REGIONAL DIFFERENCES IN THE FEEDING DAMAGE CAUSED BY THE GREEN RICE LEAFHOPPER TO PADDY RICE IN JAPAN

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Introduction

The green rice leafhopper, *Nephotettix cincticeps* Uhler, is one of the common insect pests of paddy rice in Japan except for the Hokkaido district. The damage caused by this leafhopper varies with the geographical location, namely north-eastern and south-western Japan.

In the former area which comprises the Tohoku, Hokuriku and Kanto districts, there have been many records of yield losses due to the sucking of rice plants by the green rice leafhopper (hereafter, GRL) (Ueda, 1955; Abe *et al.*, 1960; Nirei *et al.*, 1975). The outbreaks of GRL occasionally cause serious damage to paddy rice during heading and milk-ripe stages (Kawase, 1958), whereas the virus diseases of which GRL are vectors are conspicuously absent except for some localities where early planting rice is cultivated.

In the latter area which covers the Chugoku, Shikoku and Kyushu districts, GRL causes serious damage by transmitting dwarf and yellow dwarf diseases to young rice plants. But the direct feeding damage due to GRL is widely recognized as being economically negligible. The difference in the degree of feeding damage between both areas is explained by the fact that the population density in south-western Japan is very stable from late summer to early autumn and that its level is remarkably low as compared with that observed in north-eastern Japan (Kuno, 1968; Kiritani *et al.*, 1970; Hokyo, 1972). Consequently, the leafhopper density during the ripening period of rice plants is below the level where the damage by sap-sucking occurs (Nakasuji *et al.*, 1968; Kasai *et al.*, 1972).

However, the difference in the abundance of GRL between both areas is not sufficient to explain the difference in the feeding damage between the areas. As reported elsewhere (Ueda, 1957; Tamura, 1957; Suenaga, 1959), the degree of yield losses due to GRL in north-eastern Japan is surprisingly larger than that observed in south-western Japan.

In the present paper, the author reviewed results of loss assessment due to the feeding damage by GRL reported recently from Agricultural Experiment Stations located in different areas. It has been demonstrated that the regional differences in the degree of feeding damage could be ascribed not only to the abundance of GRL but also to the ripening process of rice plants.

Regional differences in feeding damage

Data concerning yield reductions caused by different density levels of GRL, mainly adults, when they were allowed to infest rice plants of different stages for various periods of time were used for analysis. The localities where the data were obtained are shown in Fig. 1. In most cases, the periods of infestation were about one to two weeks after heading (Yamaguchi *et al.*, 1969; Kasai *et al.*, 1972; Kato *et al.*, 1978 etc.). Besides these cases, some damage analyses were carried out by infesting rice with adults during the entire ripening period (e.g. Takayama *et al.*, 1976) and others were done by confining leafhoppers through one or two generations in cages from heading till harvesting of rice (e.g. Nakasuji *et al.*, 1968).

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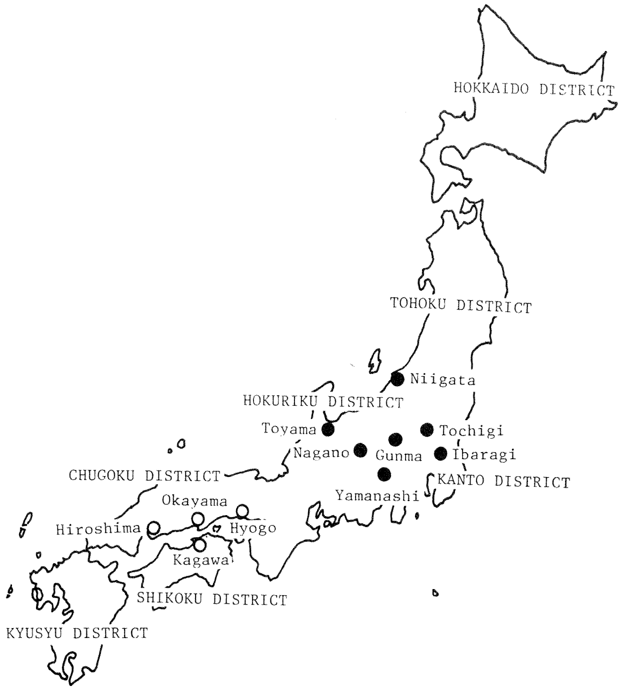

Note: ●: North-eastern Japan, ○: South-western Japan.

