3. FORECASTING AND CONTROL OF BACTERIAL LEAF BLIGHT OF RICE IN JAPAN

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Introduction

Bacterial leaf blight is one of the most intractable diseases, against which no successful control measure has yet been established in our country. So far, the use of the resistant rice varieties has played an important part of the countermeasures. However, because of the presence of the highly virulent race strain which attacks these resistant varieties, we must emphasize the urgent need of finding effective control chemicals. Recently, we have examined some new chemicals, but they could not be expected sufficiently effective.

Therefore, the countermeasures of bacterial leaf blight should be directed not only to discover as soon as possible the outbreak of the disease at the early stage of rice growth, but also should be directed to the careful farm management. Further, the effective application of control chemicals must be made at the suitable time.

For this purpose, it is very important to establish the methods appropriate to discover the outbreak of the disease at the early stage of rice, that is, the method of forecasting the onset of the disease.

The authors introduce the methods applied in Japan for forecasting the outbreak of bacterial leaf blight, especially the bacteriophage method, and at the same time will relate an outline of the control measures adopted at present.

Wintering and Life Cycle of the Causal Organism (*Xanthomonas oryzae*)

The wintering and life cycle of the causal organism, that have been clarified by many research workers in the past, are indicated diagramatically in Fig. 1.

The bacteria winter in two different forms, dry-form and growing-form. Wintering form in diseased straws and seed grains belongs to the former, and the later form is represented by those wintering on *Leersia sayanuka* Ohwi and *Leersia oryzoides* (Linn.) Sw., which are intermediate host plants, and diseased rice stubbles. Among those, the subterranean stem and hairy root of *Leersia* grasses are considered most important places for the bacteria to winter. *L. sayanuka* and *L. oryzoides* are perenial wild grasses, and grow habitually in ditches in the paddy field areas of Japan.

Relationships between Bacterial Infection and Outbreak on Rice

The above mentioned wintered bacteria disperse into the nursery through the irrigation water when there is much rain. As shown in Table 1, it has been confirmed by investigation at the Kyushu Agricultural Experiment Station that the carrier seedlings have a close connection with the outbreak of the disease after rice transplantation.

Forecasting of Outbreak

Forecasting of the outbreak of bacterial leaf blight in Japan is done after all-round con-

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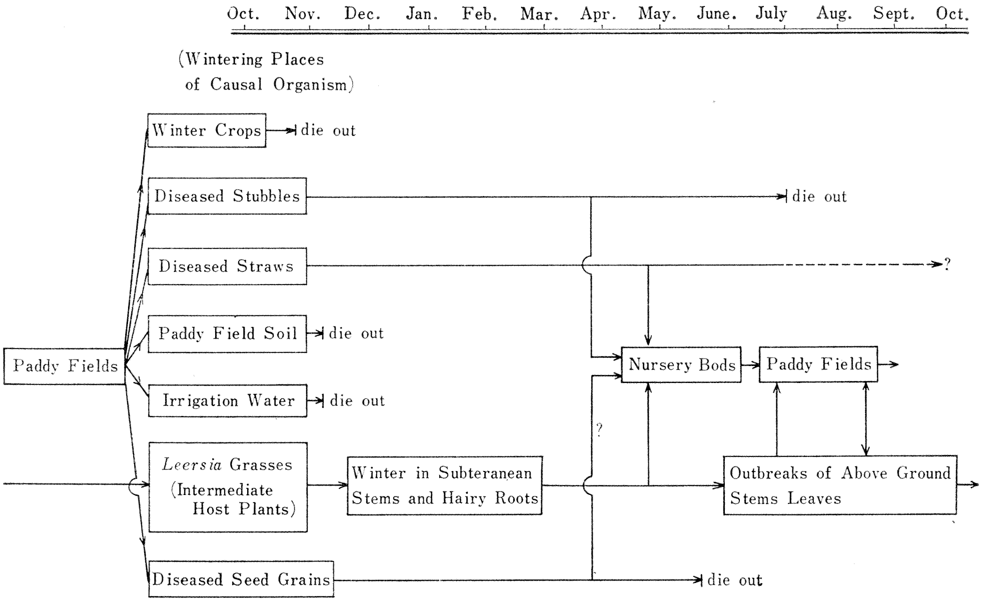


Fig. 1. Wintering of *Xanthomonas Oryzae* and its infection course to rice plant in field.

Table 1. Inoculum levels in rice seedling and successive change in the population of the causal organism on leaves after transplantation. (1962, Kyushu Agr. Exp. Sta.)

Inoculum Level*	Number of Bacteria/Plant		Process of Outbreak (after transplantation)		
	after 10 days	after 16 days	after 15 days**	after 28 days**	harvest time***
52,000 cells/ml	47,000	38,800	18	40	63
2,600 cells/ml	16,300	94,500	5	13	60
130 cells/ml	3,900	13,800	1	2	46
0	0	0	0	0	2

Remarks: * Inoculation·········Overnight submerge in bacterial suspension
** % of diseased plant
*** Degree of disease

sideration of the following three methods.

