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Short Communication

Increased hill density can compensate for yield loss from reduced nitrogen input in machine-transplanted double-cropped rice

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ABSTRACT

Reducing external inputs, including labor and N fertilizer, is critical to sustainable double-cropped rice production in China. Dense planting is a recommended strategy to reduce N rate in rice production, and this strategy may be more practical for machine-transplanted rice as machine transplanting can achieve high hill density with less labor. However, little work has been done to demonstrate the feasibility of such a strategy in machine-transplanted double-cropped rice. This study was conducted to determine the effects of reduced N rate and increased hill density on yield attributes and grain yield in machine-transplanted double-cropped rice. Field experiments were done in two years with three treatments: (1) high N rate with low hill density (HNLD), (2) low N rate with low hill density (LNLD), and (3) low N rate with high hill density (LNHD).

Results showed that LNLD had 19% and 16% less panicle number per unit land area, 27% and 26% smaller leaf area index, 18% and 14% lower biomass production, and consequently 13% and 11% lower grain yield than did HNLD in early and late season, respectively. In contrast, these yield attributes and grain yield were generally equal or higher under LNHD than under HNLD. Our study indicates that the potential negative effects of reduced N rate on yield attributes and grain yield can be compensated for by increased hill density, and suggests that dense planting is a feasible strategy to reduce N input in machine-transplanted double-cropped rice.

1. Introduction

China is the largest producer and consumer of rice in the world (Wang et al., 2005). Double rice cropping is a typical rice production system in China and is considered as an efficient system to improve multiple-crop index and total rice production (Wang et al., 2016). However, because of labor migration and increases in labor wages, the labor input for rice production has decreased significantly in China, especially in areas where economic development is more advanced (Peng et al., 2009). As a consequence, planting area of the double rice cropping system in China has continued to decline (Yu et al., 2012; Peng, 2016). Therefore, it is urgent to develop rice cultivation technologies that will be labor saving to reverse the declining trend of double-cropped rice planting area in China.

Machine transplanting is an alternative rice cultivation technology that can save labor (Thomas, 2002). Along with the popularization of efficient agriculture in recent years, machine transplanting has been developed rapidly in rice production in China (Qian et al., 2009). However, in the machine-transplanted rice production, the rice farmers basically follow the traditional management practices for field management (Huang and Zou, 2016). Previous studies have confirmed that some of these traditional management practices, typically such as N application, utilize resources ineffectively and have negative impacts on the environment (Peng et al., 2006; Ju et al., 2009). In China, the average rate of N application for rice production is 180 kg ha^{-1}, about 75% higher than the world average (Peng et al., 2002; Chen et al., 2014). Because of the high rate of N application, only 20–30% of N is taken up by the rice plant and a large proportion of N is lost to the environment (Peng et al., 2006). Over the past three decades in China, the use of large amounts of N fertilizers has imposed substantial environmental costs, including surface water eutrophication, soil acidification, increased greenhouse gas emissions, and enhanced N deposition (Ju et al., 2009; Le et al., 2010; Guo et al., 2010; Liu et al., 2013). In addition, diminishing returns are being observed with the use of N fertilizers in China. The ratio of incremental increases in rice production in response to additional applications of N fertilizer has fallen sharply since the start of Green Revolution (Peng et al., 2010). Thus, great attention should be paid to reduce external N input to obtain both environmental and economic benefits in rice production.

Dense planting is a recommended strategy to reduce N rate in rice production (Huang et al., 2013a). In the study area, Qin et al. (2013) observed that an improved practice with increased hill density (early-

