

Geographic Variation of Nymphal Diapause in the Small Brown Planthopper in Japan

Hiroaki NODA*

Section of Plant Diseases and Insect Pests, Shimane Agricultural Experiment Station
(Izumo, Shimane, 693 Japan)

Abstract

Photoperiodic stimuli which induce and terminate nymphal diapause in the small brown planthopper, *Laodelphax striatellus*, were examined with the nine local populations in Japan to identify geographic differences in their diapause pattern. The nymphal diapause was induced by short-day photoperiod. The population from Kamikawa, the northernmost region, diapaused even under 14L-10D photoperiod, while the population from the southernmost region, Ishigaki, did not diapause. There was a geographic cline in critical photoperiod for diapause; the populations from the higher latitude had longer critical daylength. The diapausing nymphs became adults in a certain period of time after being transferred to a long-day photoperiod. The period for the Kamikawa population, however, was longer than that for the other populations. This difference was caused mainly by retardation of the first moult after diapause in the Kamikawa population. The geographic differences in diapause termination were also observed among the local populations. The absolute photoperiod was unlikely to be an important factor for the diapause termination, while extension of daylength appeared to act as a terminating stimulus.

Discipline: Insect pest

Additional key words: diapause induction, diapause termination, *Laodelphax striatellus*, photoperiod

Introduction

Among the three economically important rice planthoppers, i.e. *Nilaparvata lugens*, *Sogatella furcifera* and *Laodelphax striatellus*, the first two are unable to live through winter in the temperate regions, including Japan, Korea, and northern China. They migrate into these regions every early summer and increase in paddy fields. *Laodelphax striatellus*, which is an important vector of rice stripe virus in the temperate regions, also flies over a distance^{3,7)}. However, it hibernates in the temperate regions, where its immigrants do not predominate, in general, in the field population. *L. striatellus* ceases development in autumn and the nymphs diapause. In the western part of Honshu island of Japan, adults

emerge in the period from late March to the end of April (Noda, unpublished), while in Hokkaido, northernmost island of Japan, they come out in May⁴⁾.

Short-day photoperiod induces and maintains nymphal diapause of *L. striatellus*⁵⁾. This species has a wide range of distribution all over Japan, which extends from approximately 24°N to 45.5°N. Kisimoto⁶⁾ reported that critical photoperiods for diapause varied among the populations, indicating that the northern populations required longer critical daylength as compared with the southern populations with a declining trend from the north to the south. Such geographic variations in diapause of this important virus vector, however, are still not fully understood in detail.

The purpose of this study is to disclose geographic

* Present address: Department of Insect Physiology and Behavior, National Institute of Sericultural and Entomological Science (Tsukuba, Ibaraki, 305 Japan)

changes of diapause induction and termination in *L. striatellus*, the information which would contribute to forecasting its occurrence.

Materials and methods

Nine local populations of *Laodelphax striatellus* (Homoptera: Delphacidae) in the following locations were used for the present study: Kamikawa (Ka, 43.8°N), Sendai (Se, 38.3°N), Tsukuba (Tk, 36.0°N), Odawara (Od, 35.2°N), Tsu (Ts, 34.7°N), Izumo (Iz, 35.4°N), Kagoshima (Kg, 31.6°N), the East China Sea (Ec, 31°N, collected on a ship and imported with the permission of the Ministry of Agriculture, Forestry and Fisheries, Japan under No. 931 dated 1 June 1984), and Ishigaki (Ig, 24.3°N). The planthoppers were stock-cultured on rice seedlings at 25°C under 16L-8D. They were raised in the laboratory for several generations before use.

The planthoppers were individually reared under several thermal and photoperiodical conditions. Each 0-day-old nymph was put in a glass tube (135 mm in length and 12 mm in diameter) containing rice seedlings. The seedlings were changed every one (at 25°C) or two to three weeks (at 20 and 15°C).

Results and discussion

1) Developmental period of nymphs

The nymphal period of non-diapaused nymphs was

examined among the following three local populations: Kamikawa population from the northern region, Izumo population from the central region, and Ishigaki population from the southern region. These three populations showed almost the same egg and nymphal periods; nymphal periods of Ka, Iz, and Ig at 20°C were 23.4 ± 1.7 , 22.9 ± 1.8 days, and 23.2 ± 1.8 days, respectively, and at 25°C, 13.4 ± 1.1 , 13.8 ± 1.2 , and 12.9 ± 0.9 days, respectively⁸⁾.

