
I. Effects of the Heading Time of Rice Varieties on the Oviposition and Propagation of the Second Generation

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Seasonal population trend and peak density of *Nephotettix cincticeps* differ considerably between southwestern and northern Japan. In southwestern Japan, the peak density is relatively low and very stable, whereas in northern Japan it sometimes reaches a higher level and causes economic damage to the rice yield. To elucidate causal factors responsible for this difference, several rice varieties differing in their heading date were tested for the oviposition of *N. cincticeps* in the second generation. In the field, the population density in the third generation in each varietal plot was correlated with the heading date of respective variety: the earlier the heading date of a variety, the higher was the density in it. When each of the potted rice plants was caged with a certain number of adults, the number of eggs laid on the early varieties after heading was much larger than it was on the late varieties before heading. Early varieties and late ones are prevalent in northern and southwestern Japan, respectively. Thus, the difference in the heading date associated with dominant varieties is considered to be one of the major factors responsible for the difference in the peak density of *N. cincticeps* between the two regions.

**Key words**: *Nephotettix cincticeps*, density, oviposition, egg, rice variety

**INTRODUCTION**

Seasonal population trends and peak density of the green rice leafhopper, *Nephotettix cincticeps* are known to differ significantly between southwestern and northern Japan (SUENAGA and NAKATSUKA, 1958; KIDOKORO, 1979; ITO and JOHRAKU, 1982; HIRANO, 1988). Here, southwestern Japan refers to Kyushu, Shikoku and the southern coastal area of Honshu, and northern Japan includes the Hokuriku and Tohoku districts. In southwestern Japan this species, although important as a major vector of the rice dwarf virus, never causes serious direct damage to rice plants. **KUNO** (1968) reported that in northern Kyushu the density in the peak generation was 14 individuals per hill, except young larvae, over an average of 6 years, and the yearly fluctuation was very small. He concluded that population density of this species is self-regulated through
density-dependent dispersal of adults. HOKYO and KUNO (1977) and KIRITANI et al. (1970) also supported this idea.

In northern Japan, however, it often reaches a higher level and sometimes causes economic damage to rice yields. For example, JOHRAKU et al. (1983) showed that in Hokuriku the density in the peak generation was 77 per hill at the highest within a 4-year period. An extreme density of 1,500 insects per hill, including young larvae, was recorded in Miyagi, Tohoku in 1969 (Miya-giken, 1969). Although several studies have been conducted since then to detect the difference in regulatory mechanism between the two populations, it still remains undefined.

The difference in the peak density between the 2 regions seems to be attributable mainly to that in the reproduction of the second generation. In Hokuriku the population density in paddy fields increases remarkably from the second to the third generation (JOHRAKU et al., 1983), but in Kyushu the increase is limited (KUNO, 1968).

As the difference in density of N. cincticeps between an early variety of rice and a late one has been reported (SEKIGUCHI et al., 1979; NAGATA and SATOMI, 1985), the difference in prevailing varieties between the 2 regions was suspected to be the cause of the regional differences in the abundance of this species in later season. Thus, since 1984, I have conducted intensive studies on the oviposition and reproduction of the second generation as they relate to the time of heading of the rice varieties through field surveys and pot experiments, and have reached the conclusion that the difference in heading time of the rice varieties between the 2 regions is one of the major factors responsible for the regional differences in seasonal population growth. This paper reports on the results of these surveys and experiments.

MATERIALS AND METHODS

Census field. The field study was carried out at the experimental farm of the Hokuriku National Agricultural Experiment Station in Joetsu, Niigata Prefecture, in 1985 and 1986. A paddy field of about 10a (56×18 m) was used for the study. Ten plots were arranged side by side in the field. Each plot (15×3.7 m) was surrounded by 4 rows of a resistant variety, Miyang 40, to prevent larval movement between plots. No insecticide was applied in the field throughout the year.

In 1985, young seedlings of varieties Akihikari (early variety), Koshijiwase (early), Koshihikari (medium), and Nipponbare (late) were transplanted on May 15 and those of Akihikari, on June 7 (hereafter referred to as Akihikari-L), each in a different plot in 2 replications. In 1986, susceptible varieties Koshijiwase, Akichikara (early), Hokuriku 127 (late) and Akenohoshi (late) were transplanted on May 14 in 2 replications.

