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NEW CHALLENGES AND TECHNOLOGICAL OPPORTUNITIES FOR RICE-BASED PRODUCTION SYSTEMS FOR FOOD SECURITY AND POVERTY ALLEVIATION IN ASIA AND THE PACIFIC

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New Challenges and Technological Opportunities for Rice-Based Production Systems for Food Security and Poverty Alleviation in Asia and the Pacific

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Thank you for this opportunity to speak at this milestone FAO Conference on Rice in Global Markets and Sustainable Production Systems—as part of the kickoff to celebrate the International Year of Rice. This event is providing us with a great opportunity to raise public awareness on subjects that are so important to us all—namely, the key economic and production issues that will shape the world rice economy. We are especially honored to be able to give this presentation during this influential forum in front of so many distinguished representatives from concerned governments, international and non-governmental organizations, and the private sector.

Rice—the First-Ever "Crop of the Year"—Comes Full Circle

As you all know, 2004 marks the second time that the UN has designated a year for rice. Thirty-eight years ago—back in 1966—rice became the first-ever agricultural commodity to be declared *Crop of the Year*! Of course, whenever something unprecedented is suggested, some of the overly cautious will always have reservations. According to O.E. Fischnich, then assistant director general of the FAO, when the idea was first proposed, a number of the representatives of national governments expressed some reluctance to putting a "year tag" on any one crop. However, he later pointed out that—as the proposal was more fully discussed; as the facts established the preeminent position of rice as human food; and as thinking people reviewed the world food position and determined to exploit every possibility to encourage more food production—all resistance to the idea of declaring an International Rice Year disappeared (IRRI 2003a).

The objective of International Rice Year 1966 was to encourage concerted efforts to promote rice and improve understanding of the world's most widely eaten grain, especially in the context of its role in furthering the UN's Freedom From Hunger campaign back then. The big Asian news story of 1966 was indeed hunger. In recalling that year, the *Far Eastern Economic Review* pointed out that 1966 brought into sudden and sharp focus the fact that the largely agricultural economies of Asia were failing to produce sufficient food to feed the region's rapidly rising populations. Asia, once a net exporter of food, the domain of some of the world's lushest rice bowls and wheat lands, home of some of the world's most skilled and industrious farmers, was a food-deficit region, literally dependent on the West to stay alive (Davies 1967).

According to the *Far Eastern Economic Review* (Anonymous 1967), the tragedy of the food situation in Asia was underlined by the fact that, in the year dedicated by

FAO as the International Rice Year, grave shortages of rice supplies had developed. Asia in 1966 had to struggle to fill its rice bowls. According to the *Review,* the only heartening development on the Asian food scene was the appearance of some positive signs that the official agencies responsible were willing to change their approach and give agriculture the priority that it deserved in the war on poverty.

Yet, 1966 truly was an International Rice Year. Year-tagged conferences and events played a role in making it so. IRRI's release—in November of that year—of IR8 as the first modern semidwarf rice variety and other achievements during those thrilling days of publicly funded international rice research left indelible marks. A year of living dangerously, teetering at the brink of mass famine, galvanized policymakers and donors to take the bold steps that launched the Green Revolution (IRRI 2003a). Whatever branded 1966 as International Rice Year, its legacies today are lasting improvements in rice farmers' productivity and poor rice consumers' diets. And while we can't say for sure that this designation was a major factor in the success that was achieved during the remainder of the 20th century, we can't deny the fact that probably it had an impact in mobilizing resources for rice research that helped lead to those successes.

We believe that it is very appropriate that we have come full-circle in declaring 2004 the 2nd International Year of Rice. Today, we have some new challenges to face—maybe not on the mammoth scale of those of 38 years ago, but perhaps even more difficult from a technology standpoint. The challenges for rice farmers and researchers in 1966 were fairly straightforward. Renowned economist Dr. Peter Timmer, formerly of Harvard University, points out that the task of agricultural development was much easier back then when the need for greater cereal output to accomplish national food security was met by new seed-fertilizer technologies, which were already in fairly advanced stages of development (Timmer 2003). So, let's use this International Year of Rice 2004 to elevate the awareness—again—of key policymakers and donors to be able to face the new—and much more complicated—challenges of the 21st century.

Rice Is Asia's Lifeline

Before we move on to discuss these challenges, we want to make sure that everyone here understands that we are framing our discussion in the context of rice-based cropping systems in countries and areas of the world that are dominated by rice. Other speakers today will be listing the challenges and opportunities for rice in sub-Saharan Africa, Latin America and the Caribbean, and the Near East and North Africa—all important to be sure for the people living there. But the magnitude pales in these regions when compared with that of Asia. As was pointed out during FAO's Expert Consultation on Bridging the Rice Yield Gap in Asia and the Pacific, rice is the lifeline of the region where 56% of humanity—including about 70% of the world's 1.3 billion poor people—lives, producing and consuming around 92% of the world's rice (Papademetriou 1999).

