Expansion of Distribution Area of the Rice Water Weevil and Methods of Controlling the Insect Pest in Japan

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The rice water weevil, *Lissorhoptrus oryzophilus* Kuschel, was first discovered in 1976 in Aichi Prefecture situated in the central district of Japan.[24] Thereafter the rice water weevil spread rapidly year after year, and by 1986 it covered all the prefectures of Japan. The total area of infested paddy fields by this insect pest in 1986 amounted to 1,032,526 ha corresponding to 46% of the total paddy fields in Japan. As climate and cultural practices in Japan are different from those in the United States, from which the pest entered into Japan, many investigations on ecology and methods of control have been done very actively during these ten years. In the present paper results of investigations conducted in Japan on ecology of the insect, including the process of spread, and countermeasures to the crop damage caused by the insect are introduced.

The process of invasion and spread

The place of origin of the rice water weevil is North America. In southern states of U.S.A. a bisexual strain of the rice water weevil inhabits. In California the rice water weevil was found out in 1959 and in this region a parthenogenic strain inhabits. In Japan only parthenogenic females with triploid chromosomes were found.[23] The rice water weevil found in Japan was perhaps derived from the population inhabited in California. The invasion route of the rice water weevil to Japan was searched by Nagoya Plant Quarantine Station, and it was suggested that the insect was carried into Japan with hay imported from the United States.

Yearly process of the distribution of the rice water weevil in Japan during a period from 1976 to 1986 is shown in Fig. 1. The area of distribution was limited only in Aichi Prefecture until 1977, and thereafter it continued to expand to adjacent prefectures in a period from 1978 to 1981. The average speed of the expansion was supposed to be 20–30 km/year in those years. After 1982 the distribution area expanded not only to adjacent prefectures, but also to the distant prefectures several hundreds km away.

One of the most important causes for such a rapid expansion of the distribution area is the phenomenon of flying adults carried on the wind. The adults were captured by a net trap lifted to a height of about 50 m by a balloon,[13] and also captured by net traps set on a sea berth standing about 10 km away from the coast.[19] The spreading directions of the rice water weevil were related closely to the wind directions during the migratory periods.[25] In another case it was suggested that a small number of the adults of the rice water weevil were carried into distant virgin lands by traffic facilities and there they increased in number. Such a rapid expansion in the distribution and in the number of the rice water weevil in Japan perhaps depends on the continuous existence of paddy fields and no existence of influential natural enemies and competitors. It is also very important that the rice water weevil is parthenogenic

