The transition of noteworthy rice diseases and their control in Korea.

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SUMMARY

In Korea the most important plant industry is the rice-growing but she has not yet attained self-sufficiency with regard to rice which is the basic food of Korean. In the past, various measures of increasing rice production have been tried with some success but the increasing rate of did not show the sufficient result. Judging from experiences, disease control may be the most important factor which has influence on increasing of rice production in Korea.

During the past 60 years three periods divided by the transition of rice diseases were noted, and especially the recent transition attracted much attention. That is, sheath blight and stripe which were minor diseases in the past have promptly spread all over the country and caused heavy losses to rice plant, and also local outbreak of bacterial leaf blight and dwarf were noticed. Various environmental factors are related to such transition of rice disease. Above all, cultivated varieties susceptible to these diseases, increase of application of nitrogenous fertilizer, earlier transplanting and density of transplanting are considered to be more closely related to the development of these diseases and successive development of blast. On the other hand, application of forage fungicides such as organic mercury compounds specific to blast contributed to reduce prevalent area of blast in spite of wide spread of susceptible varieties and increase of application of nitrogenous fertilizer. These facts were confirmed by Korean investigators.

At the present which various diseases to control coexist in the same region, no one variety resistant to all of these diseases is provided and cultural practices for the control of these diseases often do not produce sufficient yield of rice, it is emphasized that a role of pesticides is very great.

I The importance of rice disease control in South Korea.

The most important plant industry in Korea is the rice-growing and the basic food of Korean is rice. The importance of rice in Korean economy has been over-emphasized from the remote time. In total production it is first among various food crops but Korean has not been free from the deficit of rice in the past. For post-war years noticeable growing of population in Korea brought about big deficit of rice and even in the year of its large yield its deficit amount to about 200,000 M/T. So it is a burning problem to increase her rice production to meet the needs of her growing population.

In the past, various measures of increasing rice production have been tried with some success but unfortunately the increasing rate of rice production did not show the sufficient result. Experience shows that the use of improved seed or fertilizer alone will not produce the maximum results unless disease control is also provided simultaneously. Judging from the recent status of rice cultivation, disease

Table 1. Rice production of Korea.

Year	Planted area (ha)	Production (t)	Yield per Tanbo(kg)
1936~'40*	1102358	2117620	188
1941~'45*	1009466	1861320	187
1946~'50*	1100428	2036944	186
1951~'55*	998145	1878259	187
1956~'60*	1118078	2236779	200
1961	1137484	2722013	239
1962	1148491	2295122	200
1963	1165022	2765859	237
1964	1205168	2921886	242
1965	1238357	2590838	209

*Average of 5 years

Table 2. Diseased area and loss of rice in South Korea.

Year	Diseased area(ha)	Loss(t)
1954~'58*	77695	50416
1960~'62**	49745	32275
1963	69523	12018
1964	13384	2885
1965	65919	22221

* Average of 5 years ** Average of 3 years

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control may be rather the most important factor which has influence on the increasing of rice production in Korea. In fact, the outbreak of the destructive diseases such as 'Blast' · 'Sheath blight' and 'Stripe' very often caused heavy losses to rice plant in the past. It is true that best control of the destructive diseases is an urgent need for a solution of the deficit of rice in Korea.

Ⅱ The transition of noteworthy rice diseases in South Korea.

Scientific studies on the rice diseases started in 1906 by the workers of Suwon Agricultural Experiment Station in Korea. Since then various diseases of rice plant, parasitic or non-parasitic, were reported. These diseases have showed more or less differences in their severity, geographical distribution and vicissitude.

Some of them such as 'Blast' · 'Brown spot' · 'Sheath blight' · 'Bacterial leaf blight' · 'Stripe' and 'Dwarf', are very destructive while many others are minor diseases which have been excluded from the control calendar in the past. Among the destructive diseases, a few of them such as 'Blast' · 'Brown spot' · 'Sheath blight', and 'Stripe' are spread all over the country while the others such as 'Bacterial leaf blight' and 'Dwarf' are locally distributed in the southern region of Korea. In the recent years, 'Sheath blight' · 'Stripe' and 'Dwarf' as well as 'Blast' attracted much attention in Korea. 'Blast' has been known

Table 3. Geographical distribution of the noteworthy rice diseases in South Korea.