Release of insects. Owing to 3 successive winters of deep snow from 1983 to 1986, natural population of N. cincticeps in Joetsu was extremely low. Therefore, insects reared in groups under laboratory conditions were released to establish field populations as follows: In 1985, a total of 270 third to fourth-instar larvae per plot (including ca. 945 rice hills) were released on June 12, 14, and 18 as the first generation. In 1986, 100 fourth to fifth-instar larvae were released per plot on June 23 and July 1.

Census method

1) Larvae and adults. Population censuses of larvae and adults were done by using sticky boards: A glass board, 24×18 cm in size, was coated with an adhesive, AP-1 (SDS Biotec Co., Ltd.). The board was positioned horizontally on one side of the
hill at a height of ca. 10 cm above the ground, and then the hill was vigorously struck once by hand on the other side to dislodge the insects. Two rows per plot were selected systematically in each census so as not to overlap each other within the period of the same generation. Insects on every other or every third 20 hills in a row were thus transferred onto the sticky board at intervals of 7 to 10 days.

2) Eggs. The eggs laid by \( N. \) cincticeps could be detected in leaf sheaths of rice plants in good condition even 3 weeks or so after hatching. To estimate egg density, rice hills were sampled and dissected to find the egg-masses, from which the number of total, living, hatched, parasitized and dead eggs were determined under a stereo-zoom microscope. In 1985, 15, 10, and 10 hills were sampled from a plot of Koshijiwase, Koshihikari, and Nipponbare, respectively on August 21–22. In 1986, 3 hills each were sampled from the respective 2 plots of Koshijiwase, Akichikara, Hokuriku 127 and Akenohoshi on August 28 and 30.

**Field-cage experiment.** Two wooden field cages (1.8 × 1.8 × 1.8 m) covered with plastic screen were set up on a plot at Akichikari and Nipponbare in 1985. Each cage covered 60 hills. Twenty pairs of adults were introduced into each cage on June 26. Population census was carried out by using the sticky board. On July 24, August 1, 20, September 4 and 27, leafhoppers on 10 hills, all different from one another throughout the period, were collected on the sticky board by single blows to the hills. The egg density was estimated by sampling 4 hills from each cage on August 29–30.

**Pot experiment.** The same lots of seedlings as were planted in the field were planted in 1/5,000 a Wagner pots and the potted plants were covered by cages (40 × 40 × 91 cm) made of wooden frames and plastic screens. In 1986, varieties Koshijiwase, Akichikara, Hokuriku 127, and Akenohoshi were potted. Each of the potted rice plants was caged with 25 females and 20 males of adults for 9 days from August 15 in 2 replications. In this period the 2 early varieties were after heading, while the 2 late varieties were before heading. The number of eggs laid on each plant was counted separately in every leaf sheath position after the removal of insects. In 1989, Koshijiwase and Nipponbare, both before the heading period, were tested. Each of the potted plants was caged with 1 female and 2 males for 13 days from July 5 in 6 replications.

**RESULTS**

**Population growth in the field**

Population growths in each varietal plot in 1985 and 1986 were plotted as numbers of leafhoppers, including larvae and adults, per 20 single blows to the rice hills in Figs. 1 and 2, respectively. The heading date of each variety for each year was also shown in these figures.

In 1985, the density in the second generation in July was nearly equal among the varieties. The peak density in the third generation was highest in Koshijiwase and Akihikari, followed by Akihikari-L and Koshihikari, and was lowest in Nipponbare. This descending order of density among varieties, from high to low, corresponded to that of the heading dates from early to late. That is, the earlier the heading date, the higher was the density. In 1986, the density in the second generation up to August 14 was also nearly equal among the varieties. In the third generation, the peak density in each variety could be arranged in descending order as Akichikara, Koshijiwase, Hokuriku 127 and Akenohoshi. This order again corresponded with that of their heading dates.
Fig. 1. Population growth of *N. cincticeps* on different rice varieties in relation to their heading dates in 1985. Arrows show heading date of each variety indicated by the symbols above each of them. Rice variety: ○: Koshiwase, ■: Akihikari, ●: Akihikari-I., ▲: Koshihikari, △: Nipponbare.

