Ecology and Control of Rice Virus Diseases in Japan

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Kinds of Virus Diseases

There are four kinds of virus diseases of the rice plant in Japan: dwarf (or stunt), yellow dwarf, stripe-disease and black-streaked dwarf. These diseases are widespread in the middle and southern parts of Japan, but their occurrences have not yet been reported from Hokkaido and northern Honshu. Annual crop losses caused by them amount to several ten thousands of tons.

All these diseases are transmitted by leafhoppers: dwarf by *Nephotettix cincticeps*, *N. apicalis*, and *Inazuma dorsalis*; yellow dwarf by *N. cincticeps*, *N. impicticeps*, and *N. apicalis*; stripe-disease by *Laodelphax striatellus*, and *Unkanodes sapporona*; and black-streaked dwarf by *L. striatellus* and *U. sapporona*. In the field, only *N. cincticeps* (in the cases of dwarf and yellow dwarf) and *L. striatellus* (in the cases of stripedise ase and black-streaked dwarf) play major roles in transmission.

In dwarf and stripe-disease, the viruses are passed through eggs to progeny of infective females. This makes it possible for these viruses to persist in the leafhoppers through generations in the absence of diseased plants in the field. The rate of virus passage is very high in stripe-disease – *L. striatellus* combination, but lower in dwarf – *N. cincticeps* combination. In yellow dwarf and black-streaked dwarf, there is no indication of virus passage through eggs.

In dwarf and stripe-disease, only limited percentages of individuals of the respective leafhopper species appear to be able to acquire virus and become infective, even when they are fed with diseased plants for a long time. In yellow dwarf and black-streaked dwarf, on the other hand, most individuals of the respective leafhopper species become infective if they are fed with diseased plants for sufficient period.

Virus transmission, in all cases, is of typical persistent type, and once leafhoppers become infective, they remain so practically as long as they live. Infectivity, however, decreases as the leafhoppers become old. Feeding on diseased plants for 1 to 3 days is usually enough for the leafhoppers to acquire virus. Incubation period within the insect, *i. e.* time from virus acquisition to outset of infection, in warm seasons, is around two weeks in dwarf, stripe-disease and blackstreaked dwarf, while it is about four weeks in yellow dwarf. To infect plants, one to several hours of feeding is usually enough. Incubation period within the plant, *i. e.* time from infection to symptom appearance, when rice plants are infected young, is about two weeks in dwarf and stripe-disease, three weeks in black-streaked dwarf, and four weeks in yellow dwarf.

In addition to rice, a number of gramineous plants are known to be susceptible to these viruses, but these alternative host plants are not important in the virus successions in the field, except in black-streaked dwarf, to which corn, wheat, and barley are susceptible.

Life Cycles of Virus-transmitting Leafhoppors

The rice cropping season in Japan is from March to November. Times of sowing, transplanting, and harvesting differ according to localities, but there are roughly two kinds of cultivation practices: conventional or ordinary cultivation in which seedlings are reared in open nurseries, and recently developed early seasonal cultivation, in which seedlings are reared in protected nurseries. In any case, during winter season there is no rice planted in the field.

The leafhopper *N. cincticeps* passes winter mostly in the form of diapausing nymphs at 4th instar, living among weeds on fallow fields, dikes, and embarkments. Passing through

5th instar, they emerge into adults from March to April. Some of these adults move into early rice nurseries, but majority lay eggs on gramineous weeds. Nymphs therefrom, which are of 1st generation of the year, feed on weeds, and emerge in middle to late June, in warm areas. The adults of this 1st generation move to rice nurseries and rice fields, and lay eggs there. In ordinary cultivations, this is about the time of transplanting, while in early seasonal cultivations the rice plants are at tillering stage. Adults of the next (2nd) generation emerge from July to August. In most places, there occur 4 to 6 generations a year, and nymphs from eggs laid in September usually go into diapause and pass winter.

The life cycle of *L. striatellus* is, in outline, rather similar to that of *N. cincticeps*. Overwintering is done mostly in the form of diapausing nymphs at 4th instar, which live among weeds on fallow fields, dikes, embarkments, and also grasslands. In early spring, they proceed to 5th instar, and then emerge into adults. Some of these adults lay eggs on gramineous weeds, while others move into wheat or barley fields and lay eggs there. When there is an early planting of rice, a few may come in, but apparently they do not care so much for rice in this season as in *L. striatellus*. Adults of the next (1st) generation occur in early to middle June, in warm areas. These move from wheat and barley fields and grasslands into rice nurseries and fields, in enormous flocks. A few more generations may be repeated in rice fields, and in late summer when rice plants become older they gradually move back to grasses. Nymphs from eggs laid in September to October usually go into diapause and pass winter.

