4. RICE BREEDING FOR RESISTANCE TO RICE VIRUS DISEASES IN JAPAN

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Introduction

Major rice virus/mycoplasma diseases in Japan are stripe, dwarf, black-streaked dwarf and yellow dwarf. Rice waika disease occurred recently in Kyushu was identified due to virus.

Some of these virus diseases do not occur in the northern part of Japan. Stripe disease has been reported in the area from Tohoku to Kyushu and most widely in Kanto, and dwarf disease in the area from Kanto to Kyushu and most conspicuous in Kyushu.

Black-streaked dwarf and yellow dwarf have not infested many acreage so far and the statistics of infested acreage due to these diseases have recently been found to be negligible[21]. Rice waika disease is restricted only to Kyushu.

Breeding for resistance to virus diseases has now become very active in several breeding stations after the successful introduction of resistant genes of stripe virus disease into japonica paddy varieties[21,22]. However, as a commercial variety with resistance to stripe disease, only one variety, MINEYUTAKA (formerly called Chugoku No. 46), has been registered so far[24], and resistant commercial varieties to other virus disease except rice waika disease are not yet developed. As for waika disease, several resistant varieties are found among japonica varieties[15].

Breeding system and breeding procedures in Japan

The breeding system and breeding procedures in Japan were reported recently elsewhere[14]. At present, the national rice breeding network in Japan has 14 breeding stations located all the way from Hokkaido down to Kyushu based on the ecological conditions and also more than 50 local stations are allotted for testing local adaptability and evaluating the special characteristics. Besides this network, the breeding work in several prefectures are also active to serve their special needs.

The breeding procedures taken in each station are not always the same, and even at the same station the procedure adopted may depend on the breeding objects and materials they have. However, most of the breeding stations have adopted the bulk method, keeping the population until the individual plants become genetically near homozygous. Fig. 1 shows the typical procedure adopted at the Kyushu National Agricultural Experiment Station[15].

In early generations, we keep the hybrid populations in mass with medium scale (1000–2000 individuals) and advance the generations by growing the materials in a greenhouse or paddy field. During these segregating generations, we sometimes try mass selection on maturity, and diseases and insects resistances with moderate selection pressure.

After individual selection, we make lines from individual plants, and test the homogeneity of the lines, grain quality, plant type and diseases resistance simultaneously. After this process, selected lines will be evaluated—their yield potential, adaptability and so forth.

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Around F_8 generation, only desirable lines having characteristics with higher or at least the same level of commercial varieties will be given local names (e.g., Saikai, Chugoku). Then in the prefectures, adaptability trial will be conducted at least three years before releasing a line as a commercial variety. During this period, evaluation of several important characteristics will be held at the breeding station.

When a person wants to introduce a desirable gene from exotic germplasm, backcross process proceeds normally before entering the normal procedure.

Stripe disease

The maximum acreage infested by the disease was recorded around 620,000 ha, in 1967. The infested acreage is decreasing and in 1973 it was 202,000 ha (7.9% of the total cultivated acreage). In Kyushu the trend of percentage of infective planthopper was reported to be drastically decreasing with unknown factors[9].

Breeding works on stripe disease resistance are undertaken now at most of the rice breeding stations except those in Tohoku and Hokuriku where the disease has not caused any serious damage in rice production.

The donors of resistant genes to stripe disease used in Japan so far are Rikuto Kanto 72, Modan[22,23] and Tjina. In the breeding program at most rice breeding stations, they use as one of parents in cross combinations Chugoku No. lines (e.g., St. No. 1, Chugoku Nos. 31 and 51), and Aichi No. lines (e.g., Shimahashirazu, Aichi Nos. 8 and 15 developed from St. No. 1) for the improvement of their breeding lines.

The breeding lines under testing for local adaptability trials for the present are: Chugoku Nos. 49, 56, 68 and 69 (bred at the Chugoku National Agricultural Experiment Station), Aichi Nos. 16, 21, 23, 24, 29, 31, 33 and 34 (bred at the Aichi Prefectural Crop Research Institute), and Saikai No. 154 (bred at the Kyushu National Agricultural Experiment Station).

