Journal of Integrative Agriculture 2017, 16(7): 1451–1466

Available online at www.sciencedirect.com

ScienceDirect

RESEARCH ARTICLE

Comparison of yield traits in rice among three mechanized planting methods in a rice-wheat rotation system

XING Zhi-peng[1, 2], HU Ya-jie[1, 2], QIAN Hai-jun[1, 2], CAO Wei-wei[1, 2], GUO Bao-wei[1, 2], WEI Hai-yan[1, 2], XU Ke[1, 2], HUO Zhong-yang[1, 2], ZHOU Gui-sheng[1, 3], DAI Qi-gen[1, 2], ZHANG Hong-cheng[1, 2]

[1] *Key Laboratory of Crop Genetics & Physiology of Jiangsu Province/Agricultural College, Yangzhou University, Yangzhou 225009, P.R.China*

[2] *Innovation Center of Rice Technology in Yangtze Rice Valley, Ministry of Agriculture, Yangzhou 225009, P.R.China*

[3] *Jointing Laboratory in Agricultural Sciences Between Agriculture and Agri-Food Canada (AAFC) and Yangzhou University, Yangzhou 225009, P.R.China*

Abstract

Understanding the differences in yield traits of rice among pothole seedling of mechanical transplanting (PSMT), carpet seedling of mechanical transplanting (CSMT) and mechanical direct seeding (MDS) is of great importance not only for rice scientists but also for rice farmers to develop a high-yield production system under mechanical conditions in a rice-wheat rotation system. However, such traits are yet to be studied among rice varieties of *japonica-indica* hybrid rice (JIHR), *japonica* conventional rice (JCR) and *indica* hybrid rice (IHR). Field experiments were conducted in 2014 and 2015, where six cultivars of the three rice types JIHR, JCR and IHR were grown individually with PSMT, CSMT and MDS methods, under respective managements for each method to achieve the maximum attainable yield. Results showed that (i) the PSMT significantly increased grain yield of JIHR by 22.0 and 7.1%, of JCR by 15.6 and 3.7% and of IHR by 22.5 and 7.4%, compared to MDS and CSMT on average across the two years, respectively. The highest yield was produced by the combination of JIHR and PSMT; (ii) high yield under PSMT was mainly attributed to large sink capacity and high-efficient dry matter accumulation. With sufficient panicles per hectare, the increase of spikelet number per panicle, especially the increase in spikelet number of the secondary rachis-branches was determined to be the optimal approach for developing a large sink capacity for rice under PSMT. The optimal tillers development, large leaf area index at heading stage, and high leaf area duration, crop growth rate and net assimilation rate during grain-filling phase could be the cause of sufficient dry matter accumulation for rice under PSMT; (iii) moreover, the PSMT favored plant growth as well as enriched the stems plus sheaths during grain-filling phase, as compared with CSMT and MDS. These results suggest that PSMT may be an alternative approach to increasing grain yield in a rice-wheat rotation system in the lower reaches of the Yangtze River in China.

Keywords: rice, grain yield, mechanized planting method, pothole seedling of mechanical transplanting

Received 12 August, 2016 Accepted 20 December, 2016

XING Zhi-peng, E-mail: xing_pengpeng@126.com; Correspondence ZHANG Hong-cheng, Tel: +86-514-87979220, E-mail: hczhang@yzu.edu.cn; XU Ke, Tel: +86-514-87979220, E-mail: xuke@yzu.edu.cn

doi: 10.1016/S2095-3119(16)61562-9

1. Introduction

Rice is the staple food in various countries, particularly those in the Asian continent. China is the largest rice producer and consumer, with a total cultivated area of 3×10^7 ha and a total output of 20×10^7 t, accounting for 21% of total rice cultivated

area and 37% of total rice output in the world, respectively (Huang *et al*. 2001). Rice ranks as the important cereal crop in China, thus a continuous increase in rice production is crucial to ensure sufficient food in China. Several studies have indicated that accelerating the agricultural mechanization process of rice production may contribute to an increase in rice yield (Wang 2010; Zhang *et al*. 2013a).

Extensive efforts have been made to achieve high rice yield through whole process mechanization, which in turn contributes to saving labor and improving production efficiency (Zhang *et al*. 2013a). However, the main obstacle of whole process mechanization is mechanized planting, which is not only a crucial part, but also a relatively difficult part of whole course mechanization of rice production (Wang 2010; Zhang *et al*. 2013a).