Fig. 2. Population growth of *N. cincticeps* on different rice varieties in relation to their heading dates in 1986. Rice variety: ◇: Akichikara, ○: Koshiwase, ●: Hokuriku 127, ▲: Akenohoshi.

**Egg density in the field**

Egg density in different varieties in the field is shown as the number of eggs laid per hill in Fig. 3. In 1985, the egg density in Koshiwase was the highest, followed by Koshihikari and Nipponbare. It was 10 times as high as that in Nipponbare. The difference between Koshiwase and the other 2 was significant (ANOVA, *p*<0.05). In 1986, the egg density in each variety was, in a descending order, Koshiwase, Akichikara, Hokuriku 127, and Akenohoshi, although the difference between Koshiwase and Akichikara was small. Again, these orders in both years corresponded with those of the heading dates. The egg density in the 2 early varieties was about 4 times higher...
Oviposition of *Nephotettix* in Northern Japan

Fig. 3. Egg density of *N. cincticeps* in the third generation on different rice varieties in the field. Attached bars indicate S.E. KOJ: Koshijiwase, KOH: Koshihikari, NIP: Nipponbare, AKI: Akichikara, H127: Hokuriku 127.

Fig. 4. Population growth of *N. cincticeps* on an early rice variety and a late one in field cages.

than in the 2 late varieties, and the difference between them was highly significant \( p < 0.01 \).

Population growth in field cages

The trend of the density (larvae and adults, except as otherwise stated) in each field cage is plotted in Fig. 4. The larval density in the period of the second generation was almost equal for the 2 varieties. In the next generation, however, the density in Akihikari, an early variety, was about 10 times higher than that in Nipponbare, a late
variety. The egg density per hill on August 29–30 was 690 and 188 in Akihikari and Nipponbare, respectively.

*Egg density and distribution in potted plants*

The number of eggs laid per caged plant of each variety is shown in Fig. 5. When adults were allowed to oviposit in the period between the heading dates of the early varieties, Akihikari and Koshijiwase, and those of the late varieties, Hokuriku 127 and Akenohoshi (Fig. 5, Left), the number of eggs laid was significantly larger in the early varieties than in the late ones (p<0.01), when the 2 respective varieties were treated together as replications in the same groups. However, in the case when the oviposition period of the early variety, Koshijiwase, and the late variety, Nipponbare, both occurred before the heading date (Fig. 5, right), the number of eggs laid was almost equal for both varieties.

For the former case, the distribution of eggs among the leaf-sheath positions on a rice plant is shown in Fig. 6. In the early varieties, the total number of eggs laid in the first and second leaf sheaths, counting from the top of the stem, was nearly equal to that in the leaf sheaths below the third position, while in the late varieties most of the eggs were laid below the third leaf sheath. Thus, the total number of eggs laid below the third leaf sheath was nearly equal among the 2 varieties. In other words, the number of eggs laid in the early varieties increased by eggs being added to the first and second leaf sheaths.
DISCUSSION

There are several works dealing with the regional differences in the seasonal population trends or population dynamics of $Nephotettix cincticeps$ between southwestern and northern Japan. At first, the difference in the peak density between Hokuriku (in northern Japan) and southwestern Japan was confirmed to be large (ITO and JOHRAKU, 1982; ITO et al., 1983; JOHRAKU et al., 1983; HIRANO, 1988). The existence of density-dependent process in the reproduction of the second generation was detected also in Hokuriku, particularly in years of little snowfall (JOHRAKU et al., 1983; HIRANO, 1988).

Based on these findings, the next important problem is to determine the factors responsible for the difference between the 2 regions. These factors can be divided into 2 categories: the genetic characters of $N. cincticeps$ itself, such as biotypes, and the environmental factors, such as the developmental and maturation stages of the rice plant and the abundance of natural enemies.

So far, most of the efforts have concentrated on the detection of differences in genetic characters of the insects. GU and ITO (1981, 1982, and unpublished) compared the distribution patterns of the numbers of individuals per rice hill, the longevity of adults in field cages, and the intrinsic rate of increase between the populations in, or collected from, Hokuriku and southwestern Japan. However, they could not find any significant differences between them.

