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Polycultural manipulation for better regulation of planthopper populations in irrigated rice-based ecosystems

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ABSTRACT

The frequent outbreaks of rice planthoppers, especially brown planthopper *Nilaparvata lugens* (Stål), in the last ten years in China and other Asian countries have caused serious rice (*Oryza sativa* L.) yield losses. The key problem is possibly due to biodiversity loss in rice ecosystems. We examined the potential of intercrops of soybean (*Glycine max* L.) and corn (*Zea mays* L.), both of which are more profitable than rice and mostly planted in levees, to diversify rice ecosystems and enhance insect pest management. We studied the impacts of such intercrops on planthopper populations and their natural enemies. The results showed significantly lower numbers of rice planthoppers in rice fields with intercrops of corn than in rice monocultures and rice fields with intercrops of soybean. Rice fields with corn intercrops had 26–48% fewer planthoppers than rice monoculture. Rice fields with soybean intercrops had lower rice planthopper abundance compared to rice monoculture in 2008 but higher in 2009. However, neither parasitoid nor predator numbers were significantly affected by intercropping. There were no significant differences in directional movements of planthoppers or natural enemies between crop subplots in the different cropping systems. Moreover, movement of planthoppers was very limited. Our study indicated that soybean and corn intercrops do not greatly enhance the ability of natural enemies to suppress planthoppers. However, rice fields with intercrops of corn had lower abundance of planthoppers and this strategy may be useful as part of an integrated pest management strategy for the sustainable rice production.

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1. Introduction

Rice (*Oryza sativa* L.) is widely cultivated throughout the world and serves as a basic food staple for over half the world's population (FAO, 2004). Its sustained production is vital especially for Asian counties (Maclean, 2002). However, recently, two migratory planthoppers, *Nilaparvata lugens* (Stål) (brown planthopper; BPH) and *Sogatella furcifera* (Horváth) (white-backed planthopper; WBPH) and a less migratory species, *Laodelphax striatellus* (Fallén) (small brown planthopper; SBPH), were listed as new threats to sustainable rice production (Heong and Hardy, 2009). These three species of rice planthoppers (RPH) cause damage to rice directly by sucking the phloem sap and indirectly by transmitting viral diseases (Heong and Hardy, 2009). Outbreaks of RPH can completely destroy crops, causing "hopper burn".

Currently, RPH population management depends heavily on insecticides and resistant rice varieties (Heong and Hardy, 2009). However, pesticides are often considered environmentally harmful, and can have detrimental effects on natural enemies (Schoenly et al., 1996), causing resurgence (Chellial and Heinrichs, 1980) and resistance (Nagata, 2002). Additionally, Chen (2009b) has shown that within several generations in the laboratory and several years in the field, the virulence of RPH, especially BPH, can overcome the resistance of certain resistant rice varieties deployed against such pests.

Frequent RPH outbreaks have been recorded since late 1960s in China, and occurrences have worsened since 2000 (Chen, 2009a). Among the reasons explaining these new outbreaks, simplification of the rice ecosystem appears to play the most important role (Chen et al., 2008; Chen, 2009a). Biodiversity loss in modern intensified agriculture may be linked to increasing pest problems (Way and Heong, 1994; Gurr et al., 2003; Altieri and Nicholls, 2004). Biodiversity enhancement of agroecosystems has been promoted under

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integrated pest management and other sustainable management practices. It is considered more sustainable and aims to reduce pesticide use and prolong the effectiveness of resistant rice varieties (Gurr, 2009).

In southern China, rice field borders or marginal areas, especially levees, are usually used for planting more profitable vegetables (e.g. soybean (*Glycine max* L.) and corn (*Zea mays* L.)), which take full advantage of the land and completely coincide with self-sufficiency and small farm economics (Xie and Xia, 1992; Lin, 1996). It was suggested that soybean and corn may be beneficial to parasitoids in rice fields, as they supply nectar and pollen (Lu et al., 1995; Zheng et al., 2003). However, few studies have empirically examined the roles of these intercrops on insect communities, especially parasitoids at the field or landscape level. In this study, we examined the role of soybean or corn intercrops within a rice ecosystem. Our objectives were to (1) assess the effects of intercrops on the abundance of rice planthoppers; (2) examine the roles of soybean and corn in the population increase of natural enemies of planthoppers; and (3) determine whether intercrops can influence insect movement between habitats.

2. Materials and methods

2.1. Study site and experimental design

The experiments were conducted in 2008 and 2009 at the research station of Institute of Applied Ecology, Fujian Agricultural and Forestry University (IAE, FAFU) in Mount Wuyi, Northwest of Fujian province, China (27°39′8.12″N, 117°53′19.38E). This study site is a subtropical ecosystem, subjected to monsoon, an average annual temperature of 16.2 °C, annual precipitation of 2190 mm, 78% relative humidity, and over 120 days of frost-free period.