Disease	Major region of distribution	Number of province distributed
Blast(Piricularia cryzae)	All over the country	8 provinces
Brown spot(Cochliobolus miyabeanus)	All over the country	8 provinces
Sheath blight(Pellicularia sasakii)	The central and southern region	8 provinces
Seed and seedling rot(Spp. of Pythium, Achlya, Pythiomorpha and dictyuchus)	The northern region	2 provinces(Kangwon and Chungpuk)
Bacterial leaf blight	The west-southern region	6 provinces(except Kyongpuk and Chungpuk)
Stripe(Rice stripe virus)	The Central and Southern region	8 provinces
Dwarf(Rice dwarf virus)	The east-southern region	3 provinces(Kyongnam, Kyongpuk and Chungpuk)

to be the most destructive disease of rice plant during the past 40 years and it is still widespread with its great damage while the other diseases except 'Brown spot' were not noticed until about 1960. During the last 5 years 'Stripe' and 'Sheath blight' were promptly widespread all over the country and they caused heavy losses to rice plant. Although 'Bacterial leaf blight' and 'Dwarf' are not yet widespread they are also very destructive in the certain region. On the contrary, a few of diseases such as 'Seed and seedling rot' and 'Bakanae disease' which caused heavy losses to rice plant in the past, are not noticed because of striking decrease of the disease occurrences by the effective control practice such as seed disinfection in the recent years.

During the past 60 years which have scientific studies on the rice diseases, three periods divided by the transition of occurrence of rice diseases were noted as shown in table 4. In the lst period from 1906 to 1929, the outbreak and

Table 4. Periodical transition of rice diseases.

Period & term	Major diseases to control	Characteristic
1st period 1906~'29	'Blast' · 'Brown spot'	The outbreak and widespreading of 'Blast'
2nd period 1930~'33	'Blast' · 'Brown spot' · 'Seed ant seedling rot' · 'Bakanae disease'	The severe and extensive occurrence of 'Blast' and local outbreak of new diseases such as 'Sheath blight', 'Bacterial leaf blight' and 'Stripe'
3rd period 1960~'56	'Blast' · 'Brown spot' · 'Sheath blight' · 'Stripe' · 'Bacterial leaf blight' · 'Dwarf'	The severe and extensive occurence of 'Sheath blight' and 'Stripe' and local outbreak of 'Dwarf'

widespread of 'Blast' attracted much attention and accelerated the study on the control measures of 'Blast' in the next period. In the 2nd period from 1930 to 1959 the severe and extensive outbreak of 'Blast' with great damages and local outbreak of 'Sheath blight' 'Bacterial leaf blight' and 'Stripe' were noticed. Simultaneously 'Brown spot' · 'Seed and seedling rot' and 'Bakanae diseases' caused considerable losses to rice plant. In the 3rd period, from 1960 to the present year, the widespread of 'Sheath blight' and 'Stripe' with great damages and local outbreak of 'Dwarf' attracted much attention. And the severe occurrence of 'Blast' has been more often seen in the northern rice-growing region such as Kangwon Kyongki and Chungpuk provinces than in the southern rice-growing region known as the severe-occurred region of 'Blast' in the past.

To such transition of the rice diseases above-noted various environmental factors are considered to be related. Above all cultivated varieties, fertilizers, transplant time, and spray of preventive chemicals are closely relat

to it for sure. More detailed investigations on the transition of noteworthy rice diseases are not only necessary for the prevention of the diseases but also very helpful to make a prediction about the other diseases.

