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Short communication

The occurrence of rice planthoppers in diversified farming on Chongming Eco-Island in China

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ABSTRACT

Nine-year data were collected to analyze the occurrence of rice planthoppers in diversified farming on Chongming Eco-Island in China from 2006 to 2014, the most important pests of rice in agroecosystems. We found a significantly linear decrease in the average numbers of adult rice planthoppers trapped per light trap per day. Using quadratic regression polynomial analysis we concluded that four meteorological indicators (average daily temperature, daily rainfall, sunshine duration, and average daily wind velocity) had significant effects on the numbers of brown planthopper (*Nilaparvata lugens*) and white-backed planthopper (*Sogatella furcifera*) trapped in the lamp, and that average daily temperature had a significant effect on the number of small brown planthopper (*Laodelphax striatella*) trapped in the lamp. These findings suggest that increasing temperature related to climate change might promote the occurrence of rice planthoppers in diversified farming in the future.

1. Introduction

Ecological engineering of diversified farming management has been widely adopted as one of the most important ways of managing landscape biodiversity (Mitsch et al., 2002; Mitchell et al., 2014). Diversified farming can promote biocontrol services (Wan et al., 2014b, 2016a,b), enhance the abundance of natural enemies (Landis et al., 2000) and support arthropod diversity (Symstad et al., 2000).

Chongming Island in the Yangtze River delta is the third largest island in China and the largest alluvial island in the world, with a total area of 1267 km^2 (Meng et al., 2011). The island has 2.6×10^4 ha under rice cultivation, and a yield of 2.1×10^8 kg per year. Diversified farming as a model was introduced here in the 2000s. At present, diversified farming is considered an important tool for developing ecological agriculture (Wan et al., 2013), and this production model has been widely adopted by farms on Chongming Island. However, the effect of diversified farming on the occurrence of rice planthoppers has not yet been reported.

The brown planthopper (*Nilaparvata lugens*), white-backed planthopper (*Sogatella furcifera*), and small brown planthopper (*Laodelphax striatella*), are the most important pests of rice in Asia (Zhang et al., 2014). The brown planthopper feeds on rice phloem and transmits viral diseases like grassy stunt and wilted stunt (Powell et al., 1995). The white-backed planthopper can frequently cause significant direct damage and transmit southern rice black-streaked dwarf virus (SRBSDV) (Zhang et al., 2008). Meanwhile, the small brown planthopper transmits rice stripe virus and rice black streaked dwarf virus (Zhang et al., 2012b). Since farmers adopted green revolution technologies in the 1960s, these three rice planthopper species have become a major threat to rice production (Bottrell and Schoenly, 2012). The potential for ecological engineering to control these rice planthoppers through diversified farming has largely remained poorly unexplored. On Chongming Island of China, the three planthopper species are the most destructive insect pests of rice. This study was therefore conducted to monitor the occurrence of rice planthoppers using insecticidal lamp traps and

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correlated meteorological analysis to predict their group trends under diversified farming on Chongming Island, China.

2. Materials and methods

2.1. Study sites

Our study was conducted at the Shanghai SIIC Modern Agriculture Development Co., LTD., Chongming Island, China (30.5°N, 121.9°E). At this site, the main rice varieties cultivated were "Xiushui" types provided by the Crop Research Institute, Shanghai Academy of Agriculture Sciences. A total of 1.67 thousand hectares of rice were sown, which produced an average yield of 13.8 thousand tons (Wan et al., 2015). One insecticidal lamp (solar frequency vibration lamp 1.5 m in height, PS-15II type, manufactured by Jiaduo Company Limited of Henan province, China) was installed in the center of each rice field (reaearch plots) to monitor the occurrence of the rice planthoppers.

Eco-engineering practices of diversified farming used in the study region included: (1) postponement of transplanting date (compared to conventional practice) by 7 days to late June to avoid damage from the small brown planthopper, whose first generation disperses from wheat field to rice fields; (2) use of a rice–milk vetch rotation to improve soil fertility and use of rice–wheat rotation to enhance the economic efficiency of the land; (3) retention of grassy field edges to promote the abundance and diversity of natural enemies of rice pests; and (4) use of crops such as corn, soybean, watermelon and other vegetables cultivated near rice fields to maintain biodiversity and promote biocontrol services. Pest control, fertilization and irrigation were the same throughout the rice fields. A variety of insecticides, including Chlorantraniliprole SC (Suspension Concentrate), Thiamethoxam WG (Waterdispersible Granule), Chlorpyrifos EC (Emulsifiable Concentrate), Pymetrozine WP (Wettable Powder), Nitenpyram WP and Buprofezin WP were used to control rice planthoppers according to the pest forecast information offered by the Plant Protection Station on Chongming Island.

2.2. Data collection

In the monitoring field, full-time workers counted the number of adult rice planthoppers trapped in the insecticidal lamp. Sampling was done every day from late June to early October from 2006 to 2014 (with some delays because of rain or other contingencies), for a total of 94, 92, 90, 92, 87, 92, 92, 86 and 91 sample dates in 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013 and 2014 respectively. Meteorological data, including average daily temperature (°C), daily rainfall (mm), sunshine duration (h), and average daily wind velocity (m/s) were collected from the Chongming Meteorological Bureau of Shanghai, China.

