Journal of Integrative Agriculture 2017, 16(5): 992–999

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REVIEW

Research progress on the breeding of *japonica* super rice varieties in Jiangsu Province, China

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Abstract

In this study we report the results of a decade-long breeding program for *japonica* super rice made by Nanjing Branch of Chinese National Center for Rice Improvement in Jiangsu Academy of Agricultural Sciences. We concluded that selection of parents with good comprehensive traits and complementary advantages and disadvantages of both parents in the hybrid combination, and early selection of high heritability traits in earlier segregating generations could significantly improve the breeding efficiency. The use of closely-linked functional markers in pyramiding of multiple genes could greatly increase breeding efficiency, avoiding time-consuming and laborious steps that were used in traditional breeding program. It is also important to coordinate the yield components with variety characteristics such as yield stability, wide adaptability, lodging resistance, and an attractive grain appearance during late growth stage of rice.

Keywords: *japonica* super rice, eating quality, disease resistance, breeding strategy

1. Review of 20-year research on super rice in China

In 1996, the Ministry of Agriculture of China started the "China Super Rice Research" Key Project, and the China Agricultural Science and Technology Fund started the "Super Rice Breeding and Cultivation System" Project (Chen *et al.* 2007). The Ministry of Agriculture organized experts to discuss and put forward the three-staged goals to achieve the maximum yield from super rice: By the year 2000, the average yield should be 10 500 kg ha^{-1} (first stage) and 12 000 kg ha^{-1} by 2005 (second stage), and 13 500 kg ha^{-1} by 2015 (third stage). In 1997, Prof. Yuan Longping (China National Hybrid Rice Research and Development Centre) proposed a three-stage development strategy for breeding high-yield hybrid rice (Chen *et al.* 2009). To accomplish it, the "Super Hybrid Rice Breeding" Program was set up by the Premier Fund of the Chinese government in 1998. Following this Program, the Ministry of Science and Technology established the "863" Program for "Super Hybrid Rice Research" (Yuan 1997), and in 1999, the Ministry of Agriculture set up an agricultural science and technology program for "Chinese Super Rice Breeding and Experimental Demonstration". In 2000, Chinese rice producers accomplished the first yield goal for large-scale rice production, and the yield goal for the second stage was reached one year ahead of schedule in 2004. In 2002, the Ministry of Science and Technology set up the Key Project "High Quality Super Rice Breeding" in

Received 30 September, 2016 Accepted 24 February, 2017
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doi: 10.1016/S2095-3119(16)61580-0

accordance with the "863" Program (Cheng *et al.* 1998). In 2005, the Chinese government set up the "China Super Rice Promotion" Project, and the Ministry of Agriculture issued the document "Measures for the Confirmation of Super Rice". In the same year, the Ministry of Agriculture launched the Project "Breeding and Demonstration of New Super Rice Varieties", followed in 2006 by the "China Super Rice Research and Promotion Plan (2006–2010)". In 2008, the Ministry of Agriculture again issued the formal document of "Measures for the Confirmation of Super Rice" (Document No. 38 in Nongban Division of 2008). In April 2012, Prof. Yuan Longping launched the fourth stage of the plan to achieve the maximum yield from super hybrid rice. Under this mandate, the average yield is expected to reach 15 000 kg ha^{-1} no later than 2020, and possibly as early as 2015. In 2013, the average yield of super hybrid rice was more than 13 500 kg ha^{-1} in Longhui County, Hunan Province and Ningbo City, Zhejiang Province. On 10 October 2014, the panel of experts organized by the Ministry of Agriculture checked the average yield of hybrid rice "Liangyou 900" cultivated by the research team of Prof. Yuan Longping in Hongxing Village, Hengbanqiao Town and Xupu County of Hunan Province and confirmed the average yield over 6.7 ha reached 15 401 kg ha^{-1}. This result demonstrated that the fourth stage yield goal for super rice had been reached. On October 21, 2014, Prof. Yuan Longping held the "Xiangjiang Forum" in Changsha and put forward a fifth yield goal of 16 t ha^{-1} for Chinese super rice.

However, in addition to increased yield, Chinese super rice varieties also have specific requirements for quality and disease resistance. Super rice varieties or combinations refer to new rice varieties which were bred by combining ideal plant types and utilization of heterosis. Such varieties are expected to have substantially improved yield potential over existing rice varieties because of their high quality for consumers, disease resistance, and the availability of high-yield cultivation technology. China has vast, arable territory and lots of rice varieties. The document "Measures for the Confirmation of Super Rice" (Document No. 38 in Nongban Division of 2008) dictated the main characteristics for *japonica* super rice in six regions of China (Table 1).

If a variety has the required characteristics, the Ministry of Agriculture will identify it as a super rice variety. If a super rice variety has been revoked from the management registration of the Provincial Crop Variety Appraisal Committee or to shows a major defect, or causes a great economic loss in agricultural production, or its largest planted area for a single year falls below 20 000 ha in the three years after identification as a rice variety, the designation of super rice will be revoked the title of the super rice variety by the Ministry of Agriculture, China.

2. Breeding achievements of *japonica* super rice varieties in Jiangsu Province

By 2016, a total of 156 varieties were identified as super rice in China, 125 of which retained the designation of super rice after removal of 31 varieties due to failure to meet the standards of the 2008 mandate. In Jiangsu Province, out of 24 varieties originally identified as super rice, only 18 varieties retained the super rice designation. Only 4 of these varieties were *indica* hybrid rice while the remaining 14 were conventional *japonica* varieties, accounting for 46.7% of the 30 *japonica* conventional super rice varieties. Among the 14 *japonica* conventional super rice varieties, the number of late rice, late-maturity medium rice and medium-maturity medium rice varieties were 6, 5 and 3, respectively (Table 2).

3. Research progress of *japonica* super rice breeding in Jiangsu Province

Jiangsu is the main province for production of rice in China. In recent years, the area used for rice cultivation accounted for about 2.3 million ha, of which, nearly 2 million ha were

Table 1 Targets of rice quality, resistance to pests and yield of super rice (Ministry of Agriculture, China, 2008)

Trait	Rice type and region[1)]					
	1	2	3	4	5	6
Growth duration (d)	≤105	≤115	≤125	≤132	≤158	≤170
Average yield of 6.7 ha kg^{-1}	≥550	≥600	≥660	≥720	≥780	≥850
Grain quality	*japonica* rice in North China reaches the second class standard of Ministry of Agriculture; late-season *indica* rice in South China reaches the third class; early-season *indica* rice and single season rice in South China reaches the fourth class					
Resistance	Resistant to 1–2 major pests and diseases in local district					
Application area	More than 3 300 ha per year in two years after registration					

[1)] 1, early-maturing and early-season rice in the Yangtze River Valley; 2, medium- or late-maturing and early-season rice in the Yangtze River Valley; 3, middle-maturing and late-season rice in the Yangtze River Valley, and photo-sensitive late-season rice in South China; 4, early-and late-season rice in South China, late-maturing and late-season rice in the Yangtze River Valley, and early-maturing *japonica* rice in northeast of China; 5, single season rice in the Yangtze River Valley, medium-maturing *japonica* rice in Northeast China; 6, late-maturing and single season rice in upstream of the Yangtze River Valley, and late-maturing *japonica* rice in Northeast China.

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