1. Rice varieties related to the transition of noteworthy rice diseases.

Cultivated varieties of rice plant are considered to be the most important factor which has influence on the transition of rice diseases. A few of rice varieties such as 'Hayasinriki' • 'Hinode' and 'Kokuryomiyako' which were major leading varieties from 1920 to 1940 contributed to the outbreak and widespread of 'Blast' in South Korea. Especially 'Hayasinriki' which is very susceptible to 'Blast' was cultivated all over the country and occupied 28.5 percent of the planted area in 1930, and so it is supposed that the variety was responsible for the terrible epidemics of 1926 and 1928. Since then the primary object of rice breeding in South Korea was to develop 'Blast' resistant varieties with high yield if possible. In spite of such

Table 5. The transition of cultivated rice varieties and their resistance to noteworthy diseases.

Variety	Percentage of cultivated area in the year					Resitance to			
	'20	'30	'41	'55	'64	Blast	Stripe	Dwarf	Bacterial leaf blight
layasinriki	16.3	4.6	3.2	—	—	VS*	—	—	—
okuryomiyako	15.7	28.5	9.1	1.1	—	S	MS	—	—
'amanishiki	10.2	10.4	2.8	0.3	—	MS	—	—	—
inode	2.8	2.7	—	—	—	S	MS	—	—
ishiki	2.0	4.2	3.0	—	—	S	—	—	—
amenoo	0.6	5.6	0.3	—	—	S	MR	—	—
kuu No. 132	—	—	13.4	1.2	1.6	MS	MR	—	—
kuu No. 137	—	—	0.4	0.5	0.3	MS	MR	—	—
nachi	—	3.1	0.1	0.8	—	MS	VS*	—	—
nbosu	—	2.3	27.5	4.1	3.8	S	MS	—	—
ıuseiginbosu	—	—	6.0	2.9	—	MS	VS	—	—
seiginbosu	—	—	—	7.4	—	MS	—	—	—
nseiginbosu	—	—	—	7.0	—	MS	VS*	—	—
ıbosu No. 101	—	—	—	5.4	1.1	VS*	S	—	—
hin	—	—	5.4	1.8	0.3	VS*	S	—	—
edal	—	—	—	5.9	0.7	VS*	MR	—	—
ngock	—	-	7.5	9.3	5.9	VS*	MR	MS	MR
rin No. 8	—	—	1.6	4.5	1.9	MS*	S	—	—
altal	—	—	—	10.3	13.8	VS*	S	S	MR
ınseo	—	—	—	7.5	3.0	VS*	MS	—	MS
)kwang	—	—	—	6.2	0.5	VS*	VS*	S	—
ılkyong	—	—	—	7.0	9.4	MS	S	MS	—
bonasahi	—	—	—	6.3	5.0	VS*	S	VS*	—
von No. 118	—	—	—	0.1	0.4	S	MS		—
in No. 6	—	—	—	5.3	15.1	S	S	MS	—
in No. 29	—	—			9.5	VS*	MS*	S	—
ıgkwang	—	—	—	—	4.1	S	S	S	
ogane	—	—	—	—	1.3	VS	S	S	R
ceon	—	—	—	—	1.1	S	S	MS	S
ıung	—	—	—	—	0.8	S	MS	MS	S
isaka No. 5	—	—	—	—	0.1	MS	MR	—	—
ıphung	—	—	—	—	0.01	S	MR	MS	S
maze	—	—	—	—	0.01	MR	VS*	S	VS*

: resistant, VR: very resistant, MR: moderately resistant
susceptible, VS: very susceptible, MS: modcrately susceptible

efforts, very few 'Blast' resistant varieties exactly cultivated with sufficient results.

The outbreak and spread of 'Stripe' from 1935 to 1941 and in the recent years are also closely related to rice varieties cultivated at those times. A few of varieties of rice plant which susceptible to 'Stripe' such as 'Omachi' and 'Ilchin' contributed to the outbreak of the disease in the 2nd period of the transition of rice diseases and also the most of leading varieties which is very or moderately susceptible to 'Stripe' such as 'Banseiginbosu' • 'Ginbosu No.101' • 'Seonseo' • 'Chokwang' • 'Phaltal' • 'Phalkyong' • 'Norin No.6' • 'Norin No.29' • 'Nongkwang' and 'Jaekeon' which have been cultivated from 1955 occupying 50 to 60 percent to the planted area during the last 10 years were responsible for the outbreak and widespread of the disease in the recent years.

