Rice and the Global Economy: Designing Rice to Meet Social, Economic and Environmental Challenges

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Abstract

Across the world, rice is a favorite and an important species. The present rice production scenario will take care of food needs for the next 20 years. In the backdrop of limited natural resources like land and water, decreasing soil health and inevitable adverse effects of the changing climate, designer rice may just be the effective solution for the growing demand for rice globally. Advances in the use of molecular markers for rice breeding present promising prospects to make designer rice a reality in the coming years and meet the growing demand. Research revelations in rice genetics offer opportunities to create a platform for making modern and high-yielding varieties of rice for future.

Keywords: Rice, environmental challenges, breeding

One of the greatest contributions of research on rice production over the last half century has been the development of "mega" rice varieties that have been grown on millions of hectares for many years, leading to the "Green Revolution". These varieties typically are semi-dwarf, photo-period insensitive, weakly dormant, with multiple disease and insect resistance, have excellent yield potential and grain quality that is compatible with at least one major international market category. They are adapted to irrigated systems in which water supply is assured. Indeed, the characteristics of the way irrigated rice systems are managed essentially have meant that these mega varieties were grown over rather uniform mega environments across the world. Well – controlled irrigation schemes with proper water, soil and fertilizer management could be seen as great environmental equalizers. By tailoring rice varieties to mega environments a "one size fits all" approach to breeding could be, and was, highly successful. These varieties, their sister lines, and/or their descendents have served and continue to serve as parents in many breeding programs around the world.

However, one of the criticisms of the Green Revolution in Asia was that the modern rice varieties were not well adapted to the other 50% of global rice area that was not irrigated. These rainfed areas are home to hundreds of millions of the world's poorest rice farmers and consumers who were largely bypassed by the Green Revolution. Among the defining characteristics of rainfed rice systems is their exposure to a range of serious abiotic constraints to production: drought, floods, and salinity, especially in coastal areas. Almost paradoxically, a crop may experience drought and floods at different times during the same season. Until very recently it was practically impossible to identify and transfer tolerance to these constraints in a breeding program, let alone combine them in a background that farmers would be willing to grow. That is, had the right maturity, grain type, yield potential, and other traits that all go in to making a variety attractive to farmers.

Looking into the future of rice production we are faced with a number of uncertainties. The availability of land, water and labor for rice production will almost certainly deteriorate. This will require rice varieties that are adapted to growing with less water and tolerate direct seeding and that fit into different cropping patterns and systems. As direct seeded rice almost certainly becomes the norm so will increased mechanization of both crop establishment and harvest. Mechanical transplanting may well take hold across large areas. Regardless there will be demand for varieties that show excellent early vigor and tolerate herbicide applications. It is noteworthy that many of the traits that will be in demand to meet that changing socioeconomic circumstances of rice farmers will also be in demand to create rice – based systems that better tolerate climate change. As many of these traits will differentially target the poorest rice farmers, I have in the past referred to the dual benefits of addressing future climate change and the needs of today's poorest farmers as a "convenient convergence".

With the advances in the use of molecular markers for rice breeding and the greater certainty of the location and effect of rice QTLs for a wide array of traits, the dream of combining QTLs to overcome previously intractable constraints is now becoming a reality. Early successes have built on the mega variety approach by transferring tolerance for flooding (the *Sub1* QTL) into popular mega varieties like Swarna and IR 64, making them attractive to farmers in flood prone regions of South and Southeast Asia. However, when we look to the future of rice breeding – "designer rice" – should we direct our attention to creating mega varieties with more traits of interest? Or should we make a subtle, yet fundamental, shift towards focusing breeding on targeting rice varieties towards ever more specialized environments and markets? It may in the end be a blend of the two.

The following discussion represents my personal view on how rice breeding – or, at least the part IRRI is engaged in – might look in the coming decades:

1) We should consciously and aggressively create a platform for creating future modern, high – yielding varieties. Ten years from now I would like to see IRRI breeding products shared with an IR designation having at a minimum: Semidwarf stature, photoperiod insensitivity, flood tolerance (*Sub1* +), anaerobic germination, specific drought QTLs, three to four key bacterial leaf blight resistance genes, three to four broadest spectrum blast resistance genes, and, pending our latest rounds of research, the proper brown planthopper resistance genes and tungro tolerance. Competition for water may drive large areas that are currently irrigated into an alternating wet – dry cultivation making drought tolerance attractive even for irrigated systems. Materials with this combination would merit the label "IRRI inside" and can form the basis for the creation of "designer" rice varieties.