The methods of evaluating the characteristics adopted in the breeding program are: 1) a seedling inoculation method[17], and an early planting method in the field condition or in the paddy field. The difficulties faced by breeders are in rearing enough infective planthopper for their own use, and the data depending on the percentage of infective planthopper in the natural field condition.

Most breeders still find several undesirable agronomic traits in their breeding lines, such as uneven ripening, poor grain quality, dark brownish colored panicle (caused by fungi or bacteria?) and low yield performance. They are now in the secondary or tertiary step breeding by using their own primary step bred lines.

Dwarf disease

Infested acreage by dwarf disease is suspected to be increasing. In 1973, 311,000 ha were infested by the disease, and in Kyushu the infested acreage was almost 60% of its cultivated paddy field.

Breeding program on dwarf disease resistance has just been started in several breeding stations in the central and the western parts of Japan.

Major donors of the resistance to dwarf disease are Tetep, C 203-1, Pebifun, Tadukan, Kaladumai and Rantaj Emas. They have now the breeding materials B_3F_1–B_4F_1 at the Central Agricultural Experiment Station; B_8F_2–B_3F_1 at the Aichi Prefectural Crop Research Institute; B_1F_5–B_3F_4 at the Kyushu National Agricultural Experiment Station and B_1F_3–B_1F_4 at the Miyazaki Prefectural Agricultural Experiment Station.

The testing methods are: 1) a seedling inoculation method[8] and 2) an early transplanting method. The difficulties in the testing methods may be the same or more than that of the case in stripe disease. The essential point is how to rear sufficient infective leafhopper early. In an early transplanting method with a favorable natural condition to vectors, we can get 30–40% infected plants in the case of susceptible varieties at Chikugo, and at Aichi they reported 10–80% of the plants infected by the disease in the infested area.

Black-streaked dwarf disease

Statistics of infested acreage by this disease are not available, but breeders have found the infestation by this disease among the breeding materials with resistance to the stripe disease at Saitama and Aichi breeding stations.

Breeding programs are undertaken at Chugoku and Central Agricultural Experiment Stations. Major donors are Tetep, Tadukan and Pebifun. They have now the materials B_3F_5 and B_4F_4 at Chugoku and B_2F_3–B_3F_1 at the Central Agricultural Experiment Station.

Testing methods are: 1) a seedling inoculation method[12] and 2) an early planting method. By an early planting method, the maximum percentage of infested plants is reported to be 10% at Konosu.

We have not had an active breeding program at present as for yellow dwarf.

Rice waika disease

Studies on rice waika disease are now underway and there are still many problems yet to be solved.

Typical symptoms of the infected plant were reported—shortening of culm length, discoloration of leaf blade, leaf yellowing and brownish necrosis in leaf blade[25].

However, further examinations of several susceptible varieties have shown that these symptoms do not always occur and stable symptoms of infected rice plant may be only in metric traits such as culm length and leaf blade shortening, poor grain quality and yield[4]. Culm length may be the best criterion when they test the materials on this disease, but even in culm length the degree of shortening is around 10% even in 2 to 3 leaves stage inoculation.