The outbreak and spread of 'Bacterial leaf blight' is considered to be more closely related to cultivated varieties. In fact, the outbreak of the disease has a tendency to attract much attention in the restricted area cultivating susceptible varieties such as 'Gimmaze' • 'Jaekeon' and 'Shinphung'. Especially 'Gimmaze' which is very susceptible to the disease is closely related to the outbreak of the disease in the west-southern rice growing region, and a few of susceptible varieties such as Jaekeon and Shinphung are considered to be responsible for the outbreak of the disease in the northern rice-growing region.

Relation between rice varieties and the outbreak of 'Sheath blight' is not yet distinct, but a few of susceptible varieties such as 'Suwon No.118', 'Shinphung' and 'Fujisaka No.5' might be responsible for the widespread of the disease in the recent years.

Experiences and the results of 'Blast' resistance tests showed that no variety has kept its character of disease resistance. In fact, a few of varieties such as 'Ginbosu' and 'Tamanishiki' were resistant to the disease between 1920 and 1930 but rapidly deteriorated and were listed in the susceptible varieties about 1949. A similar example was shown in the blast resistance of 'Suwon No.101'. The variety resistant to 'Blast' about 1950 was listed in the susceptible varieties at the present. Such transition of the disease resistance by the appearance of new races of the fungus has undoubtedly influenced on the outbreak and geographical distribution of the disease.

2. Application of fertilizers related to the transition of noteworthy rice diseases.

Application of fertilizers in South Korea started from 1925. Since then consumption of fertilizers, especially nitrogenous fertilizer, strikingly increased during the past 40 years except 10 years between 1941 and 1950. It is supposed that striking increase of application of nitrogenous fertilizer between 1925 and 1940 was responsible for the terrible epidemic of 1926, 1928 and 1933 in which very extensive outbreak of 'Blast' and local outbreak of 'Sheath blight' were noted. This fact was confirmed by many investigators of the central and provincial agricultural experiment station. Their experimental results showed same conclusion that nitrogenous fertilizer favoured the development of 'Blast' and 'Sheath blight', and moreover excessive application of nitrogenous fertilizer intensified the diseases.

Table 6. Consumption of fertilizers in South Korea.

(unit:t)

Year	Elements of fertilizer		
	Nitrogen	Phosphorus	Potash
1925	2508	1680	98
1930	22210	8325	427
1935	57275	25966	3282
1940	75527	28432	376
1945	1245	749	34
1950	14598	1217	–
1955	146476	28218	884
1960	217128	55206	709
1965	238249	165615	8199

Same fact was recognized in the outbreak and widesp read of 'Stripe' and 'Sheath blight' during the last 1 years. Investigators of Yeongnam Agr. Expt. Sta. reporte that 'Dwarf' also was intensified by excessive applicatio of nitrogenous fertilizer in the paddy field of the east southern rice growing region in 1965. It is supposed tha striking increase of application of nitrogenous fertliiz during the last 10 years closely related to the outbrea and development of 'Sheath blight' • 'Stripe' • 'Dwarf' a

Table 7. Change of 'Blast' resistance of 306 local varieties of rice plant by application of different volume of fertilizer.