1. Field Investigation

Field investigation in the disease areas are made in order to observe the earliness and progress of the disease of the rice in the observatory fields and their adjacent areas. In this case, the growth density of *Leersia* grasses, outbreak of the disease on those grasses, and the rate of cultivated areas of susceptible varieties in the district are also investigated as supplementary materials for forecasting the outbreak of the disease.

2. Analysis of Meteorological Factors in the Cultivation Period of Rice

The precipitation, the number of rainy days, temperatures, and typhoon exert a wide effect on the development of the disease. And the damage caused by the disease becomes severe especially in such cases that the nursery or the paddy field at the early stage of rice is submerged.

Table 2 shows the forecasting formula set up by the Saga Agricultural Experiment Station according to the climatic conditions.

As observed in the table, there are close interrelationships among the degree of the outbreak of bacterial leaf blight, precipitation during the early stage of rice in paddy field, and the number of rainy days.

3. Forecasting by Bacteriophage Population

The method to forecast the outbreak of bacterial leaf blight by bacteriophage population was newly added to the "General Rules for Forecasting Survey," amended by the Ministry of Agriculture and Forestry in 1965.

It is explained as follows how the phage method had come to be adopted and utilized:

(1) Basis for the adoption of phage method in the forecasting of disease:

Wakimoto et al. (1954–1955) devised a quantitative determination method of causal organism by means of phage with a view to ascertain the existence of the causal organism and the state of its multiplication in the samples.

Thereafter, Tagami et al. (1956) made use of the method to detect the seasonal changes of the causal organism in rice and irrigation water during the rice cultivation period. While they were counting the number of phage in the samples along with the quantitative determination of the causal organism, they discovered the fact that the population of phage existing in paddy water is greater in the fields where the disease becomes severe afterward, and also that the multiplication of phage does occur before the onset of the disease. On the contrary, the phage was usually detected in the rice leaves after the outbreak of the disease.

Fig. 2 shows an example from the results of the experiment related to the above mentioned matters.

Thereupon, authors suggested the possibility of forecasting the earliness and degree of the outbreak of the disease in the paddy field or in the diseased area by detecting the existence and the number of phage in paddy water or irrigation water.

Table 2. Forecasting of the degree of the disease outbreak by weather conditions. (1960, Saga Agr. Exp. Sta.)

Factors	Forecast. Formula	Correl. Coef.	Mean Value	y	Grade of Disease Outbreak
(Precipitation)					
Month *Decade*					
July last	y=1. 507+0. 043x	0. 902	3. 24	2. 82	Moderate
Aug. 2nd	y=2. 035+0. 0097x	0. 915	3. 25	2. 59	Moderate
Aug. 1st & 2nd	y=1. 621+0. 009x	0. 829	3. 25	2. 13	Moderate
Aug. 2nd & last	y=1. 259+0. 0098x	0. 924	3. 25	1. 98	Slight
Aug. (Total)	y=0. 489+0. 011x	0. 961	2. 75	1. 31	Slight
(Rainy Days)					
July last	y=0. 214+0. 793x	0. 605	3. 23	4. 18	Severe
Aug. 2nd	y=1. 809+0. 596x	0. 794	4. 01	4. 79	Severe
Aug. 1st & 2nd	y=0. 610x−1. 427	0. 752	3. 27	1. 62	Slight
Aug. last	y=0. 689x−0. 309	0. 842	3. 20	1. 76	Slight
Aug. 2nd & last	y=0. 435x−0. 519	0. 958	3 27	2. 96	Moderate
Aug. (Total)	y=0. 481x−2. 963	0. 976	3. 29	0. 89	Slight

