Comparative Studies on two Rice Fungi: the Foot-Rot-Fungus in India and the "Bakanae"-Fungus in Japan.

By

Yosikazu Nisikado, Hiroyoshi Matsumoto and Kiyû Yamauti.(92)

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I. Introduction.

Specimens of rice seedlings attacked by the so-called foot-rot disease and two test-tube cultures of a Fusarium, the causal fungus of the said disease, were sent by A. S. SUNDARARAMAN, the Government Mycologist of India, to the Director of the Bureau of Agriculture, Department of Agriculture and Forestry, Japan. He asked the Director to have the fungus compared with the causal fungus of the rice "bakanae" disease in Japan. According to the request of the Bureau, the writers carried out comparative studies of both fungi, the "bakanae"-fungus in Japan and the foot-rot-fungus in India.

The Indian foot-rot disease of rice seedlings was first described by K. M. THOMAS (1931) from Godavari Delta and then in other parts of the Madras Presidency. The more important features of the disease described by him (THOMAS 1931, 1933) are here given.

When the seedlings are attacked in the nursery they grow pale and thin and die either before or after transplantation. In a mature crop the most characteristic external symptom is the sporadic appearance of tall, lanky tillers which came into shot blade before the rest of the crop and bear pale green flags shooting up con-

spicuously above the general level. The abnormal elongation of infected tillers appears to be due to an accelerated growth at the expense of lateral development and a premature effort at reproduction on the part of the plant. Such plants are invariably attacked at the collar region and die within two to six days. Another symptom of the disease is the development of adventitious roots from the first, second, and sometimes the third node above the ground level. Some affected plants show externally a white or pink bloom of fungus growth at the lowest one or two nodes, this feature often being conspicuous on the dead sheaths. Eventually this growth develops into a pink incrustation consisting of a thick matting of mycelium bearing innumerable conidia. When pulled out the dead plants snap off at the collar. Further, an abnormally profuse branching of the main roots was seen on well-established plants affected with the trouble, a feature which, together with the production of adventitious roots from the upper nodes of infected fully grown plants, and complete failure of transplanted infected seedlings to recover, seems to distinguish this disease from the Japanese "bakanae" disease, with which it has many features in common.

The comparative studies of the present writers on the two rice fungi, the foot-rot-fungus in India and the "bakanae"-fungus in Japan, showed that the both are one and the same fungus. The results are here given in some length.

II. Fungus Cultures Studied.

The fungus cultures used in the present study were the following four strains of the Japanese "bakanae"-fungus, and two strains of the causal fungus of the Indian foot-rot disease of rice seedlings sent by SUNDARARAMAN. The "bakanae"-fungus tested, had been already proved to have strong pathogenecity by the writers' previous investigations (NISIKADO etc., 1933).

Strain No. 791. This is a strain of the Fusarium, causing foot-rot in rice seedlings. It was collected and isolated by K. M. THOMAS in Madras, India, and sent to Japan for identification.

Strain No. 792. Another strain of the same Fusarium, sent by SUNDARARAMAN. It is similar to the above strain, morphologically as well as physiologically.

Strain No. 414. *Gibberella Fujikuroi* (SAW.) WR., the causal fungus of the "bakanae" disease in rice seedlings in Japan. The strain was isolated by K. SAWADA in Formosa. It is an authentic culture of the "bakanae"-fungus of rice seedlings.

Strain No. 484. *G. Fujikuroi*, isolated by K. KUWADUKA from a diseased rice plant, collected in Sinkawa-mati, Hekikai-gun, Aiti Prefecture.

Strain No. 487. *G. Fujikuroi*, isolated by K. KUWADUKA from diseased rice straw, collected in Mutumi-mura, Hekikai-gun, Aiti Prefecture.

Strain No. 624. *G. Fujikuroi*, isolated by R. TAKAHASI in June 1933 from diseased rice straw, collected in Ooita Prefecture.

III. Characteristics on Culture Media.

For the comparison of the cultural characteristics, the fungus cultures from Japanese and Indian sources were grown on asparagin agar (distilled water 1,000 cc., potassium acid phosphate, second., 5 g., asparagin 2.5 g., magnesium sulphate 2 g., saccharose 10 g. and agar 20 g.), HOPKIN's agar (distilled water 1,000 cc., potassium nitrate 2 g., magnesium sulphate 0.5 g., potassium acid phosphate, prim., 0.1g., glucose 10 g. and agar 20 g.), RICHARD's agar (distilled water 1,000 cc., potassium nitrate 10 g., potassium acid phosphate, prim., 5 g., magnesium sulphate 2.5 g., saccharose 20 g. and agar 20 g.) and onion soja agar (concentrated onion decoction 100 cc., soja 50 cc., saccharose 50 g., water 850 cc. and agar 20 g). The diameter of the colonies was measured after 3, 5, 7 and 9 days' incubation respectively. The formation of aerial mycelium and micro- and macroconidium was recorded with together the color of the colonies. All the data secured in this experiment are summarized in tabular form and given in Tables I—III.

Table I.

Comparison in the Mycelial Growth of the Foot-Rot-Fungus of Rice in India and the "Bakanae"-Fungus in Japan.

Temperatures tested: 20°, 25° and 30°C.
Strains tested: Nos. 414 and 624 (Japanese fungus) and Nos. 791 and 792 (Indian fungus).