(Yeongnam Agr. Expt. Sta., 1965)

Volume of fertilizer (kg. per 10 a)			Percentage of varieties teste			
N	P	K	R	MR	MS	S
0	0	0	41.8	57.2	1.0	
8	5	5	6.5	49.7	31.0	12
16	10	10	1.6	17.0	37.5	4
24	15	15	0.3	9.5	37.5	5

R: resistant, MR: moderately resistant
S: susceptible, MS: moderately susceptible

'Bacterial leaf blight' in the recent years

3. Early season and earlier cultivation related to the transition of noteworthy rice diseases.

The seedling culture by vinyl nursery recommended in order to escape from cold injury exactly started from 1950, but its extensive practice has been noted in the recent years in Korea. As the results, the outbreak of a few of new diseases such as 'parasitic damping-off of seedling' and 'non-parasitic Mure-nae', and also earlier occurrence of 'Seedling blast' attracted much attention while the outbreak of 'Seed and seedling rot' often caused serious damage in the northern rice growing region strikingly decreased. In fact, seedling blast often appeared first at the end of April or the beginning of May in vinyl nursery and the transplanting of diseased seedlings caused the increasing of leaf blast in the early stage of paddy field.

Advancement and spread of the technique of seedling culture by vinyl nursery for early season cultivation and earlier cultivation for high yield resulted in earlier transplanting in the recent years. During the last 10 years, the time of transplanting generally advanced about 7 days on the average in the region of earlier cultivation. It was recognized that early season and earlier cultivation favoured

Table 8. Area of early season and earlier cultivation of rice plant in South Korea (unit: ha).

Year	Area of		
	Early season cultivation	Earlier cultivation	Total
1962	—	—	35670
1963	4193	28892	33085
1964	4593	37774	42367
1965	13513	53669	67182

e outbreak and widespread of 'Stripe' and 'Sheath ght', and also local outbreak of 'Dwarf' and 'Bacterial f blight' in the recent years. This fact was confirmed investigators of Office of Rural Development(1965). above noted, it is sure that seedling culture by vinyl

able 9. Relation between the time of transplanting and the development of 'Stripe'(ORD, 1965).

ime of splanting	Percentage of diseased hills				
	Jul. 6	Jul. 19	Jul. 27	Aug. 9	Aug. 23
ay 23	4	5	42	45	51
n. 6	1	3	4	5	14
n. 20	0	0	5	2	10
l. 15	0	0	0	0	2

nursery results in earlier occurrences of seedling blast and leaf blast in the early stage of paddy field, but it is not clear that earlier transplanting favour or not the development of 'Blast' in the later stage of paddy field. The author(1949) and other investigators concluded that earlier transplanting considerably retarded the development of 'Blast' in the paddy field. According to the recent survey (Table 10) prevalent area of 'Blast' more or less decreased while that of 'Sheath blight' • 'Stripe' and 'Bacterial leaf blight' considerably increased in the recent years. Judging from these facts it is supposed that earlier transplanting retard the development of 'Blast' in the paddy field.

Table 10. Prevalent area of noteworthy rice diseases by year (Ministry of Agr. & For.).

Year	Prevalent area (ha) of			
	Blast	Sheath blight	Stripe	Bacterial leaf blight
1962	91622(8)*	—(3)*	1509(5)*	21(1)*
1963	61917(8)	20(3)*	2488(6)	196(2)
1964	13008(8)	409(5)	2170(7)	50(3)
1965	48636(8)	1036(8)	12223(8)	297(6)

4. Application of pesticides related to the transition of noteworthy rice diseases.

Since the terrible epidemic, 'Blast' brought about great losses to rice plant from about 1926, application of fungicides has been recommended in a series of combination practice for the control of 'Blast', but it was rare for farmers to do chemical control except seed treatment for control of 'Blast' as well as other diseases of rice plant until about 1953. Seed treatment by chemicals such as form-aldehyde and organic mercury has been practiced with some success since pre-war, so that the outbreak of seed-borne diseases such as 'Bakanae disease' • 'Seedling blast' and 'Brown spot' considerably decreased in the nursery stage. In fact, it is not so easy to find out 'Bakanae disease' at the present. Wide application of organic mercury compounds as forage fungicides of rice plant started from 1954, and since then its consumption considerably has increased year by year. So it is supposed that wide application of organic mercury compounds more or less contributed to the control of 'Blast' in spite of more extensive spread of susceptible varieties and increase of application of nitrogenous fertilizer. On the other hand any of forage fungicides besides organic mercury compounds specific to 'Blast' has never been applied to the control of rice diseases, so that other diseases such as 'Sheath blight' and 'Bacterial leaf blight' were intensified under the favorite environments such as spread of susce-

ptible varieties, earlier transplanting cultivation and increase of application of nitrogenous fertilizer in the recent years.