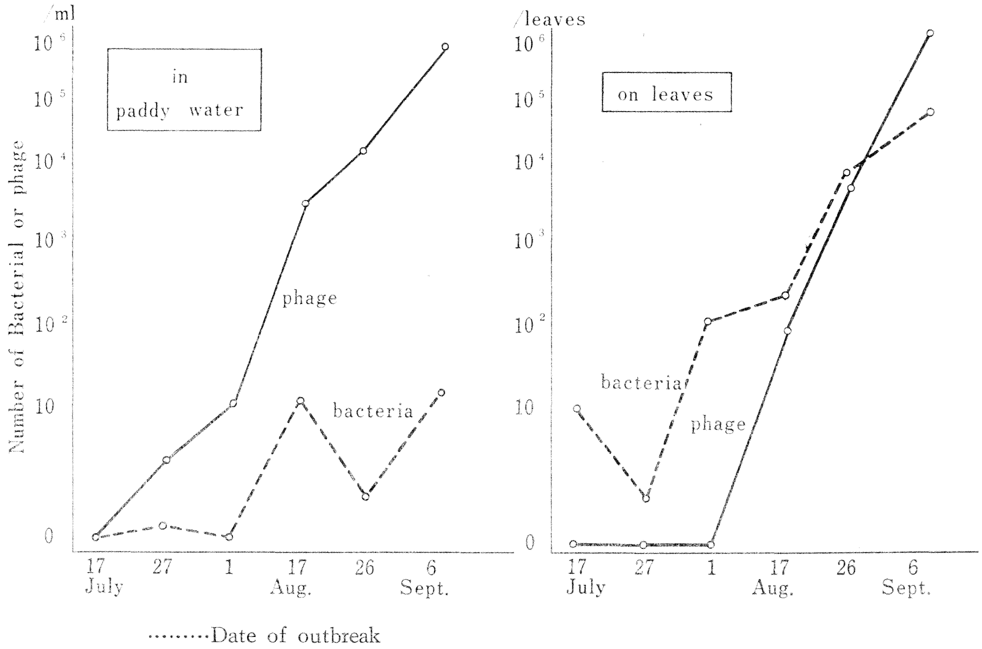


Fig. 2. Seasonal change in the population of the causal organisms and phage on rice leaves and in paddy water during rice growing period. (1959, Kyushu Agr. Exp. Sta.)

This method is designed to grasp indirectly the tendency of the increase of bacterial population by determining the number of phage which increases with the multiplication of bacteria on rice.

The determination of the phage population in irrigation water is quite simple as mentioned later and is highly practical.

(2) Seasonal changes of phage population in paddy water and the disease development:

Phage population in the paddy water increases gradually after the transplanting of rice, and the increase become particularly remarkable at the most active tillering stage of rice.

According to the results of the experiments that have been conducted so far, the number of phage is small in general in paddy water at the early stage of tillering in the Kyushu District, and relation to the outbreak of the disease is obscure. However, the results obtained show that there are considerably close relationships between the disease development and the number of phage in paddy water after the most active tillering stage, especially at the max. number of tillers stage.

Therefore, the authors consider that the population of phage at this time might suggest the possibility of forecasting the onset of the disease, as shown in Table 3.

Fig. 3 is a comparative chart illustrating the relationships between the outbreak of the disease and phage in paddy water at the most active tillering and max. number of tillers stages in chronological order, compiled from the data obtained through the investigation conducted during the period of 1957–1959.

As shown above, in the year when phage is detected earlier and more in number in paddy water, there is a tendency to the early outbreak of bacterial leaf blight and a high degree of disease development in the ripening stage.

Table 3. Phage population in paddy water and outbreak of the Bacterial Leaf Blight of rice. (1959, Kyushu Agr. Exp. Sta.)

No. of Phage /ml	% of Diseased Hill at Booting Stage						Grade of Disease at Harvest						Total
	0	0.1≧	1>	1−4	5−10	30≧	non	sca.	slight	mod.	sev.	very sev.	
(Early Tillering Stage)													
0	53	14	7		1		55	9	4	4	3		75
10≧	8	9	4	2	2		5	8	5	5	2		25
10^2≧		3	1		1	2		2	1	1		3	7
10^3≧						2						2	2
Total	61	26	12	2	4	4	60	19	10	10	5	5	109
Correl. Coef.	r=0.335	P<0.001					r=0.641	P<0.001					
(Most Active Tillering Stage)													
0	47	10	3		1		46	7	4	2	2		61
10≧	8	8	5	2	1		10	6	2	5	1		24
10^2≧		7	2		1	1		5	2	2	1	1	11
10^3≧			1		1	3					1	4	5
Total	55	25	11	2	4	4	56	18	8	9	5	5	101
Correl. Coef.	r=0.643	P<0.001					r=0.639	P<0.001					
(Max. Number of Tillers Stage)													
0	39	4	2	1			38	4	2	2			46
10^2≧	14	5					14	4	1				19
10^3≧	5	10	3	1	1		5	6	5	3	1		20
10^4≧	1	6	7		3	1	1	5	2	5	3	2	18
10^4<		1				3					1	3	4
Total	59	26	12	2	4	4	58	19	10	10	5	5	107
Correl. Coef.	r=0.638	P<0.001					r=0.708	P<0.001					

