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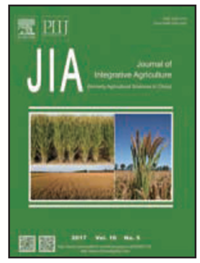

RESEARCH ARTICLE

Effects of soilless substrates on seedling quality and the growth of transplanted super *japonica* rice

LEI Wu-sheng[1, 2], DING Yan-feng[1], LI Gang-hua[1], TANG She[1], WANG Shao-hua[1]

[1] *Jiangsu Collaborative Innovation Center for Modern Crop Production/National Engineering and Technology Center for Information Agricultrue/Key Laboratory of Crop Physiology and Ecology in Southern China, Nanjing Agricultural University, Nanjing 210095, P.R.China*

[2] *Jiangsu Vocational College of Agriculture and Forestry, Jurong 212400, P.R.China*

Abstract

This study was conducted to investigate the effects of soilless substrates of hydroponically grown long-mat seedlings (HLMS) on seedling quality and field growth characteristics of transplanted super *japonica* rice. A widely grown conventional super *japonica* rice cultivar (Wuyunjing 23) was selected as the test material. The effect of HLMS on seedling quality, mechanical transplantation quality, field growth characteristics, yield, and benefit-cost ratio were compared with seedlings grown in organic substrates and traditional nutritive soil, which was selected as the control. Root number, root twisting power and root activity of seedlings cultivated by HLMS were decreased compared to that of the organic substrates and control. However, seedling root length as well as aboveground growth were increased compared to the organic substrates and control seedlings. In the HLMS, the content of gibberellin acid (GA_3) decreased while abscisic acid (ABA) content increased compared to that of the organic substrates and control seedlings. During the early stages after transplanting, the re-greening of HLMS was delayed compared to that of the organic substrates and control seedlings. Nevertheless, there were no significant differences in tiller dynamics and crop yield among the HLMS, organic substrates and control treatments. The effects of HLMS on seedling production were similar to those of the organic substrates and traditional nutritive soil in the present study, suggesting that HLMS have the potential to replace traditional nutritive soil in seedling production without decreasing crop yield. Finally, it is important to reduce organic substrates and topsoil dependence during rice seedling production and worthwhile to consider HLMS popularization and its application on a larger scale.

Keywords: super hybrid rice (*Oryza sativa* L.), mechanical transplantation, seedling quality, yield, seedling raised method

1. Introduction

Rice (*Oryza sativa* L.) is the staple food of humankind and provides 35–60% of the dietary calories consumed by three billion people, making it inarguabe the most important crop worldwide (Confalonieri and Bocchi 2005). The demand for increased rice production is particularly urgent, because the populations of traditional rice-producing countries will require 70% more rice by 2025 (Swaminathan 2007).

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LEI Wu-sheng, E-mail: leiwsh@163.com; Correspondence LI Gang-hua, Tel/Fax: +86-25-84396475, E-mail: lgh@njau.edu.cn

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Driven by increasing demands for food in the following decades, breeding high-yielding rice varieties and developing high-yielding cultivation techniques are thought of as two key methods to meet this challenge (Peng *et al*. 1999). A national programe on super rice breeding was established in China in 1996 which mainly focuses on breeding super hybrid rice. Since the late 1970s, the area of agricultural land dedicated to super hybrid rice has rapidly increased throughout Asia, particularly in China. The pace of super *japonica* rice adoption compared to conventional varieties has significantly changed the rice landscape. In China, the percentage of transplanting in super *japonica* rice production exceeds 99%. The most popular seedlings for super *japonica* rice transplanting are referred to as mat type seedlings and they are grown on soil in a seedling box.

In recent years, with the development of urbanization and the acceleration of industrial restructuring in China, there is an urgent need to shift rice production towards mechanized production. There are three seedling production methods for mechanized rice transplantation: the soft plate seedling production method (Zhang *et al*. 2008), the two-layer plastic film seedling production method (Shao *et al*. 2004; Shen *et al*. 2004), and the plastic disk seedling production method (Sun *et al*. 2014), which have been used to varying degrees. Most current seedling production methods use soil or a new matrix as the cultivation medium. Currently, seedbed soil fertilization is one of the key measures for producing mechanical transplanting rice seedlings. Seedbed soil for seedling production is usually almost taken from the topsoil of cultivated land, which then causes deterioration of the soil structure and subsequently reduces crop yield. Moreover, a plastic seedling box with soil weighs approximately 6 kg, and the preparation of the soil and the box is time-consuming and labour-intensive.

