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Short communication

Comparisons of regeneration rate and yields performance between inbred and hybrid rice cultivars in a direct seeding rice-ratoon rice system in central China

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ABSTRACT

Ratoon rice system is one method to increase food production in areas where the annual accumulation of temperature and light resources are considerably more than that required for single-cropping rice but not enough for double-season rice. Direct seeding rice-ratoon rice (DSR-RR) is an alternative rice planting system to traditional transplanted rice-ratoon rice (TTR-RR) in central China, requiring less labor. Hybrid rice has higher yield potential than inbred rice under TTR-RR. However, little attention has been paid to the differences in growth and yield performance of inbred and hybrid rice cultivars in DSR-RR. Field experiments were conducted to evaluate the performance of widely grown inbred and hybrid rice cultivars in central China in 2016 and 2017. Significantly higher ratoon season yields were observed in hybrid rice cultivars than inbred rice cultivars. The ratoon season yield that was achieved was 4.19 t ha^{-1} in inbred rice cultivar and 5.71 t ha^{-1} in hybrid rice cultivar in 2016. Similarly, the ratoon season yields ranged from 2.39 to 3.99 t ha^{-1} in inbred rice cultivars and from 3.84 to 4.90 t ha^{-1} for hybrid rice cultivars in 2017. Significantly higher regeneration rates contributed to the higher ratoon season yield in hybrid rice cultivars than inbred ones. Further research indicated that higher regeneration rate was associated with higher dry weight per stem after harvesting of the first crop in hybrid rice cultivars as compared with inbred ones. Furthermore, higher annual grain yields were observed in hybrid than in inbred rice cultivars in both years, indicating that hybrid rice cultivars may be more suitable for DSR-RR. To achieve high ratoon season and annual yields in DSR-RR in central China, cultivars should be selected with comprehensive considerations of high regeneration rates and lodging resistance.

1. Introduction

Rice (*Oryza sativa* L.) is the staple food for more than half of the global population and is the main staple in tropical Latin America and east, south and southeast Asia (Seck et al., 2012). Rice yield must increase by at least 1% annually to meet the growing demand for food that will result from population growth and economic development (Normile, 2010). Future increases in rice production depend on higher grain yield (Cassman et al., 2003) and more frequent harvests on the existing land (Ray and Foley, 2013). Ratoon rice has been considered an effective approach to improve the multiple-crop index and to increase grain yields, especially for increasing rice production without expanding land area (Xiong et al., 2000). Ratoon rice systems have drawn much attention from farmers in central China, where the annual accumulation temperature and light resources are considerably greater than that required for single cropping rice but are too low for double-season rice (Dong et al., 2017).

Ratoon rice is the practice of obtaining a second harvest from tillers originating from the stubble of the previously harvested crop (main crop). At present, the major crop establishment method of the main season rice in ratoon rice systems is traditional transplanted rice (TSR) (Liu et al., 2012). However, TSR is associated with high energy and labor costs (Bhushan et al., 2007). Direct seeding rice (DSR) has been proposed as an alternative rice production strategy because it reduces water consumption and labor requirements and increases system productivity and resource use efficiency (Jiang et al., 2016; Tao et al.,

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2016). The adoption of direct seeding methods for rice crop establishment in place of transplanting has continuously increased in Asia because of increased labor costs and an improvement in direct seeding technology (Liu et al., 2015). Direct seeding rice-ratoon rice (DSR-RR) combines the advantages of ratoon rice and DSR, which might be a promising planting pattern in central China and could be extended to elsewhere in Asia. Dong et al. (2017) concluded that DSR-RR is an alternative rice planting system to traditional transplanted ratooning rice (TTR-RR) in central China, and comparable ratoon season yields between DSR-RR and TTR-RR were observed.

There are differences in performances of growth, tillering ability and yield between inbred and hybrid rice cultivars (Yuan et al., 2017). It is well documented that hybrid rice has a higher yield potential and tillering ability than inbred cultivars (Yuan et al., 1994; Peng et al., 1999; Zhang et al., 2009). Peng et al. (1999) and Yuan et al. (2017) reported that hybrid rice has approximately 20% higher yield potential than inbred cultivars in TTR. It has been documented that there was over 30% higher yield in a hybrid rice cultivar (YLY1) than in an inbred rice cultivar (HHZ) in DSR (Sun et al., 2015). However, the comparisons between inbred and hybrid rice cultivars were often in single or double rice-cropping systems (Islam et al., 2007; Katsura et al., 2007; Yuan et al., 2017). The results from Dong et al. (2017) implied that hybrid rice cultivar had superiority on regeneration rate and ratoon season yield compared with inbred rice cultivar in DSR-RR. However, one only inbred rice cultivar and one hybrid rice cultivar were tested in the study of Dong et al. (2017). The mechanisms underlying the higher regeneration rate in hybrid rice cultivar over inbred rice one have not been further addressed. In this study, we incorporated a series of inbred and hybrid rice cultivars in DSR-RR (1) to examine the differences in the growth, regeneration rate, and ratoon season yield between inbred and hybrid rice cultivars and to explore the possible mechanisms; and (2) to examine the characteristics of the optimum cultivars for DSR-RR.