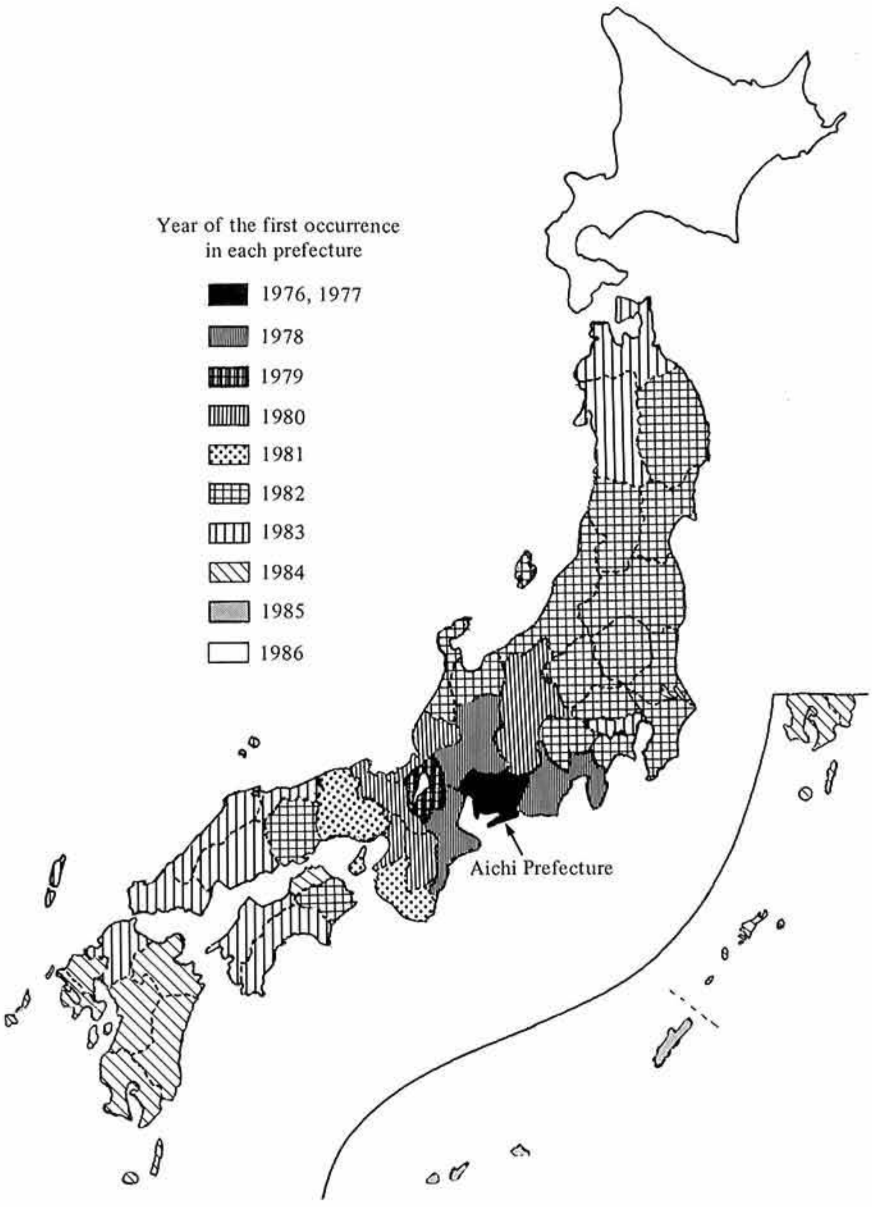

Fig. 1. The course of yearly spread of the rice water weevil in Japan

and has the wide adaptability to the environmental circumstances in Japan.

Life history

The life history of the rice water weevil in Aichi Prefecture is shown in Fig. 2.[26] The adults hibernated under the leaf litter of groves or under dried grasses on banks or levees. In early or middle April, the adults started feeding on leaves of weeds such as *Graminae*, at hibernated sites, and flied into paddy fields. After feeding on leaves of rice seedlings the adults came to have matured eggs soon. The developmental rates of eggs and from larva to adult emergence were investigated.[29,30] The effective accumulative temperature for from-egg-to-adult emergence

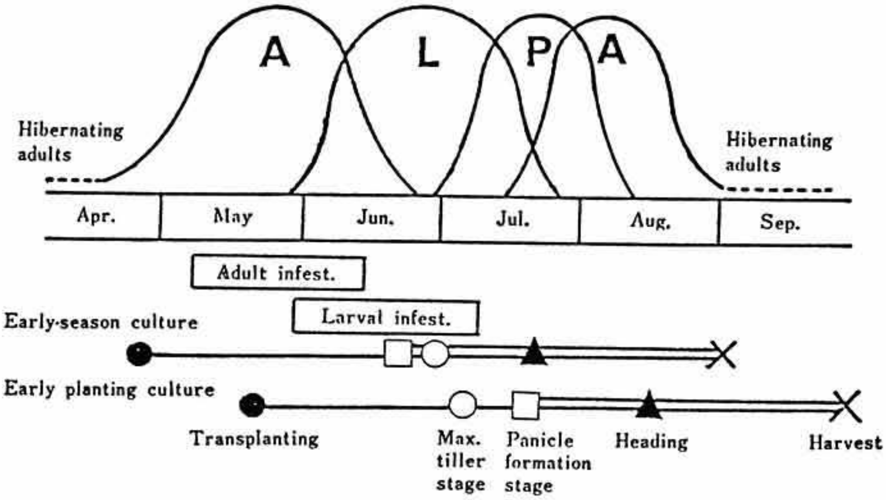

Fig. 2. Schematic diagram of life cycle of the rice water weevil in relation to the growth pattern of rice plants in different cultivation types in Aichi Pref. (Tuzuki et al., 1983)
A: Adults, L: Larvae, P: Pupae.

