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Variation in Yield and Physicochemical Quality Traits among Mutants of Japonica Rice Cultivar Wuyujing 3

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Abstract: To select elite germplasms, 112 mutants derived from japonica rice cultivar Wuyujing 3 were evaluated. The yield components such as panicle number per square meter, grain number per panicle, and grain weight were measured. The quality traits such as percentage of chalky grains (PCG), brown rice yield (BRY), milled rice yield (MRY), degree of milling (DM), amylose content (AC), protein content (PC), and relationships among traits were inverstigated. Results showed that grain yield ranged from 2.15 to 12.49 t/hm^2 with a mean of 6.4 t/hm^2 and number of grains per square meter contributed for 94.64% in grain yield variation. For quality traits, all rice mutants had short size (grain length ≤ 5.5 mm) and bold shape (grain length to width ratio = 1.10–2.00). Most of rice mutants (87.5%) had PCG values below 20%. All mutants had MRY values above 50%, AC values below 20%, and PC values below 10%. Percentage of chalky grains was significantly negatively correlated with MRY and positively correlated with DM. BRY and MRY were significantly negatively correlated with DM. PC was significantly and positively correlated with MRY and negatively correlated with DM, while AC had no significant correlation with these quality traits. It was concluded that there were 25 rice mutants which fulfilled the major requirements of Jiangsu standard japonica rice such as low percentage of chalky grains, low amylose content, optimal protein content, and which could be used as elite germplasms. Thus the mutants identified may lead to significant progress in improvement of rice quality.

Key words: japonica rice; mutant; yield; appearance quality; milling quality; nutritional quality

Cereals are the most important food for humans. Among them, rice is the staple food for more than half the world's population (Champagne, 2004; Bhattacharya, 2011). China is the largest rice producer in the world, contributing 27.27% of the global rice production in 2013 (FAOSTAT, 2013). Rice varieties, divided into two major types, indica and japonica, are being grown in different parts of China (Ikehashi, 2009), as a result of extreme variation in agro-climatic conditions, varying from the warm and humid tropics in the south, to the cooler subtropics in the central and to northern China with its much cooler climate and shorter growing season (Hansen et al, 2002). The south of China, especially the lower Yangtze River valleys in Jiangsu, Zhejiang and Anhui provinces, is characterized by the substitution of indica by japonica cultivar in the last three decades (Hansen et al, 2002), japonica rice previously grown and consumed primarily in the northern provinces. The expansion was a result of the growing consumer preference for japonica rice and its competitive price (Chen et al, 2006). However, the expansion is constrained by temperature; for example, in the Yangtze River Valley the daily temperature variation during rice growing season is not large enough to produce high quality japonica rice. A regular period of cooler temperatures at night, found in the farther north of China, is required for high quality japonica varieties because it

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allows the plant to fully develop starch molecules (Hansen et al, 2002).

Researchers and breeders have been working to increase grain yield and improve the quality of japonica rice since it was introduced and became popular in Yangtze River Valley (Chen et al, 2006; Qiao et al, 2011; Yang et al, 2013). Considerable progress in the improvement of rice quality has been achieved (Chen et al, 2006), with particular emphasis in Jiangsu Province. Yang et al (2013) reported that springiness, stickiness, and hardness of cooked Jiangsu japonica rice were similar to northeast japonica rice, which is considered to be the best japonica rice in China in terms of quality. Similarity was also reported for amylose content, whereas protein content was slightly higher for Jiangsu japonica rice than that from northeast of China (Yang et al, 2013). Yang et al (2013) reported that generally japonica rice in Jiangsu Province has good cooking and eating quality. Furthermore, there is higher grain yield in Jiangsu than other parts of China (Chen et al, 2006). However, occurrence of high chalkiness grains negatively affects the appearance of japonica in this province (Cheng et al, 2002). As an example, Yang et al (2013) reported chalkiness grain rate of 26.57%, a value corresponding to class-III according to China's standard appearance quality classification. In turn, chalky grains influence milling quality, i.e., they are more susceptible to breakage during milling which reduces the overall rice grain quality affecting consumer acceptability and lowering market value (Singh et al, 2003).

Rice grain quality is generally classified into four major physical and chemical indicators, i.e., appearance quality (grain length, grain width, length/width ratio, and chalky grain), milling quality (brown rice yield and milled rice yield), cooking and edibility characteristics (amylose content), and nutritional quality (protein content) (Koutroubas et al, 2004; Li et al, 2004). The integrated knowledge of their roles in final rice quality and relationships among them is key to manipulating their composition through breeding programs and thus developing new rice varieties with better quality. The research programs in Jiangsu Province are focused on chalky grains, amylose content and protein content. Firstly, chalky grain is considered as the greatest issue for the appearance of japonica rice (Cheng et al, 2002; Qiao et al, 2011). Secondly, the consumers prefer softer rice, hence varieties with low to medium amylose content are very popular in Jiangsu Province, and Nanjing 46 is ranked as the top among all the samples tested with AC of 13% (Yang et al, 2013). Lastly, the protein content is considered as the main determinant of nutritional value for rice consumers (Ning et al, 2010). These indicators are also correlated with each other; for example, breakage of grains during milling is associated with chalkiness (Singh et al, 2003), also milling reduces protein in rice (Ressureccion et al, 1979; Vilareal et al, 1991), resulting in loss in nutrient content for the milled rice (Champagne, 2004).

Wuyujing 3 has become one of the most important rice cultivars in Jiangsu Province since it was bred in 1992 (Yang et al, 2013), and it exhibits excellent eating quality (Gu et al, 2011). However, in the course of time, Wuyujing 3 has showed relatively lower grain yield potential, susceptibility to sheath blight and having a high chalky rate (Xi et al, 2014). The present study was conducted to evaluate yield and physico-chemical quality trait variation of the mutants of japonica rice cultivar Wuyujing 3 for selecting elite germplasms of rice quality.

MATERIALS AND METHODS

Materials and experiment field conditions

In China, Wuyujing 3 is a high quality benchmark for japonica rice cultivar. In 2007, Wuyujing 3 as mother plant M_1 was grown in the field. In 2009, seeds obtained from M_1 plant were sown in the field as M_2 generation. The plants M_2 that differed from the plants M_1 were marked. Seeds of the M_2 panicle were sown in separate rows in nursery beds. The maintenance process generations were successively repeated to obtain seeds from plant M_5 in 2012. In 2013, seeds of plants M_5 were sown as 112 different mutants of Wuyujing 3. The seeds were soaked for 6 h in distilled water, and then treated with 0.5% ethyl methane sulfonate (EMS) for 16 h at room temperature of about 25 ºC. After 16 h, the seeds were rigorously washed. Before sowing, seeds were soaked for 24 h and then drained 24 h. The seedlings of 112 mutants were transplanted on 25 June, 2013, and harvested at early November at the experimental farm of Nanjing Agricultural University, Danyang (31°54′31″N, 119°28′21″E), Jiangsu Province, China. All the rice mutants are shown in Supplemental Table 1.

Field preparation and experiment design

Samples were pooled from two treatments of nitrogen fertilizer, N0 (no nitrogen fertilizer) and N (200 kg/hm^2)