2) On that platform we could then refine varieties for different ecologies and markets by manipulating maturity, nutritional value, grain type, starch quality, and aroma. There probably will be increased use of rice in processed foods so the demands on starch quality/composition will be quite different than it has been over the last couple of decades. Transgenic traits such as beta carotene, higher iron levels and at some point C4 photosynthesis would be built upon the same platform. Other niche traits, for example tolerance to stagnant flooding, could also be added. While there appears to be a general trend towards farmers demanding early maturity, a range of maturities will probably need to be made available for different ecologies.

For a practical plant breeder, this no doubt sounds like an impossible dream. But, is it? Within a few years we will have the sequence of thousands, possibly in excess of 10,000, of carefully selected rice varieties and their wild relatives. Associated with extensive and precise phenotype data, we will have the tools to routinely follow multiple traits through multiple generations using high throughput genotyping facilities.

From the perspective of the International Rice Research Institute this will present a major new challenge to how we organize our breeding programs, the nature of the products we produce, and perhaps most importantly, how we relate to our partners.

The creation of a standard platform for all materials that IRRI distributes will be a long term undertaking. Showing us the way forward, work has already begun with the mega varieties that have been converted to submergence tolerance with the addition of Sub1 using marker assisted selection. The platform will most likely always be evolving as new key traits are recognized and become amenable to transfer. Indeed, the platform will in all likelihood not be a discrete entity. Rather, it will be a relatively large collection of traits of known value and genetics that are the minimum that is required to be considered as "IR".

Into which genetic backgrounds will these traits be placed to create the new platform(s)? No doubt much like our breeders and geneticists examined which varieties should be the first sequenced. A similar analysis of rice breeding programs around the world will help us to determine which lines should be the highest priority for inclusion into the platform. A simple criterion could be derived from the most frequently used parents in breeding programs in the ten most important rice growing countries in the world with breeding programs. Converting these widely used parents to the minimum set of traits would be the first step towards creating the platform required to build high quality designer rice varieties.

It makes little sense for IRRI to try to breed rice platforms and rice varieties for all ecologies. Instead, we will provide our partners – both in the public and in the private sectors – with the essential elements to create very high quality varieties specifically tailored to their farmers needs. We should be able to provide "tool kits" that will enable breeders to mix and match traits all on the same broad modern set of traits. The components of the tool kits will have to be carefully managed (or protected) in a way that ensures that all parts of the rice community enjoy fair access to them. Much like the trail blazed by the Hybrid Rice Development Consortium, access and licensing terms will be favorable to national research programs and be structured to encourage small and medium size seed companies to enter the rice seed market. Indeed, a subset of materials in this vision of the future of rice breeding will be lines intended to serve as candidate parents in hybrid rice breeding programs.

The very high performance of inbred lines that will be developed from this approach will set a high bar for hybrid rice to compete against. It is quite possible that over the next 20 years as the creation of the modern rice platform steadily plays out there will be a steady injection of novel inbred varieties with a succession of new traits. This could create an environment in which farmers who typically saved their seed from their harvests instead find it attractive to purchase the next round of improved inbreds. Thus, a steady demand could be created that leads to the development of a vibrant inbred rice variety seed industry in which small seed companies servicing relatively small areas play an important role. An early example of this is already taking shape with the addition of drought tolerance to Swarna *Sub1* and IR 64 *Sub1*. Farmers who have adopted the Sub1 versions should have confidence to "trade up" to the drought tolerant version. When BLB is added, then anaerobic germination etc. there will be continued appetite for purchasing seed of inbred varieties.

The opportunities offered by the stunning advances in rice genetics now offer us the opportunity to develop advanced rice breeding platforms and tool kits. How these fundamental changes in rice breeding translate through the rice industry and value chain remains to be seen. It will be intriguing to see 20 years hence historical documentation of how advances in the most fundamental arenas of plant genetics moved through society to transform rural economies and the lives of the most humble rice farmers.

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