L. striatellus completed nymphal development in 23 days on an average at 20°C. Therefore, if it took more than 30 days for the nymphs to become adult under certain conditions, developmental delay was distinct and they were regarded as diapausing nymphs in this paper.

2) Adult emergence under different environmental conditions

Fig. 1 shows adult emergence curves of the nine populations tested under the 12L-12D photoperiod at 20°C. The Ig and Ec populations mostly emerged in 20-30 days after hatching. Some of the Kg population showed a developmental delay. The Ts and Od populations required more time to complete nymphal development. The Iz and Tk populations emerged slowly and a majority of the Se and Ka populations did not emerge even in 70 days after hatching. Under the photoperiodical conditions of the experiment; i.e. 12L-12D photoperiod at 20°C, those populations from the southern regions emerged

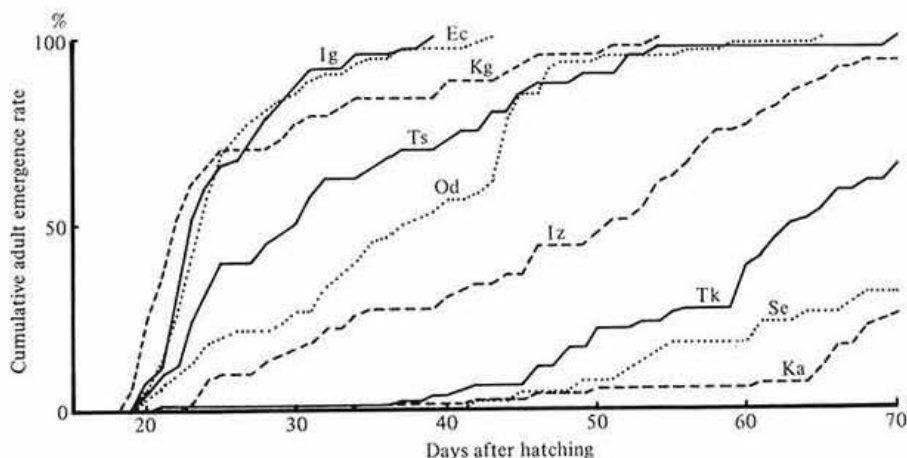


Fig. 1. Adult emergence curve of the 9 local populations under 12L-12D at 20°C
Ig: Ishigaki, Ec: East China Sea, Kg: Kagoshima, Ts: Tsu, Od: Odawara,
Iz: Izumo, Tk: Tsukuba, Se: Sendai, Ka: Kamikawa.

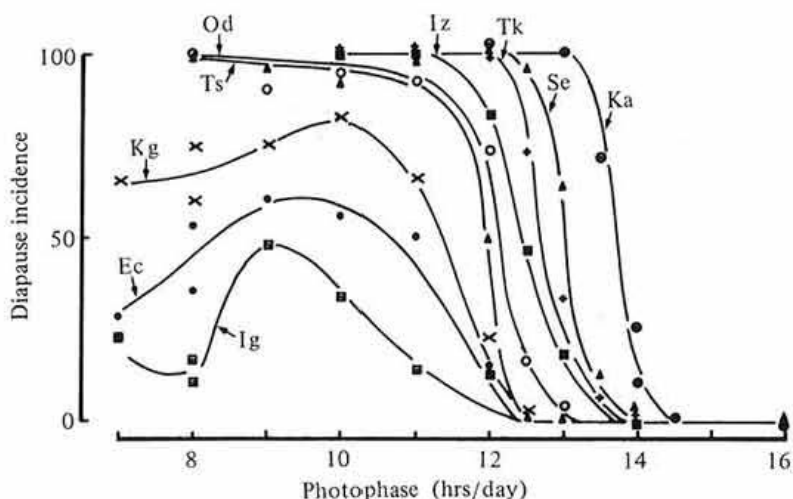


Fig. 2. Effect of photoperiod on diapause incidence of the 9 populations

without delay, while the populations from the north showed a considerable delay in nymphal development.