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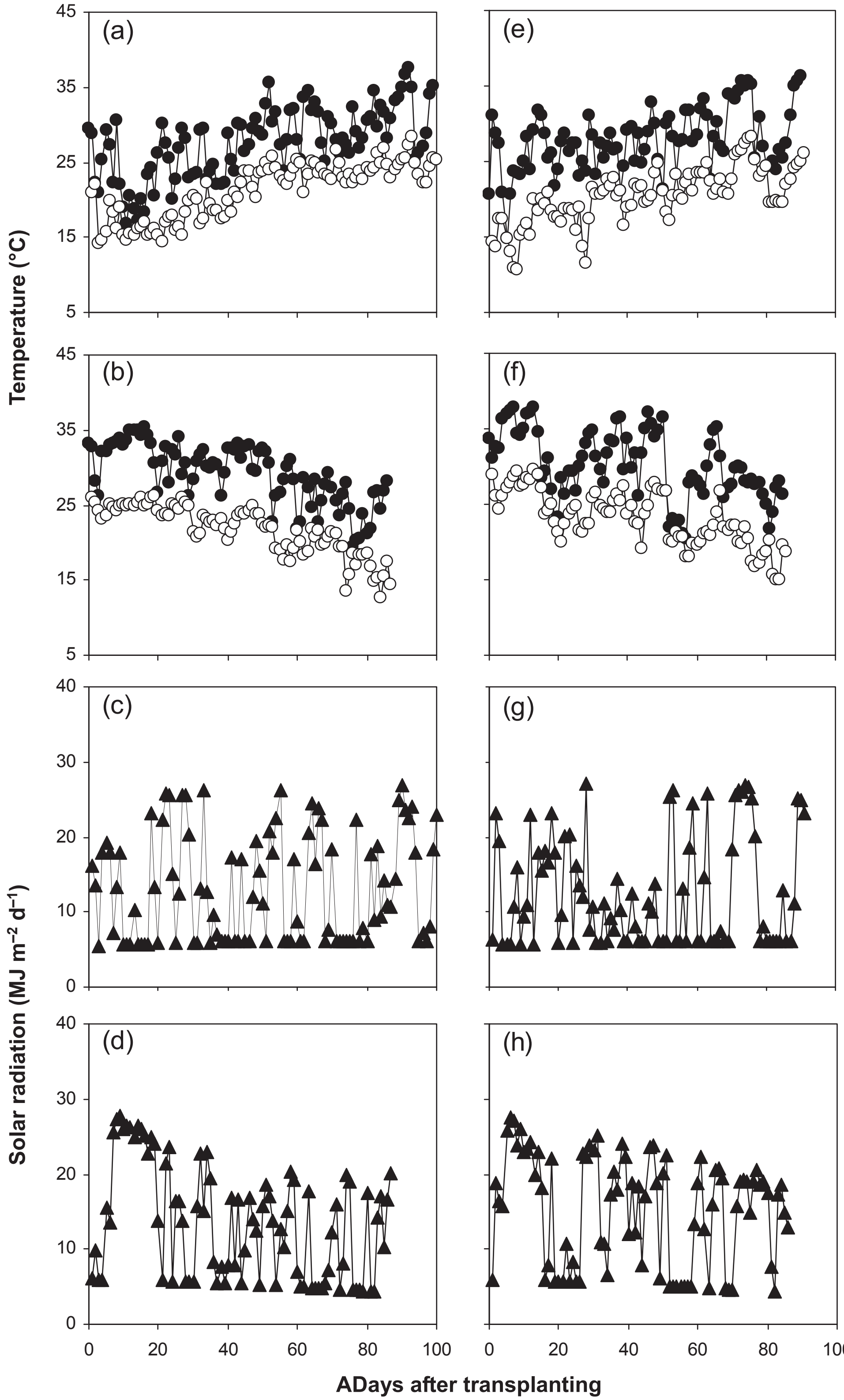

Fig. 1. Daily maximum temperature (●), minimum temperatures(○) and solar radiation (▲) during early season (a, c, e, g) and late season (b, d, f, h) in 2014 (a–d) and 2015 (e–h).

season: 16.7 cm × 20 cm; late season: 20 cm × 20 cm), reduced N rate (early-season: 120 kg N ha^{-1}; late season: 135 kg N ha^{-1}) and other agronomic options produced about 15% more grain yield than did the farmers' practices (early-season: 20 cm × 20 cm, 150 kg N ha^{-1}; late season: 23.3 cm × 23.3 cm, 165 kg N ha^{-1}) in hand-transplanted rice. The strategy may be more practical for machine-transplanted rice, because high planting density can be achieved easily with less labor by using machine transplanting. However, little work has been done to demonstrate the feasibility of such a strategy in machine-transplanted double-cropped rice. To shed light on this little-studied topic, in the present study we determined the effects of reduced N rate and increased hill density on yield attributes and grain yield in machine-transplanted double-cropped rice in two years.