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Head rice yield of "super" hybrid rice Liangyoupeijiu grown under different nitrogen rates

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ABSTRACT

"Super" hybrid rice varieties have been widely grown in farmers' fields since the late 1990s in China due to their high yield potential. The objective of this study was to compare head rice yield and related grain quality traits between a "super" hybrid variety, Liangyoupeijiu (LYPJ), and an ordinary hybrid variety, Shanyou 63 (SY63), across a wide range of nitrogen (N) rates. The two hybrid varieties were grown under field conditions with seven and six N treatments in 2004 and 2005, respectively, in Hubei province, China. Grain yield, head rice yield, head rice percentage, chalky rice rate and other grain quality traits were measured in the two years. Although the difference in grain yield was small between the two varieties, the average head rice yield across N treatments for LYPJ was 34% and 24% higher than that for SY63 in 2004 and 2005, respectively. Head rice percentage was significantly affected by N rates, but LYPJ maintained higher head rice percentage than SY63 across a wide range of N rates. The higher head rice percentage of LYPJ was associated with its lower chalky rice rate compared with SY63. LYPJ had higher amylose content, greater gel consistency, and lower protein content than SY63, suggesting a better palatability of cooked rice for LYPJ than for SY63.

1. Introduction

Rice (*Oryza sativa* L.) provides 35–60% of the dietary calories consumed by more than 3 billion people, and is the major source of dietary protein for many rice consumers (Fageria, 2007; Juliano, 1992). The world has to produce 50% more rice with improved quality to meet the demand of consumers in 2025 in order to assure food security in the rice-consuming countries (Peng and Yang, 2003). The improvements of grain yield and quality are the two most important objectives in rice research and technology development (Zhang, 2007).

Increasing rice yield potential has been the main breeding objective in rice improvement program (Peng et al., 2008). China established a nationwide mega project on the development of "super" hybrid rice, which aimed to breed new rice varieties with 10% yield increase over local check varieties, improved grain quality, and adequate resistances to major insects and diseases (Cheng et al., 2007; Yuan, 2001). Many "super" hybrid rice varieties have been commercially released and grown in farmers' fields in China (Peng et al., 2008). Among these "super" hybrid rice varieties, Liangyoupeijiu (LYPJ), an intersubspecific hybrid rice, has been widely grown in 13 provinces in China since the late 1990s (Cheng et al., 2007). Shanyou 63 (SY63), an intrasubspecific hybrid rice, was the most popular variety in the late 1980s in China (Katsura et al., 2007; Lü and Zou, 2003; Xie, 1987). It was gradually replaced by the "super" hybrid rice varieties, including LYPJ.

Numerous studies were conducted to compare the grain yield between LYPJ and SY63 and to determine the physiological and morphological traits that explain their yield differences. LYPJ had a higher total biomass production than SY63 at high nitrogen (N) rates (He et al., 2007; Huang et al., 2008), which was the result of a higher crop growth rate due to higher leaf net photosynthetic rate during flowering and ripening phase in LYPJ than in SY63 (Wang et al., 2000). The higher total biomass production of LYPJ was also due to greater leaf area index compared with SY63. LYPJ had a more erect leaf canopy than SY63 as reflected by a lower extinction coefficient of canopy at heading for LYPJ than for SY63 (Zong et al., 2000). The more erect leaves of LYPJ were associated with their higher specific leaf weight compared with SY63. The erect leaf canopy is generally associated with high leaf area index. Furthermore, the lodging resistance of LYPJ was higher than that of SY63 because LYPJ had stronger stems than SY63 (Lü and Zou, 2003). Therefore,

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LYPJ had a potential to produce higher grain yield than SY63, especially under the high level of N inputs (He et al., 2007; Huang et al., 2008).

Rice quality includes milling, appearance, cooking, eating, and nutritional properties. The rice quality traits were influenced by varieties, environmental conditions, and crop management practices (Fitzgerald et al., 2008; Tan et al., 2001). Processing quality traits are consisting of brown rice percentage, milled rice percentage, and head rice percentage. Head rice percentage is one of the most important rice quality traits as it is directly related to economical value and thus influences income of rice producers (Fitzgerald et al., 2008; Juliano, 1992). Several studies reported that head rice percentage was affected by N management. It was reported that top-dressing applications of N during booting and early heading stages increased grain yield and head rice percentage (Wopereis-Pura et al., 2002). In studies conducted in Mississippi, USA, rice hybrids often achieved higher grain yield and head rice percentage when N was top-dressed at early heading stage (Walker et al., 2006). Perez et al. (1996) reported that N topdressing at flowering resulted in an increase in not only grain yield but also head rice percentage in four varieties developed by the International Rice Research Institute (IRRI). Head rice percentage is also affected by other grain quality traits. Chalkiness reduced grain resistance to forces applied during the milling process, causing a decrease in head rice percentage (Counce et al., 2005; Lisle et al., 2000). Brown rice with high protein content was more resistant to abrasive milling than that with low protein content for the same variety (Leesawatwong et al., 2005).

Most studies on comparing LYPJ and SY63 focused on grain yield and yield-related traits. Relatively fewer studies were conducted to compare LYPJ and SY63 in grain quality traits. Experiments on N response of rice varieties generally emphasized grain yield. There were relatively fewer studies that determined the effect of N management on the head rice yield. The objectives of present study were (1) to compare head rice percentage and head rice yield between LYPJ and SY63 under different N rates, (2) to identify other grain quality traits that explain the difference in head rice percentage between the two varieties, and (3) to determine the N responses of the two varieties in head rice percentage and head rice yield.