The testing method proposed are: 1) a seedling inoculation method (2 to 5 leaves

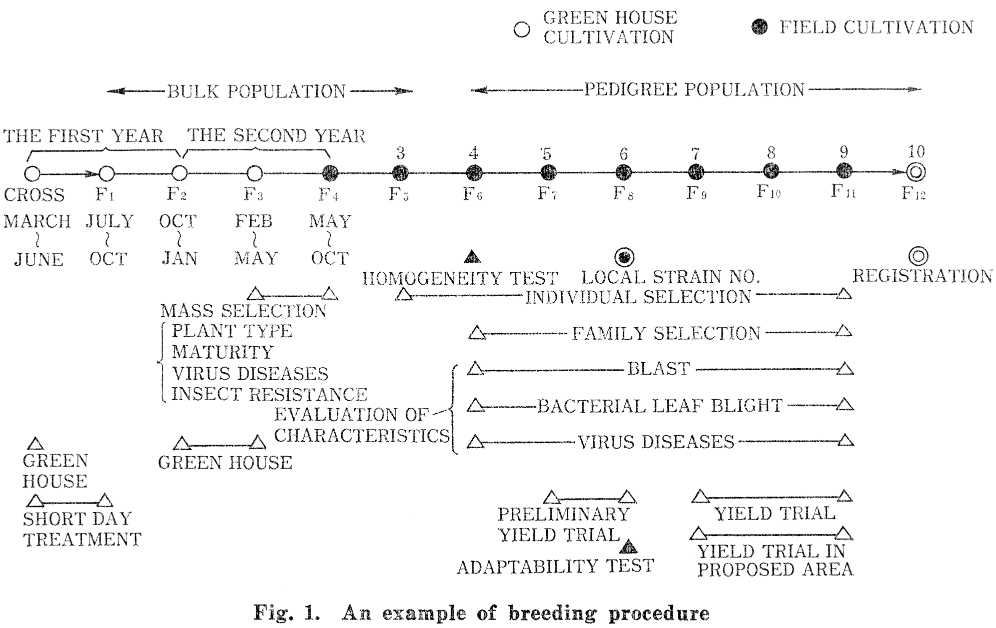

Fig. 1. An example of breeding procedure

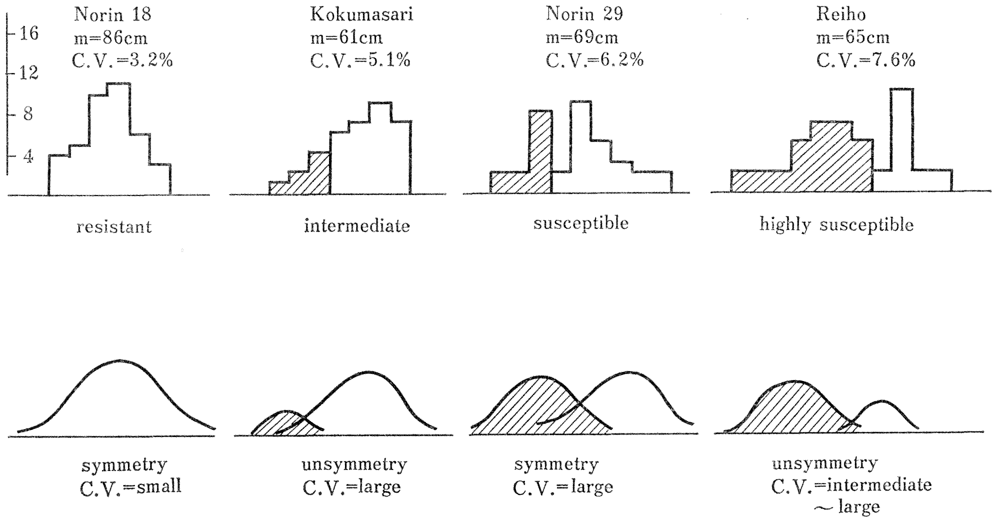

Fig. 2. Pattern of reaction of rice variety to rice waika disease in culm length

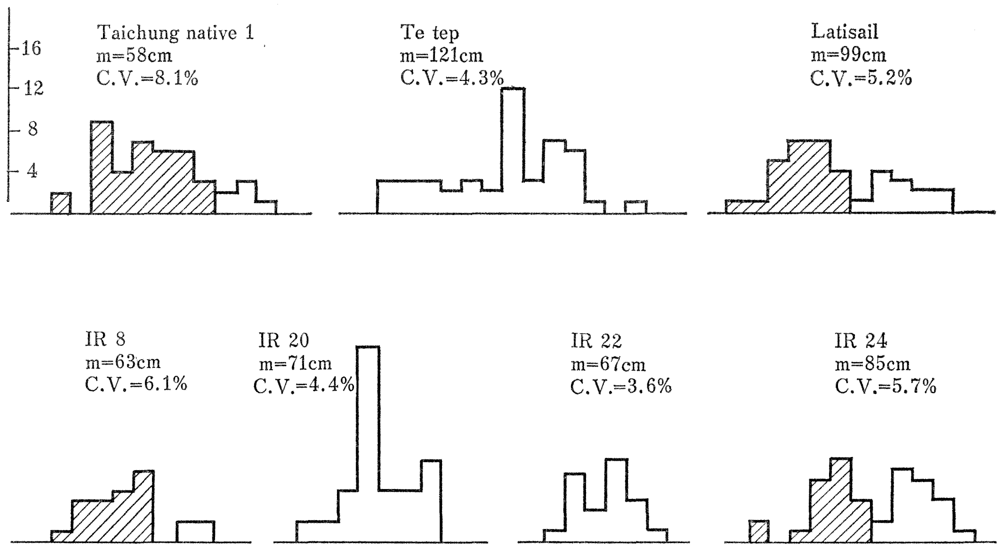

Fig. 3. Reaction pattern of indica type varieties to rice waika disease in culm length

stage) and 2) an early planting with infected plants before June 20, considering the building up the insect vector population. There are still several difficulties to identify the infected plants in the field condition. The most difficult point is that they cannot identify an individual infected plant except by comparing with the check.

Furthermore, if there is not a better criterion than culm length, they need to handle the data statistically. In the breeding work, they can evaluate the degree of resistance of lines only in the later generations when the variation in culm length due to genetic segregation is detected to be negligible. However, we have fortunately found resistant varieties to the disease among japonica varieties, by which we are able to control the outbreak of the disease effectively and quickly[7].

Table 1. Varieties response to rice waika disease in 1975 at Chikugo

Resistant (0%)	Moderately resistant (0–10%)	Moderately susceptibl (30–50%)	Susceptible (30–50%)	Very susceptible (more than 50%)