Fig. 1 Localities with data analysis of damage

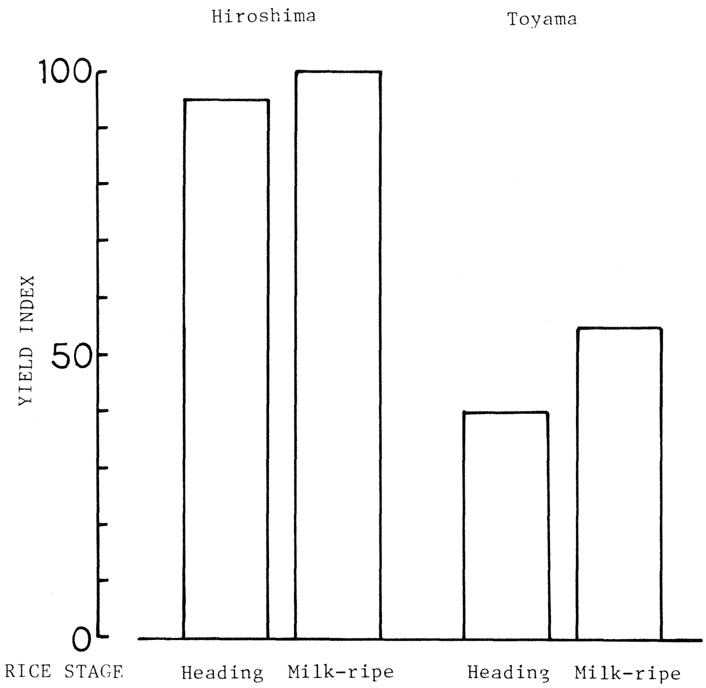

Fig. 2 Relation between rice yield reduction and the stage of rice plants infested with 400 leafhopper adults (Naba unpublished and Kato *et al.,* 1978)

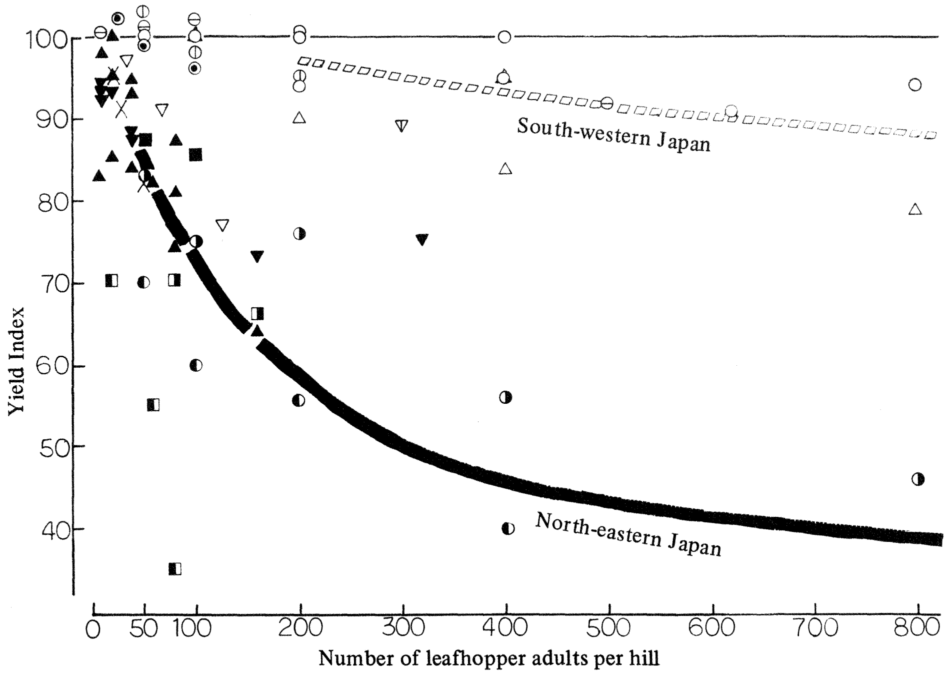

Fig. 3 Relation between rice yield reduction adult and leafhopper adult density

Note;