was about 665 degree-days. According to the photothermograph of the rice water weevil, this species could pass 2 generations in a year in the southwestern districts of Japan.[4,14,22] But three conditions had to be satisfied at the same time for the newly emerged adults to oviposit. These conditions were high temperature, long photoperiod and existence of rice seedlings.[4,22] In a part of the paddy fields of late-planting culture, the second generation was recognized.[1,32,33] But the larval density was much lower than that of the first generation.

Flight activity

The adults of the rice water weevil began to fly after the development of flight muscles.[16] The development of flight muscles depended on temperature and feeding. The period of the departure flights of the overwintered adults from hibernated sites could be simulated using a logistic equation related to the effective accumulative temperature and the cumulative percentage of the adults which initiated to fly in the laboratory[17] (Fig. 3). The overwintered adults began to fly one or two hr before sunset from hibernated sites and the

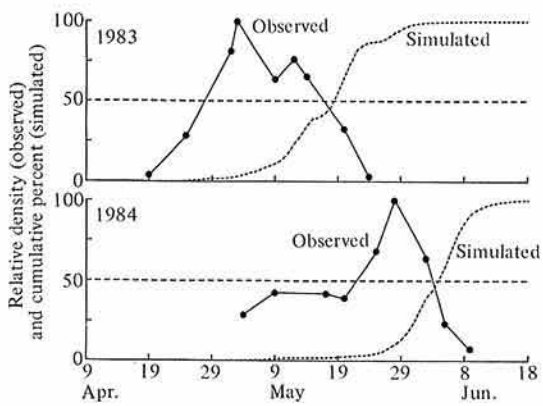

Fig. 3. Occurrence of overwintered adults of the rice water weevil on bamboo grasses in woodlands and simulated trends of cumulative percentage of flight-departure adults

newly emerged adults began to fly after sunset.[3,10,13] The overwintered adults sometimes took off in swarms and were caught concentrically in light traps from middle May to early June when the temperature of the daytime exceeded 25°C.[2] The flight activity of the overwintered adults was observed at the temperature over 20°C and most active at 25–27.5°C in the laboratory.[17]

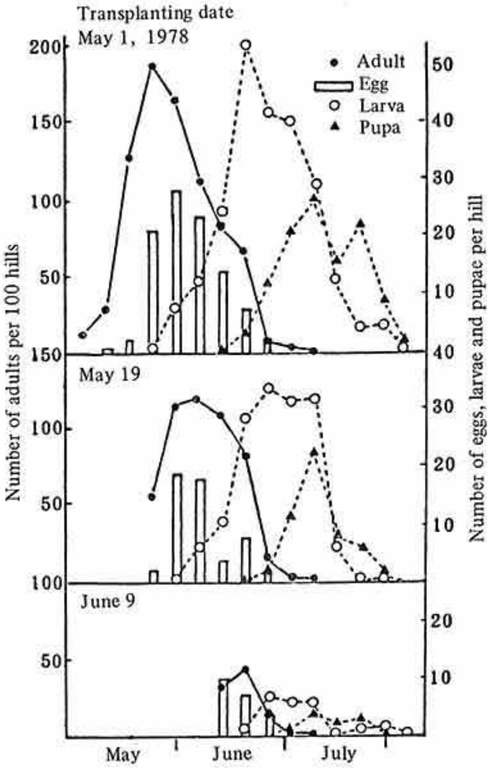

Fig. 4. Occurrence of the rice water weevill at each developmental stage in paddy fields differing in the data of rice transplanting (Asayama et al., 1984)

