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Effects of different fertilization practices on the incidence of rice pests and diseases: A three-year case study in Shanghai, in subtropical southeastern China

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ABSTRACT

To implement organic rice farming around a drinking water source in the western suburbs of Shanghai, pioneering field experiments on the relationships between fertilizer applications and occurrences of rice pests and diseases were performed without the use of pesticides and fungicides from 2012 to 2014. The rice plants treated with chemical fertilizers (CF) accumulated higher content of available nitrogen ($NH_4^+ + NO_3^-$) and grew higher and more luxuriantly, but they were more susceptible to pests and diseases. Comparatively, the plants treated with organic manure demonstrated higher resistance to rice pests and diseases and grew more healthily. However, excessive application of organic manure also increased the risks of pests and diseases. The unfertilized plants were highly deficient in nutrients, but they maintained the lowest rates of pests and diseases. This suggests that rice pests and diseases were easily triggered by a high content of N-related nutrients in plant tissues and inhibited by nutrient deficiency. Annual climatic conditions also deeply affected the occurrences of rice pests and diseases. Long-term warm and humid weather in the growing areas favored the development of herbivorous pests and fungal diseases. The incidence of migratory pests in Shanghai is also linked to violent summer storms. Frequent rain storms in southern or southwestern China increased the chance of infestations of migratory pests in Shanghai. Rice yield was primarily determined by the infestations of pests and diseases. In the pest-infested year of 2012, the grain yield for the different fertilizers was only 40%–44% of that under conventional farming practices, and the yield in CF was even significantly lower than that in the unfertilized CK. In 2013, with lower infestation rates, the grain yield of the different fertilizers was more than 80% of the conventional yield. The application of a lower amount of organic manure, 2100 kg ha^{-1} of cake manure, was recommended for the implementation of organic rice farming in the water source areas in Shanghai.

1. Introduction

Situated in the upper reaches of the Huangpu River in the western suburb of Shanghai, Dianshan Lake is a major drinking-water source of the metropolitan area (Fig. 1). To ensure the safety of the water supply for the city, any industrial activities and livestock breeding around the lake have long been forbidden. However, diffusion of agricultural pollution from paddy fields around the lake, which is approximately 11.0×10^3 ha in area, still poses a threat to the lake.

Farmers in the suburbs of Shanghai mostly grow single-crop rice in direct-seeded systems due to the high cost of labor, which requires greater use of herbicides and pesticides to control weeds and pests. Moreover, the costs of labors and agrochemicals have continuously increased in recent decades, but the purchase price of rice remains low, only approximately 0.55 USD per kg. As a result, money earned from grain sales is only sufficient to pay for laborers and agrochemicals, and to earn a living, the farmers mainly depend on agricultural subsidies, which are granted by the municipal government each year based on the total cultivated area. In

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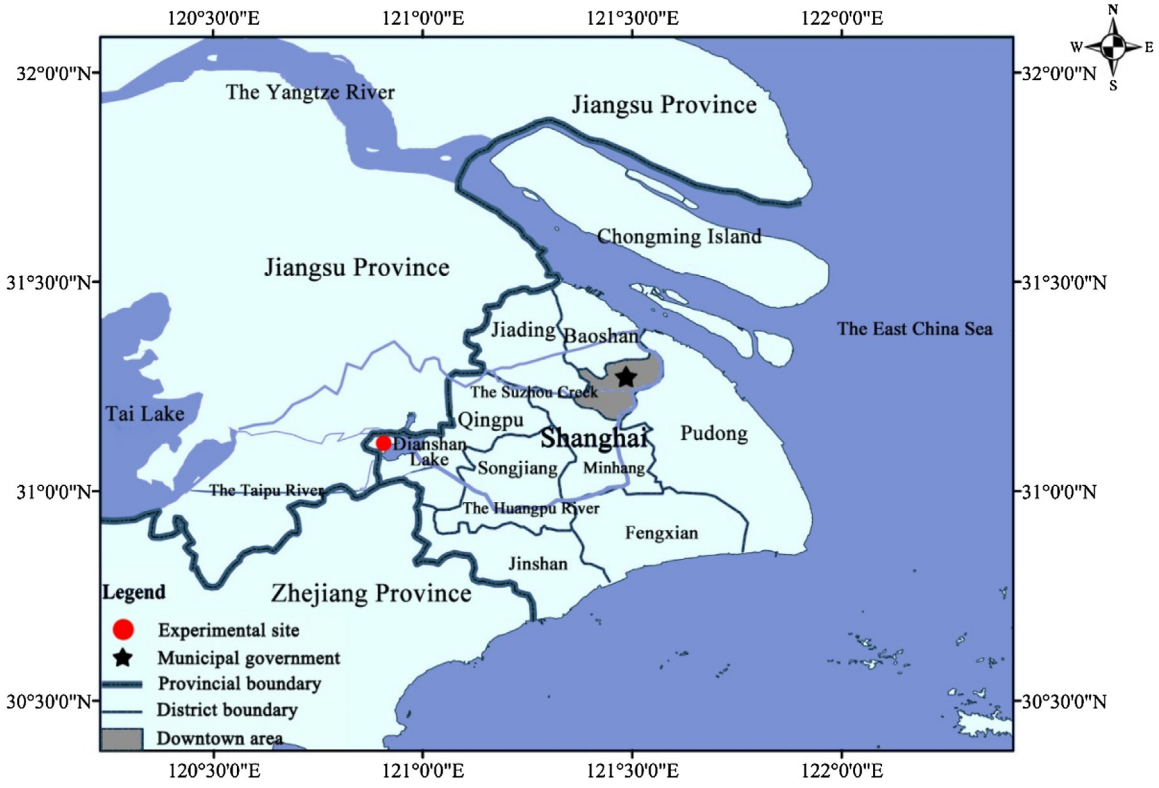