Since the Ig and Ec nymphs developed without distinct delay, the effect of the short-day condition was investigated at 15°C. The nymphal periods of the Ig population under the 16L-8D and 10L-14D photoperiods at 15°C were 43.2 ± 2.7 and 54.3 ± 5.4 , respectively, and a half of those nymphs became adults on the day 43 and 53, respectively. It was confirmed that the Ig population was responsive to photoperiod at low temperature, while it was not clearly so at high temperature.

3) Critical photoperiod for nymphal diapause

The nine populations were reared at 20°C under different photoperiods to examine critical daylength for nymphal diapause. Fig. 2 presents ratios of nymphs 30 days after hatching under the varying photoperiods. Some of the Ka nymphs showed a developmental delay even with the 14L-10D photoperiod, under which all the other populations became adult in 30 days. The critical photoperiod for diapause in the Ka population was approximately 13.7 hr and that of the Se population was approximately 13 hr. The critical photoperiod was gradually shorter as the sites for collecting planthoppers were situated further south. Almost all the six populations collected from the northern and central regions diapaused under short day photoperiod of 10L-14D, whereas some nymphs in the Kg, Ec, and

Ig populations did not diapause under any photoperiods tested. The three populations from the south expressed the highest rate of diapause under 9 or 10 hr daylength. Critical photoperiods for diapause varied among the local populations, which showed such a geographic cline in critical photoperiods for nymphal diapause. These results in the small brown planthopper are in good accordance with those of Kisimoto⁶⁾, and in some other species^{1,2)}.

The second generation from the fast-grown parents in the Ig nymphs grew faster than that from the slowly-grown parents. This result indicates that the responsiveness to photoperiod is inherited from parents to their progenies. The F₁ generation derived from the crosses between the north and south populations showed intermediate behavior of diapause of its parents (data not published).

4) Diapause termination

The geographic differences in diapause termination were also examined. Five populations, i.e. Ka, Se, Tk, Iz and Ts, were reared from the stage of first instar nymph under 8L-16D at 20°C for 30 days, and the diapausing nymphs were then transferred to 16L-8D at the same temperature. Most nymphs of the Se, Tk, Iz and Ts populations became adults in approximately 15 days after the transfer. The Ka population, however, started its adult emergence in 18 days, requiring more than three weeks on an average to become adult (Fig. 3).

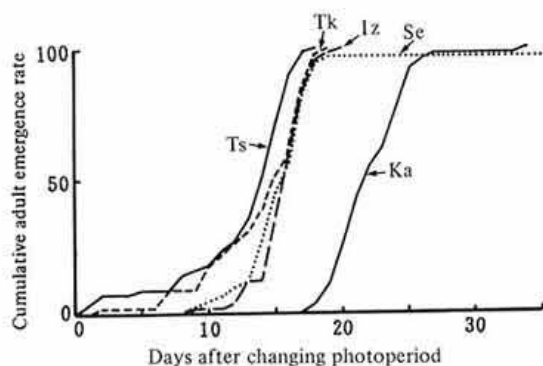


Fig. 3. Adult emergence curves of the 5 populations which were moved to 16L-8D, following the rearing under 8L-16D for 30 days after hatching at 20°C

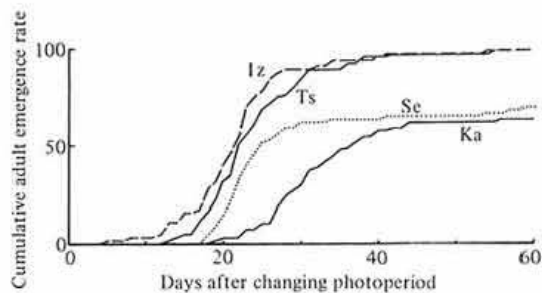


Fig. 4. Adult emergence curves of the 4 populations which were moved to 12L-12D, following the rearing under 10L-14D for 28 days after hatching at 20°C

No distinct difference was however observed among the Se, Tk, Iz and Ts populations. Another series of experiments was conducted, where nymphs of the Ka, Se, Iz and Ts populations were reared under 10L-14D at 20°C for 28 days and transferred to 12L-12D; the daylength was longer by two hours compared with that before the transfer. Post-diapaused adults emerged in the order of the Iz, Ts, Se and Ka strains (Fig. 4). The Iz and Ts populations showed normal sigmoidal emergence curves, having some delayed individuals. The Se strain showed the other pattern of response to environmental change which was different from the Iz and Ts populations. Similar results were also observed when the temperature was raised from 17°C to 26°C under 10L-14D (data not published). The extension of daylength or raising of temperature acted as diapause terminating stimuli in those populations tested.