Population fluctuation

When rice was transplanted before the peak departure flights of the adults from hibernated sites, the population density of the overwintered adults in the paddy fields was high, but it was low when late transplanting was made in June[1,8] (Fig. 4). The patterns of population growth in the different locational conditions were simulated by logistic equations (Fig. 5). And the equilibrium densities were estimated at 0.38, 1.78 and 2.44 overwintered adults per hill in coastal plains, interior hilly and mountain areas, respectively. Equilibrium densities of overwintered adults in different localities seemed to be determined by the proportion of favorable overwintering sites which depended on the topographical conditions of the area. And the densities of the overwintered adults came to

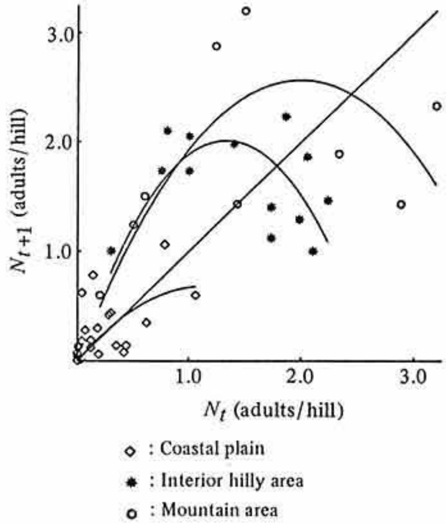

Fig. 5. Reproduction curves and equilibrium densities in areas differing in their topography

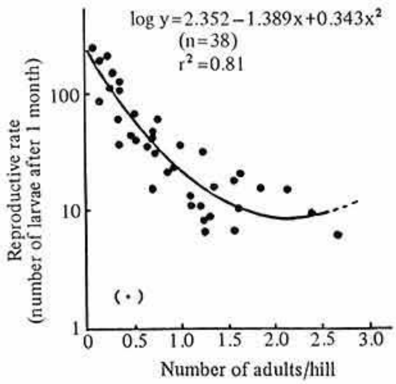

Fig. 6. Relationship between the density of overwintered adults and their reproductive rates (Asayama et al., 1984)

be in an equilibrium 4 years later after the first occurrence.[8] Density effects were observed in the number of eggs oviposited by overwintered adults and in the larval population (Fig. 6).[5,8] The survivorship curves suggested that the mortality from egg to adult emergence was highest in the period from egg to young larva.[8] The reproductive rate (newly emerged adults per overwintered adults) decreased remarkably according to the increase of the density of overwintered