Infection of Rice Plants

Susceptibility of the rice plant to these viruses generally decreases with age. The plant becomes practically immune after flower primordium initiation, except for the case of yellow dwarf, in which infection may take place even after heading, diseased shoots coming out from cut stubbles. Plant susceptibility is also dependent on nutritional conditions. Excessive nitrogenous fertilizer, in particular, is known to enhance susceptibility. In seed nurseries, chances of infection are usually small, because of very low leafhopper-seedling ratio as well as of low nitrogen level, particularly in later stages. After transplanting, seedlings appear to remain for some time rather resistant, due possibly to injured roots and diminished nutriment uptake. When new roots come out and active uptake commences, plant susceptibility becomes very high. This is thought to be the most critical period.

As a rule, crop loss is heavier the earlier in the growth stage infection occurs. Late infection, however, may often cause a considerable loss, in the form of unfilled grains, especially in the case of stripe-disease.

Time of major infection can be determined either by covering parts of nurseries or fields with insect-proof screens or by intensively spraying with insecticides for certain peroids. In yellow dwarf, it was found that primary infection is caused by adult *N. cincticeps* of overwintered generation. They ought to have acquired virus in the previous autumn from diseased shoots growing from cut stubbles. In dwarf, on the other hand, the overwintered generation plays only a minor role in infecting rice plants, except in cases of very early cultivation. Major infection in most cases was found to be due to adults of 1st generation and often also nymphs of the generation which follows (2nd generation). In stripe-disease, likewise, infections caused by adults of the 1st generation and nymphs of 2nd generation of *L. striatellus* are most significant. In both these diseases, the virus sources, therefore, are not diseased plants but viruses maintained in the leafhoppers by virtue of passages through eggs. In the case of black-streaked dwarf, there is still some uncertainty about whether leafhoppers of overwintered generation or of the next generation cause major infection on rice and corn.

Forecasting of Disease Occurrence

Time of occurrence and population densities of leafhoppers vary year after year. Several techniques for assessing population densities of leafhoppers in the field, light trap, sticky trap, water basin trap, sweeping net, suction catcher, blower-and-net, etc., are being used according to occasion and purpose. Percentages of infective individuals may be assessed by caging field-collected leafhoppers singly with young test rice seedlings. Use of newly sprouted seed in a small test tube instead of larger seedling in a cage was found to be more convenient, and this improved technique is more increasingly employed. A recently developed serological technique of sensitized blood-cell agglutination is extremely sensitive, being capable of detecting virus in a single leafhopper individual. This technique is also extensively used.

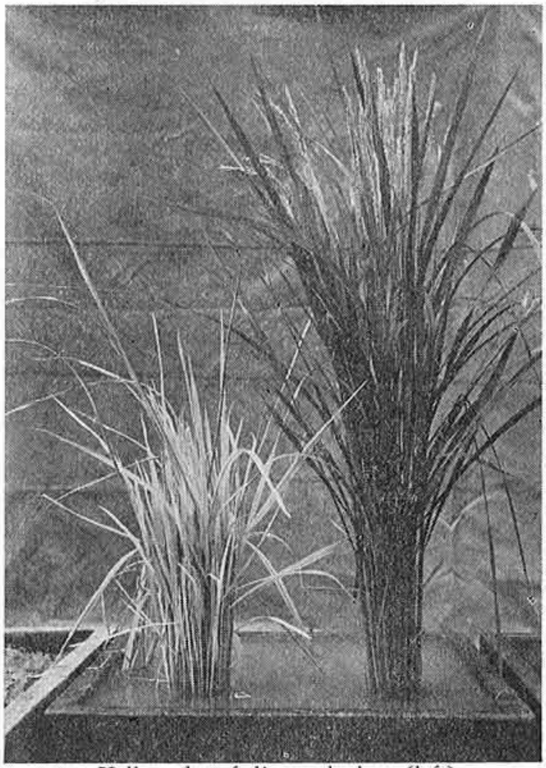
In dwarf and stripe, it was confirmed that disease incidence is much dependent on population density of 1st generation leafhoppers. Percentages of infective individuals, which in these diseases are usually rather low, differ from place to place but fluctuate only slightly according to season and year. Time and mode of occurrence of 1st generation adults are also important, inasmuch as disease incidence becomes highest when majority of these adults invade rice fields right after transplanting.