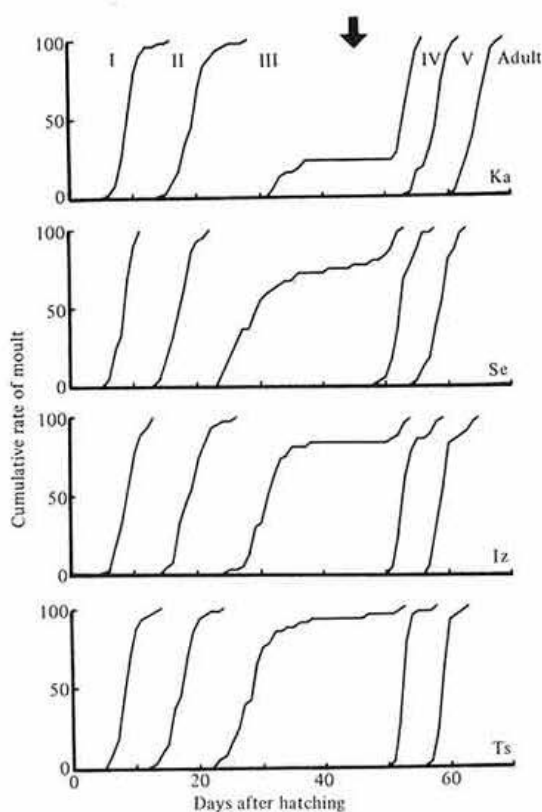


Fig. 5. Pre- and post-diapause development of the 4 populations at 15°C
Nymphs were first reared under 10L-14D for 45 days and transferred to 16L-8D.

The diapausing nymphs of the Ka population required greater changes in day length and temperature to induce its termination. Some variations were observed within the local populations in termination as well as in induction of diapause. The Se population terminated its diapause under 12L-12D at 20°C after being transferred from 10L-14D at the same temperature (Fig. 4). However, this population diapaused under the same photoperiod, i.e. 12L-12D (Figs. 1 and 2). The absolute photoperiod does not seem to be an important factor for the diapause termination, while extension of daylength appears to act as a terminating stimulus. Raising temperature also has a similar effect on the termination of diapause.

The Ka population required more time to become adult as compared with the other populations, although its nymphal period was almost the same

as that of the Iz population. The mechanism of the delay in adult emergence in the diapaused nymphs of the Ka strain was examined by investigating growth development before and after the diapause. In order to identify diapausing stages of the four populations, i.e. Ka, Se, Ts and Iz, the nymphs were reared under 10L-14D at 15 or 20°C. The result at 15°C is presented in Fig. 5. In the Ka population, 78% of the diapausing nymphs were in the third instar stage, while the others were mostly in the fourth instar stage. The ratio of diapausing third instar nymphs was low in the latter three populations. Since the post-diapause third instar nymphs require more time to complete their nymphal development than the fourth instar nymphs, diapausing in

earlier stage is apparently one of the reasons why the Ka population emerged late.

However, when they were reared at 20°C, most of the nymphs of the four populations diapaused in the fourth instar (Fig. 6). Nevertheless, the adult emergence of the Ka population was late (see the vertical line in adult moult in Fig. 6). The period of fifth instar shows no marked difference among the four populations. The delay in adult moult was reflected by the slow moult for the fifth instar after its diapause completion (see the vertical line in the fifth instar moult in Fig. 6). A physiological change may take place during this period to complete the diapause as pointed out as diapause development⁹. The Ka population may need more time to complete diapause development than the other populations.