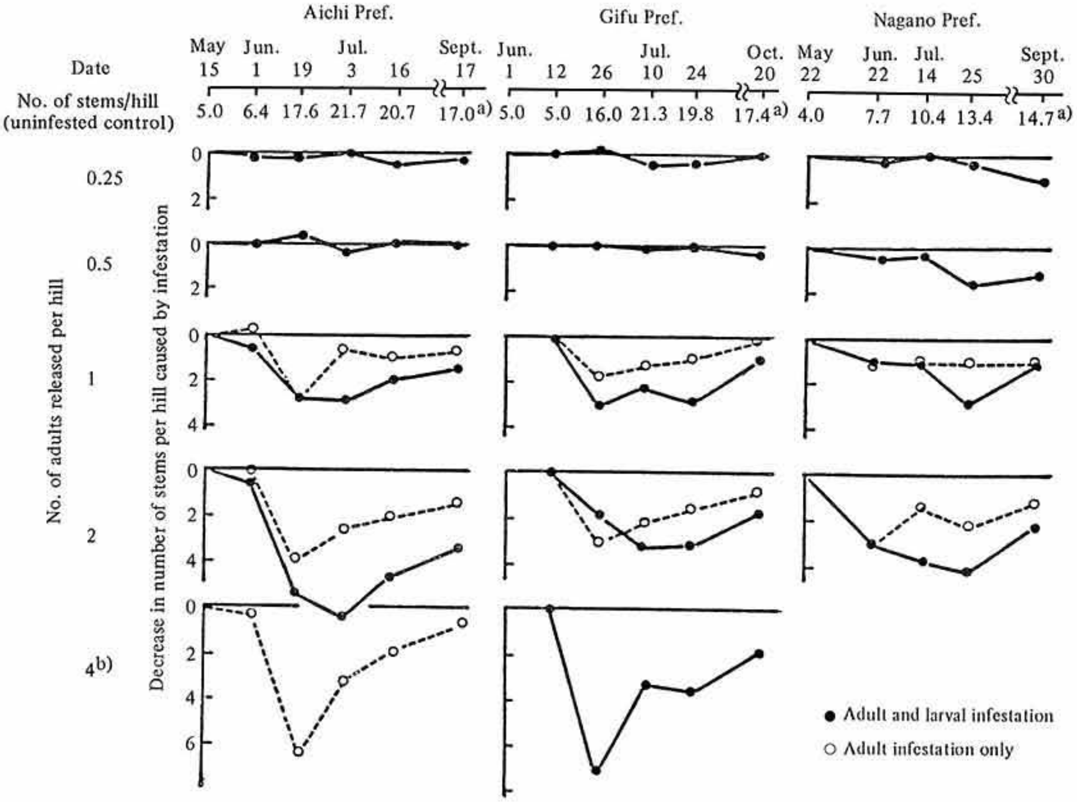

Fig. 7. Effect of adult and larval infestation on the growth (in terms of number of stems/hill) of rice plants (Tuzuki et al., 1983)
a): Number of panicles at harvest, b): 3 adults per hill in Gifu Pref.

adults.[5,8] The densities in which the reproductive rate became 1 were estimated at 2.8, 2.4 and 1.6 overwintered adults per hill in early-season culture, early-planting culture and late-planting culture, respectively.[7] Influential natural enemies of the rice water weevil in field conditions were not known yet in Japan, but a few fungi, for example, *Beauveria bassiana*, were known to be infectious.[6]

The survival rate of the overwintering adults was high under favorable hibernating sites like groves, but low at dry levees. The overwintering adults could survive even under deep snow and at very low temperature, for example 60% of the adults survived until April under −18.6°C (minimum temperature) and −6.0°C (minimum soil temperature).[14] The laboratory experiments on the overwintering adults exposed to different low temperatures for 3 months showed that the critical minimum temperature was from −5 to −10°C.[28] The supercooling point of the overwintering adults under the wet condition was from −6.2 to −17.6°C (average −11.7°C).[18]

The diagrams which determine the sample size required to estimate the mean density of the overwintered adults, larvae and cocoons with desired precision were drawn.[15] The instar of the larvae could be determined by the widths of the head capsule.[12,30]

Damage caused by the rice water weevil

Damage of rice plants caused by the rice water weevil tended to occur in hilly and mountainous regions. The yield loss of rice was caused mainly by larvae which fed on

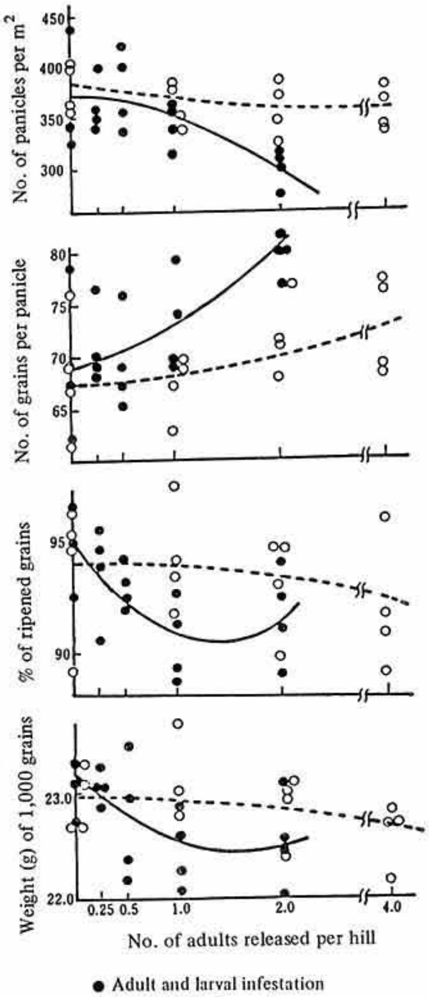

Fig. 8. Relationship between number of adults released hill and yield components (Tuzuki et al., 1983)