Table 11. Consumption pesticides in South Korea control of for rice diseases and insects(Ministry of Agr. & For.)(unit:t).

Year	Organic mercury compounds for				Insecticides
	Seed treatment	Spray	Dust	Total	
1946~'50*	—	—	—	50	162
1951~'55*	—	—	—	393	9
1956~'60*	—	—	—	(7389)	2379
1961	41	—	720	761	806
1962	25	3	4025	4053	1000
1963	54	115	13563	13732	819
1964	55	35	4123	4213	822
1965	39	4081	7395	11515	731
1961~'65*	214	4234	29826	34273	4178

* Total of 5 years

Table 12. Consumption of organic mercury compounds for the control of rice diseases in Korea (Ministry of Agr. & For.)(unit: t).

Year	Organic mercury compounds for			Total
	Seed treatment	Spraying	Dusting	
1946~'50*	—	—	—	10
1951~'55*	—	—	—	79
1956~'60*	—	—	—	1478
1961	41	—	720	761
1962	25	3	4025	4053
1963	54	115	13563	13732
1964	55	35	4123	4213
1965	39	4081	7395	11515

* Average of 5 years

Ⅲ Control of rice diseases.

In Korea, control of rice diseases has put great emphasis on a combination practice for the control of blast which has been known to be the most destructive disease during the past 40 years. Undoubtedly it has contributed not only for the control of blast but also partially control of other diseases such as 'Bakanae' disease, seed and seedling rot, stem rot and brown spot. But the rapid development of noteworthy diseases such as sheath blight, bacterial leaf blight, stripe and dwarf in the recent years showed that blast control alone will not produce sufficient yield of rice. So that new combination practice not alone for blast control but also for the control of other noteworthy diseases as noted above necessarily must be adopted, in which these diseases are prevalent.

Stripe as well as blast is spread all over the country and often bring about great damage, so growing promising resistant varieties both stripe and blast, adjustment of the time of transplanting, eradication of weeds such as foxtail which often become the locus of overwintering of insect vector(small brown planthopper, Delphacodes striatella) and application of organic phosphor insecticides such as Malathion in the later stage of nursery and in the paddy field, and also replacing diseased hills with healthy ones are recommended for stripe control in addition to blas control in the central and southern rice-growing regions By the same control measures, another virus disease, dwar by a virus transmitted by green rice leafhopper(Nephotetti bipunctatus cincticeps) and zigzag-striped leafhopper (De tocephalus dorsalis) is controlled simultaneously in the eas southern rice-growing region which the disease is prevalen

Sheath blight which is now prevalent in the west-sou hern region must be controlled principally by adjustme of transplanting time and application of forage fungicid such as organic arsenic compounds, and elimination overwintering sclerotia in the paddy field if possib Bacterial leaf blight which is now prevalent in the rest cted area of the west-southern rice-growing region m be controlled by prevention of overflow, avoiding cultivat of susceptible varieties such as 'Gimmaze' · 'Jaekeon 'Shinphung' and application of forage fungicides such copper-mercury compounds and antibiotics, and also er ication of the weed hosts such as Zizania latifolia. Lee sayanuka.

No one variety resistant to all of these disease is prov and cultural practices which are efficient for the cor of these diseases often do not produce sufficient yiel rice. In such cases it is considered that applicatior pesticides is the most effective control measure. In fac experimental result by the author (1948) showed application of forage fungicides was indispensable co measure in the control of blast, especially in the p field that applied heavy nitrogenous fertilizer for high- cultivation. Moreover, at the present which various dis to control coexist it is considered that a role of applic of pesticides is very great.