Fungus strains tested	Growth at 20°C.				Growth at 25°C.				Growth at 30°C.			
	Diameter of colonies after		Margin of colonies*	Formation of aerial mycelium**	Diameter of colonies after		Margin of colonies*	Formation of aerial mycelium**	Diameter of colonies after		Margin of colonies*	Formation of aerial mycelium**
	3 days	7 days			3 days	7 days			3 days	7 days		
Asparagin agar												
	mm.	mm.			mm.	mm.			mm.	mm.		
No. 414	17.5	47.2	Cr	+	26.5	66.5	Ctr	++	24.7	61.0	Ci	++
624	14.8	36.0	Ctr	+	21.0	46.6	Ctr	++	20.8	48.8	Cr	++
791	14.3	42.2	Ctr	+	22.0	65.6	Ctr	++	20.5	55.0	Cti	++
792	13.2	44.8	Ctr	+	23.0	64.8	Ctr	++	20.0	55.8	Cti	++
HOPKIN's agar												
	mm.	mm.			mm.	mm.			mm.	mm.		
No. 414	17.7	47.3	Cr	++	26.5	64.4	Crr	++	25.5	62.7	Crr	++
624	12.7	40.0	Ctr	+	24.2	59.2	Cr	++	22.3	47.5	Crr	++
791	12.5	43.0	Ctr	+	20.3	63.5	Ctr	++	20.2	53.8	Ctr	++
792	13.0	43.3	Ctr	+	21.5	62.0	Ctr	++	25.0	67.5	Ctr	++

(Continued to the next page.)

Table I. (Continued.)

Fungus strains tested	Growth at 20°C.				Growth at 25°C.				Growth at 30°C.			
	Diameter of colonies after		Margin of colonies*	Formation of aerial mycelium**	Diameter of colonies after		Margin of colonies*	Formation of aerial mycelium**	Diameter of colonies after		Margin of colonies*	Formation of aerial mycelium**
	3 days	7 days			3 days	7 days			3 days	7 days		
Richard's agar												
No. 414	mm. 14.7	mm. 48.8	Ctr	+	mm. 25.0	mm. 69.3	Crr	|||	mm. 26.7	mm. 70.0	Crr	|||
624	9.7	33.4	Ctr	±	18.0	51.3	Ctr	++	19.8	35.0	Ci	−
791	8.8	36.5	Ctr	+	15.7	52.8	Ctr	++	17.0	/	Ctr	+
792	9.5	35.2	Ctr	+	16.8	48.3	Ctr	++	17.7	41.0	Ctr	+
Onion Soja agar												
No. 414	mm. 17.3	mm. 50.3	Ctr	++	mm. 29.2	mm 78.5	Ctr	|||	mm. 32.8	mm. /	Ctr	|||
624	14.7	37.5	Ctr	+	23.2	49.3	Ctr	++	29.8	64.2	Ctr	++
791	15.0	44.8	Ctr	+	23.5	65.3	Ctr	++	28.8	73.3	Ctr	++
792	14.0	42.8	Ctr	+	23.3	66.8	Ctr	++	25.3	72.3	Ctr	++

Remarks: The temperature in the incubators used vibrated in the following range: 19—20°C. for the 20°C. and 29—30°C. for the 30°C.

* In this column R means that the margin of the colonies is of regular circle, I irregular, T thin and C compact. Ri or Ct means it is the transition of the both.

** The plus signs show the formation of the aerial mycelium, and minus sign no formation. The more the plus signs the better the formation.

Table II.

Comparison in the Conidium Formation of the Foot-Rot-Fungus of Rice in India and the "Bakanae"-Fungus in Japan.

Conidium formation after 9 days' culture.

Culture media	Fungus strains tested	20°C.				25°C.				30°C.			
		Micro-conidia	Macroconidia			Micro-conidia	Macroconidia			Micro-conidia	Macroconidia		
			1-sept.	3-sept.	5-sept.		1-sept.	3-sept.	5-sept.		1-sept.	3-sept.	5-sept.
Asparagin agar	No. 414	++	+	−	−	++	+	−	−	++	+	−	−
	624	+	++	++	−	+	+++	+++	++	+	+	+	−
	791	+	++	−	−	++	+++	++	−	+	++	+	
	792	+	++	+		++	+	+		+	+	−	−
Hopkin's agar	No. 414	−	−	−	−	+	−	−	−	+	−	−	−
	624	+	+	+	−	+	+	−	−	−	−	−	−
	791	+	++	++	−	++	+++	++	−	++	++	+	−
	792	−	++	+	−	++	++	++	−	+++	+	−	−

Table II. (Continued.)

Culture media	Fungus strains tested	20°C.				25°C.				30°C.			
		Micro-conidia	Macroconidia			Micro-conidia	Macroconidia			Micro-conidia	Macroconidia		
			1-sept.	3-sept.	5-sept.		1-sept.	3-sept.	5-sept.		1-sept.	3-sept.	5-sept.
Richard's agar	No. 414	−	−	−	−	−	−	−	−	−	−	−	−
	624	−	−	−	−	−	−	−	−	−	−	−	−
	791	+	+	−	−	+	+	−	−	+	−	−	−
	792	−	+	−	−	−	+	−	−	−	+	−	−
Onion Soja agar	No. 414	+	−	−	−	++	−	−	−	++	−	−	−
	624	+	−	−	−	++	−	−	−	++	−	−	−
	791	+	−	−	−	+++	−	−	−	+++	−	−	−
	792	+	−	−	−	++	−	−	−	+++	−	−	−

Remarks: In this table the plus signs mean the formation of the conidia and minus sign no formation. The more the plus signs the better formation.