2. Materials and methods

2.1. Site description

The study was conducted in Jiupu Village (30°14′N, 115°25′E), Chidong Town, Qichun County, Hubei Province, China, during the rice growing seasons of 2016 and 2017. Total nitrogen (N), available phosphorus, potassium, and organic matter in the upper 20 cm of soil were 0.22%, 6.9 mg kg^{-1}, 160 mg kg^{-1}, and 34.7 g kg^{-1}, respectively, in 2016 and 0.22%, 7.5 mg kg^{-1}, 190 mg kg^{-1}, and 34.9 g kg^{-1}, respectively, in 2017.

2.2. Experimental design

In 2016, one indica inbred rice cultivar Huanghuazhan (HHZ) and one hybrid rice cultivar Tianyouhuazhan (TYHZ) were used. These two rice cultivars are mega rice cultivars for ratoon rice in central China. Based on the field experiment in 2016, more cultivars were grown in the field experiment in 2017. In 2017, indica inbred rice cultivars were used (i.e., Huanghuazhan (HHZ), Zhongxiang1 (ZX1), Zhongjiazao17 (ZJZ17), and Zhongzao35 (ZZ35)) and hybrid rice cultivars were used (i.e., Tianyouhuazhan (TYHZ), Huiliangyou898 (HLY898), Liangyou287 (LY287), and Liangyou76 (LY76)); these experimental cultivars are major rice cultivars for ratoon rice in central China.

Experiments were completely randomized using four replicates (4 m × 8 m). All plots were ploughed and puddled before seed sowing. The seeds were sown manually in rows spaced 25 cm apart on April 10, 2016, and April 12, 2017. The sowing rate was 60 kg ha^{-1} for the inbred rice cultivars and 30 kg ha^{-1} for the hybrid rice cultivars. In both years, a main season fertilizer dose of 150:40:100 of N: P: K kg ha^{-1} was applied to all treatments. All of the P, one-third of the N, and half of the K were applied as a basal starter dose, while the residual N was equally split at the middle tillering stage and the panicle initiation stage, and the other 50% of the potassium was top-dressed during panicle initiation. A ratoon season fertilizer dose of 150:50 of N: K kg ha^{-1} was applied equally to all treatments. Half of the N and all of the potassium were applied 15–20 days after flowering of the main season rice, and the other 50% of the N was applied 3 days after the main season rice was harvested. The sources of N, P, and K were urea, calcium superphosphate, and potassium chloride, respectively. Weeds, diseases, and insects were intensively controlled throughout the entire growing season in both years.

2.3. Data recorded

The main season rice was harvested manually and the stubble height was maintained at 40 cm. The number of regenerated buds was recorded dynamically after the harvesting of the main season in the fixed zone (0.25 m^2). The main season yield and ratoon season yield were measured using 5 m^2 sample areas. In the mature period of the ratoon rice, a 0.5 m^2 sample was selected to calculate the yield components, regeneration rate and grain-leaf ratio. The regeneration rate was calculated as the ratio of “the number of panicles in the ratoon season” to “the number of panicles in the main season”. Dry weight per stem after harvesting of the first crop was measured as the ratio of “the dry weight of stubble per m^2 left behind after the main crop has been harvested” to “stem number per m^2”.

2.4. Weather data

Meteorological data were collected from a weather station (AWS800; Campbell Scientific, Inc., USA) near the experimental field; data included solar radiation, minimum temperature and maximum temperature.

2.5. Data analysis

Data were analyzed by analysis of variance using Statistix 9.0. The differences between treatments were separated using the least significance difference (LSD) test at the 0.05 probability level. Graphical representation of the data was performed using Sigmaplot 12.5.

3. Results

3.1. Weather conditions

The weather data revealed that the daily average temperature and solar radiation during the course of study were similar in 2016 and 2017 (Fig. 1). Nonetheless, data regarding solar radiation and daily maximum temperature showed significant variations between the two years, but it was not much different from the previous 10-year average (data not shown). The average daily solar radiation, minimum temperature, and maximum temperature during the crop growing season in the main and ratoon season were 13.5 and 14.2 MJ m-2, 20.7 and 20.2 °C, and 28.6 and 28.5 °C in 2016 and 2017, respectively (Fig. 1). High temperature (daily maximum temperature ≥ 35° C) occurred more frequently in 2016 (Fig. 1b) than 2017 (Fig. 1e).

3.2. The growth durations of the main season and ratoon season in DSR-RR

The growth durations of the main season and ratoon season in DSR-RR are shown in Table 1. Similar growth durations of the main season, ratoon season and whole crop season were observed between HHZ and TYHZ in 2016. The whole growth durations of HHZ were the same in 2016 and 2017, while the whole growth duration in TYHZ was longer in 2017 than in 2016. Longer whole crop growth durations were mainly attributed to the later heading date of the ratoon season in 2017 than 2016. The longest whole crop growth duration was 204 days, which occurred in TYHZ and HLY898, and the shortest whole crop growth

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