To reduce the dependence on rice soil during seedling production, researchers have utilized many inorganic substrates such as vermiculite, perlite, and asbestos instead of rice soil (Huang *et al*. 2014). As environmental awareness is enhanced these days, the utilization of non-renewable resources such as quartz sand, vermiculite, and pearlite have been dramatically reduced. Searching for and developing renewable and eco-organic substrates for seedling cultivation has attracted extensive attention. At present, seedling boxes may use organic substrates such as bark, rice husk, wood sawdust, straw, and food industry waste, which includes grape residue, apple residue and fungus dregs (Lu *et al*. 2012; Shao 2013; Gao *et al*. 2014). Usually, mixing these organic substrates with inorganic substrates such as vermiculite and peat soil at certain proportions will achieve good performance in seedling production (Song *et al*. 2014; Lin *et al*. 2016).

In the past few decades, researchers have developed a long-mat seedling production technology based on existing soilless cultivation technologies (Tasaka *et al*. 1996, 1997; Tasaka 1999; Wang *et al*. 1999). According to the method, non-woven fabric is used as the matrix instead of topsoil (Li *et al*. 2012, 2014). Theoretically, with the advantages of being permeable, breathable free of pathogenic bacteria and inexpensive to buy, it was thought that economic benefits would be obtained when hydroponically grown long-mat seedlings (HLMS) were applied to rice seedling production. However, there are only a few studies on its practical applications during rice seedling production.

Thus, in the present study, three seedlings cultivation substrates, including organic substrates, HLMS, and nutritive soil (control), were employed to investigate the differences of these methods on seedling quality, field growth characteristics, and yield performance of super hybrid rice. The corresponding results will lay a theoretical foundation and provide a practical reference for the large-scale application of HLMS in seedling production.

2. Materials and methods

2.1. Plant materials and growth conditions

The cultivation matrix for HLMS consisted of 20 g of white spunbond non-woven cloth (Nantong Kangda Composite Materials Co., China) and 1 cm of rice husks (Li *et al*. 2014a). The nursery bed was 4 m in length and consisted of four nursery trays (0.28 m×4 m). The nutrient solution for HLMS was as follows: 17.5 mg L^{-1} N as NH_4NO_3, 2.72 mg L^{-1} P as KH_2PO_4, 7.46 mg L^{-1} K as KCl and KH_2PO_4, 6.61 mg L^{-1} Mg as Mg $SO_4·7H_2O$, 1.5 mg L^{-1} Fe as Fe-EDTA, 0.1781 mg L^{-1} Mn as $MnCl_2·4H_2O$, 0.0050 mg L^{-1} Mo as $Na_2MoO_4·2H_2O$, 0.2985 mg L^{-1} B as H_3BO_3, 0.0280 mg L^{-1} Zn as $ZnSO_4·7H_2O$, 0.0075 mg L^{-1} Cu as $CuSO_4·5H_2O$, 19.2 mg L^{-1} Si as $Na_2SiO_3·9H_2O$, and 7.71 mg L^{-1} Ca as $CaCl_2$. HLMS were grown in one nursery bed (0.28 m×4 m) with three replicates.

The accession of super *japonica* rice cultivar Wuyunjing 23, provided by the Jiangsu (Wujin) Rice Research Institute, China was used in this study. The experiment was performed in a greenhouse at the Jiangsu Vocational College of Agriculture and Forestry, China. Seeds (120 g) were sowed at May 15, 2013 and May 17, 2014 on transplanting disks (58 cm×28 cm×3.5 cm) containing organic substrates, HLMS and nutritive soil (control).

The traditional nutritive soil originated from the Danyang Experimental Station, Nanjing Agricultural University, China. The soil was composted and covered with agricultural film to facilitate a complete maturing of the soil. Additionally, sieved fine soil was prepared to serve as the seed-covering layer. Prior to sowing, 5.5 kg of soil was added to each nursery tray; after the seeds were sown, the tray was placed in a