MIGRATION PREDICTION AND MONITORING OF RICE PLANTHOPPERS IN JAPAN

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Summary

This paper presents a new method of migration prediction for rice planthoppers. Using this new method, a three-dimensional backward trajectory analysis was conducted to find migration sources of rice planthoppers that immigrated into Japan. The results showed that the coastal regions of Fujian province in China and Taiwan were possible sources of the whitebacked planthopper (WBPH) that immigrated into Kyushu, Japan. The source areas of brown planthopper (BPH) that immigrated simultaneously into western Japan, Korea, and central China in 2005 were also analyzed. The results of monitoring for population characteristics such as insecticide resistance, virulence to resistant rice varieties, and wing-form ratio of Japanese BPH immigrants suggest that the recent ones differ in population characteristics from those captured in previous years, indicating a different geographic source.

Key words: brown planthopper, insecticide resistance, long-distance migration, resistant variety, simulation, whitebacked planthopper, wing-form ratio

1. Introduction

The brown planthopper (BPH), *Nilaparvata lugens* (Stål) and the whitebacked planthopper (WBPH), *Sogatella furcifera* (Horváth) (Homoptera: Delphacidae) are widely distributed throughout Asia and are considered as the two major pests of rice in the region. Neither of these species is able to overwinter successfully in temperate countries such as Japan and colonization occurs annually following long-distance migration from southern China during the *Bai-u* rainy season from June to July. Thus, monitoring technologies are necessary and have been developed as a basis for management of these migratory pests. This paper introduces a new method of migration prediction and its application to estimate migration source of rice planthoppers. It also presents the results of monitoring for population characteristics such as insecticide resistance and virulence to resistant rice varieties in Japanese BPH immigrants.

2. Migration Prediction

To analyze and forecast planthopper migration, several methods have been proposed. In Japan, a prediction model that utilizes low-level jet-stream development over East China Sea was proposed (Seino et al. 1987). Based on this model, a computer software application to predict migrations was developed (Watanabe et al. 1990). However, analytical and forecast qualities of this method are limited spatially and temporally because they use only weather data at a particular pressure level at long-time interval such as 6 or 12 h. To improve analytical quality, a new three-dimensional migration simulation model was developed.

(1) Real-time prediction system

In order to achieve high-precision migration prediction for rice planthoppers, a real-time prediction system was developed (Otuka et al. 2005c, 2006; Furuno et al. 2005). In this system, the latest meteorological data are supplied online to an advanced numerical weather prediction model, MM5. The model forecasts three-dimensional atmospheric fields at one-hour intervals. In these fields, a planthopper migration simulation model, GEARN, calculates movement of a number of modeled planthoppers and predicts their relative aerial density at three-hour intervals. The results are converted to maps and are available on the web (*http://agri.narc.affrc.go.jp/*) since 2004. The maps of relative aerial density provide information about the timing and area of migrations over the next two days. During the main migration season in June and July 2003, the system achieved a prediction quality that was comparable to that of rainfall forecasts by the Japanese Meteorological Agency.

(2) Backward trajectory analysis

A three-dimensional backward trajectory analysis method was developed to find migration sources of rice planthoppers (Otuka et al. 2005a). The method consists of meteorological simulation with a numerical weather prediction model, and trajectory calculation using simulated wind data. Trajectories started at different heights over a survey site at capturing hours, traveled backwardly, and ended at possible takeoff times. The method could explain temporal changes in hourly catches of BPH and WBPH captured by a net trap at Chikugo, located in western Japan, in 1969, and estimated various parameters such as migration source, migration route, and flight height. The source of the event at Chikugo was estimated to be the coastal region of Fujian province in China, which was a more spatially-restricted region than the previous two-dimensional estimations.

To estimate major sources of planthoppers immigrating into Japan, this method was applied for light trap caches of WBPH monitored in Kyushu, western Japan in June from 1987 to 2001. The results showed that the coastal regions of Fujian province in China and Taiwan were found to be possible sources (Otuka et al. 2005b). The migration duration taken to travel between the sources and Kyushu was estimated to be about 36 or 48 h. The comparison between two-dimensional and three-dimensional analyses indicated that the former method had a bias toward the southwest in estimating the source.