Ariake	Akebono	Aichi-asahi	Asakaze	Akanemochi
Asahi	Akibare	Aikoku	Chugoku 45	Akiji
Fukumasari	Chikara-sembon	Asahi	Chugoku 51	Harebare
Norin 6	Ginbozu	Asominori	Fukunishiki	Homarenishiki
Norin 18	Hiyokumochi	Ayanishiki	Hamakaze	Houyoku
Omachi	Kameji	Benisengoku	Honenwase	Jikkoku
	Kimmaze	Chujo 2	Iwaimochi	Kuji
	Norin 27	Chukyo-asahi	Koganenishiki	Mineyutaka
	Norin 37	Futaba	Miishinriki	Nagomasari
	Pi No. 2	Hayatomo	Norin 22	Nangokumochi
	Ryoseki 1	Hokushin 1	Norin 29	Nihonbare
	Saikai 59	Kokumasari	Reimei	Ooba
	Saikai 91	Koshihikari	Sachiwatari	Reiho
	Saikai 139	Kurenaimochi	Saikai 85	Saikai 94
	Sasanishiki	Kyushu 8	Saikai 135	Saikai 132
	Sembon-asahi	Mizuho	Satominori	Saikai 134
	Tosasembon	Nankai 24	Shinriki 1	Saikai 138
	Ukon-nishiki	Norin 8	Shinyamabuki	Sachikaze
	Yamadanishiki	Norin 12		Sendai
	Yutakasembon	Ooita-mii 120		Shinzan
		Pi No. 3		Shiranui
		Pi No. 4		Tachikara
		Saikai 115		Toyotama
		Saikai 125		
		Saikai 130		
		Toyonishiki		
		Tsukushibare		
		Zensho 26		
		Zuiho		

Data from the test field where infected source plants were planted every 12 m vertical to the test plot.

Although the studies on the varietal differences to the disease and the genetic control of the resistance are now undertaken, the method for the evaluation of varietal resistance and a part of the result are presented here (manuscript under preparation).

