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Short communication

Tillering responses of rice to plant density and nitrogen rate in a subtropical environment of southern China

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ABSTRACT

Plant density and nitrogen (N) input are two important factors influencing the tiller production in rice. However, it is not clear whether the negative effect of reducing planting density on tiller number per unit land area and consequently on grain yield can be offset by applying more N fertilizer. To address this question, field experiments were conducted at the Experimental Farm of Guangxi University, Guangxi Province, China in early and late rice-growing seasons in 2012. Two hybrid rice cultivars, Shenyou 9516 and Y-liangyou 087, were grown under two combinations of plant density and N rate: a locally recommended combination (*C1*); a combination of a reduced plant density and an increased N rate (*C2*). Y-liangyou 087 had higher tillering capacity than Shenyou 9516. Tiller number was largely lower in late season than in early season. High leaf area index and low N concentration in shoot were responsible for the low tiller number in late season. Number of maximum tillers and panicles per m^2 and grain yield were lower in early season but higher or equal in late season under *C2* compared to those under *C1*. The higher maximum tillers per m^2 under *C2* in late season was attributed to large increase in maximum tillers per hill. Although maximum tillers per hill under *C2* in early season were also increased, this increase was not sufficient to compensate for the reduced plant density. Similar to maximum tillers per hill, N uptake per hill was largely higher under *C2* than under *C1* in late season, while in early season the difference was relatively small. Daily temperature during the initial 20 days after transplanting was approximately 5 °C higher in late season than in early season, which was partly responsible for the larger difference in N uptake per hill between *C1* and *C2* in late season than in early season. Our results suggest that the decreased tiller number per unit land area and grain yield caused by reducing plant density cannot necessarily be compensated for by applying more N fertilizer.

1. Introduction

Rice is the staple food crop for about 65% of the population in China (Zhang et al., 2005). However, in the past 10 years, yield stagnation of rice has been observed in most rice-producing provinces of China (Fan et al., 2009). One of the main constraints to increasing rice productivity in China is the inappropriate crop management practices of farmers (Peng et al., 2009). Recently, an on-farm survey conducted in Hunan, the largest rice-producing province of China, showed that rice yield was positively related to panicle number per unit land area, which suggests that increasing the panicle number is an effective approach to enhance farm yield of rice in this province (Huang et al., 2011a). A similar case has also been reported in several other major rice-producing provinces of China, such as Zhejiang, Jiangxi and Guangxi (Li et al., 2011).

Panicle number is largely determined by the number of tillers that develop during the vegetative stage (De Datta, 1981). So far, many studies have been carried out to identify the genes involved in the control of rice tillering (Li et al., 2003; Zou et al., 2005). However, the tillering characteristics are altered by the environment and by agronomic practices (Huang et al., 2011b). Plant density is one of the important factors influencing the tiller production in rice (Wu et al., 1998). In general, increasing plant density leads to increased tiller number per unit land area. Fertilization is another important factor affecting the tillering of rice (Yoshida and Hayakawa, 1970). Nitrogen (N) fertilizer is usually applied to enhance tillering (Zhong et al., 2003). In China, some farmers transplant rice at extremely wide spacing to reduce labor input, and they think that the potential reduced tiller number caused by the low plant density can be

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compensated for by applying more N fertilizer. Yet, limited information is available to support this statement.

Plant N status and leaf area index (LAI) are two major determinants of the tiller number in rice plants (Zhong et al., 2002). There is a positive correlation between tillering and plant N status (Tanaka and Garcia, 1965). On the contrary, LAI has a negative effect on tillering (Yoshida and Hayakawa, 1970). In addition, there has been evidence showing that plant N status and LAI depend on each other in determining tillering. Zhong et al. (2003) observed that higher plant N concentration was needed to prevent tillers from dying when LAI was high, and vice versa.

In the present study, we measured tiller production and some related characters of two rice cultivars grown under two combinations of plant density and N rate in two seasons in a subtropical environment of southern China. Our objective was to determine the effect of plant density and N rate on rice tillering to identify whether the negative effect of reducing planting density on tiller number per unit land area and consequently on grain yield can be offset by applying more N fertilizer.

2. Materials and methods

Field experiments were conducted at the Experimental Farm of Guangxi University (22°51′ N, 108°17′ E, 78 m above sea level), Guangxi Province, China in early and late rice-growing seasons in 2012. The site is located in a subtropical monsoon climate zone, with a mean annual temperature of 22.4 °C, a mean annual precipitation of 1174 mm, and a mean annual sunshine of 1668 h. The soil of the experimental field was a Laterite with pH 6.33, organic matter = 24.2 g kg^{-1}, NaOH hydrolysable N = 142 mg kg^{-1}, Olsen P = 34.8 mg kg^{-1}, and NH_4OAc extractable K = 123 mg kg^{-1}. The soil test was based on samples taken from the upper 20 cm of the soil.