Table III.

Comparison in the Coloration of the Foot-Rot-Fungus of Rice in India and the "Bakanae"-Fungus in Japan.

Temperatures tested: 20°, 25° and 30°C.
Strains tested: Nos. 414 and 624 (Japanese)
Nos. 791 and 792 (Indian).

Fungus strains tested	20°C.		25°C.		30°C.	
	Color name	Degree	Color name	Degree	Color name	Degree
Asparagin agar						
No. 414	13‴d Light vinaceous-fawn	+	17″d Pinkish buff	+	13‴f Pale vinaceous-fawn	+
624	Almost colorless	±	13‴f Pale vinaceous-fawn	+	Almost colorless	±
791	9″f Pale vinaceous-pink	+	9″d Vinaceous-pink	++	9″f Pale vinaceous-pink	+
792	9‴d Light grayish vinaceous	+	9‴f Pale grayish vinaceous	++	9‴f Pale grayish vinaceous	++
Hopkin's agar						
No. 414	Almost colorless	±	Almost colorless	±	Almost colorless	±
624	"	±	17″f Pale pinkish buff	±	"	±
791	15″f Pale pinkish cinnamon	++	15″d Light pinkish cinnamon	+++	15″f Pale pinkish cinnamon	++
792	15″f Pale pinkish cinnamon	++	15″f Pale pinkish cinnamon	++	15″f Pale pinkish cinnamon	++
Richard's agar						
No. 414	17″d Pinkish buff	++	19″f Chamois	++	17″d Pinkish buff	++
624	Almost colorless	±	19″ Honey yellow	+	19″ Honey yellow	++
791	9″f Pale vinaceous-pink	++	9″f Japan rose	+++	9″f Japan rose	+
792	11″d Buff-pink	++	11″d Buff-pink	+++	11″d Buff-pink	+++

Remarks: The color names in this table are given after Ridgway's Color Standard and Color Nomenclature.
In the column of degree the number of the plus signs mean breadth of the colored parts of the colonies.

With many more strains of the fungi, the second experiment was carried out. Currie's agar (distilled water 1,000 cc., ammonium nitrate 2.5 g., potassium acid phosphate, prim., 1 g., magnesium sulphate 0.25 g. and agar 20 g.) malt-extract agar (tap water 1,000 cc., malt-extract 30 g. and agar 20 g.), rice-straw-decoction agar (tap water 1,000 cc., rice straw 100 g. (decocted) and agar 20 g.), steamed rice, steamed ears of wheat, steamed rind of water-melon etc. were used for the culture study. Diameter of the colonies, formation of aerial mycelium and macro- and microconidium, shape of the colonies and color of the mycelium and the medium after 7 days' culture at 30°C. are given in Table IV.

Table IV.

Comparison in the Cultural Characteristics of the Foot-Rot-Fungus of Rice in India and the "Bakanae"-Fungus in Japan.

Growth after one week's culture at 30°C.

Culture media	Strains tested	Diameter of colonies	Aerial mycelium	Margin of colonies	Coloration of colonies				Formation of	
					Mycelium	Degree	Medium	Degree	Macroconidia	Microconidia
Potato-dextrose agar	414	79.3	++++	Rcc	Light loberia violet	++	Slate purple	++	+	++++
	484	69.3	++++	Ricc	"	++	"	++++	++	++++
	487	55.3	++++	Rcc	Pale loberia violet	+	"	+	++	++++
	624	44.3	++++	Icc	"	++	"	+	+	++++
	791	75.5	++++	Rc	Light pinkish lilac	++++	Vinaceous lavender	++++	++	++++
	792	77.5	++++	Rc	"	++++	"	++++	++	++++
Currie's agar	414	56.2	++++	Ricc	Pinard yellow	++	Cadmium orange	++++	+	+
	484	39.2	++++	Rcc	Rose pink	++	Grenadine red	++++	+	+
	487	39.8	++++	Rcc	Light ochraceous salmon	++++	"	++++	+	+
	624	37.8	++++	Icc	Rose pink	++	Cadmium orange	++++	+	+
	791	44.0	++++	Ricc	White		Capucine buff	+	++	++++
	792	45.0	++++	Rcc	"		Pale orange yellow	++++	++	++++
Malt-extract agar	414	57.0	—	Rtt	Colorless		Colorless		+	++
	484	45.0	—	Rtt	"		"		++	++
	487	44.8	—	Rtt	"		"		++	++
	624	48.5	—	Rtt	"		"		++++	++++
	791	45.5	—	Ritt	"		"		++	++++
	792	45.5	—	Ritt	"		"		++	++++
Rice-straw-decoction agar	414	65.0	+	Rct	Colorless		Colorless		+	++
	484	52.8	+	Rct	"		"		+	++
	487	55.8	+	Rct	"		"		+	++++
	624	52.7	—	Rct	"		"		+	++++
	791	64.8	—	Rt	"		"		++	++++
	792	67.8	—	Rt	"		"		++	++++
Steamed rice	414		++++		Vinaceous lilac		Deep purplish vinaceous	++	—	+
	484		++++		Deep purplish vinaceous		Dull Indian purple	++	—	+
	487		++++		Pinkish cinnamon		Cinnamon buff	++	—	+
	624		++		Vinaceous cinnamon		Orange cinnamon	++	—	++++
	791		++		Light perilla purple		Perilla purple	++++	—	++++
	792		+		Hellebore red		Deep hellebore red	++	—	++++

Table IV. (Continued.)