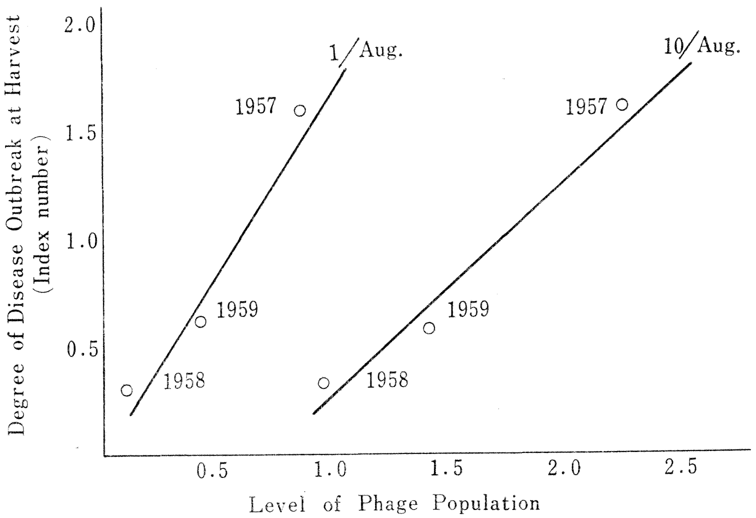
Remark: Figures in this table indicate the number of paddy field.

(3) Seasonal changes of phage population in irrigation water and disease development:

The determination of phage population in paddy water is applicable in forecasting the outbreak of the disease in an individual paddy field and its adjacent areas. However, it is necessary to determine the number of phage in many other paddy fields when making more extensive forecasting the disease development covering large area.

In this regard, if phage population in water of irrigation paths in the diseased area are determined, and the results obtained have a close connection with the state of the outbreak of the disease in that area, such a finding will be very useful in forecasting the disease development in extensive areas.

In most cases, the supplied and drained water mix together in irrigation paths and the distribution of these paths is much complicated. However, it is assumed that phage population



Level of phage population: $\log(1+x)$, x……No. of phage/ml

$$\text{Degree of disease outbreak}=\frac{a\times 0+b\times 0.13+c\times 1+d\times 2+e\times 3+f\times 4}{\text{No. of paddy field}}$$

a……No. of non-diseased field
b……No. of scarcely diseased field
c……No. of slightly diseased field
d……No. of moderately diseased field
e……No. of severely diseased field
f……No. of most severely diseased field

Fig. 3. Phase population in paddy water and outbreak of the Bacterial Leaf Blight of rice. (1957–1959, Kyushu Agr. Exp. Sta.)

in irrigation water, like those in paddy water, in the diseased area reflect the infected stage of rice or the multiplication of the causal organism in the adjacent paddy fields.

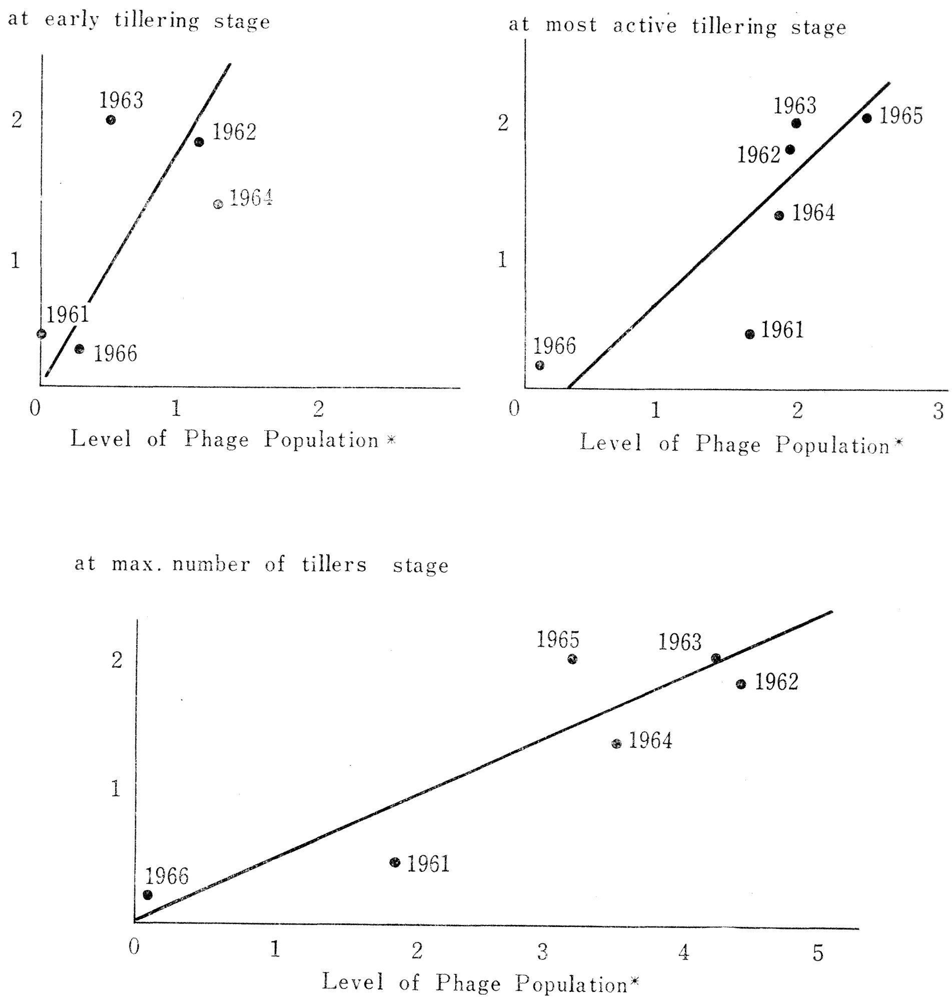
Table 4 indicates the results of the investigation on the relationships between the phage population in irrigation water and the outbreak of the disease, conducted in the Kyushu District during the period of 1960–1965.