On the other hand, SOGAWA and SATO (1983) and NARUSE (1986) compared the morphological and/or physiological characteristics of Hokuriku and Chikugo (in south-
western Japan) populations under laboratory conditions and found some differences between them. Naruse reported that females in a Hokuriku population laid many more eggs than those in a Chikugo population at temperatures anywhere from 20 to 35°C in contrast with the results of Sogawa and Satō, in which the females in a Chikugo population laid more eggs than those in a Hokuriku population at 28°C. Fecundity of N. cineticeps may vary with various environmental factors. In my unpublished experiment, the number of eggs laid per female per day under laboratory conditions varied primarily with the condition of the plants provided for food and oviposition. The difference of fecundity among local strains of N. cineticeps seems negligible as compared with that related to environmental conditions.

In recent years, as a result of the failure to detect factors responsible for the regional difference from the genetical characteristics or population traits of N. cineticeps, cultural conditions of rice plants came under scrutiny as a causal factor. However, these never have been investigated experimentally.

Sekiguchi et al. (1979) compared the seasonal population trends of N. cineticeps in paddy fields of an early variety in Toyama (in Hokuriku) and a late one, and showed that the density in and after the second generation in a late variety was much lower than that in an early variety. They found that the size of adults collected from the early variety was larger than that from the late variety, and deduced that this would cause a difference in the fecundity of females followed by an increase in density (Sekiguchi and Naruse, 1980). However, in my experiment (unpublished), there was no significant difference in the size of adults in the second generation between those collected from an early variety and a late one.

In the present study I demonstrated that the difference in the population density between early and late varieties was caused by an increase in the number of eggs laid after heading, and not by the other characteristics of specific early and late varieties. The reason for more eggs being laid on rice plants after the heading has not yet been determined. In the pot experiment (Fig. 6), the total number of eggs laid in the leaf sheaths below the third position was nearly equal for both the early and the late varieties. The number of eggs laid in the early varieties increased apparently by the addition of eggs in the first and second leaf sheaths. Adults suck sap mainly from the first and second leaf blades, rachises and rachis branches after heading (Ogane et al. 1979). The elongation of upper internodes accompanied by heading furnishes many suitable oviposition sites near the feeding sites. This may stimulate the oviposition.

As for the field-cage experiment, the census method involving collection of insects on a sticky board removes them from caged plants, and may thus affect the population growth thereafter. In general, this is not an adequate sampling method to apply to a narrow, closed plot. In the present case, however, it is probable that the densities in the period of second-generation larvae were not so low as to be greatly affected by the removal of insects, so that the trends of density in the following generation became clearly different between the plots.

In northern Japan the heading dates of prevailing varieties are distributed around early August, whereas in southwestern Japan they are distributed around late August. The heading date of the "Reiho" variety, with which Kuno (1968) and Hokyo and Kuno (1977) worked, is around the beginning of September. In their work, Hokyo and Kuno (1977) reported that the density of eggs in the fourth generation was much higher than in the third generation, sometimes more than 1,000 per hill. Since the
third-generation adults emerge between the end of August and early September in Chikugun, they can deposit their eggs after the heading of such a late variety. Thus the similar relationship between the heading date and the oviposition exists also in southwestern Japan, but appears 1 generation later than it does in northern Japan.

Consequently, in northern Japan, the adults in the second generation emerge after the heading of rice plants and lay many eggs on these plants, whereas in southwestern Japan they emerge before the heading of rice plants and lay relatively few eggs. This is considered to be one of the most significant factors in the difference in the peak density of *N. cincticeps* between the 2 regions.

Besides the time of heading, the time of transplanting also differs between the 2 regions. In northern Japan, transplanting of rice seedlings is usually done in early to mid-May, while in southwestern Japan it is done in mid- and late June. As a result, the growth stage of rice plants and microclimate in the paddy fields, where the second-generation leafhoppers grow, are also different between the regions. This may affect the fecundity of the second-generation adults in each region. This aspect will be the subject of future reports.

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REFERENCES


