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Effects of nitrogen level on yield and quality of *japonica* soft super rice

ZHU Da-wei, ZHANG Hong-cheng, GUO Bao-wei, XU Ke, DAI Qi-gen, WEI Hai-yan, GAO Hui, HU Ya-jie, CUI Pei-yuan, HUO Zhong-yang

Jiangsu Key Laboratory of Crop Genetics and Physiology/Jiangsu Co-Innovation Center for Modern Production Technology of Grain Crops, Yangzhou University, Yangzhou 225001, P.R.China

Abstract

Although studies on the balance between yield and quality of *japonica* soft super rice are limited, they are crucial for super rice cultivation. In order to investigate the effects of nitrogen application rate on grain yield and rice quality, two *japonica* soft super rice varieties, Nanjing 9108 (NJ 9108) and Nanjing 5055 (NJ 5055), were used under seven N levels with the application rates of 0, 150, 187.5, 225, 262.5, 300, and 337.5 kg ha^{-1}. With the increasing nitrogen application level, grain yield of both varieties first increased and then decreased. The highest yield was obtained at 300 kg ha^{-1}. The milling quality and protein content increased, while the appearance quality, amylose content, gel consistency, cooking/eating quality, and rice flour viscosity decreased. Milling was significantly negatively related with the eating/cooking quality whereas the appearance was significantly positively related with cooking/eating quality. These results suggest that nitrogen level significantly affects the yield and rice quality of *japonica* soft super rice. We conclude that the suitable nitrogen application rate for *japonica* soft super rice, NJ 9108 and NJ 5055, is 270 kg ha^{-1}, under which they obtain high yield as well as superior eating/cooking quality.

Keywords: soft super rice, grain yield, rice quality

1. Introduction

Rice (*Oryza sativa* L.) is the most important grain crops in the world, especially in Asia (Narpinder *et al.* 2005; Areum *et al.* 2015). In order to ensure the food security, many countries have regarded high yield as the primary objective of rice breeding. For example, in the 1980s, Japan started its study on super high yield of rice (Higashi 1987). In 1989, the International Rice Research Institute (IRRI) started new plant type (NPT) breeding (Peng *et al*. 1994). In 1996, Ministry of Agriculture of China officially started super rice research to cultivate new rice varieties with high yield potential, good quality, and strong resistance (Yuan *et al*. 1997; Cheng *et al*. 1998; Chen *et al*. 2007). In recent years, the application of super rice has significantly increased the rice production in China. Some studies have, however, indicated deterioration in grain quality in the high yielding super rice cultivars (Zhang 2007). With the improvement of living standards, consumers pay more attention to rice quality, particularly the eating/cooking quality. It is generally accepted that rice varieties with high amylose content have bad eating/cooking quality (Zhu *et al*. 2004), while those with low amylose content usually have good eating/cooking quality.

Nitrogen is the most important element in fertilizers,

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ZHU Da-wei, E-mail: nxyzdw@163.com; Correspondence ZHANG Hong-cheng, E-mail: hczhang@yzu.edu.cn; XU Ke, E-mail: xuke@yzu.edu.cn

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which can significantly affect the grain yield and quality of rice. Several studies have shown that an optimum amount of nitrogen application is essential for high rice yield. For example, Fu and Yang (2011) suggested that, compared with the conventional rice varieties, the nitrogen application rate on super rice should be increased by 12–14% to obtain high yield. Cui *et al*. (2010) concluded that the nitrogen application rate of *japonica* super rice in the northern China should be appropriately reduced to 147 kg ha^{-1}. Li *et al*. (2011) studied the super rice Xinliangyou 6 in the southern China and found a suitable nitrogen application rate of 270 kg ha^{-1} in order to obtain the yield of 7.5 t ha^{-1}. Xie *et al*. (2011) studied the effect of nitrogen application rate on the quality of Yongyou 6 rice variety and concluded that nitrogen application increased the milling quality and protein content, while it hampered the pasting properties. Zhu *et al*. (2015) investigated the nitrogen application rate on grain yield and quality of *japonica* rice Wuyunjing 27 and found the optimum amount of nitrogen fertilizer for increasing grain yield and quality was 225–300 kg ha^{-1}. The variations in the suitable nitrogen application rates in the above studies were due to differences in super rice varieties and ecological zones. Soft rice is a rice variety that has amylose content between 2–15% (Zhu *et al*. 2015). Nitrogen application affected many grain quality indexes, while eating/cooking quality was the most important index that consumers were concerned. In recent years, the *japonica* soft super rice, Nanjing 9108 (NJ 9108) and Nanjing 5055 (NJ 5055) are widely cultivated in the low reach of Yangtze River, because of their low amylose content (less than 15%), soft taste, and lesser tendency to retrograde after cooling.