Fig. 1. Sketch map showing the geographical position of Shanghai and the location of the experimental site in the western suburbs of Shanghai.

this case, efforts to raise their incomes by increasing grain yield through excessive application of chemical fertilizers continue. The amount of mineral nitrogen applied to single-crop rice paddies is estimated at approximately 270–300 kg N ha^{-1}, and it sometimes even exceeds 350 kg N ha^{-1} in the Taihu Lake catchment of Southeast China (Peng et al., 2002; Li et al., 2003).

Rice in Shanghai, in subtropical Southeast China, is susceptible to pests and diseases within the growing season due to the warm, rainy subtropical weather. Moreover, the municipal government has implemented a series of policies to support and benefit farmers, and the pesticides and fungicides specifically used for rice cultivation have been dispensed to farmers freely in recent years. As a result, more pesticides and fungicides are applied to paddy fields in the suburbs of Shanghai. Agrochemicals applied in excess to the fields are mostly leached or removed by runoff, which poses threats to the lake and other nearby water bodies. The excessive inputs of agrochemicals also degrade soil quality and reduce soil biodiversity (Oehl et al., 2004).

Approximately 29.4 million hectares of paddy fields exist in China (Hu and Ding, 2008; Lou et al., 2013). The hazards of agricultural pollution from paddy fields under conventional farming practices have attracted wide concern. Organic farming practices, therefore, are highly encouraged worldwide (Wood et al., 2006; Garratt et al., 2011). According to a global survey, the area of land under organic management has reached more than 24 million ha globally (Tu et al., 2006). Organic management has also been developing quickly in China in recent decades. In Shanghai in particular, many organic farms have been established over the past two decades. However, organic or low-input farming may cause infestations of crop pests and diseases, thus significantly reducing the yield, especially during the transitional period from conventional to organic systems, when pesticides, fungicides and herbicides are suddenly withdrawn (Tu et al., 2006).

The occurrence of crop pests and diseases is also linked to fertilization (Hasken and Poehling, 1995; Bethke et al., 1998; Malav and Ramani, 2015). High levels of available nutrients, particularly mineral nitrogen, in crop tissues caused by excessive use of chemical fertilizers often increases the risk of pest infection (Jauset et al., 2000; Bi et al., 2001; Lu et al., 2007). The population of aphids on winter wheat increases significantly with increasing levels of mineral nitrogen applied to the fields (Hasken and Poehling, 1995). More aphids were found on melons treated with the highest level of chemical nitrogen fertilizer (Bethke et al., 1998). Both adult and immature whiteflies on corn increase with increasing chemical nitrogen application (Bi et al., 2001). In contrast, organic farming practices can diminish herbivorous populations (Culliney and Pimentel, 1986; Eigenbrode and Pimentel, 1988; Phelan et al., 1995). A 2-year field experiment indicated that tomatoes treated with synthetic (NPK) chemical fertilizers are more severely infected by aphids than those treated with organic manure (Yardım and Edwards, 2003). The density of the pest population on rice plants under organic farming is much less than that under conventional chemical farming (Kajimura et al., 1995a,b).

Long-term application of organic manure or low inputs of chemical fertilizers are beneficial to maintain soil health and cause crops to be less susceptible to pests and diseases (Kajimura et al., 1995a,b; Phelan et al., 1995; Lu et al., 2007; Garratt et al., 2011), thus minimizing the application of pesticides and fungicides. Rice-frog or rice-duck integrated farming systems, which are recently becoming more common in China, can effectively control rice pests and diseases and significantly reduce the required amount of pesticides (Zhu, 2000; Tong 2002; Zhen et al., 2008; Teng et al., 2015). Implementing organic rice farming around Dianshan Lake can not only produce high-quality organic rice but also protect water bodies from agricultural pollution. However, the regularity of the occurrence of rice pests and diseases under the subtropical monsoon climate of Shanghai requires further examination. Therefore, field

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