This table shows a close connection between the mean value of the number of phage determined in irrigation water at several spots in four diseased areas and the degree of the development of the disease. And a comparison of the above mentioned relationships in chronological order is made in Fig. 4, from which it can be seen that the greater the number of phage in irrigation water is, the more severely the disease tends to break out.

The similar investigation had been conducted also in the diseased areas of the Hokuriku District during the period of 1958–1961. The results of the investigation are indicated in Table 5.

Phage is detected in irrigation water as early as in April but usually in May in the Hokuriku District. Although phage increases in number thenceforth, the number detected in May is comparatively small and is usually less than 100/ml even in June. However, phage rapidly multiplies in July, and the number exceeds 10^3/ml.

Referring to the relationships between the number of phage and the outbreak of the disease, the disease starts in some paddy fields in the area subjected to the investigation



Remark: * see Fig. 3.

Fig. 4. Chronological comparison of phage population in the water of irrigation paths and outbreak of the Bacterial Leaf Blight of rice. (1961–1966, Kyushu Agr. Exp. Sta.)

when the number of phage exceeds 100/ml, and the disease breaks out in various places in the area as the number of phage detected goes over 10^3/ml.

Moreover, it is not rarely the case that the number of phage in irrigation water exceeds 10^4/ml when the disease becomes serious. Also the phage population in irrigation water when the disease develops, is in line with the multiplication of the causal organism, the outbreak and the tempo of the development of the disease.

As mentioned above, the proper selections of irrigation water course, in which main currents of irrigation water running through the diseased areas are well seized, periodical determinations of the phage population in irrigation water throughout the rice cultivation season and comparisons in chronological order of the results obtained will combine to serve as the data for forecasting the earliness and degree of the outbreak of the disease in the year.

(4) Procedures for counting the number of phage:

Table 4. Phage population in the water of irrigation paths and outbreak of the Bacterial Leaf Blight of rice. (1960–1965, Kyushu Agr. Exp. Sta.)

Year	Area	No. of Phage in Irrigation Water (mean value/spot)			Degree of Disease Outbreak*
		early tillering stage	most tillering stage	max. tillers stage	
1960	A	0	0. 18	17	0. 35
	B	2	0. 8	335	1. 97
	C	1	0	95	2. 24
	D				0
1961	A				0. 04
	B	0	80	298	0. 70
	C	0	10	225	0. 14
	D				0
1962	A	0. 6	2	4, 522	0. 93
	B	34	399	55, 210	1. 93
	C	2	23	4, 490	1. 57
	D	0	0. 8	341	0. 11
1963	A	0	4	3, 957	0. 99
	B	3	111	21, 990	2. 01
	C	1	74	15, 000	2. 33
	D	0	2	2, 080	0. 03
1964	A	0. 7	2	712	0. 89
	B	30	328	5, 760	1. 56
	C	10	9	16, 880	1. 17
	D	1	3	4	0. 02
1965	A	0. 2	7	217	0. 99
	B	5	1, 296	3, 440	2. 14
	C	2	411	7, 095	2. 17
	D	0	1	36	0. 06

Remark: * see Fig. 3.

One ml of irrigation water collected from the paddy field or irrigation paths is mixed with 2 ml of *Xanthomonas oryzae* dense suspension; about 5 ml of potato-semi-synthetic medium which was previously melted and cooled down to 55 °C is added; the mixture is poured into a petri-dish, and incubated at 25° C. About 15 hours later, clear bacteriophage plaques are formed and the measurement is made by counting them. The number of these plaques represents the number of phage in 1 ml of the water samples.

(5) Problems in counting phage:

There are various problems in the measurement of the number of phage in order to heighten the dependability of the figures obtained:

(i) Selection of bacterial strain:

Most widely distributed phages in our country are OP_1, OP_{1h} and OP_2. However, the presence of these strains varies with locality. It is, therefore, necessary to investigate previously the distribution of phage strains. From the affinity of phages to the bacteria, it is sufficient to use bacterial types A and B in general for the detection of the phages.