Severe outbreaks of BPH occurred simultaneously in western Japan, Korea, and central China in 2005. To understand migrations responsible for these area-wide outbreaks, two analyses have been performed: one is generation analysis using total effective temperature (TET) in order to find major migrations; and the other is migration simulation to estimate source regions. The results suggest that the source area for Japan and Korea in June to July 2005 was estimated to be the coastal regions in Fujian or Guangdong province in China. The source for Fuyang, Hangzhou province in central China was estimated to be the southern paddy regions in Guangdong. Therefore, Guangdong could be a common source for the immigrants in Japan, Korea, and central China in 2005 (Otuka et al., unpublished).

3. Recent Status of Population Characteristics in Japanese

Immigrants of BPH

Population characteristics such as insecticide resistance, virulence to resistant rice varieties, and wing-form response to density in BPH vary considerably among populations collected from different countries throughout Asia. Inter-country differences in such characteristics could arise in response to selection from different management practices throughout the geographic range of the BPH (e.g., the use of different insecticides or resistant rice varieties). BPH immigrates to Japan every year from northern Vietnam and southern China where the planthopper successfully overwinters. To assess source-pool variation, the population characteristics of BPH immigrants arriving in Japan were monitored.

(1) Insecticide Resistance

The LD50 of the BPH population collected in July 2005 in Japan was detected using a standardized topical application method (Nagata 1982). A total of nine insecticides (malathion, fenitrothion, MIPC, BPMC, carbaryl, imidacloprid, etophenplox, dinotefuran, and fipronil) were tested. LD50 values were compared with those obtained from planthoppers collected in 1999-2001 in Japan by Nagata et al. (2002) and Nagata and Kamimuro (2002). In general, no significant change was observed in any of the nine insecticides tested between 2001 (Nagata and Kamimuro 2002) and 2005. The LD50 value for imidacloprid for the 2000 population was ten-times larger than the 1999 population (Nagata et al. 2002), and this trend has continued up to 2005 (Matsumura et al., unpublished).

(2) Virulence to resistant rice varieties

Virulence of the BPH population immigrating into Japan to rice varieties carrying the resistance gene *Bph 1* began to increase around 1988-1990 (Sogawa 1992). The BPH population rapidly became virulent to the rice variety ASD7 (carrying *bph 2* gene) beginning in 1997, and the virulence remained at a high level through 1999 (Tanaka and Matsumura 2000). The virulence to resistant rice varieties in the BPH populations immigrating into Japan from 2001 to 2005 was also monitored using Tanaka's (2000) method. BPH populations collected in Japan from 2001 to 2005 remained highly virulent to IR26 (carrying

Bph 1) and ASD7. By contrast, the virulence of the BPH populations to Mudgo (carrying *Bph 1*) and IR42 (carrying *bph 2*) decreased to a low level from 2003 to 2005. It was found that there was no marked change in the virulence to Norin PL10 (carrying *Bph 3*) or Babawee (carrying *bph 4*). The changes in response to Mudgo and IR42 in the 2003-2005 populations suggest that the geographic source areas of Japanese immigrants may have changed recently (Matsumura, unpublished).

(3) Wing-form ratio

Nagata and Masuda (1980) found that tropical populations (Thailand and the Philippines) of BPH showed a remarkably high proportion of brachypters (short-wing form) in laboratory cultures compared with the Japanese populations. The density/wing-form response among BPH populations colonizing Japan from 1997 to 2005 was compared. The BPH population collected in 2005 produced abundant brachypters at high densities compared with those collected in previous years (Matsumura 2002; Matsumura, unpublished). This altered density/wing-form response may have contributed to BPH outbreaks in Japan during 2005, which ultimately resulted in "hopper-burn" on rice. Present results suggest that recent immigrants of BPH to Japan differ in population characteristics from those captured in previous years, suggesting a different geographic source (e.g., Southeast Asian countries such as the Philippines).

The migration simulation described above was applied to analyze migrations of BPH from the Philippines to Taiwan, southern China, and southern Japan (Otuka et al. 2005d). The results strongly suggested that the Southeast Asian population of BPH mixes with the East Asian population. This fact highlighted the possibility that planthoppers from the Southeast Asian population, which have properties different from those in the East Asian population such as virulence to resistant rice varieties and wing-form ratio, could migrate to Japan via southern China and Taiwan.

4. Concluding Remarks

As described above, the population characteristics of the BPH vary from year to year, and from place to place. The source areas of rice planthoppers immigrating into temperate regions could also change from year to year according to weather conditions. Thus, it is important to establish an area-wide international network to predict migration and monitor the population characteristics including genetic structures of the planthopper populations throughout Asia.

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