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RESEARCH ARTICLE

Comparisons of yield performance and nitrogen response between hybrid and inbred rice under different ecological conditions in southern China

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Abstract

In order to understand the yield performance and nitrogen (N) response of hybrid rice under different ecological conditions in southern China, field experiments were conducted in Huaiji County of Guangdong Province, Binyang of Guangxi Zhuang Autonomous Region and Changsha City of Hunan Province, southern China in 2011 and 2012. Two hybrid (Liangyoupeijiu and Y-liangyou 1) and two inbred rice cultivars (Yuxiangyouzhan and Huanghuazhan) were grown under three N treatments (N1, 225 kg ha^{-1}; N2, 112.5–176 kg ha^{-1}; N3, 0 kg ha^{-1}) in each location. Results showed that grain yield was higher in Changsha than in Huaiji and Binyang for both hybrid and inbred cultivars. The higher grain yield in Changsha was attributed to larger panicle size (spikelets per panicle) and higher biomass production. Consistently higher grain yield in hybrid than in inbred cultivars was observed in Changsha but not in Huaiji and Binyang. Higher grain weight and higher biomass production were responsible for the higher grain yield in hybrid than in inbred cultivars in Changsha. The better crop performance of rice (especially hybrid cultivars) in Changsha was associated with its temperature conditions and indigenous soil N. N2 had higher internal N use efficiency, recovery efficiency of applied N, agronomic N use efficiency, and partial factor productivity of applied N than N1 for both hybrid and inbred cultivars, while the difference in grain yield between N1 and N2 was relatively small. Our study suggests that whether hybrid rice can outyield inbred rice to some extent depends on the ecological conditions, and N use efficiency can be increased by using improved nitrogen management such as site-specific N management in both hybrid and inbred rice production.

Keywords: hybrid rice, inbred rice, N use efficiency, grain yield

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1. Introduction

Rice is the stable food for about 65% of the population of China. Rice productivity is critical to the national food security. The development of hybrid rice has dramatically

increased the yield potential of rice in China (Yuan *et al*. 1994). It is consistently reported that grain yield of hybrid rice is higher than that of inbred by more than 10% (Zhang *et al*. 2009; Huang *et al*. 2010). Grain yield is determined by panicle number per unit land area, spikelet number per panicle, spikelet filling percentage, and grain weight. Zhang *et al*. (2009) stated that high grain yield of hybrid rice was attributed to large panicle size (spikelet number per panicle). However, Huang *et al*. (2010) observed that panicles m^{-2} had the highest positive contribution to grain yield in hybrid rice. Hongthong *et al*. (2012) suggested that developing cultivars with high grain weight may also be a feasible approach to achieve high grain yield in hybrid rice. In another approach, grain yield is determined by biomass production and harvest index. Because there is little scope to further increase harvest index, achieving higher rice yields depends on increasing biomass production (Peng *et al*. 1999). Biomass increase can be achieved by increasing crop growth rate (CGR) or growth duration or both. Ao *et al*. (2008) and Zhang *et al*. (2009) reported that long growth duration was partially responsible for high biomass production in hybrid rice. While Ibrahim *et al*. (2013) stated that high biomass production in hybrid rice was attributed to great CGR during vegetative period.

Rice yield depends upon not only genotype but also agronomic practices (Zou *et al*. 2003). Nitrogen (N) fertilizer application plays an important role in increasing yield in rice production. However, to maximize grain yield, farmers often apply a higher amount of N fertilizer than the minimum required for the maximum crop growth (Lemaire and Gastal 1997). The average rate of N application for rice production in China was 180 kg ha^{-1}, about 75% higher than the world average (Peng *et al*. 2002). Due to the high rate of N application, only 20–30% of N is taken by the rice plant and a large proportion of N is lost to the environment (Peng *et al*. 2006). Moreover, over-application of N fertilizer may actually decrease rice yield by increasing susceptibility to lodging and damage from pests and diseases (Peng *et al*. 2009). It is therefore important to increase grain yield together with N use efficiency in Chinese rice production systems to achieve a sustainable increase in rice productivity. One efficient way to increase the N use efficiency is to adjust N fertilizer input according to crop N demand. Site-specific N management (SSNM) was developed in this way (Dobermann *et al*. 2002). In SSNM, plant N status was monitored using a chlorophyll meter (SPAD) or leaf color chart. There have been reports describing yield performance and N use efficiency of hybrid rice under SSNM in China (Huang *et al*. 2008; Li *et al*. 2012). Their results showed that adoption of SSNM could increase N use efficiency without sacrificing grain yield in hybrid rice production.

In addition to genotype and agronomic practices, rice crop performance also can be affected by environmental conditions (Ibrahim *et al*. 2013). The information available on the effects of environmental conditions on hybrid rice performance over a wide range of regions would be useful for guiding the extension of hybrid rice. However, previous studies on yield performance and N response of hybrid rice in China were usually conducted in one site (Huang *et al*. 2008; Li *et al*. 2012) or in several sites in one province (Ao *et al*. 2008). Based on the results of these studies, it is difficult to understand the environmental effects on yield performance and N response of hybrid rice across a wide range of regions in China. In our current study, we compared hybrid rice with inbred rice under three N treatments in three sites located in three major rice-producing provinces in southern China in 2011 and 2012. Our objectives were to (1) determine the differences in yield performance and N response of hybrid rice among different ecological conditions in southern China and to (2) identify the critical factors that contributed to the differences.

2. Results

2.1. Temperature conditions and growth duration

Average daily minimum and maximum temperatures during sowing (SO) to full heading (HD) were higher in Changsha than in Huaiji and Binyang by 1.8–5.0°C, whereas the temperatures during HD to maturity (MA) were 0.4–2.3°C lower in Changsha than in Huaiji and Binyang (Table 1). Active accumulated temperatures during SO to HD and HD to MA were, respectively, 5–25% and 29–51% higher in Changsha than in Huaiji and Binyang. In Huaiji and Binyang, average daily minimum and maximum temperatures during SO to HD and HD to MA were generally similar or higher for hybrid than for inbred cultivars; active accumulated temperature during SO to HD was higher for hybrid than for inbred cultivars, whereas the cultivar difference in active accumulated temperature during HD to MA was not consistent. In Changsha, average daily minimum and maximum temperatures during SO to HD were similar for hybrid and inbred cultivars, whereas the temperatures during HD to MA were 1.2–2.2°C lower for hybrid than for inbred cultivars; active accumulated temperatures during SO to HD and HD to MA were higher for hybrid than for inbred cultivars.

Growth duration from SO to HD were generally shorter in Changsha than in Huaiji and Binyang, whereas growth duration from HD to MA were longer in Changsha than in Huaiji and Binyang (Table 1). In Huaiji and Binyang, growth duration from SO to HD were longer for hybrid than for inbred cultivars, while the cultivar differences in growth duration from HD to MA were inconsistent and very small. In Changsha, growth duration from SO to HD and HD to