Culture media	Strains tested	Diameter of colonies	Aerial mycelium	Margin of colonies	Coloration of colonies				Formation of	
					Mycelium	Degree	Medium	Degree	Macro-conidia	Micro-conidia
Steamed wheat	414	###	###		Colorless				###	###
	484	###	###		Dull Indian purple	###			###	++
	487	####	###		Colorless				+	++
	624	####	++		"				###	###
	630	####	###		"				+	++
	657	####	++		"				+	++
	791	++	+		"				+	S ####
	792	++	+		"				+	S ####
Steamed potato	414	###	###		Colorless				+	###
	484	###	++		Dull Indian purple	###			++	###
	487	####	###		Colorless				+	++
	624	####	###		Cameo pink	+			+	####
	630	####	####		Pale vinaceous	+			+	++
	657	####	####		"	+			+	###
	791	++	+		Flesh color	+			+	P ####
	792	++	+		"	++			+	P ####
Steamed water-melon	414	###	###		Colorless				+	++
	484	###	###		"				++	###
	487	####	###		"				+	++
	624	####	###		"				+	####
	630	####	####		Pale vinaceous	+			+	++
	657	####	####		"	+			+	###
	791	++	+		Colorless				###	P ####
	792	++	+		"				###	P ####

Remarks: In the columns of the formation of the aerial mycelium and macro- and microconidium, the plus signs mean the formation and the minus sign no formation. The more the plus signs the better the growth. P means that the conidium formation is pionnotal, and S sporodochial. The color names are given after RIDGWAY's Color Standard. The Number of the plus signs in the column of coloration means the breadth of the colored parts.

From the results given in the foregoing four tables, the cultural characteristics of the Japanese and Indian fungi are summarized as follows:

In the radial growth of the colonies on agar media, for instance, asparagin agar, HOPKIN's agar, RICHARD's agar, CURRIE's agar, potato-glucose agar, malt-extract agar, rice-straw-decoction agar and onion soja agar, the Formosan strain (No. 414) of the "bakanae"-fungus was the best among the strains tested. The

two Indian strains were next and the other Japanese strains, No. 484 and 487 from Aiti Prefecture and No. 624 from Ooita Prefecture, were smaller than these as regards the size of the colonies.

The formation of aerial mycelium on malt-extract agar or rice-straw-decoction agar was poor in all the strains tested. On those media like potato-glucose agar, CURRIE's agar, steamed rice, steamed wheat, steamed potato, steamed rind of water-melon, the formation of the aerial mycelium was poorer in the Indian strains, No. 791 and No. 792 than in the Japanese strains. Especially in the strains, No. 414, No. 487 and No. 630, the formation was rich.

The shape of the colonies grown on agar media, was more regular in the Indian strains than in the Japanese strains, and the margins of the colonies of the former were thinner than those of the latter.

The microconidium formation was observed on almost all the culture media used, in the Japanese as well as in the Indian strains; but the formation in the Indian strains was more copious; the surface of the media seemed frequently to be covered with white powder. The macroconidium formation of the Japanese and the Indian strains on steamed potato and steamed water-melon was pretty rich and sometimes pionnotal. The pionnotes on steamed potato were flesh color (after RIDGWAY). On steamed wheat ear, sporodochial conidium formation was frequently observed.

On steamed wheat ears, steamed potatoes, and steamed rind of water-melon, neither the Indian nor the Japanese fungi produced any color. On steamed rice, the media and the colonies of the Japanese fungus colored to reddish purple, while those of the Indian fungus were a stronger red. The details of the color name after RIDGWAY are given in Table III and IV.

In short, the Japanese and the Indian fungi showed pretty clear differences in the cultural characteristics, and both fungi might be assumed to be physiologically different. The divergencies in the cultural characteristics of the two fungi were, however, not larger than those between two of the various strains of the Japanese rice-"bakanae"-fungus.

IV. Morphological Characteristics.

As the rice-"bakanae"-fungus belongs to an ascomycete, it may produce perithecia. But the perithecium formation is comparatively rare, while the conidium formation is quite common. Therefore the writers will present the results of their comparative study on the conidium.

In regard to the mycelium and the conidiophore, neither the Indian nor the Japanese fungi showed any remarkable differences. The hyphae are colorless, about 2 μ when young and sometimes they attain to 5 μ. At a distance of 16–60 μ they produce septa, where there is little or no constriction.

The Indian and the Japanese fungi under consideration produce two types of conidia, both of which the writers will here compare.

I) Microconidia.

Both the Japanese and Indian fungi produced microconidia on the tips of the aerial mycelium in long chains, which may be observed by the naked eye as a white powder over the surface of the medium. The microconidium is colorless, continuous, obovate or long obovate, sometimes elliptical or spherical, and contains one or two small light-refrecting bodies. The size of the microconidia developed on steamed rind of water-melon and on steamed ears of wheat are given in Table V.