Table 5. Seasonal change of phage population in the water of irrigation paths and degree of the outbreak of Bacterial Leaf Blight of rice.
(1958–1961, Hokuriku Agr. Exp. Sta.)

Investigated Area		No. of Phage /ml in Main Irrigation Paths				No. of Phage /ml in Small Irrigation Paths				Period of Rice Growing
Year		1958	1959	1960	1961	1958	1959	1960	1961	
(Month)	(Decade)									
Apr.	1st			0	0	0	1	0	0	
	2nd		0	0	0		2	0	0	
	last		1	0	0		6	0	0	Seedling stage
May	1st		5	0	0	0	21	0	6	
	2nd		2	1	0	6	4	3	1→	Transplantation
	last	1	3	7	2	6	2	9	9	
June	1st		8	7	6		19	11	10	
	2nd	46	21	29	2	13	17	24	4	
	last		93	85	69		73	16	44	
July	1st	36	**420**	169	**330**	45	**148**	90	**824**→	Most active tillering stage
	2nd	**395**	495	**900**	463	**260**	860	**170**	2,320	
	last	2,100	2,140	6,750	4,880	3,560	1,810	1,500	4,800→	Max. number of tillers stage
Aug.	1st	1,740		4,600	7,520	4,520		2,600	7,200→	Young ear formation stage
	2nd	92,000	1,170	500	10,560	20,000	680	750	7,800	
	last	12,200	2,400	1,100	880	16,000	2,040	3.000	890→	Heading stage (Late variety)
Sept.	1st	3,300	1,570	550		159,000	3,750	620		
	2nd	3,000	20	1,200	37	3,500	1,510	210	1,180→	Drainage
	last	1,200	3,345		90	400	2,200		3,240	
Oct.	1st		70	35	850		160	40	1,300→	Harvest time
	2nd	14,500	134	16		1,300	350	65		
	last		7		110		24		24	
Degree of Outbreak		Severe	Very severe	Slight	Mod.	Severe	Very severe	Slight	Mod.	

Remark: Condensed numbers indicate the initiation of outbreak.

(ii) Selection of spots to collect samples:

In the case of paddy water, the samples can be collected from the vicinity of drainage exit. However, it is desirable to collect the samples from irrigation paths, the spot of collection should be determined after carefully investigating the distribution of irrigation paths and the relationships between the drain and supply channels in the subjected area. The spots which are not suitable for the collection of the samples are small ditches and irrigation paths in which the number of phage detected fluctuates greatly.

(iii) Variation of the number of detected phage affected by environmental conditions:

The number of phage detected in irrigation water varies with time in day, the amount and speed of the current, turbidity and water temperature.

The number of phage tends to increase after a rainfall and decrease suddenly after the drought season or the drain period. Regarding these problems, the only possible way to heighten the dependability of the determined values is to collect the samples more frequently.

The authors have introduced an outline of forecasting the outbreak of bacterial leaf blight by bacteriophage population based on the experimental results. The practical investigations and special surveys are carried out at four prefectural agricultural experiment stations designated by the Ministry of Agriculture and Forestry (Pl. Prot. Sec.), besides the National Kyushu Agricultural Experiment Station.

Control Measures

The control of bacterial leaf blight in our country is practised by the use of resistant rice varieties, the improvement of rice cultivation and the application of chemicals.

1. Use of Resistant Varieties

The following rice varieties are comparatively resistant to the causal organism belonging to patho-type II (moderate strain), which is widely distributed in Japan.

Ohu 244	Fujiminori	Honen-wase
Shin 2	Nakashin 120	Koshihikari
Hagareshirazu	Shirogane	Norin 27
Hoyoku	Kokumasari	Shiranui

2. Application of Chemicals

(1) Kinds of chemicals:

Before 10 years, the application of Bordeaux mixture or coppermercurials was the only chemical control measure against bacterial leaf blight. However, the use of copper compounds discontinued, the reason being that the effects of such chemicals were not sufficient while the phytotoxicity was evident often decreasing the yield of rice.

Thereafter, antibiotics, such as streptomycin, chloramphenicol and cellocidin have been found effective. Among them, chloramphenicol and cellocidin which exert a comparatively less harmful influence upon the ripening of rice, have been practically used as control chemicals.

On the other hand, synthetic compounds, such as dithianon, dimethylnickel carbamate, fentiazon and phenazine, have been confirmed to be effective with less phytotoxicity. At present, they are considered to be of most practical in Japan. However, they just do not satisfy our requirements, and, therefore, it is necessary to make efforts to produce more effective chemicals.

(2) Time to apply chemicals:

The invasion and infection of bacterial leaf blight organism occur almost throughout the rice growing season. Therefore, the application of chemicals should be done at the most effective time. In connection with the selection of suitable time to apply chemicals the seasonal changes of bacterial population on the rice leaves on which the disease is still latent, and the progress of the disease in the field are given diagrammatically in Fig. 5.