Fig. 2 shows the reaction pattern of several varieties to rice waika disease tested in the field condition. As most of the Japanese commercial varieties show small coefficient of variation in culm length (3% or so with 50 individual population), the healthy field plot will indicate small coefficient of variation and normal distribution in culm length without any disturbance during the growing period (left most in Fig. 2), while the plot infected by the disease will show different patterns depending on the degree of resistance.

The degree of susceptibility depends on the percentage of infected plants and we may roughly classify the group into three cases: moderately susceptible (unsymmetry, cv=large), susceptible (symmetry, cv=large), and very susceptible (unsymmetry, cv=

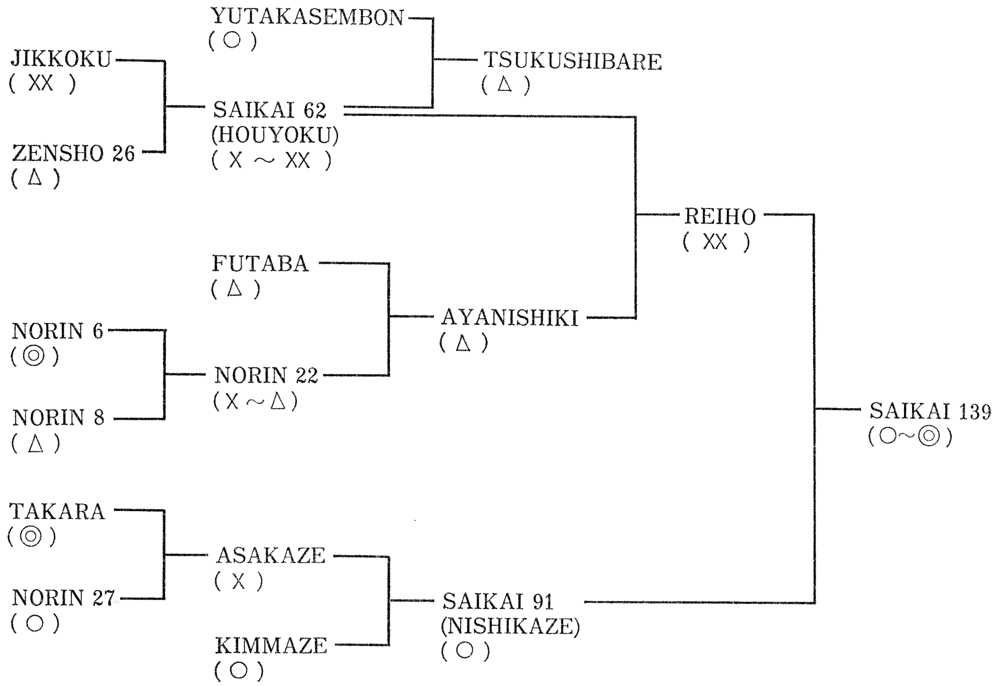

Fig. 4. Reaction of a group of varieties in a lineage to rice waika disease
◎: resistant, ○: moderately resistant, △: moderately susceptible,
×: susceptible, ××: very susceptible.

large—intermediate). In this method, we have to discard the data of the dwarf plant and other unhealthy plants from calculation.

By this criterion, we classified the japonica verieties into 5 groups (Table 1). In the case of indica type varieties, this method cannot always be applied because most of the introduced indica varieties show a little larger variation than that of the Japanese varieties, and sometimes there is segregation even in one variety.

However, considering this situation, we tried the method on several typical indica varieties cultivated at Chikugo. The result is shown in Fig. 3. IR 20 and IR 22 may be sure to be resistant to rice waika disease, but Taichung No. 1, IR 8 and IR 24 are suspected to be susceptible. But in the test of recovering virus from inoculated Taichung No. 1 and Latisail by insect vector was negative (Kimura T., personal communication).

To know the genetic control of the resistance roughly, the group of varieties in the lineage including susceptible variety Reiho were tested in the field condition in 1975 and the result is indicated in Fig. 4. The susceptibility to the disease seems from Jikkoku and the resistance from Kimmaze.