2.3. Data analysis

Quadratic regression polynomial analysis was used with SPSS 16.0 to analyze the relationship between the four meteorological indicators (average daily temperature X_1, daily rainfall X_2, sunshine duration X_3, and average daily wind velocity X_4) and the number (square root-transformed) of the brown planthopper, the white-backed planthopper, or the small brown planthopper trapped in the lamp. For a total of 816 meteorological data (94, 92, 90, 92, 87, 92, 92, 86 and 91 data in 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013 and 2014 respectively) were selected to analyze the relationships.

3. Results

From 2006 to 2014, there was a significantly linear decrease in the average numbers of adult rice planthoppers trapped per light trap per day in diversified agro-ecosystems on Chongming Eco-Island of China. The average daily numbers of trapped adult brown planthopper, white-backed planthopper and small brown planthopper populations were 7.24 ± 1.45, 19.40 ± 4.34 and 11.40 ± 2.81 individuals respectively in 2006, and gradually decreased to 4.11 ± 0.73, 6.59 ± 0.86 and 6.25 ± 1.41 individuals respectively in 2014 (Fig. 1).

Four meteorological indicators had significant effects on the numbers of brown planthopper and white-backed planthopper trapped in the lamp, and average daily temperature (X_1) had significant effect on the number of small brown planthopper trapped in the lamp. The interactive effects [daily rainfall (X_2) × daily rainfall (X_2), and average daily temperature (X_1) × daily rainfall (X_2)] positively affected while the interactive effects [average daily wind velocity (X_4) × average daily wind velocity (X_4), average daily temperature (X_1) × sunshine duration (X_3), and average daily temperature (X_1) × average daily wind velocity (X_4)] negatively affected the number of brown planthopper. As for white-backed planthopper, the interactive effects [daily rainfall (X_2) × daily rainfall (X_2), sunshine duration (X_3) × sunshine duration (X_3), and average daily temperature (X_1) × daily rainfall (X_2)] were positively significant, while the interactive effects [average daily wind velocity (X_4) × average daily wind velocity (X_4), average daily temperature (X_1) × sunshine duration (X_3), average daily temperature (X_1) × average daily wind velocity (X_4), and sunshine duration (X_3) × average daily wind velocity (X_4)] were negatively significant. The effect of the single factor [average daily temperature (X_1)] on the number of small brown planthopper was positively significant, while the interactive effects [average daily temperature (X_1) × average daily temperature (X_1), and sunshine duration (X_3) × sunshine duration (X_3)] were negatively significant (Table 1). The equations for brown planthopper, white-backed planthopper and small brown planthopper were $Y_1 = -0.045 + 0.015\ X_1 - 0.010\ X_2 + 0.041\ X_3 + 0.589\ X_4 + 0.\ 203 \times 10^{-4}\ {X_2}^2 - 0.025\ {X_4}^2 + 0.320 \times 10^{-3}\ X_1{}^*\ X_2 - 0.779 \times 10^{-3}\ X_1{}^*\ X_3 - 1.963 \times 10^{-3}\ X_1{}^*\ X_4 - 6.996 \times 10^{-3}\ X_3{}^*\ X_4$, $Y_2 = -0.045 + 0.015\ X_1 - 0.010\ X_2 + 0.041\ X_3 + 0.589\ X_4 + 0.203 \times 10^{-4}\ {X_2}^2 - 0.025\ {X_4}^2 + 0.320 \times 10^{-3}\ X_1{}^*\ X_2 - 0.779 \times 10^{-3}\ X_1{}^*\ X_3 - 1.963 \times 10^{-3}\ X_1{}^*\ X_4 - 6.996 \times 10^{-3}\ X_3{}^*\ X_4$ and $Y_3 = -15.098 + 1.112\ X_1 - 0.017\ {X_1}^2 - 5.514 \times 10^{-3}\ {X_3}^2$ respectively.

4. Discussion

The ecological engineering of diversified farming in agroecosystems is an important means to increase farmers' income as it can produce high-value products such as vegetables, meat and fish (Zhang et al., 2012a), and a scientific way to manage water resources, decrease environmental pollution and improve environmental quality (Yang et al., 2014). Additionally, it is a valuable method for preserving and protecting natural enemies and controlling insect pests (Wan et al., 2014b). According to our preliminary estimates, if diversified farming was widely adopted, serious outbreaks of rice planthoppers could be largely prevented and the abundance of rice planthoppers could decrease by more than ten percent. Improved rice yield and quality would result from such biocontrol services, while preserving natural enemies and reducing the need for pesticides and fertilizers. Neighboring crops such as watermelons and corns could meanwhile provide extra income for farmers.

Studies have found that outbreaks of rice planthoppers mainly stemmed from agricultural intensification and the overuse of