Table V.

Size of the Microconidia of the Foot-Rot-Fungus of Rice in India and the Rice-"Bakanae"-Fungus in Japan.

Microconidia developed after 2 weeks' culture at 37°C.

Micro-conidium	Fungus strains studied		No. measured	Steamed water-melon		Steamed wheat ears	
				Range	Mean	Range	Mean
Length	No. 791 (Indian)	I	50	6—11 μ	7.98±0.111 μ	6—11 μ	8.12±0.108 μ
		II	50	"	7.82±0.102	5—10	7.74±0.093
		Average	100	"	7.90±0.107	5—11	7.93±0.110
	No. 792 (Indian)	I	50	6—12	8.64±0.119		
		II	50	"	8.42±0.121		
		Average	100	"	8.53±0.120		
	No. 484 (Japanese)	I	50	6—12	9.10±0.127	5—11	7.32±0.121
		II	50	7—12	9.10±0.124	5—9	7.40±0.088
		Average	100	6—12	9.10±0.125	5—11	7.36±0.106
Width	No. 791 (Indian)		100	2—3	2.36±0.022	2.5—4.5	3.31±0.026
	No. 792 (Indian)		100	"	2.44±0.022		
	No. 484 (Japanese)		100	2—3.5	2.44±0.024	2.5—4.5	3.08±0.039

From the figures given in Table V, the differences in the mean size of the conidia of various strains were computed. The results are given in the following table.

(See Table VI on next page.)

According to the above table, the differences of the conidium length as well as the width between two of the various strains studied, were less than 5 times their probable errors, with the one exception of the difference in length between the strains No. 484 and No. 791.

Table VI.

Comparison in Size of the Microconidia between the Foot-Rot-Fungus of Rice in India and the Rice-"Bakanae"-Fungus in Japan.

Microconidia developed after 2 weeks' culture at 30°C.

Micro-conidium	Fungus strains studied	Steamed rind of water-melon		Steamed ears of wheat	
		Difference in mean	Ratio $\frac{M_{diff.}}{E_{diff.}}$	Difference in mean	Ratio $\frac{M_{diff.}}{E_{diff.}}$
Length	791 I ~ II	0.16±0.157	1.03	0.36±0.143	2.52
	792 I ~ II	0.22±0.170	1.30		
	484 I ~ II	0 ±0.178	0	0.08±0.150	0.54
	484 ~ 791	1.21±0.165	7.33	0.38±0.146	2.60
	484 ~ 792	0.57±0.173	3.29		
	791 ~ 792	0.64±0.160	3.96		
Width	791 ~ 792	0.08±0.039	2.59		
	484 ~ 791	0.08±0.032	2.48	0.23±0.046	4.92
	484 ~ 792	0 ±0.032	0		

II) Macroconidia.

The macroconidia are colorless, fusiform or falcate, more or less curved to one side and narrowing near the apex. They are 0-5-septated but 3-septated conidia are common. The premature conidium has a round apex. At the base the conidium has a papillate foot. The size of the macroconidia of both fungi is subject to variation. The writers' measurements of the conidium size of various strains grown on steamed rind of water-melon and on steamed ears of wheat at 30°C. after 2 weeks' culture, are given in Tables VII—IX.

Table VII.

Length of the Macroconidia of the Foot-Rot-Fungus of Rice in India and of the Rice-"Bakanae"-Fungus in Japan. I.

Macroconidia developed after 2 weeks' culture on steamed water-melon at 30°C.

Fungus strains studied		No. measured	1-septated conidia		3-septated conidia	
			Range	Mean	Range	Mean
			μ	μ	μ	μ
No. 791 (Indian)	I	50	20—34	26.72±0.480	32—52	41.18±0.728
	II	50	22—38	27.04±0.493	32—54	41.72±0.622
	Average	100	20—38	26.88±0.487	"	41.45±0.677
No. 792 (Indian)	I	50	20—30	23.60±0.360	30—52	37.92±0.715
	II	50	18—30	24.48±0.346	"	38.58±0.676
	Average	100	"	24.03±0.357	"	38.25±0.697
No. 484 (Japanese)	I	50	20—38	26.36±0.584	34—52	42.16±0.661
	II	50	22—38	27.20±0.483	"	43.70±0.656
	Average	100	20—38	26.78±0.536	"	42.93±0.658

Table VIII.

Length of the Macroconidia of the Foot-Rot-Fungus of Rice in India and the Rice-"Bakanae"-Fungus in Japan. II.

Macroconidia developed after 10 days' culture on steamed wheat ears at 30°C.

Fungus strains studied		No. measured	1-septated conidia		3-septated conidia	
			Range	Mean	Range	Mean
No. 791 (Indian)	I	50	20—32 μ	24.24±0.234 μ	32—60 μ	43.50±0.883 μ
	II	50	„	25.54±0.422	34—50	42.80±0.659
	Average	100	„	24.89±0.340	32—60	43.15±0.515
No. 792 (Indian)	I	50	20—32	24.24±0.340	28—48	33.18±0.741
	II	50	22—32	25.54±0.375	„	32.84±0.563
	Average	100	20—32	24.89±0.358	„	33.01±0.638
No. 484 (Japanese)	I	48	22—34	25.90±0.425	34—66	49.86±0.869
	II	49	„	27.02±0.479	34—70	48.36±0.922
	Average	97	„	26.46±0.452	„	49.11±0.596
No. 414 (Japanese)	I	46	20—36	24.34±0.551	32—56	43.04±0.785
	II	49	„	25.70±0.507	„	42.42±0.776
	Average	95	„	25.02±0.532	„	42.63±0.782

Table IX.