Two newly developed hybrid rice cultivars, Shenyou 9516 (SY9516) and Y-liangyou 087 (YLY087), were used in this experiment. These two cultivars have been well received by farmers because of their good yield and palatability. In each season, SY9516 and YLY087 were grown under two combinations of plant density and N rate: a locally recommended combination with a hill spacing of 30 cm × 10 cm and a N rate of 165 kg ha^{-1} (*C1*); a combination of a reduced plant density (30 cm × 15 cm) and an increased N rate (240 kg ha^{-1}) (*C2*). Plot size was 21 m^2 (5 m × 4.2 m), and the plots were arranged in a completely randomized design with three replications.

Pre-germinated seeds were sown in a seedbed. Four-leaf-age seedlings were transplanted at two seedlings per hill on 8 April and 2 August in early and late seasons, respectively. In addition to the N fertilizer treatments, all plots received 54 kg P_2O_5 ha^{-1} and 180 kg K_2O ha^{-1}. N and K_2O were split-applied: 50% at basal, 30% at 7 days after transplanting, and 20% at panicle initiation. P_2O_5 was applied at basal. The experimental field was flooded from 4 days after transplanting until 7 days before maturity. Pests and weeds were controlled using chemicals.

Ten hills in each plot were marked to count the tillers (including main stems) starting at 10 days after transplanting at a 5-day interval until the number diminished. Tillers with at least one visible leaf were counted. At maximum tillering stage, 10 hills were sampled from each plot and were separated into leaves and stems. Area of each leaf was determined by measuring leaf length and maximum leaf width and calculated as: leaf area = leaf length × maximum leaf width × 0.75 (Umashankar et al., 2005). Leaf area index (LAI) was calculated by dividing the measured leaf areas by the ground surface area. Dry weights of the leaves and stems were determined after oven drying at 70 °C to constant weight. Shoot biomass was the summation of the dry weights of leaves and stems. N concentrations of oven-dried leaf and stem samples were determined by a Fourier transform infrared spectrophotometer (Perkin–Elmer Spectrum One, Perkin-Elmer Co., Norwalk, CT, USA) to calculate N concentration and uptake in shoot. At maturity, 10 hills were sampled for each plot to determine panicle number. Grain yield was determined by harvesting the whole plot and adjusted to the standard moisture content of 0.14 g H_2O g^{-1}. Temperature data were collected from the local weather station.

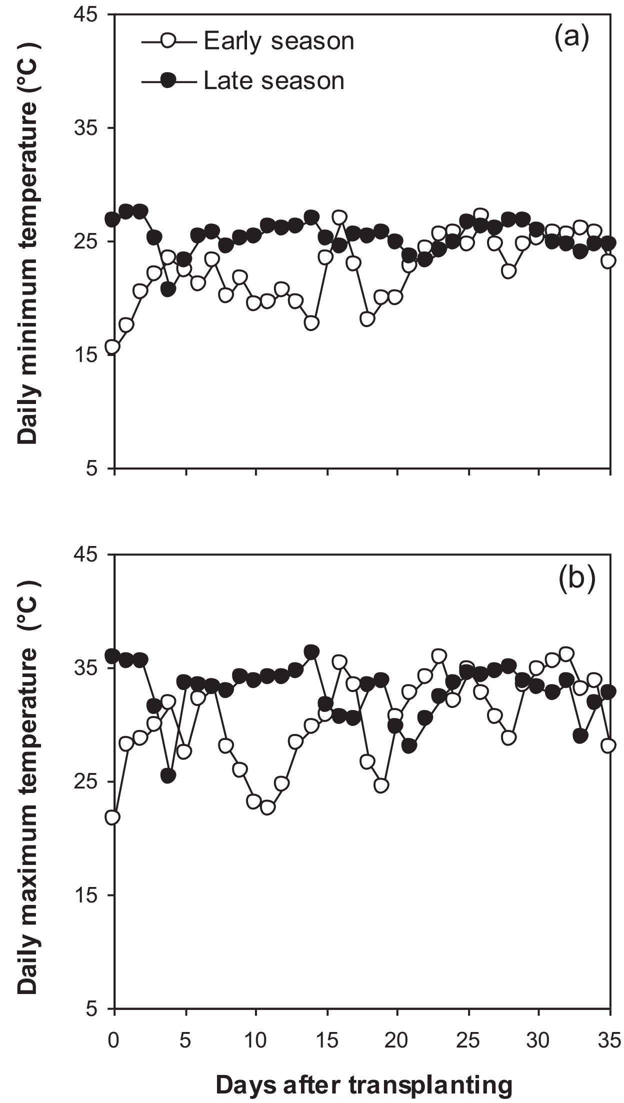

Fig. 1. Daily maximum and minimum temperatures at the Experimental Farm of Guangxi University, Guangxi Province, China in early and late seasons in 2012.

Tiller number (y) was fit with a logistic equation:

$$y = \frac{k}{1 + \exp(a - bx)} \quad (1)$$

where k is the maximum tiller number, x is days after transplanting, and a and b are rate-controlling parameters (Caton et al., 2003). The fitting was performed by using DPS software (Tang and Feng, 2007).

3. Results

Temperature varied with rice-growing season, especially during the initial 20 days after transplanting (Fig. 1a and b). Average daily minimum and maximum temperatures from transplanting to 20