	+		+	+		+	+		+					+								+	+					
12. Ptb 16			+	+	+											+	+		+									
13. Podiwee a-8	+		+	+	+	+	+	+	+	+				+	+	+	+		+			+	+	+				
14. Aichiasahi	+	+	+	+	+	+	+	+	+	+	+			+	+	+	+	+	+	+	+	+	+	+	+		+	
15. P.Perumal	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
International race:	A 81	A 81	C 1	C 1	C 1	C 17	C 17	C 17	C 17	C 17	C 17	C 17	C 18	D 1	D 1	D 13?	D 13	D 13	D 14	D 15	D 16	E 1	E 1	E 1	E 1	E 1	G 1	
Number of isolates:	3	1	1	3	2	2	10	2	26	14	11	35	7	1	5	2	23	6	7	2	2	10	16	18	4	13	4	21

International race numbers are based on the proposed number by IRRI.

Table 4. Reaction of international rice differentials to pathogenic races of *Pyricularia oryzae* in India

International race group	International race	Reaction per differential variety: Ramiraad Str. 3	Zenith	NP 125	Usen	Dular	Kanto 51	C.I. 8970 (S)	Caloro	No. isolates
IA	1* (97)**	+			+	+	+	+	+	3
	4 (113)	+				+	+	+	+	5
	5 (101)	+			+	+		+	+	1
	6 (65)	+		+	+	+	+	+	+	3
	7 (114)	+				+	+	+		2
	8 (116)	+				+	+			1
	9 (122)	+					+	+		1
	10 (121)	+					+	+	+	1
	11 (81)	+		+		+	+	+	+	13
IC	1 (1)			+	+	+	+	+	+	12
	3 (17)			+		+	+	+	+	31
	4 (19)			+		+	+		+	1
	6 (18)			+		+	+	+		3
	7 (20)			+		+	+			1
	8 (24)			+		+				1
ID	1 (1)				+	+	+	+	+	19
	3 (5)				+	+		+	+	1
	10 (15)				+				+	1
	12 (2)				+	+	+	+		1
IE	1 (1)					+	+	+	+	13
	2 (3)					+	+		+	1
	3 (6)					+		+		1
	4 (4)					+	+			3
	5 (2)					+	+	+		1
	6 (5)					+		+	+	1
	7 (2)					+	+	+		1
	8 (8)					+				1
IF	1 (1)						+	+	+	5
	3 (2)						+	+		2
	4 (4)						+			1
IJ(II)**	1 (1)									1

blank: resistant
+ : susceptible
* : International race number in original paper
** : International race number proposed by IRRI.
(S.Y. Padmanabhan *et al.* 1970)

Table 5. Races of *Pyricularia oryzae* in the Philippines in international numbers (1967)

	International race No.												
variety	IA-45	IA-46	IA-65	IA-109	IA-110	IA-111	IA-112	IA-126	IB-45	IC-1a	ID-13	ID-14	ID-16
Raminad str. 3	+	+	+	+	+	+	+	+					
Zenith	+	+							+				
NP 125			+							+			
Usen	+	+	+	+	+	+	+		+	+	+	+	+
Dular			+							+			
Kanto 51			+							+			
Sha-tiao-tsao S	+	+	+	+	+			+	+	+	+	+	
Caloro	+		+	+		+			+	+	+		
No. of isolates	28	28	25	230	81	8	29	5	6	14	21	7	6

(from IRRI Annual Report 1967)

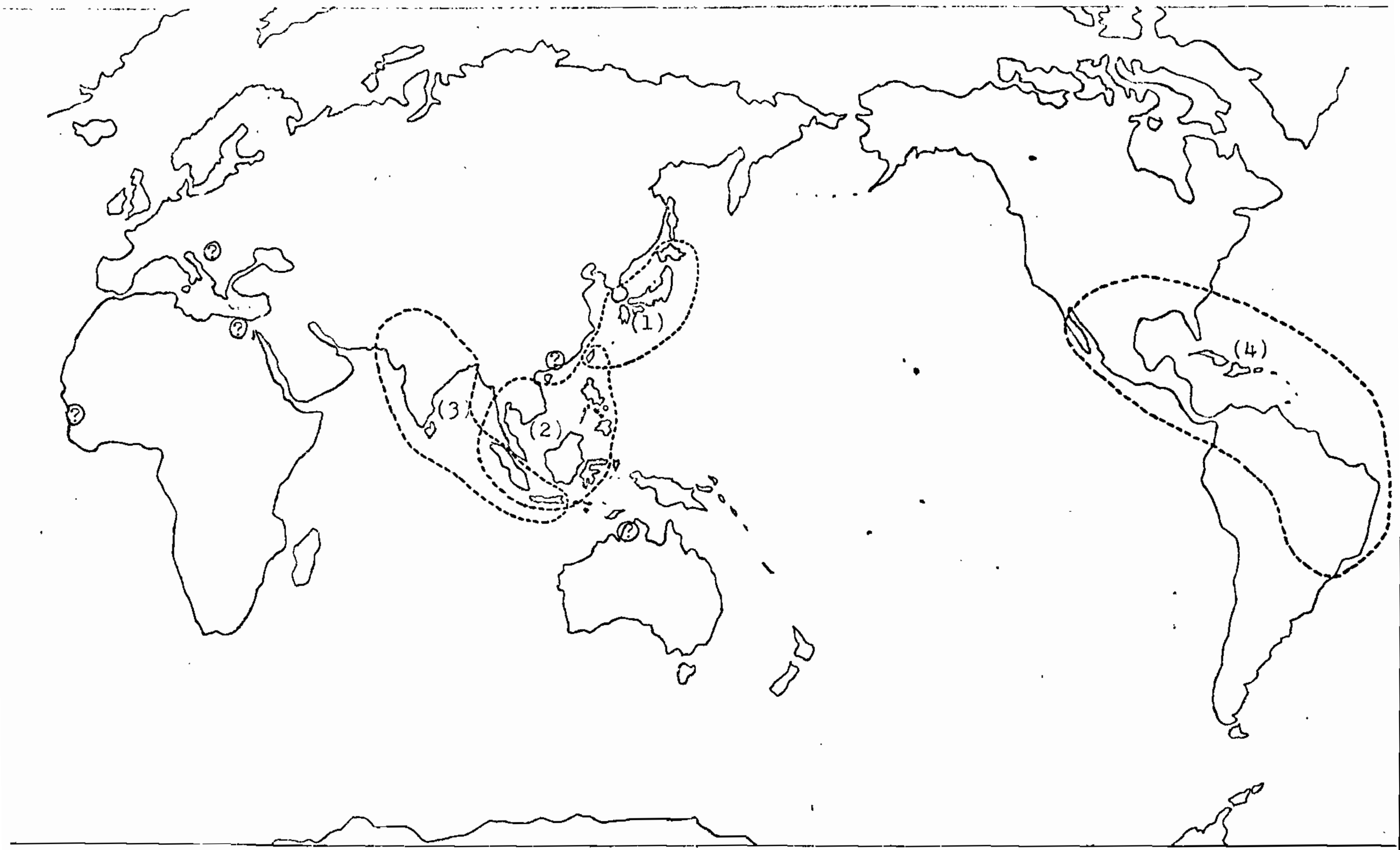

Fig. 1. Geographical grouping of pathogenic races of *Pyricularia oryzae*

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