Development of Hybrid Rice to Ensure Food Security

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Rice is the staple food for more than half of the world’s population and for more than 60% of China population. Increasing rice yield is therefore crucial for solving food shortage problem, ensuring food security, and reducing poverty. Given the vast population and limited per capita cultivated land in China, meeting food demands by increasing the yield per unit area with the aid of advanced sciences and technologies would be the only option. Several alternative measures for increasing crop yield, such as building water conservancy facilities, increasing fertilizer application, improving soil texture, forming interrelated cultivation techniques, more effective controlling of pests and diseases, and using of elite varieties, have been undertaken. Among these alternative measures, adopting elite varieties, particularly popularizing super hybrid rice, proves to be the most economical and effective option.

China launched hybrid rice research in 1964 and began massive production in 1976 after achieving initial success in 1973. Due to a significant increase in the yield, the cultivated area of hybrid rice expanded greatly, reaching around $1.67 \times 10^7$ hm$^2$ in recent years and accounting for 57% of the total national rice-growing area in China. Hybrid rice accounts for 65% of the total national rice yield. In recent years, the average yield of rice in China is approximately 6 450 kg/hm$^2$, 7 500 kg/hm$^2$ for hybrid rice, and 6 150 kg/hm$^2$ for conventional rice. The increased production of hybrid rice each year provides food for more than 70 million people.

To meet food requirements in the 21st century, the Ministry of Agriculture in China initiated a super rice breeding program in 1996, stipulating the following yield indices for hybrid rice:

The first phase (1996–2000), 10.5 t/hm$^2$ (the average yield is measured in two demonstration areas with an area of at least 6.67 hm$^2$ each in the same ecological region in two consecutive years);

The second phase (2001–2005), 12.0 t/hm$^2$;


The China National Hybrid Rice Research and Development Centre in collaboration with Jiangsu Academy of Agricultural Sciences successfully bred a pioneer combination of super hybrid rice, Liangyoupeijiu. In 1999, four 6.67-hm$^2$ demonstration areas were established in Hunan Province, China, with a yield exceeding 10.5 t/hm$^2$. In 2000, sixteen 6.67-hm$^2$ and four 66.7-hm$^2$ demonstration areas reached the standards. Due to its high yield and good quality, Liangyoupeijiu has expanded its cultivated area to approximately $10^7$ hm$^2$ each year in recent years and become the hybrid rice combination with the largest cultivated area in China. The average yield of Liangyoupeijiu is about 8 250 kg/hm$^2$, which is 750 kg/hm$^2$ higher than the average yield of common high-yielding hybrid rice. In 1999, the super hybrid rice combination P64S/E32, planted in a small-area tested field in Yongshe, Yunnan Province, China, recorded a yield of 17 085 kg/hm$^2$.

Being guarded through the technical route of combining morphological improvement along with the use of intersubspecific heterosis, the China National Hybrid Rice Research and Development Centre successfully developed the second-phase super hybrid rice. Four 6.67-hm$^2$ demonstration area were established in Hunan in 2003. In 2004, twelve 6.67-hm$^2$ demonstration area, with a yield of more than 12.0 t/hm$^2$, were established in four southern provinces of China. Among these 12 areas, 3 in Hunan reached the standards in two successive years, meeting the yield indices for the second-phase super hybrid rice a year ahead in 2004.

Since 2006, China has continued studying on the third-phase super hybrid rice, targeting a yield of 13.5 t/hm$^2$ in most demonstration areas. In the same year, the second-phase super hybrid rice was widely spreaded, with the cultivated area exceeding $6.67 \times 10^7$ hm$^2$ in 2010 and a yield of approximately 750 kg/hm$^2$ higher than that of the first-phase super rice. In 2011, based on the principles of ‘elite varieties, improved methods, fertile farmlands, and good conditions’, the research team set an impressive super-high-yielding record of 13 899 kg/hm$^2$ in the 7.5-hm$^2$ demonstration area in Longhui, Hunan Province, China. In 2012, the team again achieved an average yield of 13 766 kg/hm$^2$ in the 6.87-hm$^2$ demonstration area in Xupu, Hunan.
Province, China, achieving the goal for the third-phase super hybrid rice in China.

Based on the aforesaid achievements and progress as well as the theoretical yield potential of rice, China proposed the fourth-phase super hybrid rice breeding program, targeting a yield of $15.0 \, \text{t/hm}^2$ in single-season rice in most demonstration areas in 2020. Approved by the Ministry of Agriculture of China, this program was officially initiated and launched in April 2013. For this effort, ‘Y Liangyou 900’, a pioneer middle-season combination of the fourth-phase super hybrid rice, was developed. This hybrid set a new record of the average yield of $14,821 \, \text{t/hm}^2$ on September 28, 2013 when planted in Longhui County, Hunan Province, China. Given these initial results, we are confident that we will achieve the goal of $15.0 \, \text{t/hm}^2$ before 2015.