2. Materials and methods

Experiments were conducted in 2004 and 2005 in a farmer's field at Xusan village, Xinpu township, Xiaonan county, Hubei province, China (30°59′N, 113°56′E, 28 m asl). Soil in this field has the following properties: pH 6.1, 6.9 g kg^{-1} organic C, 0.83 g kg^{-1} total N, 7.3 mg kg^{-1} available P, 0.35 cmol kg^{-1} exchangeable K, 12.6 cmol kg^{-1} cation exchange capacity, 32.3% clay, 64% silt, and 3.8% sand.

Detailed information on varieties, N treatments, and cultural practices was given by Huang et al. (2008). Briefly, a split-plot design was used with N rates as main plots and varieties as subplots. The experiment was replicated four times and subplot size was 25 m^2. We selected two hybrids, Shanyou 63 (SY63) and Liangyoupeijiu (LYPJ), because they were the most popular hybrid varieties in the late 1980s and late 1990s in China, respectively. SY63 is an intraspecific hybrid rice developed with the three-line method, while LYPJ is an intersubspecific hybrid rice developed with the two-line method (Xie, 1987; Yuan, 2001). Many rice farmers in China still grow LYPJ because of its high yield potential and good grain quality. Rice breeders in China often use SY63 as a check variety because of its superior yield stability.

N treatments included zero-N control, real-time N management (RTNM), and fixed-time adjustable-dose N management (FTNM) in both years. The details of the RTNM and FTNM approaches were described by Peng et al. (1996) and Dobermann et al. (2002), respectively. In 2004, there were five RTNM treatments with chlorophyll meter (SPAD) thresholds of 35, 36.5, 38, 41 and 42.5 for both varieties. In 2005, there were four RTNM treatments with SPAD thresholds of 36, 39, 42 and 45 for LYPJ; 34, 36, 38 and 40 for SY63.

Thirty-day old seedlings were transplanted on 7 June 2004 and 8 June 2005 at a hill spacing of 0.2 m × 0.2 m with two seedlings per hill. Phosphorus (40 kg P ha^{-1}) and zinc (5 kg Zn ha^{-1}) were applied at basal. Potassium (100 kg K ha^{-1}) was split equally at basal and panicle initiation. Crop management followed the standard cultural practices. Final harvest was done on 23 September for SY63 and 25 September for LYPJ in 2004 and on 24 September for both varieties in 2005.

Twelve hills (0.48 m^2) were sampled diagonally from a 5-m^2 harvest area for each replication at maturity. Plants were separated into straw and panicles. Panicles were hand-threshed, and filled spikelets were separated from unfilled spikelets by submerging them in tap water. Dry weights were determined after oven drying at 70 °C to constant weight. Nitrogen concentrations of straw, rachis, and filled and unfilled spikelets were determined by standard micro-Kjeldahl digestion, distillation, and titration (Bremner and Mulvane, 1982) to calculate aboveground total N uptake.

At crop maturity, grain yield was determined from the 5-m^2 area (excluding plants in the borders) in each plot. The grains were threshed and filled grains were separated from unfilled grains and debris using an air blower (model NP24350, China). The filled grains were air-dried to constant weight and grain moisture was measured. Grain yield of rough rice was reported at the moisture content of 0.14 g H_2O g^{-1} fresh weight.

Around 1000 g grains for quality evaluation were obtained from each sample after they were stored at room temperature for 3 months to ensure stable grain quality (Perez et al., 1996). Rice quality evaluation was done by the Grain Quality Evaluation Center, Hubei Academy of Agricultural Sciences according to the China National Standard of grain quality measurements (GB/T 17891-1999) issued by the Ministry of Agriculture (MOA, 1999). All evaluations were conducted with two replications. Fifty grams of rough rice was de-husked using a husker and milled using a miller (both manufactured by Jiading Food and Oil Machinery Factory, Shanghai, China). Head rice was manually separated from others. Broken grains with more than four fifths length of the whole grain were included in the head rice. Weights of brown rice, milled rice, and head rice were recorded. Brown rice percentage, milled rice percentage, and head rice percentage were calculated based on the rough rice weight. One hundred head rice grains were randomly selected from each sample for measuring appearance quality characteristics. Chalky grain rate of head rice was measured using a C-300 Whiteness Tester (Kett Electric Laboratory, Tokyo, Japan). Translucency of head rice was measured with a Ricken Sanno rice meter (brown rice model, T. Igarashi, Koriyama, Fukushima, Japan). Twenty head rice grains from each sample were lined up lengthwise to measure the grain length, and then the grains were arranged breadthwise to measure the grain width. The representative head rice samples (about 5 g) were oven-dried at 60 °C to constant weight. The oven-dried samples were then ground with a stainless steel grinder (FW-100, China) with a 100-mesh sieve. These samples were used for measurements of amylase content, gel consistency, and protein content according to the China National Standard for rice quality evaluation (MOA, 1999).

Data were analyzed following analysis of variance (SAS Institute, 2003). Means of varieties and N treatments were compared based on the least significant difference test (LSD) at the 0.05 probability level for each year.