Symbols	Localities		Rice varieties	Stages of infestation	Sources and years reviewed
◐	North-eastern Japan	Toyama	Hounenwase	Heading	Kato, S. *et al.* 1978
◑		Toyama	Hounenwase	Milk-ripe	Kato, S. *et al.* 1978
◧		Niigata	Todorokiwase	First half of ripening	1974 (Hokuriku Natl. Agric. Exp. Stn.)
◨		Niigata	Todorokiwase	Latter half of ripening	1974 (Hokuriku Natl. Agric. Exp. Stn.)
×		Tochigi	Nihonbare	Heading to reaping	1975
⊙		Ibaragi	Nihonbare	Heading to reaping	1975
▼		Gunma	Nihonmasari	Heading to reaping	Takayama, T. *et al.* 1976
▲		Yamanashi	Nihonbare	Heading to reaping	1975, 1976, 1977
■		Nagano	Hounenwase	Full heading to maturity	1973
○	South-western Japan	Hiroshima	Nakateshinsenbon	First half of ripening	1973, 1974
△		Okayama	Akebono	Full heading, heading	1973, 1974
⊖		Kagawa	Tsuyuake	Full heading	Kasai, T. *et al.* 1972
⦶		Kagawa	Akebono	Full heading	Kasai, T. *et al.* 1972
▽		Hyogo	Norin No. 23	Flowering to milk-ripe	Yamaguchi, F. *et al.* 1969
⊽		Hyogo	Kinmaze	Heading	Yamaguchi, F. *et al.* 1969

Fig. 2 shows that the infestation with GRL populations at the heading stage produced less yield than that at the milk-ripe stage both in Hiroshima in south-western Japan and Toyama in north-eastern Japan. But this result suggests that the impact of injury by sap-sucking on yield at both stages of rice plants in north- eastern Japan is greater than that in south-western Japan.

The relation between leafhopper density and yield reduction is shown in Fig. 3. Although the rice varieties used, the stages of rice plants injured and the periods of infestation by GRL are different, all the collected data are treated as materials of comparable value. The indices of rice yield in the infested plots are expressed in terms of the relative weight of either perfect kernels or 1,000 grains.

Although the points are scattered, a great difference is likely to exist in the mode of yield reduction between those localities in north-eastern Japan and south-western Japan. In north-eastern Japan, the rice yield decreases by about 5 to 10 percent when 10 to 20 adults per hill infest rice plants and it is drastically reduced with the increase in adult density. Conspicuous damage of rice plants is caused by the attack of 200 to 400 adults per hill, when yield losses are estimated at about 30 to 50 percent of that of uninfested plants. On the other hand, the yield index in south-western Japan remains practically at a value of 100 below the density level of 100 adults per hill. Infestation with as many adults as 200 per hill gives rise to only 5 percent loss whereas with 600 adults per hill, a 10 percent loss is recorded.

Relation between the ripening process of paddy rice and the injury caused by leafhoppers

As described in the previous section, the range of leafhopper density which causes no yield loss in north-eastern Japan is much narrower than that in south-western Japan. The extent of yield loss at a comparable leafhopper density also differs greatly between the two areas. This suggests that some physiological changes in rice plants induced by leafhoppers should be postulated in order to explain the regional difference in the mode of feeding damage. That is to say, the pattern of the physiological responses of rice plants to the sap-sucking injury should differ between both areas during the ripening period.

Table 1 shows the meteorological conditions during the ripening period of paddy rice in various localities. The heading date of rice varieties cultivated in north-eastern Japan is mainly from late July to early August at the latest. Grain filling proceeds rapidly under high temperature and abundant sunshine, so that it takes about 35 days from heading to full ripening. In contrast, a large number of rice varieties cropped in south-western Japan come into heading from late August to mid-September followed by a ripening period of about 50 days in the cool season of autumn.

Therefore, the ripening process of paddy rice is quite different in the two areas, as shown in Fig. 4. In the case of rice varieties cultivated in north-eastern Japan, it has been widely recognized that the photosynthetic products translocate quickly from straw to panicle resulting in a rapid gain of grain weight soon after heading. Simultaneously, the amount of consumption of the assimilates by respiration increases because of the existence of high temperatures during the ripening period. The translocation rate of the photosynthetic products, represented as the increment of 1,000-grain-weight per day reaches a maximum 15-20 days after heading and then decreases rapidly for both Koshihikari in Toyama and Koshijiwase in Niigata. The heavy infestation with leafhoppers at and immediately after heading in north-eastern Japan would result in the loss of grain weight because the initial loss of the photosynthetic products cannot be easily recovered in the latter half of the ripening period due to the ripening pattern of these rice varieties.

On the other hand, the photosynthetic products formed from heading to maturity are responsible for the filling of grains in south-western Japan. The translocation rate of the photosynthetic products to panicles in Nakateshinsenbon and Akebono cultivated in Hiroshima and Okayama, respectively, is higher than that in Koshihikari and Koshijiwase from 20-25 days after heading till the maturing stage. Therefore, even if the feeding of leafhoppers would cause some delay in ripening, any substantial yield loss of rice hardly takes place except if there is a severe infestation with GRL.