Mechanical direct seeding (MDS) and mechanical transplanting are two main mechanized planting methods of rice. MDS is more cost-, labor- and water-efficient than mechanical transplanting because seedling transplanting is not required in MDS. Several previous studies have shown that compared to mechanical transplanting, MDS rice plants have bigger sufficient sink size, greater dry matter accumulation and higher yield due to its optimum seedling establishment, high tillering activity, large leaf area index and high value of crop growth rate from tillering to maturity (Kano *et al*. 1986; Schnier *et al*. 1990; Naklang *et al*. 1996; Escabarte *et al*. 1999; San-oh *et al*. 2004; Hayashi *et al*. 2007). Furthermore, during the tillering and grain-filling periods, crown roots and nitrogen accumulation in direct seeding rice plants were higher than that of transplanting rice (San-oh *et al*. 2002). Based on these features, MDS has been widely utilized in rice producing countries, as well as in industrialized nations such as the United States and Australia (Peng and Hardey 2001; Pandey *et al*. 2002). However, MDS had several disadvantages in a rice-wheat rotation system in the lower reaches of the Yangtze River. Compared to rice transplanting method, effects of wheat growth on MDS were more obvious in rice-wheat rotation system fields with lower temperature-light resources, which may delay the rice sowing, shorten the growth duration, lower the use of temperature-light resources, decrease panicle size, cause serious lodging, and induce reduction in rice yield (Li *et al*. 2011; Zhang *et al*. 2011; Xu *et al*. 2014; Zhang and Gong 2014).

Carpet seedling of mechanical transplanting (CSMT) is an important method of mechanical transplanting. Since 1980, the equipment, planting technology and field management of CSMT have been gradually developed, which in turn have boosted its application in China, particularly in rice fields of South China. According to statistics, the CSMT is now the main production technology in Jiangsu Province, with an applied area of 1.6×10^6 ha, accounting for 70% of the rice production area in 2014 (Xue *et al*. 2015). The CSMT can effectively bring forward rice suitable sowing by 20 d, prolong the entire growth period by 14–16 d, and increase grain yield by 9.4–22.1% compared to MDS in a rice-wheat rotation system (Li *et al*. 2011). However, some key technical problems have not been resolved, including: (i) The high sowing density, which may lead to weak seedlings; (ii) the short suitable seedling age (15 to 20 d) for mechanical transplanting; (iii) the severe damage that machinery transplanting inflicts on seedlings, which in turn may prolong the duration for seedlings to recover to develop leaves (Li *et al*. 2011; Hu *et al*. 2014a; Zhang and Gong 2014). To resolve these problems, researchers have focused on improving the machinery and equipment, as well as modify the rice seedling cultivating method.

In 2010, a new planting method named pothole seedling of mechanical transplanting (PSMT) was developed in China (Hu *et al*. 2014a). Compared to CSMT, PSMT brings forward rice suitable sowing by more than 10 d, extends the suitable seedling transplant age by 12–17 d, protects the root system from damages incurred during machinery transplanting, and increases rice yield by at least 5% (Hideo 1962; Senbokukoku 1989; Zhang *et al*. 2013b; Hu *et al*. 2014a; Xu *et al*. 2014; Zhang and Gong 2014). All these observations indicate that PSMT is a promising mechanized planting method that maximizes rice yield potential. However, the comparative analysis of the three main mechanized planting methods of PSMT, CSMT and MDS in terms of traits and differences in yield and dry matter accumulation is limited.

To date, several new rice varieties, particularly *japonica-indica* hybrid rice (JIHR), which has a higher yield potential than *indica* hybrid rice (IHR) and *japonica* conventional rice (JCR), have been released to generate rice plants with large panicle size (Yuan 1994; Peng *et al*. 1999; Yang *et al*. 2002; Cheng *et al*. 2007; Wei *et al*. 2016). Reports have shown that high yield (>13.5 t ha^{-1}) has been achieved in the rice variety, Yongyou 2640 (JIHR), using PSMT in rice demonstration areas in rice-wheat rotation system for several consecutive years since 2012 (Hu *et al*. 2014b). However, our understanding of the effects of current mechanized planting methods on the yield and dry matter accumulation among rice varieties of JIHR, JCR and IHR is limited. Knowledge in this particular area is of great importance not only for rice scientists, but also for rice farmers in order to develop a high-yield production system under mechanical conditions.

The objectives of the present study are to: (i) Compare the differences in yield traits of various rice varieties using PSMT, CSMT and MDS; and (ii) evaluate the adaptability of the three mechanized planting methods in different types of rice varieties in a rice-wheat rotation system.