Width of the Macroconidia of the Foot-Rot-Fungus of Rice in India and the Rice-"Bakanae"-Fungus in Japan.

Macroconidia developed after 2 weeks' culture at 30°C.
Measurement of each 100 conidia.

Fungus strains studied		No. of septa	Steamed wheat ears		Steamed water-melon	
			Range	Mean	Range	Mean
No. 791 (Indian)		1-sept.	2.5—3.5 μ	2.98±0.024 μ	2.5—4 μ	3.22±0.028 μ
		3- „	2.5—4	3.05±0.021	3—4	3.08±0.018
No. 792 (Indian)		1- „	2.5—3.5	2.98±0.023	2—3.5	2.84±0.025
		3- „	2.5—4	3.22±0.043	2.5—4	3.10±0.027
No. 484 (Japanese)		1- „	„	2.95±0.023	„	3.09±0.027
		3- „	„	3.01±0.022	3—4	3.19±0.026
No. 414 (Japanese)		1- „	2—3.5	2.88±0.029		
		3- „	2.5—3.5	3.06±0.019		

From the figures given in the above tables (Tables VII—IX) the differences in size of the macroconidia of the two strains were computed. The results are shown in the following table.

Table X.

Comparison in Size of the Macroconidia between the Foot-Rot-Fungus of Rice in India and the Rice-"Bakanae"-Fungus in Japan.

Macroconidia developed after 2 weeks' culture at 30°C.

Macro-conidia	Media used	Fungus strains tested	1-septated conidia		3-septated conidia	
			Difference in mean	Ratio $\frac{M_{diff.}}{E_{diff.}}$	Difference in mean	Ratio $\frac{M_{diff.}}{E_{diff.}}$
Length	Steamed water-melon	791 I ~ II	0.32±0.689	0.05	0.27±0.920	0.29
		792 I ~ II	0.88±1.498	1.77	0.66±0.931	0.70
		484 I ~ II	0.84±0.757	1.11	1.54±0.931	1.57
		791 ~ 792	2.85±0.601	4.74	3.65±0.658	5.31
		791 ~ 484	0.10±0 724	0.14	1.48±0.668	2.23
		792 ~ 484	2 75±0.642	4.28	5.08±0.678	7.49
	Steamed wheat ears	791 I ~ II	1.30±0.483	2.69	0.70±1.098	0.64
		792 I ~ II	1.30±0.507	2.57	0.34±0.910	0.37
		414 I ~ II	1.36±0,754	1.80	0.62±1.105	0.57
		484 I ~ II	1.12±0.642	1.75	1.50±1.265	1.19
		791 ~ 792	0 ±0.494	0	10.14±1.005	10.01
		414 ~ 484	1.44±0.699	2.06	6.48±1.190	5.44
		791 ~ 414	0.13±0.641	2.03	0.52±1.102	0.47
		791 ~ 484	1.57±0.566	2.78	5.96±1.185	5.03
		792 ~ 414	1.57±0.640	2.46	9.62±1.009	9.53
		792 ~ 484	1.57±0.574	2.74	15.10±1.100	13.72
Width	Steamed wheat ears	791 ~ 792	0.05±0.033	1.51	0.18±0.052	3.35
		414 ~ 484	0.08±0.037	2.04	0.05±0.029	1.71
		791 ~ 414	0.10±0.038	2.64	0.02±0.029	0.53
		791 ~ 484	0.03±0.033	0.76	0.04±0.031	1.14
		792 ~ 414	0.11±0.037	2.83	0.16±0.045	3.53
		792 ~ 484	0.03±0.030	0.94	0.21±0.048	4.41
	Steamed water-melon	791 ~ 792	0.24±0.031	7.83	0.12±0.039	3.09
		791 ~ 484	0.01±0.033	0.37	0.04±0.038	0.95
		792 ~ 484	0.25±0.036	6.87	0.09±0.038	2.27

The above figures show that the differences in size of the macroconidium of the Japanese and the Indian fungi are not larger than those between two strains of Japanese fungus or those between two Indian strains.

In short, the two rice fungi, the foot-rot-fungus in India and the "bakanae"-fungus in Japan seem indistinguishable not only in the shape of the macro- and microconidia but also in their size. Therefore the both fungi may be morphologically assumed to be one and the same species.

V. Pathogenecity to the Rice and Corn Seedlings.

For the comparison in the pathogenecity of the rice-"bakanae"-fungus in Japan and the foot-rot-fungus in India, the cultures of both fungi were inoculated to rice and corn seeds. The inoculated seeds were sown in sand in pots. The methods of inoculation and sowing are similar to those given in the writers' previous paper. (NISIKADO 1931, 1932; NISIKADO etc. 1933). The results are here given.

I) Inoculation-Experiment upon Rice Seedlings.