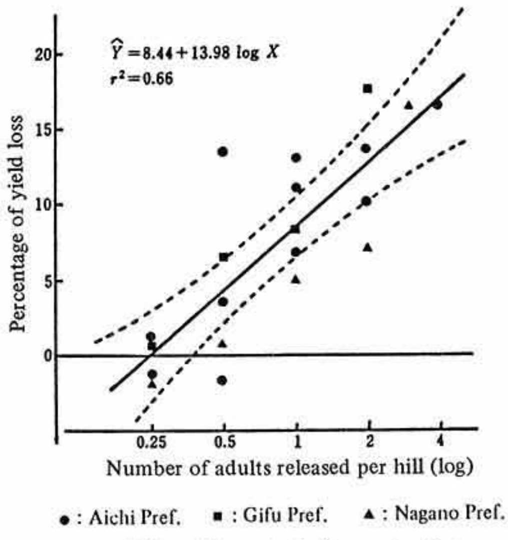

Fig. 9. Relationship between the percentage of yield loss and the log number of adults released per hill (Tuzuki et al., 1983)

roots, but it was hardly caused by overwintered adults alone which fed on leaves.[27] Moreover the damage called split-hull paddies caused by feeding of newly emerged adults was observed in a part of Hokuriku district. Infestation of adults and larvae reduced plant height and the number of stems, although the plants could recover to some extent when they reached the heading stage (Fig. 7). The most important factor for the yield loss was the decrease in the number of panicles (Fig. 8). The tolerable injury level (level of no yield loss) was estimated at 0.25 adults per hill in the case of transplanting of young seedlings (Fig. 9).[27] The tolerable injury levels of middle-aged and mature seedlings were higher than that of young seedlings. In early-season culture in which transplanting is made in April, almost no yield loss by the rice water weevil was recognized because overwintered adults flied into paddy fields after the growth of rice seedings.[26]

Control of the rice water weevil

The method for chemical control of the rice water weevil was established already. Chemicals which control simultaneously the rice water weevil and other insect pests causing damage at an early stage of rice plants must be applied. Insecticides recommended with the national registration are 9 granules for nursery box treatment, 7 granules for submerged application, and 10 dust and one oil forms for controlling the adults (as of April 1985). If the density of the overwintered adults in paddy fields is higher than that of the control threshold corresponding to 5% yield loss (0.56 adults per hill in the case of transplanting of young seedlings),[27] it is necessary to apply granules to rice nursery boxes just before transplanting of seedlings by machines. Of the chemicals with the national registration for nursery box treatment, carbosulfan granules (50–70 g/box) showed an excellent effect in reducing the number of larvae.[31] Cartap granules (100 g/box) also showed a relatively long residual effect of reducing larval density.[9,11] If the adult density in the paddy fields is very high inspite of nursery box treatment with chemicals, it is necessary to adopt the submerged application of garnules at the peak of oviposition. Additional application of dust or oil form to control the adults may be required if the adult density is very high and the feeding on rice seedlings by the adults is too severe.

It is known that some cultural control methods for the rice water weevil are effective. When rice seedlings were transplanted in April or late June, no yield loss was caused by the insect pest. By the transplanting of mature seedlings or middle-aged seedlings, it is possible to raise somewhat the density level of the control threshold. The effect of surface drainage for 15 days to suppress the densities of adults and larvae was shown.[21] About 150 rice varieties including Japanese and foreign origins were screened for the degree of tolerance. The result showed that a few varieties were highly tolerant.[20]

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