Table 1 Meteorological conditions during the ripening period of rice plants

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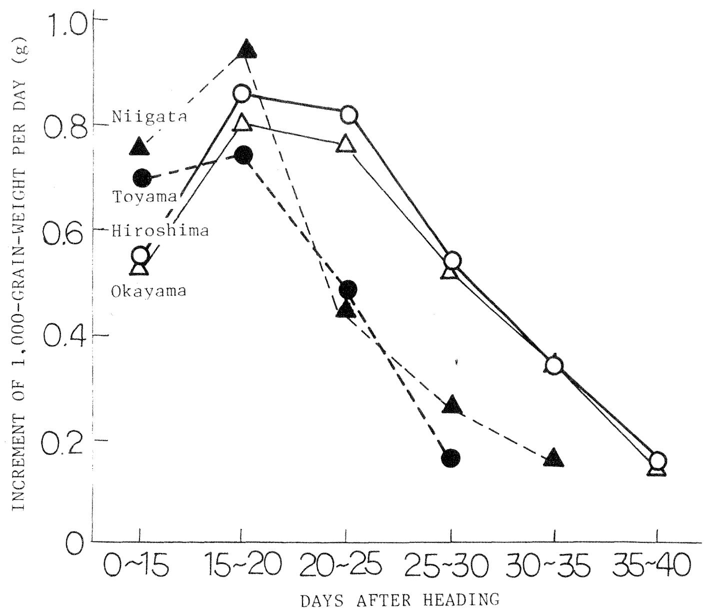
Localities		Rice varieties	Heading date	10 days after heading		30 days after heading		Days from heading to full ripening
				Mean air temperature	Total sunshine	Mean air temperature	Total sunshine	
				(°C)	(hrs)	(°C)	(hrs)	
North-eastern Japan	Toyama	Hatsukaori	Late July	26.4	75.9	26.0	196.1	36
	Niigata	Koshijiwase	Late July	26.5	78.7	26.2	213.2	34
	Tochigi	Koshihikari	Early Aug.	25.3	59.4	24.8	174.0	39
	Ibaragi	Koshihikari	Early Aug.	26.2	66.9	25.8	178.4	36
South-western Japan	Hiroshima	Nakateshinsenbon	Late Aug.	25.3	–	23.7	–	44
	Okayama	Akebono	Mid-Sept.	23.1	54.3	21.1	164.3	54
	Kagawa	Setohomare	Mid-Sept.	25.6	59.6	23.5	152.3	46
	Hyogo	Harima	Late Aug.	25.7	64.9	24.0	161.5	47

From "The annual report of forecasting of pest occurrence" in each locality.



Note;

Symbols	Localities		Rice varieties
●	North-eastern Japan	Toyama	Koshihikari
▲		Niigata	Koshijiwase
○	South eastern Japan	Hiroshima	Nakateshinsenbon
△		Okayama	Akebono

Fig. 4 Differences in the ripening process of rice plants between north-eastern and south-western Japan
From "The routine experiments on the response of paddy rice to climate (1968–72).., MAF

Note: Rice varieties Toyama: Koshihikari, Niigata: Koshijiwase
Hiroshima: Nakateshinsenbon, Okayama: Akebono

Each of the rice plants of the early-maturing variety, Akihikari (hereafter, Aki), and the medium-maturing one, Nakateshinsenbon (hereafter, Nakate), was infested with 20 adult females per panicle at the full heading stage (Fig. 5). The heading date and the ripening period of the former were July 25 and 38 days, while those of the latter were August 15 and 43 days, respectively. The decrease in yield indices, expressed as the trend of 1,000-grain- weight was the greatest in both varieties seven days after the end of the feeding experiment (Fig. 5). Aki was more severely affected by the infestation with GRL than Nakate. The yield of the infested Aki decreased by about 5 percent as compared with that of the uninfested one because the effect of sap-sucking persisted till the maturing stage. However, no yield losses occurred in Nakate. The difference in such phases of the ripening process between these two varieties contributed to the difference in the extent of the feeding damage between them (Fig. 5). These observations suggest that early-maturing varieties like Aki of which the ripening proceeds under high air temperatures and long duration of sunshine from heading to maturity are likely to be adversely affected by the feeding of GRL.

