Journal of Integrative Agriculture 2016, 15(4): 795–802

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RESEARCH ARTICLE

Intercropping of rice varieties increases the efficiency of blast control through reduced disease occurrence and variability

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Abstract

Creating a crop-heterogeneous system by intraspecific mixtures of different rice varieties can substantially reduce blast diseases. Such variety mixtures provide an ecological approach for effective disease control, maintaining high yields with the minimum fungicide applications. Whether such an approach is universally applicable for random rice variety combinations and what is the variation pattern of the diseases under intercropping still remains unclear. We conducted two-year large-scale field experiments involving 47 rice varieties/lines and 98 variety-combinations to compare the occurrence of rice blast in monoculture and intercropping plots at multiple sites. In the experiments, the plant height of the selected traditional varieties was about 30 cm taller, and their life cycle was 10 days longer, than that of the improved rice varieties. The monoculture included either traditional or modern rice varieties grown in separate plots. The intercropping included both traditional and modern rice varieties planted together in the same plots. Results from the field experiments under natural disease conditions demonstrated significant reduction for rice blast disease in intercropping plots, compared with that in monoculture plots. For traditional varieties, the average blast incidence reduced from ~26% in monoculture to ~10% in intercropping, and the disease severity reduced from ~17 in monoculture to ~5 in intercropping. For modern varieties, the average blast incidence reduced from ~19% in monoculture to ~10% in intercropping, and the severity from ~10 in monoculture to ~4 in intercropping. Traditional rice varieties (~72%) had a much greater increase in the efficiency of disease control than modern varieties (~60%). In addition, substantially lower values of variance in the blast incidence and severity was detected among the variety combinations in intercropping plots than in monoculture plots. Based on these results, we conclude that the intercropping or mixture of rice varieties greatly reduces the occurrence and variation of rice blast disease in particular variety combinations, which makes the intercropping system more stable and consistent for disease suppression on a large scale of rice cultivation.

Keywords: *Oryza sativa*, cropping system, disease suppression, disease variation, mixed-planting, pure-planting, crop heterogeneity

Received 20 March, 2015 Accepted 23 April, 2015
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doi: 10.1016/S2095-3119(15)61055-3

1. Introduction

Crop disease control is one of the major agricultural activities to maintain high crop yields (Dordas 2008). There are many

methods for crop disease control, including the application of chemical, biological, physical, and cultural approaches (Palti 1981). One of the effective and environmental friendly ways to control diseases is to apply ecological approaches in modern agricultural systems (Risch *et al.* 1983; Altieri 1999; Tilman *et al.* 2001), in which crop heterogeneity is created to provide substantial disease suppression (Garrett & Mundt 2000; Zhu *et al.* 2000; Leung *et al.* 2003). An excellent example is the successful control of rice blast disease (*Magnaporthe grisea*) demonstrated by the large-scale field experiment with mixed-planting of traditional and modern rice varieties (Zhu *et al.* 2000). This example substantiated that "intraspecific crop diversification provides an ecological approach to disease control that can be highly effective over a large area and contribute to the sustainability of crop production" (Zhu *et al.* 2000).

As an important world's cereal crop, rice (*Oryza sativa*) provides staple food for nearly one half of the global population (Lu and Snow 2015). In China, rice also serves as one of the top food crops, which is consumed across the entire country, in addition to its important cultural values such as liquor production (Luo *et al.* 2008) and religious folk services (Zeng *et al.* 2012). Therefore, the high yielding and sustainable production of rice is critical for the food security in this country. However, the sustainable rice production is threatened by various fungus diseases, particularly by the rice blast disease, which "spreads through multiple cycles of asexual conidiophores production during the cropping season, causing necrotic spots on leaves and necrosis of panicles" (Zhu *et al.* 2000). Rice blast is the major disease of the rice crop in many rice planting regions (Dean *et al.* 2005). Statistical data suggest that 10–20% of rice yield losses are caused by the severe attacks of rice blast disease in China (Sun *et al.* 1998; Liu *et al.* 2004). The commonly used methods to control rice blast disease are chemical controls (Sun *et al.* 1998; Liu *et al.* 2004; Wen *et al.* 2013), which causes considerable pollution in the rice ecosystems and increases the costs for rice production (Yang *et al.* 2012). However, Zhu *et al.* (2000, 2003a) achieved about 94% less blast disease and 89% greater grain yield for disease-susceptible traditional rice varieties only by growing these varieties in mixtures with disease-resistant modern rice varieties. The approach of Zhu *et al.* (2000, 2003a) using the ecological method of intraspecific diversity may provide an effectual alternative to control this disease in rice, in addition to its values for *in situ* conservation of rice genetic resources (Zhu *et al.* 2003b).

Undoubtedly, the above studies have set an excellent example for the ecological control of the rice blast disease using the genetic diversity of rice varieties, but only two traditional rice varieties (Huangkenuo and Zinuo) and two modern hybrid rice varieties (Shanyou 63 and Shanyou 22) with four or six variety combinations were used in the field experiments to determine the efficacy of rice blast control in the intercropping and monoculture systems (Zhu *et al.* 2000, 2003a). However, the question arises as to whether the same level of efficacy for reduced disease can be remained if a greater number of rice varieties and combinations is included in more extensive rice planting regions. This is because many rice varieties are currently grown in Yunnan and the neighboring provinces in China. Can all these rice varieties be utilized in the intercropping system for rice blast control? In other word, do randomly selected combinations of traditional and modern rice varieties in intercropping or mixed-planting have the universal effects on rice blast reduction? In addition to the generally reduced rice blast severity and occurrence in the intercropping system, are there any other reasons responsible for the control of rice blast in the intercropping system?

These questions should be addressed if a more universal application of this intercropping technique is adopted effectively for reducing rice blast in rice ecosystems. Apparently, these questions can be answered by including a greater number of rice varieties with more variety combinations at multiple field experimental sites. To meet this purpose, we conducted extensive field experiments in which the biodiversity cultivation (intercropping) of rice varieties was deployed in 2001–2002 to investigate the efficiency of disease control. The field experiments involved 76 rice varieties/lines that formed 98 variety combinations, and were located in eight districts in Yunnan Province. The objectives of this study were to determine (1) whether the efficient reduction of rice blast disease is a general pattern when a large set of rice varieties with diverse origins in random combinations were cultivated in the intercropping system; (2) what is the variation pattern of blast occurrence among the variety combinations under intercropping, compared to that under monoculture. The generated knowledge will be useful to facilitate our understanding of the dynamics of the blast disease in different rice eco-systems, and eventually to guide the design of biodiversity cultivation of rice varieties for the efficient control of the rice blast disease in the intercropping system.

2. Results

2.1. Efficiency of rice blast control in different combinations of rice varieties

In general, the occurrence of rice blast disease was significantly reduced in the intercropping (mixed-planting) plots both for the traditional and modern improved rice varieties, compared with the occurrence of rice blast in the monoculture (pure-planting) plots (Table 1, Figs. 1 and 2).