Rice plants can transform 5% of solar radiation into organic matter. If we employ a conservative figure of 2.5%, the yield of single-season rice in Changsha, Hunan Province can reach $22.5 \, \text{t/hm}^2$. Thus, achieving yields higher than $15.0 \, \text{t/hm}^2$ is theoretically possible. Hypothetically, semi-high-height rice varieties, with a height of about 1.3 m, can reach the potential yield of $15–16 \, \text{t/hm}^2$; new-plant-type rice varieties, with a height of about 1.5 m, can reach the potential yield of $17–18 \, \text{t/hm}^2$; and super-high-height hybrid rice, with a height of about 1.8–2.0 m, can reach the potential yield of $18–20 \, \text{t/hm}^2$. We shall pursue new combinations with good morphology, moderately tight type, strong tillering ability, and small differences between main panicles and tiller panicles by improving plant types. To solve the lodging problems in super-high-yielding high-height varieties, some methods can be multi-pronged, such as adopting intersubspecific combination with prominent advantages to enhance the root system, drooping their panicles to lowered gravity, as well as applying germplasm resources with solid stem and short, thick, and foot-heavy basal internodes. With these combined measures, super-high-yielding combinations with strong lodging resistance might be selected.

**Future Goals of Hybrid Rice Development**

‘Planting Three to Produce Four’ High-Yielding Project

The ‘Planting Three to Produce Four’ High-Yielding Project, proposed in response to a serious insufficiency of cultivated area in China, refers to the project in which, with the technological achievements of super hybrid rice, to achieve the total yield corresponding to 4-hectare production by only using 3-hectare farmland. Hunan Province in China aims to expand the cultivated area of super hybrid rice to $1.0 \times 10^6 \, \text{hm}^2$ in 2016, with a total yield according to $1.3 \times 10^6 \, \text{hm}^2$ in 2006, which is equivalent to an incremental area of $3.3 \times 10^5 \, \text{hm}^2$. Highly valued and supported by Chinese Government, the ‘Planting Three to Produce Four’ High-Yielding Project was first initiated and implemented in 20 counties of Hunan Province in 2007 and was promoted to 51 counties (towns and districts) by 2013, with a demonstration area of $5.9 \times 10^5 \, \text{hm}^2$ and total incremental yield of $1.1 \times 10^6 \, \text{t}$. Currently, the Project has also been implemented in Anhui, Henan, Guangdong, Guangxi, Yunnan, Guizhou, and several other provinces, aiming at achieving a total national cultivated area of $4.0 \times 10^6 \, \text{hm}^2$ by 2020, with the yield of present $5.3 \times 10^6 \, \text{hm}^2$, which is equivalent to an incremental area of $1.3 \times 10^6 \, \text{hm}^2$.

Three for One’ High-Yielding Project

The ‘Three for One’ High-Yielding Project refers to a project in which super hybrid rice technology is adopted to achieve an annual yield of 360 kg in a 3-fen (66.7 m²) farmland, providing a year’s worth of food for a person. Hunan Province plans to expand the cultivated area of super hybrid rice to $3.3 \times 10^5 \, \text{hm}^2$ in 2020, which would account for approximately 9% of the total provincial cultivated area, providing enough food for 24% of the total provincial population. The ‘Three for One’ High-Yielding Project has been tested and demonstrated in multiple sites in Hunan, Guangxi, and Guangdong provinces. In 2013, initial success was achieved in the experimental sites at Liling and Shimen in Hunan Province, China.

‘Developing hybrid rice to benefit the world population’ is my lifelong goal and pursuit. At present, hybrid rice has been introduced and promoted by more than 40 countries around the world, among which India, Bangladesh, Indonesia, Vietnam, the Philippines, and the United States have planted hybrid rice extensively. In 2012, the cultivated area of hybrid rice reached $5.2 \times 10^6 \, \text{hm}^2$ with a 2-t incremental average yield per hectare more than that of the local fine varieties. China aims at promoting its hybrid rice in more than half of the world’s rice fields, with enough incremental yield (hypothetically, a 2-t incremental average yield per hectare) for an additional 400–500 million people. Therefore, expeditiously developing the hybrid rice of our country will certainly make a great contribution to food security and world peace.