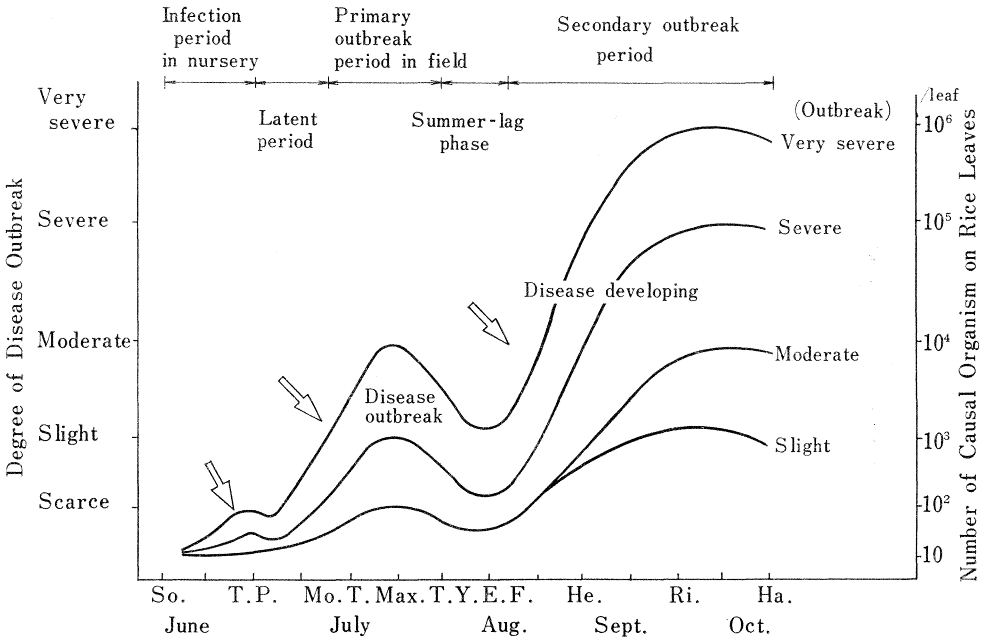
In general, the more the population of causal organism in seedlings is, the more earlier and severer the outbreak of disease after transplantation is. Further more, in Japan, the number of the causal organism decreases on the rice leaves due to the dryness accompanied with high temperatures in mid-summer and the development of the disease tends to become stationary (Summer-lag phase). However, the weather conditions thereafter, such as cloudy or rainy days and typhoons help the disease progress again. Therefore, it is rational and practically effective to apply chemicals during the later period of nursery, at the beginning of the outbreak of the disease at the most tillering stage, and at an early stage of the secondary development of the disease at the booting stage of rice growth.

(3) Chemical control in the nursery bed:

Table 6. Effect of chemical control in the nursery bed.
(1963, Fukuoka Agr. Exp. Sta.)

Treatment*	at Young Ear Formation Stage	at Harvest Time		Increased Ratio
	% of diseased hill	ditto	degree of disease (%)	in Yield
Sprayed	1.5	11.3	1.9	109
Not-sprayed	88.3	100.0	54.4	100

Remark: * Streptomycin 500 u/ml, sprayed 3 times in later period of seedling stage.



Remarks: So.……Sowing time, T. P.……Transplantation, Mo. T.……Most active tillering stage, Max. T.……Max. number of tillers stage, Y. E. F.…… Young ear formation stage, He.……Heading stage, Ri.……Ripenning stage, Ha.……Harvest time, ⇩………indicates the suitable time for chemical application.

Fig. 5. Progress of Bacterial Leaf Blight in the field and successive change of the population of causal organism on rice leaves.

Table 7. Effect of chemical control in the paddy field.
(1965, Hokuriku Agr. Exp. Sta.)

Chemicals	Dilution	% of Active Ingradients	Degree of Disease (%)	Ratio in Yield	Phytotoxicity
Sankel WP.	500 x	dimethylnickelcarbamate 0.13%	11.7	114	+
Celdion WP.	400 x	fenthiazone 0.12%	10.8	112	—
Shirahagen WP.	1,000 x	chloramphenicol 0.01% phenylmercuricacetate 0.002%	21.3	106	—
Control			37.7	100	

Remark: Time of application…………at young ear formation, booting and heading stages (3 times), sprayed 150 *l*/10 a.
Used variety………………… Kinmaze.

The application of chemicals directed to the prevention of infection in the nursery bed produces the possibility of decreasing the outbreak of the disease after transplantation. Table 6 is an example of the experiments on the chemical control in nursery bed carried out at the Fukuoka Agricultural Experiment Station.

In the year when the seedlings were severely infested, remarkable effects were observed in the nursery application of chemicals.