Although a number of studies have been made to investigate the nitrogen levels on rice yield and quality, these studies were mainly focused on increasing the yield or not concerned about eating/cooking qualities. And, there are also few researches on the balance of yield and eating/cooking quality. Besides, to the best of our knowledge, there are only few reports about yield and eating/cooking quality of *japonica* soft super rice response to different nitrogen levels. Further research in this field is of critical importance in order to find suitable nitrogen application rate to obtain high yield and good eating/cooking quality rice. Therefore, in this study, we assess the effects of nitrogen application rate on yield and quality of *japonica* soft super rice to guide the production of *japonica* soft super rice in the low reach of Yangtze River.

2. Materials and methods

2.1. Plant materials and experimental design

The experiment was conducted on the Yangzhou University Farm (119°42´E, 32°39´N), China in 2013 and 2014 during the rice cropping season. The soil type of the experimental plot was sandy loam. The crop previous to rice was wheat. The soil parameters before the experiment were as follows: 1.4 g kg^{-1} total nitrogen, 35.1 mg kg^{-1} available phosphorus, 88.3 mg kg^{-1} available potassium, 0.86% organic matter content, and pH of 8.01. Two *japonica* soft super rice varieties, NJ 9108 and NJ 5055, provided by the Jiangsu Academy of Agricultural Sciences, were used in this study. These two varieties were chosen because they are widely cultivated in the low reach of Yangtze River. NJ 9108 is a super soft *japonica* rice cultivar released in 2009 with Wujing 13 as the female parent and Guandong 194 as the male parent. NJ 5055 is a super soft *japonica* rice cultivar released in 2009 with Wujing 14 as the female parent and Guandong 194 as the male parent. NJ 9108 is late-maturing medium *japonica*, and NJ 5055 is early-maturing late *japonica*.

The experiment was arranged in a split plot design, with N level as main plot and variety as split plot. The application rate of nitrogen was 0, 150, 187.5, 225, 262.5, 300, and 337.5 kg ha^{-1}, respectively. Seeds were sown on May 25 and the seedlings were transplanted on June 15. The transplanting density was 25.2×10^4 hills per hectare (30 cm×13.2 cm) with three seedlings in each hill. The size of each subplot was 20 m^2 (4 m×5 m). The experiment was conducted in three replicates.

In all treatments, nitrogen was applied at three stages. 40% of nitrogen was applied at pre-transplanting stage (1 day before transplanting), followed by the application of 30% at early tilling stage (7 days after transplanting), and 30% at panicle initiation stage (about 35 days after transplanting). For all treatments, phosphorus (30 kg ha^{-1} as single superphosphate) and potassium (40 kg ha^{-1} as KCl) were applied as basal fertilizer 1 day before transplanting. Water, weeds, insects, and disease were controlled as required, to avoid yield loss.

2.2. Harvesting and grain quality measurement

Plants were harvested on October 16–18. Grain yield was determined by a harvest area of 12 m^2. The moisture of grain yield was determined to be 14%. The components of grain yield (i.e., number of panicles, grains per panicles, and 1 000-grain mass) were determined by plants from 4 m^2 (excluding guard rows). 50% of representative plants were randomly selected to calculate the number of panicles, and 10 of them were used to calculate the grains per panicles. After threshing the grains of 50 points, the grains were winnowed and 1 000 grains were weighed to calculate 1 000-grain mass, this step was repeated three times. Seed-setting rate was defined as the number of filled grains in the total number of spikelet.

Nitrogen agronomic efficiency=(Grain yield in the plot