

# **SUSTAINABLE MANAGEMENT OF MIGRATORY RICE PLANTHOPPERS BY CONSERVATION BIOLOGICAL CONTROL COMBINED WITH ENDOPHYTE-INFECTED PLANTS**

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## **ABSTRACT**

We developed simulation models of population dynamics and biotype evolution for rice planthoppers in order to evaluate the efficacy of conservation biological control combined with endophyte-infected rice plants exhibiting resistance. The results indicated that, if the mortality of rice planthoppers depends on the ratio of natural enemy density to planthopper density, then the combination can successfully maintain the density of planthoppers below acceptable levels and that the development of a biotype resistant to endophyte-infected rice plants can be deterred.

(Keywords: *Nilaparvata lugens*, *Sogatella furcifera*, bacterial endophytes, natural enemies, resistance management)

## **INTRODUCTION**

Rice planthoppers, *Nilaparvata lugens* (Stal) and *Sogatella furcifera* (Horvath) have been serious pests of rice in East Asia for centuries (Kiritani, 1979). *N. lugens* has grown up as a most important pest also in South and Southeast Asia since soon after the green revolution was initiated (Dyck and Thomas, 1979). Management of *N. lugens* has been heavily dependent upon either the cultivation of resistant varieties or the use of insecticides. However, the effectiveness of these control measures did not last long because of the

development of new biotypes in *N. lugens* (Nagata and Masuda, 1980; Sogawa, 1989). Thus resistance management is crucial for sustainable rice production. It is also requested for rice planthopper management to be adopted by aged farmers in monsoonal Asia that the technologies can be operated without hard labor and elaborate skill.

Recently rice plants infected with some bacterial endophytes exhibit moderate resistance against rice planthoppers. Application procedure of the endophytes to rice seedlings is very simple and easy to follow. Moreover, production cost of endophytes is estimated to be much less than that of synthetic insecticides. We are developing IPM technologies of rice planthoppers in collaboration with Hiroshima Prefecture, Maekawa MFG. Co. and Nippon Kayaku Co. by making use of the endophytes. Our preliminary simulation results revealed that the efficacy of the sole use of endophytes is not high enough to suppress the density of rice planthoppers below an acceptable level and that a new biotype resistant against endophyte infection may swiftly evolve if the biotype gene is dominant. We report in this paper the possibility of achieving sustainable rice planthopper management by combining the symbiotic endophytes with conservation biological control based on simulation results.

## THE MODEL

### Life Cycle and Population Dynamics

We developed deterministic simulation models for *N. lugens* and *S. furcifera* in both single and double cropping areas of rice. The former area represents temperate regions where the planthoppers are unable to hibernate, while the latter area represents tropical and subtropical regions where the planthoppers occur throughout the year. IPM consisting of endophyte-infected rice plants and conservation biological control is supposed to be implemented in 50% of patches in an arena and traditional chemical control in the rest. It is assumed that *N. lugens* reproduce 3 generations per crop season following after migrant invasion and that only the 3<sup>rd</sup> reproductive generation adults leave the native patch to settle in a patch randomly selected in the arena. A similar assumption applied to *S. furcifera* except that the 2<sup>nd</sup> reproductive generation adults leave the patch. In a patch, immigrants mate at random, face selection by rice plant resistance induced by endophyte infection, and then subject to the attack by natural enemies. During immature stages, rice plant resistance, natural enemies, and density dependent mortality operate in sequence. Population

parameters of rice planthoppers were obtained from Kuno (1968). Mortality caused by natural enemies is assumed to be proportional to the ratio of natural enemy density to planthopper density except for extremely low densities of planthoppers. This assumption holds if per capita consumption by natural enemies remains constant over a wide range of prey density (Sabelis and van Rijn, 1997; Urano et al., 2003).

### **Biotype Development**

We employed a simple genetic system of one-locus two-allele model for the biotype determination. Initial frequency of endophyte-resistant biotype (R) gene is assumed at 0.001. Dominance of R gene was set at 0.5 as a default value.