In yellow dwarf, disease incidence depends much on whether overwintered leafhoppers live long enough to be able to infect rice. The percentage of virus-carrying individuals in this overwintered population, which in some cases may be as high as 70 per cent, shows a high correlation with disease incidence in secondary shoots from cut stubbles in the preceding autumn.

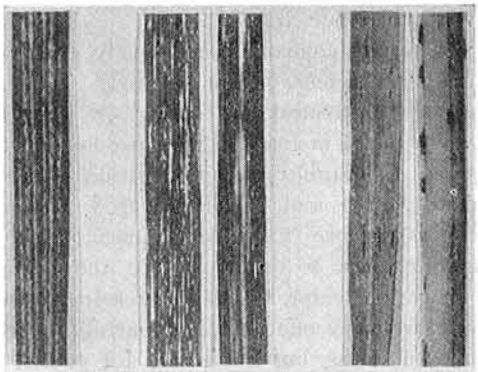
Effects of climatic factors on time of occurrence, population densities, and longevity of leafhoppers have been statistically analyzed on several instances, and usable forecasting formulae have been developed.

Control

With respect to stripe-disease, a highly resistant and high yielding variety was developed recently, by backcrossing a high yielding Japanese variety with a resistant *indica* variety. Breeding program in this line is being continued, and it is expected that some more varieties resistant to stripe-disease, and also varieties resistant to dwarf and yellow dwarf, will be obtained in the near future. Many upland rice varieties are also known to be resistant to stripe-disease. Otherwise no commercially grown Japanese varieties possess any sufficient resistance to

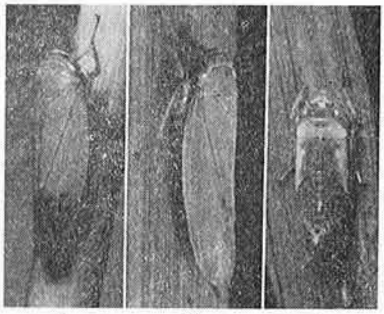


Yellow dwarf diseased plant (left)
and healthy plant (right)



1 2 3a 3b

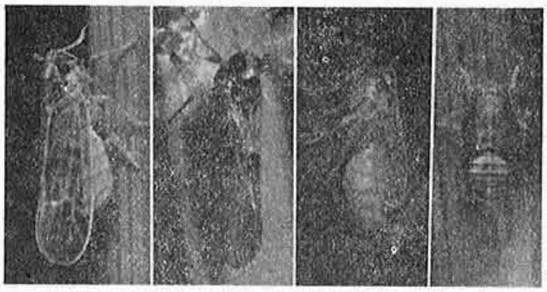
Symptoms on leaf and culm
1. Dwarf (leaf)
2. Stripe-disease (leaf)
3. Black-streaked dwarf
a (leaf), b (culm)



1 2 3

Nephotettix cincticeps. This leafhopper transmits dwarf and yellow dwarf.

1. male
2. female
3. nymph



1 2 3 4

Laodelphax striatellus. This leafhopper transmits stripe and black-streaked dwarf.

1. female, long-winged
2. male
3. female, short-winged
4. nymph

any of the four diseases.

Insecticidal control is extensively practiced. This is indispensable particularly for early seasonal cultivations. Dusting or spraying by helicopters is favored, because large areas can be thoroughly covered within a short period. Large and small powered sprayers and dusters are also used. Insecticides in granular form, to be applied to the surface of irrigation water, are also increasingly used. These are very effective in controlling leafhopper nymphs, but ineffective for adults.

Denapon, DDT, Malathion, Vamidothion, Diazinon, Mecarbam, and several other chemicals are effective for both *N. cincticeps* and *L. striatellus*. BHC is very effective for *L. striatellus* but not for *N. cincticeps*.

Choice of proper time for insecticidal application is essential. For dwarf and stripe-disease, spraying or dusting has to be made at least twice, one adjusted to the peak of occurrence of 1st generation adults, and another one to that of 2nd generation nymphs. Frequently, occurrence curve does not show a sharp peak, in which case more frequent applications become necessary. Stripe-disease is rather difficult to control particularly when population density of 1st generation *L. striatellus* is very high. For yellow dwarf, insecticidal applications may be made either in late autumn or in early spring, provided that air temperature is not too low.

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