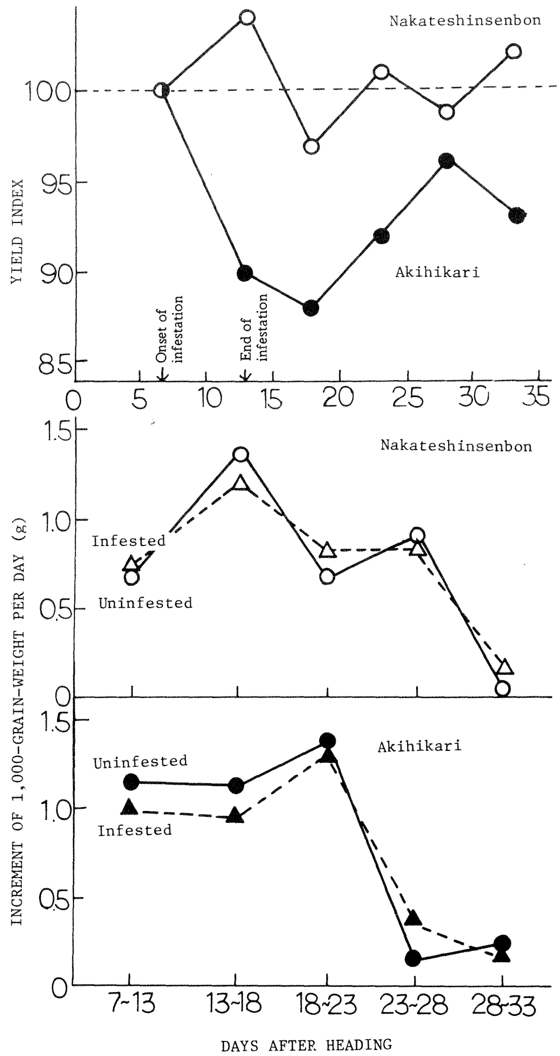


Fig. 5 Effect of the feeding of leafhoppers on rice yield and ripening process in the early- and medium-maturing variety (For particulars, see text), (Naba, 1979)

Concluding remarks

In south-western Japan, where medium- and late-maturing varieties predominate over early-maturing ones, it has been claimed that the population density of GRL is well regulated and that it rarely becomes as high as that in north-eastern Japan. In addition, the present study revealed that yield losses of medium- and late-maturing varieties due to the feeding by GRL are so negligible that they are scarcely worth considering under ordinary conditions. However, the effect of the feeding by GRL on the ripening process of the early-maturing varieties cropped in some mountainous regions of south-western Japan is a matter of dispute because a temporarily high density of GRL on early-maturing varieties could occur under such conditions as mixed cropping of early-sown rice with mid-season rice.

In north-eastern Japan, yield losses could take place with a much lower density of GRL than that in south-western Japan. Since a comparable density of GRL often causes different degrees of crop damage depending on the year, the interaction between GRL and rice plants with regard to the cropping system of paddy rice in north-eastern Japan remains to be investigated.

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Discussion

Sogawa, K. (Japan): Are the regional differences in the damage caused by the green rice leafhopper due to physiological or ecological variations? In other words, can these differences be ascribed to the existence of various biotypes of the insect?

Answer: So far differences have been thought to be due to differences in the physiology of rice plants. Undoubtedly further studies should be conducted in this regard.

Mochida, O. (Japan): You stated that the populations of green rice leafhoppers (GLH) are lower in the northern part of Japan than in the southern part, whereas the feeding damage to rice is more severe in the northern than in the southern part. I would like to know if the yield loss is higher in the northern or in the southern part of the country.

Answer: Yield loss is higher in the northern part of Japan because the effect of the feeding damage persists until the maturing stage of rice.

Ishikura, H. (Japan): You have presented very interesting studies which are however complicated by several factors including the existence of intricate relationships between biotypes of GLH, varietal difference in rice plant and climatic differences between the northern and southern part of Japan. Have you observed any difference in feeding response to rice plant?

Answer: The difference in the damage of the rice plants caused by the GLH at different locations is perhaps related to variations in physiological reactions of the rice plant.

Sadji, P. (Indonesia): Why is the yield loss of medium- and late-maturing varieties due to feeding by GLH so negligible as compared with that of early-maturing varieties?

Answer: As the ripening process of medium- and late-maturing varieties is almost identical, yield decrease seldom occurs because the initial loss of photosynthetic products is easily compensated owing to the ripening process.

Nakazawa, K. (Japan) **Comment**: I believe that this report underlines the need to consider the concepts of tolerable injury level, control threshold and economic injury level in a less rigid manner within the conditions of application of these standard populations levels which are not constant and depend on a large variety of factors.

The study carried out by Dr. Naba in the green leafhopper illustrates this point as the author suggests that the major factor which brought about variations in the tolerable injury level was the regional difference in the host plant response to the injury caused by the insect. This study should contribute to the improvement of the understanding of the concept of tolerable injury level and economic injury level in the control of the green leafhopper and other insects.