On June 16, 1933, a piece of pure culture of the Japanese "bakanae"-fungus (Strains No. 414 from Formosa, Nos. 484 and 487 from Aiti Prefecture and No. 624 from Ooita Prefecture) and of the Indian foot-rot-fungus (Strains No. 791 and No. 792) were added to several Petri dishes containing sterilized rice grains. The Petri dishes were then shaken to cover the seeds with the conidia. 128 rice-grains, thus inoculated, were sown into four galvanized iron pots (32 grains in each), to which 0.1% KNOP's solution was given. They were then grown in the net-house in the daytime and the glass-house at night. On July 1, 1933, the seedlings were pulled out from the pots for length measurement. The length from the lowest node at the base of a culm to the top of the longest leaf was measured. The lengths of the seedlings thus measured are given in the following table.

(See Table XI on next page.)

Table XI shows that the germination percentage of the rice seeds, inoculated with both the Indian and the Japanese fungi, was smaller than that of the control. However, many abnormally overgrown rice seedlings were found among those from the inoculated seeds. To compare the degree of the abnormal overgrowth of the rice seedlings, the mean length of 10 overgrown seedlings was determined. Then the ratios of the mean length of each of the inoculated ones to that of the control were computed and multiplied by 100. As in the writers' previous paper (NISIKADO etc. 1933), it is provisionally called "Overgrowth index", and is given in the last column of the table. The overgrowth indices of the rice seedlings from the seeds inoculated with the Indian strains Nos. 791 and 792 are 111.4 and 120.9, respectively and in average 116.15; while those inoculated with the Japanese strains, Nos. 414, 484, 487 and No. 624, are 110.9, 111.8, 100.9, 125.9, respectively and in average 112.38. These figures show clearly that the fungus strains studied may cause overgrowth in the rice seedlings.

Table XI.

Results of the Comparative Inoculation-Experiments of Rice Seedlings with the Foot-Rot-Fungus of Rice in India and the Rice-"Bakanae"-Fungus in Japan.

Experiment I.

The rice seeds, variety "Sinriki", were inoculated on June 16, 1933 and sown on the next day. The results were examined on July 1, 1933. Four pots, containing 32 seeds each, were used for each of the strains tested.

Fungus strains tested	Percentage of germination	Classes in length of the seedlings tested (cm.)									Total	Mean length of the seedlings tested	Mean length of 10 overgrown seedlings	Overgrowth index
		1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45				
	%											cm.	cm.	
No. 414	79.7	—	2	19	56	20	5	—			102	18.4	24.4	110.9
484	76.6	—	3	18	41	31	5	—			98	19.0	24.6	111.8
487	66.4	1	1	28	41	12	2	—			85	17.5	22.2	100.9
624	75.8	—	4	15	30	21	27	—			97	20.6	27.7	125.9
791	76.6	—	2	17	26	42	11	—			98	20.4	26.6	120.9
792	87.4	—	1	7	64	37	3	—			112	20.2	24.5	111.4
Control	90.6	—	1	33	62	20	—	—			116	21.5	22.0	100.0

Experiment II.

The rice seeds were inoculated and sown on July 3, 1933, and the results were examined on July 18, 1933. Two pots, containing 32 seeds each, were used for each strain.

	%											cm.	cm.	
No. 414	86.0	—	1	21	30	2	—	—			55	16.2	19.5	108.7
484	87.5	—	1	3	26	21	5	—			56	20.2	24.2	135.5
487	90.6	—	—	2	25	27	4	—			58	21.3	26.6	143.0
624	93.8	—	1	15	35	9	—	—			60	17.5	21.0	117.5
791	89.1	—	3	19	33	2	—	—			57	16.3	19.6	109.4
792	87.5	—	1	4	33	16	2	—			56	19.9	23.5	131.5
Control	92.2	—	—	36	23	—	—	—			59	14.9	17.9	100.0

Experiment III.

The rice seeds were inoculated and sown on July 28, 1933, and the results were examined on August 12, 1933. Two pots were used for each strain.

	%											cm.	cm.	
No. 414	61.0	—	—	1	8	12	10	7	0	1	36	24.8	32.8	171.8
484	73.4	—	—	2	5	9	20	9	2	—	47	29.8	33.6	176.0
487	28.1	—	—	—	4	7	2	3	2	—	18	26.0	30.4	159.2
624	68.7	—	—	—	15	14	12	3	—	—	44	23.6	20.9	156.6
791	76.6	—	—	—	16	17	7	8	1	—	49	24.2	31.1	162.8
792	76.6	—	—	—	7	21	15	5	1	—	49	25.6	31.5	165.0
Control	89.4	—	3	37	17	—	—	—	—	—	57	15.0	19.1	100.0

On July 3, 1933, a similar inoculation-experiment was carried out. The result was examined on July 18, 1933. The rice seedlings grown from control seeds were comparatively short and stout, while those from the seeds inoculated with the Indian and the Japanese strains were slender and yellowish. The result of the length measurement is given in Table XI. The table shows that the overgrowth indices of the rice seedlings, inoculated with the four Japanese strains are 108.9, 135.5, 143.0 and 117.5, respectively, and in average 126.23, while those inoculated with the two Indian strains are 109.4 and 131.5, respectively, and in average 120.5.

Further, the result of the third experiment, which was in progress from July 28 to August 12, 1933, was similar to those of the first and second experiments. The rice seedlings from the inoculated seeds overgrew abnormally.

