Rice Waika, A New Virus Disease, and Problems related to Its Occurrence and Control

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Rice waika, first occurred in Kyushu, a southern part of Japan, in 1971, had been called "stunting phenomenon of rice", and spread to a considerable extent without being known its causal factor. As the occurrence centered around the western part, a rice bowl, of Kyushu, the disease became to threaten the rice cultivation in Kyushu. To reveal the causal factor and establish countermeasures, a cooperative research was initiated in 1972 by the Kyushu National Agricultural Experiment Station and seven prefectural agricultural experiment stations in Kyushu. In 1974, two years later, the causal virus and its insect vector were identified, and the disease was named as "rice waika".

Since 1975, virological and ecological studies on the rice waika and the breeding work for resistant varieties have been carried out jointly by the Institute for Plant Virus Research, the University of Tokyo, and the Kyushu National Agricultural Experiment Station.

History of disease occurrence

Yearly trend of acreage of disease incidence is shown in Table 1. In 1967 stunted plants with reduced plant height appeared in spots with a variety, Hoyoku, at about the heading stage in a part of Saga Prefecture. This seems to be the first occurrence of rice waika. In 1971, four years later, the disease spread to 1,647 ha in coastal areas of Ariake-and Yatsushiro-Bay, covering Shimabara Peninsula of Nagasaki Prefecture, Saga Prefecture, Chikugo district of Fukuoka Prefecture, and Yatsushiro of Kumamoto Prefecture. In 1972, the disease spread rapidly to adjacent areas, reaching 11,924 ha which is about 7 times that of 1971. In 1973, the affected area further increased to 24,825 ha representing about 7% of the total rice area of Kyushu, about 350,000 ha, and the loss in production was estimated to be about 10,000 tons of brown rice.

Table 1. Yearly trend of area of rice waika incidence

Year	Area of incidence (ha)
1967	2
1968	50
1969	150
1970	23
1971	1, 647
1972	11, 924
1973	24, 825
1974	612
1975	24
1976	17

In the autumn of 1973, the insect vector of the disease was found, and subsequently the causal virus was discovered. Since then, countermeasures based on the control of insect vector and the adoption of resistant varieties were practiced, starting from the 1974 crop. In 1974, the first year of the control, the area of disease incidence was markedly reduced to 612 ha, which is only 2.5% of the affected area in the previous year. Since that year, the affected area has continued to decrease.

Ecology of disease occurrence

Symptoms: Visible symptoms of the disease appear in August: plants with leaf color similar to that caused by nitrogen starvation and with shortened plant height appear in round-shaped spots with several meters of diameter. At the heading stage in the early September, the diseased plants can easily be identified. Detailed observation on inoculated plants in pot experiments revealed that at about one month after the inoculation rusty spots appeared on leaves at an intermediate position, and an inward rolling of leaf tips, an increased angle between leaf and stem and a reduced elongation of upper leaf sheath occurred. However, all these changes are only transitory and do not appear on newly developed leaves. Therefore it is quite difficult to diagonize the disease at an early stage. According to Ishimaru et al.[2], the disease causes about 20% reduction in culm length, 10% reduction in panicle length with decreased number of grains per panicle, and 20–30% reduction in grain yields. Grain quality is also remarkably deteriorated.

Pathogenic virus: Nishi et al.[6] discovered spherical particles, approximately 30 nm in diameter, in diseased plants sampled from an affected area in Chikugo district of Fukuoka Prefecture in September 1973. The similar particles were observed in plants inoculated through *Nephotettix cincticeps*. Doi et al.[1] also observed the similar particles in diseased plants in the fields. This small spherical particle was identified as pathogenic virus of the disease.

Insect vector: Yokoyama and Sakai[9] discovered in 1973 autumn that the insect vector of the disease is *Nephotettix cincticeps* (Uhler) (green rice leafhopper). And later *N. virescens* (Distant) (oriental green rice leafhopper)[3] and *N. nigropictus* (Stål) (tropical green rice leafhopper)[7] were added as vectors. *N. cincticeps* is prevalent widely in Japan, particularly with high population density in Kyushu. The latter two species exist in a small number in southern part of Kyushu. *Recilia dorsalis* (Motschulsky) and *Macrosteles orientalis* Vilbaste do not transmit this virus[8].

Transmission: It is a characteristic of the transmission of the waika disease virus that it occurs only immediately after the acquisition feeding on diseased plants. Transmissible period after 24 hr of acquisition feeding is usually 1 day, and in very few cases it is 2 days. Transmissibility is lost by ecdysis.[8]

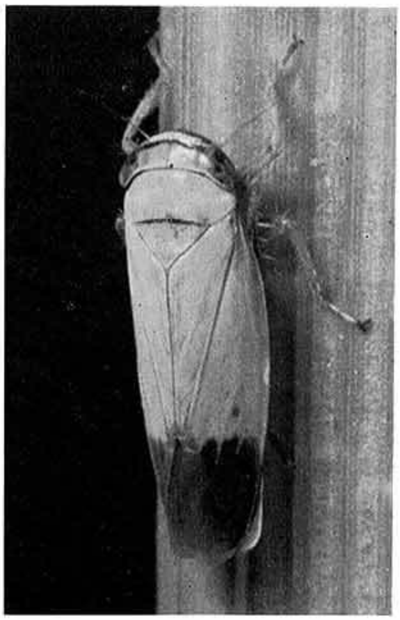
Maejima et al.[5] reported that rice plants become a source of virus for insect transmission at 7 days after inoculation feeding although any symptom is not yet shown on the plants.