(4) Chemical contral in the paddy field:

Chemical control in the paddy field should be done primarily at the beginning of the outbreak of the disease, and in the case of late-ripening varieties, it is often necessary to apply chemicals at the secondary outbreak.

Timely controls based on the careful observations on the progress of the disease can prevent the development of the disease to half or less, and an increase in yield of about 10 % can be expected.

Table 7 shows an example of the experiments carried out at the Hokuriku Agricultural Experiment Station in 1965.

Conclusion

For the control of bacterial leaf blight, as mentioned above, it is necessary to make use of the resistant varieties, and also to select the most suitable times to apply chemicals in order to promote the effects of chemical application.

To this end, the accurate and early forecasting of the disease's outbreak is all the more necessary in the control of this disease. Therefore, the development of new effective chemicals and also the further levelling up of the accuracy of the present forecasting methods still remain important.

Discussion

T. Yamaguchi, Japan: (1). You have just mentioned that the root of *Leersia* grass is the most important place for the causal bacteria to overwinter. However, I heard last year (1966) that, in Fukui prefecture, *Xanthomonas oryzae* phage is particularly detected from the roots of various Graminacious grasses besides *Leersia* in the spring time. (2). At a nursery bed, the number of *X. oryzae* phage in the irrigation water is very few and variable. Therefore, it seems difficult to forecast the outbreak of the disease according to the number of phage during the nursery period.

Answer: (1). According to the results obtained from our experiments conducted from 1956 to 1962, causal bacteria had been detected toward the end of December every year from the roots of various grasses such as *Phalaris arundinaceae*, *Zizania latifolia*, *Phagmites communis*, *Isachne globosa* and *Setaria viridis*, as well as *Leersia* grass. However, in most cases, causal bacteria had been on the decrease in number at the end of every calendar year, and had become extremely less or nil after March. I should think that there are some other plants where the bacteria overwinter besides *Leersia* grass. However, I have not investigated such places. (2). During the nursery period, phage in irrigation water is less in number, and it is, therefore, hardly possible to forecast the outbreak of the disease in the later stage of rice growth by the phage method. However, if we conduct sampling at nursery beds more extensively in order to measure the phage population, there must be some possibilities of forecasting the outbreak of the disease to some extent at the early stage of rice growing; frequent, early detection, and number of phage in the active or the maximum tillering stage may make the forecasting possible.

I believe that these problems will be of importance in our future research in this particular field.

D. V. Walter Abeygunawardena, Ceylon: In Ceylon it is observed that with indigenous varieties the disease appears mostly at heading. Could we, therefore, take phage population in irrigation water as a criterion in forecasting in a situation like this?

Answer: The Japanese scientists, who were once dispatched to your country, gave me a brief outline of the rice cultivation and the type of rice diseases in Ceylon, as well as how bacterial leaf blight was prevailing there. I feel that the application of the phage method in detecting the outbreak of the disease may be successful in your country which is an island like ours, both being under similar conditions. I certainly wish to seize an oppotunity of visiting your country in order to check the matter.

N. Murata, Japan: Do you think that climatic conditions have influence on the relative multiplication of *Xanthomonas oryzae* and its phage?

If so, do they play any role in determining the onset of the disease?

Answer: We should draw a line between the effects on phage and the effects on bacteria. First of all, the climatic conditions which we think would have direct effects on the multiplication of phage are temperature and a spell of dry weather. The influence of sunlight is unknown. However, a suitable temperature for phage to multiply is 27 °C. To the contrary, temperatures produce a direct effect on the multiplication of bacteria. A proper temperature for bacteria to multiply is 28°C, and when the temperature goes over 33°C, the multiplication falls off considerably. Meanwhile, bacteria start multipling slightly at a low temperature of 19°C. From the epidemiological standpoint of view, however, rain, typhoons and a spell of dry weather are also correlated to the multiplication and propagation of bacteria; this makes the situation much complicated. And, the climatic conditions which help determine the outbreak of the disease, if anything, are temperature and the numerical rainy days.

H. Fujii, Japan: You use the term "Patho-type" of the pathogen in the text. Is it identical with the term "Strain" of the pathogen? If so, what made you use the term "Patho-type" instead of "Strain"?

Answer: The inoculation of the isolates of *Xanthomonas oryzae* bacteria to the rice by means of Pin-pinch method produces three main categories: Type I, which is highly virulent, forms large legions both for susceptible varieties, such as Jukkoku and Kinmaze, and for resistant varieties, such as Kidama and Zensho 26. Type II forms large legions for susceptible varieties. However, this type is moderately virulent and leaves only traces, or produces small legions (not bigger than 4 mm^2) for resistant varieties. Type III produces only small legions both for susceptible and resistant varieties. For these reasons, I use the term "Patho-type" instead of "Strain."

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