In short, the rice seedlings from the seeds inoculated with the Japanese rice-"bakanae"-fungus and the Indian foot-rot-fungus show an almost similar abnormal overgrowth.

II) Inoculation-Experiments on Corn Seedlings.

Similar inoculation-experiments were carried out with corn seeds. The result of the first inoculation-experiment on corn seeds, from July 3 to July 11, 1933, is shown in Table XII. The overgrowth indices of the corn seedling inoculated with the four Japanese strains are 123.8, 122.7, 149.6, and 125.3, respectively, and in average 130.6 and those inoculated with the two Indian strains, 150.5 and 122.3 and in average 136.4.

Table XII.

Results of the Comparative Inoculation-Experiments of Corn Seedlings with the Foot-Rot-Fungus of Rice in India and the Rice-"Bakanae"-Fungus in Japan.

Experiment I.

The corn seeds were inoculated and sown on July 3, 1933, and the results were examined on July 11, 1933. For each of the strains tested two pots, each containing 16 seeds, were used.

Fungus strains tested	Percentage of germination	Classes in length of the seedlings tested (cm.)									Total	Mean length of the seedlings tested	Mean length of 10 overgrown seedlings	Overgrowth index
		1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45				
	%											cm.	cm.	
No. 414	90.6	—	—	1	7	7	10	2	1	—	29	24.5	29.7	123.8
484	65.6	—	—	—	1	14	5	1	—	—	21	24.3	29.5	122.7
487	78.2	—	—	—	—	5	6	10	4	—	25	31.2	35.9	149.6
624	96.9	—	—	—	11	7	7	4	1	—	31	24.8	30.9	125.3
791	90.6	—	—	—	—	8	10	6	2	3	29	29.8	36.1	150.5
792	84.4	—	—	—	5	13	7	2	—	—	27	24.2	29.3	122.3
Control	100.0	—	—	—	21	11	—	—	—	—	32	19.8	24.0	100.0

(Continued to the next page.)

Experiment II.

The corn seeds were inoculated and sown on July 11, 1933, and the results were examined on July 18, 1933. For each strain two pots, containing 16 seeds each, were used.

Fungus strains tested	Percentage of germination	Classes in length of the seedlings tested (cm.)									Total	Mean length of the seedlings tested	Mean length of 10 overgrown seedlings	Overgrowth index
		1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45				
	%											cm.	cm.	
No. 414	75.0	—	—	—	1	2	4	16	1	—	24	30.9	37.1	200.8
484	81.2	—	1	2	2	4	14	3	—	—	26	25.4	30.5	165.0
487	90.6	—	1	0	2	2	10	14	—	—	29	29.0	33.5	181.4
624	68.8	—	2	1	2	11	6	—	—	—	22	22.4	26.9	145.5
791	78.1	1	5	2	4	8	15	—	—	—	25	18.7	22.5	121.7
792	62.5	1	2	4	3	3	5	2	—	—	20	20.2	28.0	151.5
Control	87.5	—	2	12	14	—	—	—	—	—	28	15.4	18.5	100.0

In the second inoculation-experiment, the corn seeds were inoculated and sown on July 11, and the result was controled on July 18, 1933. The result of the second experiment was similar to that of the first experiment.

VI. Conclusions and Summary.

As stated above, the Indian foot-rot-fungus and the Japanese "bakanae"-fungus of the rice seedlings have showed no valid morphological differences between themselves so far. Therefore they must be assumed to be one and the same species, and the foot-rot-fungus of rice seedling in India is identified as *Gibberella Fujikuroi* WOLLENWEBER (=*Gibberella Fujikuroi* S. ITO), (=*Lisea Fujikuroi* SAWADA).

The Japanese and the Indian fungi were similar not only in the morphology but also in the pathogenecity or in the ability to cause abnormal overgrowth of rice or corn seedlings.

In the characteristics on culture media, however, they showed some divergences between themselves, the colonies of the both fungi being not completely similar.

In short, both the Japanese and the Indian fungi may be safely concluded that to be they are one and the same species from the morphological and phytopathological points of view, although they show some divergences in some characteristics on culture media.

P. S.

After the manuscript of this article had been put to press, the senior writer received a letter from Mr. Avl. S. Sundararaman, Government Mycologist of India. According to it, he sent similar material of the foot-rot disease of rice and cultures of the causal fungus to Professor Ashby of the Imperial Institute of Mycology, England, and Dr. H. W. Wollenweber in Berlin-Dahlem, Germany. Both of them identified the Indian fungus as *Fusarium moniliforme* Sh. var *majus* Wr. et Rg.

As to the identity of the Japanese rice-"bakanae"-fungus and *Fusarium moniliforme* Sh. var. *majus* Wr. et Rg., the senior writer carried out an experiment, physiologically and pathologically, in Berlin-Dahlem under the direction of Dr. Wollenweber. His result (Nisikado, 1931, 1932) at that time sustained the conclusion of the morphological and taxonomical studies of Dr. Wollenweber (1931, 1932), that *Fusarium moniliforme* Sh. var. *majus* Wr. et Rg. was the conidium stage of *Lisea Fujikuroi* Saw. and belonged to the genus Gibberella as *Gibberella Fujikuroi* (Saw.) Wr. and differed from *Gib. moniliformis* (Sh.) Winel.

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