Host range: Inoculation tests, carried out with about 50 species of gramineous plants, showed that there is no other host than rice plants. The virus is not transmitted to *Leersia sayanuka* Ohwi, *L. japonica* Makino, *Zizania latifolia* Turcz., *Alopecurus aequalis* Sobol., *Poa annua* L., *Bromus catharticus* Vahl, *Lolium multiflorum* Lam., *Hordeum vulgare* L., *Triticum aestivum* L., *Avena sativa* L., *Secale cereale* L., *Zea mays* L., and *Digitaria adscendens* Henr.[8]

Varietal resistance of rice plant: Remarkable differences in varietal resistance were observed in infested fields. Among varieties generally grown, Reiho suffers seriously while extremely few incidence with Tukushibare. Varietal resistance is as follows:

- Resistant — Norin 22, Koganenishiki, Norin 18, Kinmaze, Tsukushibare, Mangetsu-mochi, Saikai 139, etc.
- Medium — Nihonbare, Mine-yutaka, Asominori, Minaminishiki, Hiyokumochi, Kurenaimochi, etc.
- Susceptible — Reiho, Kuju, Akanemochi, Saikai 132, Saikai 134, Nankai 57, etc.

Infection cycle: In the lowland paddy field area of western part of Kyushu, that was the



(Male adult. Body length is 4.5 mm)
Plate 1. *Nephotettix cincticeps* (Uhler), an insect vector of rice waika virus

centre of the disease incidence, ratoons of rice plants die in the winter, making the overwintering of the virus impossible. Overwintering of the virus in the hibernated insects of *N. cincticeps* was proved to be negative. To reveal the infected wintering host as the source of the virus to the first generation of *N. cincticeps* is an important problem to be solved in future.

Factors affecting the disease occurrence

Based on the pathogenic virus, insect vector and transmission pattern it was made clear that the rice waika belongs to the same group of the tungro in Southeast Asia. Therefore, the history of the occurrence of the disease will have to be studied in relation to the tungro and rice culture in Southeast Asia. In the meanwhile, the rice cultivation in Kyushu at round 1972, when the disease outbroke, will be looked into from the following two points:

1) Spread of a susceptible variety, Reiho. This variety was used in Kyushu since 1969, but not in other regions. Area of the variety began to increase since 1969, and in 1970 it accounted for 91,800 ha, representing 27% of a total rice area. In 1972 and 1973 when the serious outbreak occurred, the area showed 150,000 ha, representing about 50% of the total rice area. Lowland paddy field area along the Ariake Bay, a central portion of the disease occurrence, was mostly being cropped to this variety.

2) High population density of *N. cincticeps*. The population density of the insect is high in Kyushu among different regions of Japan. Particularly in 1971 to 1973, idle paddy fields were increased due to rice production curtailment policy, and which promoted the population increase of *N. cincticeps* from an early stage of rice season.

It is considered, based on the pattern of virus transmission of the vector and infection of rice, that when the primary infection is established even in a smale scale the virus transmission is very much promoted by higher population density of the vector. Therefore the intensive cropping of Reiho as well as the increased population of the vector can be enough as a background of the great occurrence of the disease. However, it is not known where the infection source was located, although investigations are underway. Temperature in winter of 1972 and 1973 was higher than usual by 1.5°C. The warm winter may cause an early emergence of the vector, but an effect on the infection cycle is not known.

Control measures and future problems

The key control measures are the control of *N. cincticeps* and the use of resistant rice varieties.

In the usual rice cultivation in lowland paddy field area along the coast of Ariake Bay, where the disease was prevalent, rice is sown in late May, transplanted in late June, and harvested in late October with heading time at the early September. The disease becomes distinguishable only at around the heading time.

N. cincticeps repeats 4 generations in this area. Adults of overwintered generation emerge on weeds from late March to early May. Larvae of the first generation emerge after the mid-May, and the adults migrate into nursery beds and paddy fields from mid-June to early July. The second and third generation emerge in paddy fields from early July to mid-September. The virus transmission takes place by the first generation adults and nymphs and adults of the second generation, that emerge at an early stage of rice season.[4] Therefore, the control of vectors at an early stage is emphasized, i.e., pesticide application for the first and second generation occurring from the nursery period to the early stage after transplanting in order to reduce population density of the vector and hence to control infection. In recent years, transplanting by machines of young seedlings is prevailed. In this case, pesticide is applied to seedling boxes immediately before transplanting. It makes the insect control far more easy.

The use of resistant varieties is extremely effective. At around 1972 when the disease outbroke seriously, most of the lowland paddy fields along Ariake Bay were planted to Reiho. From the first year of the disease control, 1974, resistant varieties such as Tsukushibare and Nihonbare began to replace Reiho, but the variety still remained on 70,180 ha, 21% of the total rice area, in 1976, because of its easiness of cultivation. However, resistant varieties such as Tsukushibare, Nihonbare, Asominori and Kogane-nishiki have increased their acreage to 110,000 ha in 1976, which represent 31% of the total rice area, far exceeding that of Reiho. The shifting to resistant varieties which was undertaken since 1974 is found quite effective, and the great outbreak in 1972 and 1973 suggests that the concentrated cropping of susceptible varieties is risky.

Although the disease control by the combined effect of vector control and use of resistant varieties has proved successful, there still remain important problems. Overwintering host(s) which is at a key position of the infection cycle, has to be clarified for the understanding of the whole picture of the disease. The reason why the disease is limited to Kyushu will be clarified when the whole picture of the disease is known. The second problem is related to pesticide use. In Kyushu the pesticide use becomes fairly large amount due to large number of *N. cincticeps* existing. In future, control techniques to save pesticide use as far as possible must be established to avoid environmental pollutions. For that purpose also, the future development in screening and breeding of resistant varieties is very much desirable.

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