The experiments followed a complete randomized block design with three treatments: 1) rice monoculture (RMon), 2) rice fields with intercrops of corn (RC), and 3) rice fields with intercrops of soybean (RS). Four blocks were used in this experiment and were separated from each other by a buffer of at least 3 m. Each block was divided into three plots of 2400 m^2. Each plot (also buffered by 3 m bare soil) was further divided into six subplots of 22 × 5 m planted with one crop (rice or intercrop) in alternating pattern. Each subplot was bordered on all sides by an unplanted 0.5 m-wide earthen walkway. Fig. 1 describes the experimental design as well as the locations of the various traps used to survey insects within and between subplots (see next section for description of surveys). On 23 June 2008 and 20 June 2009, two to four thirty-day-old rice seedlings per hill were transplanted by hand (average 25 × 22.5 cm spacing). Rice (variety: T55YOU627) was harvested on 2 October 2008 and 27 September 2009. Soybean (variety: Wanfeng No.6) was sown on 27 June 2008 and 14 June 2009, and harvested on 27 September 2008 and 12 September 2009. The first crop of corn (variety: Huyunuo No.3) was sown on 29 April 2008 and 5 May 2009, and harvested on 22 July 2008 and 1 August 2009. The second crop of corn was sown on 28 July 2008 and 2 August 2009, and harvested on 20 October 2008 and 26 October 2009. Corn and soybean were both sown before transplanting rice at an average spacing of 140 × 35 cm, except for a delay for soybean in 2008 due to a heavy rain event. The crops were subsequently managed with usual agronomic practices and without any pesticide application.

2.2. Sampling communities

Planthopper species in these communities included species such as BPH, WBPH and SBPH. Natural enemy communities of planthoppers included (1) egg parasitoids: *Anagrus nilaparvatae* Pang *et* Wang, *Anagrus longitubulosus* Pang et Wang, and *Panstenon oxylus* (Walker); (2) nymph or adult parasitoids: *Gonatopus flavifemur* (Esaki et Hashimoto), *G. nigricans* (R. C. L. Perkins), *Haplogonatopus apicalis* R. C. L. Perkins, and *Haplogonatopus oratorius* (Westwood); and (3) egg predators *Microvelia horvathi* Lundblad and *Cyrtorrhinus lividipennis* Reuter). Egg parasitoids are considered to be specialist, nymph and adult parasitoids mainly parasitize rice planthoppers but occasionally parasitize rice leafhopper, and egg predators can also feed on eggs of rice leafhoppers (He and Pang, 1986; He et al., 2004).

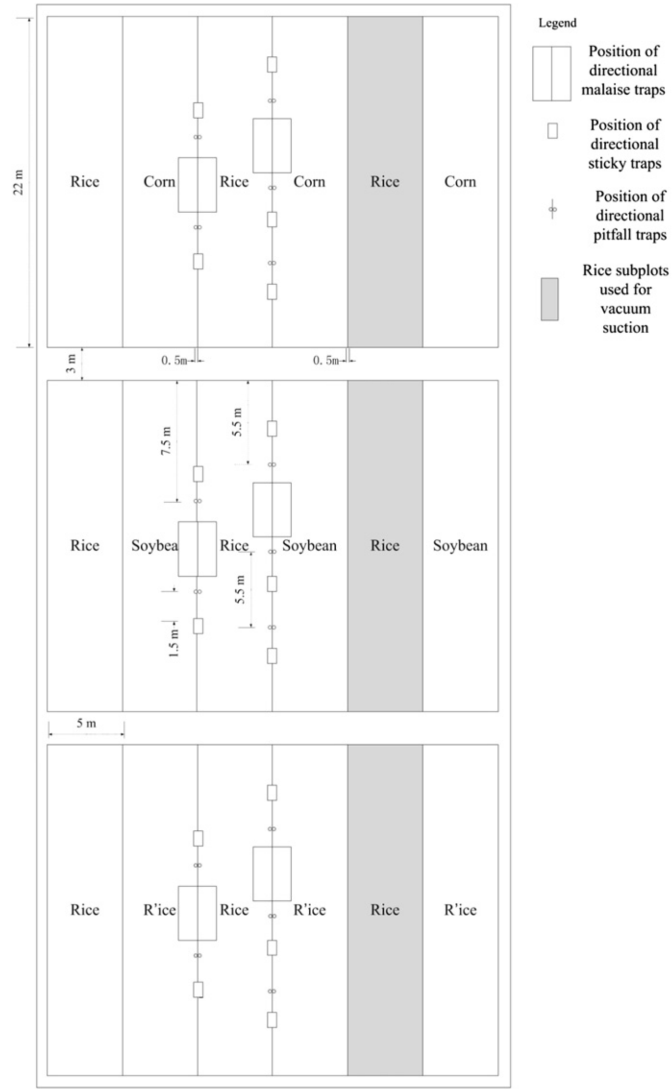

Fig. 1. Layout of one of the experimental blocks and sampling patterns. Three treatments: rice monoculture (RMon); rice fields with intercrops of corn (RC); rice fields with intercrops of soybean (RS). R′, rice subplot on the same side with corn or soybean subplot.

2.2.1. Subplot surveys

Communities of rice planthoppers and their natural enemies were surveyed using the suction equipment used by Lin et al. (2010). In this case, arthropods in nine rice hills (ca. 0.25 m^2) were collected as one of five sub-samples per plot. Those five sub-samples were randomly sampled (Chen et al., 2007) in subplots not used for monitoring the movement of insects (Fig. 1). Sampling was conducted in the morning, on average every 15 days starting one week after transplantation and continued until the rice was fully

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