Several problems in rice breeding for virus resistant varieties in Japan

1. Most donors of virus disease resistant genes are indica or intermediate types[11]. It has taken and also will take a long time and much work to introduce resistant genes into japonica varieties with moderate yield potential.

In the breeding work for the resistance to stripe disease after St. No. 1 and Chugoku No. 31, many cross combinations have been tried at several breeding stations, and many undesirable agronomic traits combined with the genes have been found in their breeding materials. This means that breeders have to conduct continuous breeding for more refined and well balanced characteristics as a commercial variety.

For this purpose, a more easier way of making cross and effective evaluation system must be developed. The backcross method involving male sterility genes[1] may be one of the useful methods to apply in such a breeding process.

2. In the evaluation of the resistance to virus diseases, the degree of resistance is normally measured by the percentage of infected plants. Therefore, when they want to make a selection in an early generation, pedigree method may be more effective, but more facilities and labor will be required than those at most breeding stations in Japan.

3. Even if they get a resistant line to one of the major diseases, other virus disease may prevail by the same or different insect vectors. Then, the multiple disease resistant lines will be required to save the amount of chemicals applied.

When they desire to develop multiple diseases and insects resistant lines from the same or limited indica varieties, the breeding line will have more chances to accompany the so-called undesirable agronomic traits if the resistant genes are independent because the gene block[2] of donor parent will be more persistent through the breeding process. To break the gene blocks and linkage of an indica type variety more effectively, it will be desirable to use several different donors and making intermation within the population[2,20]. For this purpose, it will be necessary to search and evaluate new germplasm continuously.

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Discussion

W. P. Ting, Malaysia: In your test method you measure percentage of infected plants and classify them to resistant, intermediate etc. If there is no complete resistance, then isn't there a danger of recommending varieties which may serve a wide source of inoculum?

Answer: There may be some danger. But when one wants to develop a commercial cultivar, one needs to make so-called multi-resistant lines with moderate or high yield potential. In the breeding program, not complete but moderate resistant ones seem more practical. This is the reason why we evaluate the degree of resistance to virus disease by the percentage of infected plants.

K. C. Ling, IRRI: Are there any difficulties to apply the international scale (0=resistant, 9=susceptible) for varietal reaction to rice virus diseases in Japan?

Answer: Yes, there may be some difficulties because breeders consider the weights of the diseases in rice production in their regions, and the stress of the diseases differs by the regions or localities. Even in Japan, we make different standards for different regions, e.g., blast. However, we have also some standards to check the values to be able to compare the degrees of resistance among regions.

I. N. Oka, Indonesia: What is the yield loss of rice due to the Waika disease of rice?

Answer: They say there were 10 to 20% yield loss because of the outbreak of Waika disease. The information will be presented by Dr. Shinkai in the afternoon session. The yield loss may be not much, but the degeneration of grain quality is so severe, that the commercial value of the infested rice grain seems far lower than the one evaluated by the weight or pounds of grain yield.

H. Inoue, Japan: How to detect the damage caused by Waika disease and other pest when you proceed to screen a resistant variety in the experimental field? Several pests exist together and making a damage in shortening the culm length too.

Answer: As for the yield loss caused by diseases and pests, many pathologists and entomologists have strong concern, but I may say not much concern among breeders because the mechanism is not so simple in the field condition. We have not tried to evaluate the loss by Waika disease accurately so far. In our screening test of resistant varieties in a field condition, there are several causal factors for shortening the culm length as you pointed out. We think that it is better to evaluate the total effect of the disease in the field condition, excluding the other obvious factors causing damage.

S. Yoshimura, Japan: Waika disease has been rarely observed since last year. As you know, this new rice virus disease was never occurred in Japan in the past. We still did not know the cause of this disease ocurrence. So, my question is to ask the opinion of breeders side on the reason why this new disease occurrence was limited in the southern part of the country and why the decrease was remarkable recently. Can you give me any reasonable causes on these problems?

Answer: We do not know reasonable reasons on the occurrence of this disease yet. And as for the decreasing of the occurrence, we also do not know the reasons clearly, although we have had taken several measures such as replacing recommended varieties for resistant ones.