In conclusion, *L. striatellus* showed geographic differences in various aspects of nymphal diapause; i.e. critical photoperiod for diapause induction, environmental stimuli for diapause termination and period for diapause completion. Each population seems to have its own fitness in diapause adapted to the respective local environment. Although this species migrates over a long distance, the populations tested in the present study showed persistent conservatism in the nature of diapause. This conservatism seems to be maintained by advantageous selections for the planthoppers which have tolerance to winter cold to survive.

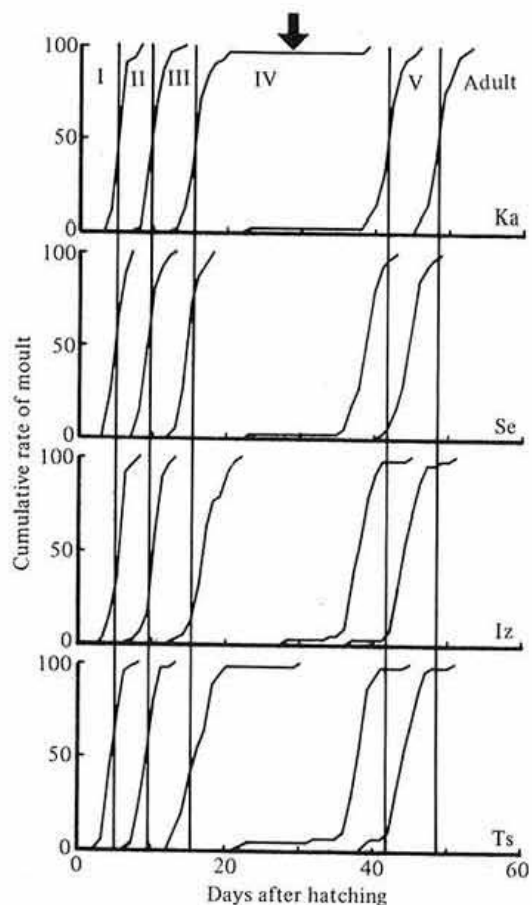


Fig. 6. Pre- and post-diapause development of the 4 populations at 20°C
Nymphs were first reared under 10L-14D for 28 days and transferred to 16L-8D.

References

- 1) Back, S.D. (1980): Insect photoperiodism. (2nd ed.) Academic Press, New York, pp 387.
- 2) Danilevsky, A. S. (1965): Photoperiodism and seasonal development of insects. [Japanese translation by Hidaka, T. and Masaki, S., Tokyo University Press, pp 293].
- 3) Hirao, J. & Ito, K. (1980): Observations on rice planthoppers collected over the East China Sea in June and July, 1974. *Jpn. J. Appl. Entomol. Zool.*, **24**, 121-124 [In Japanese].
- 4) Kazino, Y. & Hachiya, K. (1983): Ecological studies of the small brown planthopper, *Laodelphax striatellus* Fallén. II. Local differences in the development of hibernating larvae and wing-forms of the first adult. *Bull. Hokkaido Pref. Agr. Exp. Sta.*, **50**, 76-82 [In Japanese with English summary].
- 5) Kisimoto, R. (1958): Studies on the diapause in the planthoppers. I. Effect of photoperiod on the induction and the completion of diapause in the fourth larval stage of the small brown planthopper, *Delphacodes*

- striatella* Fallen. *Jpn. J. Appl. Entomol. Zool.*, **2**, 128-134.
- 6) Kisimoto, R. (1976): Climate and rice insects: Climate and rice. *In Proc. Symposium of International Rice Research Institute*, 367-391.
 - 7) Noda, H.(1986): Pre-mating flight of rice planthopper migrants (Homoptera: Delphacidae) collected on the East China Sea. *Appl. Entomol. Zool.*, **21**, 175-176.
 - 8) Noda, H. (1990): Developmental zero and total effective temperature of three rice planthoppers (Homoptera: Delphacidae). *Jpn. J. Appl. Entomol. Zool.*, **33**, 263-266 [In Japanese].
 - 9) Tauber, M.J., Tauber, C.A. & Masaki, S. (1986): Seasonal adaptations of insects. Oxford University Press, New York, pp 411.

(Received for publication, Dec. 5, 1991)