## **RESULTS**

Simulation results of rice planthopper population dynamics indicated that the IPM program may successfully suppress the densities of *N. lugens* and *S. furcifera* below acceptable levels in both single and double cropping areas even if the immigrant planthopper density fluctuates considerably. Conditions for this to hold were that the natural enemy density in IPM fields can be raised to 4 times as high as that in traditional control fields and that the susceptible biotype suffers from 50% mortality in each generation. Making use of symbiotic endophytes promoted the efficacy of natural enemies because it works to double the natural enemy/planthopper ratio every generation. The above synergistic effect was essential for the success of IPM in cases where massive immigration of rice planthoppers takes place. It should be mentioned, however, that our simulation results were obtained by assuming that R gene frequency remains constant at 0.001.

Simulation of biotype development was exclusively carried out with planthopper populations inhabiting double cropping areas. This is because the selection operating in temperate regions such as Japan and Korea does not affect the gene frequency in the source area of migrants (Suzuki, 2004). The results depended on the intensity of chemical control in paddy fields where IPM is not implemented (non-IPM patch). Non-IPM patches serve as the refuge for susceptible biotype. Therefore the frequency of R gene increased rapidly as the difference in the population growth rate between non-IPM patches and IPM patches decreased. Under the assumption of implementing traditional chemical

control in non-IPM patches, simulation results showed that the development of resistant biotype can be prevented for more than 10 years.

## DISCUSSION

It is well known that rice planthoppers were no longer economic pests in Southeast Asia until green revolution, an intensification program of rice cultivation came into operation (Dyck and Thomas, 1979). The program consisted of cultivation of such high-yielding varieties as IR8, application of synthetic fertilizers, and use of non-selective insecticides. Gallagher et al. (1994) revealed that *N. lugens* outbreaks following after the intensification program were due to the misuse of non-selective insecticides that cause resurgence. In other words, natural enemies were so effective that the density of *N. lugens* was suppressed to very low levels even in the absence of resistant varieties. Sawada et al. (1993) compared the population dynamics of *N. lugens* between rainy and dry season crops in West Java, Indonesia. They found that *N. lugens* immigrants are more abundant in dry season crops than in wet season crops, yet the frequency of hopperburn is much less in dry season crops for reasons that the natural enemy density is also high in this season. In contrast, rice farmers in East Asia intermittently experienced destructive outbreaks of rice planthoppers for centuries. What makes the sharp contrast between temperate and tropical rice fields is the natural enemy density in early stages of rice growth. This leads to an idea that rice planthoppers can be successfully managed by increasing the natural enemies in young rice stages.

There are at least two possibilities to achieve this. One is the augmentative release of migratory natural enemies whose density is usually very low in most temperate paddy fields. Matsumura et al. (2005) tested the effects of augmentative release of an important migratory natural enemy, *Cyrtorhinus lividipennis*. Although their field experiments were conducted in a small spatial scale, they could halve the density of *N. lugens* at its peak generation. Augmentative release of natural enemies seems highly promising if this technique is implemented in a large scale. However, we are afraid that its supposed cost may not be acceptable for rice farmers. Another possibility is conservation biological control. Unlike augmentative release, implementation of conservation biological control may not require additional cost. *Pardosa pseudoannulata* and other spiders are important predators of rice planthoppers. Introduction of organic farming, for example, contributes to increase dipteran prey for spiders early in rice growth, which results in the increase in the density

of spiders. Being polyphagous predators, the menu of spiders depend on the composition of potential prey in paddy fields (Sasaba and Kawahara, 1970). However, since the emergence of dipteran prey concentrates in early stages of rice growth, spiders mainly prey upon rice planthoppers after they become dominant species in paddy ecosystems.

Nevertheless, our simulation results suggested that the conservation biological control itself may not be always sufficient in preventing rice planthoppers from reaching economic levels in temperate regions where the variance of immigrant planthopper density is quite large. By combining the use of resistance-inducing endophytes with conservation biological control, sustainable management of rice planthoppers may be achieved. Further discussion and improvement of simulation models are needed to realize our goal.

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