In terms of rice, there are more poor people—and starving children—in eastern India alone than in all of Africa! Among the most important African food crops, rice ranks in a distant seventh place behind cassava, yam, maize, plantain, sorghum, and millet (Hartmann 2003). However, rice is by far the most dominant crop in Asia where, in many countries, it covers half the arable land cropped.

The Current Challenges

Clearly, there are two integral major challenges—for now and well into the future—involving rice in Asia. The first is the ability of nations to meet their national and household food security needs with a declining natural resource base, two of the critical resources being water and land. How the current level of annual rice production of around 545 million tons can be increased to about 700 million tons to feed an additional 650 million rice eaters by 2025 (D. Dawe, IRRI, 2003, personal communication) using less water and less land is indeed the great challenge in Asia.

The second is—as has been stated so eloquently by the United Nations as one of its eight Millennium Development Goals (www.undp.org/mdg)—the eradication of extreme poverty and hunger. Rice is so central to the lives of most Asians that any solution to global poverty and hunger must include research that helps poor Asian farmers reduce their risks and earn a decent profit while growing rice that is still affordable to poor consumers.

Scarcity of water and land

Water. As put forth by the CGIAR Challenge Program on Water and Food, increasing water scarcity and competition for the same water from non-agricultural sectors points to an urgent need to improve crop water productivity to ensure adequate food for future generations with the same or less water than is presently available to agriculture (www.waterforfood.org). About 70% of the water currently withdrawn from all freshwater sources worldwide is used for agriculture and to grow rice requires about two times as much water as other grain crops such as wheat or maize. In Asia, irrigated agriculture accounts for 90% of the total diverted freshwater used, and more than 50% of this is used to irrigate rice (IRRI 2001). Until recently, this amount of water has been taken for granted, but this cannot continue.

The reasons for the looming water crisis are diverse and location-specific, but include decreasing water quality (chemical pollution, salinization), decreasing water resources (falling groundwater tables, silting of reservoirs), and increased competition from other sectors such as urban and industrial users (IRRI 2003b). Though a complete assessment of the level of water scarcity in rice production is still lacking, there are signs that declining quality and availability—as well as increased competition and increasing costs—are affecting the sustainability of the irrigated rice production system already. By 2025, it's expected that 2 million hectares of Asia's irrigated dry-season rice and 13 million hectares of its irrigated wet-season rice will experience "physical water scarcity," and most of the approximately 22 million hectares of irrigated dry-season rice in South and Southeast Asia will suffer "economic water scarcity" (Tuong and Bouman 2002). Drought is one of the main constraints to high yield in rainfed rice production systems in both the lowlands and the uplands.

With increasing water scarcity, rice land will shift away from being continuously flooded (anaerobic) to being partly or even completely aerobic. This shift will cause profound changes in water conservation, soil organic matter turnover, nutrient dynamics, carbon sequestration, soil productivity, weed ecology, and greenhouse gas emissions. Whereas some of these changes can be perceived as positive (e.g., water conservation and decreased methane emissions), some are perceived as negative (e.g., release of nitrous oxide from the soil, decline in soil organic matter). The challenge will be to develop effective integrated natural resource management interventions, which allow profitable rice cultivation with increased soil aeration while maintaining the productivity, environmental protection, and sustainability of rice-based ecosystems.

To assist in meeting this challenge, the International Platform for Saving Water in Rice (www.irri.org/ipswar/about_us/ipswar.htm) was created during an international workshop, Water-Wise Rice Production, held at IRRI (Bouman et al 2002). IPSWAR is a mechanism to increase the efficiency and to enhance the coherence of research on water savings in rice-based cropping systems in Asia. The overarching goal is to conserve water resources, which will in turn safeguard national and household food security and alleviate poverty.

Land. The lands most at threat in Asia are the fragile rainfed or upland environments where the poor are forced to use whatever resources are available to produce the food they need. As the Asian population is expected to increase from 3.7 billion in 2000 to 4.6 billion in 2025, pressure to intensify land use, in both favorable and marginal areas, will thus increase. One study (Beinroth et al 2001) shows that most Asian countries will not be able to feed their projected populations without irreversibly degrading their land resources, even with high levels of management inputs.

In the marginal areas, intensification of land use will lead to degradation of resources through loss of biodiversity, deforestation, buildup of pest infestations, depletion of natural soil fertility, and soil erosion. These changes will ultimately affect the functioning of the ecosystems. Deforestation and soil losses from upland environments also have off-site effects through changed patterns of water flow, leading to increased frequency and intensity of flooding and consequent damage to infrastructure. Similarly, excessive use of inputs such as chemical fertilizers and pesticides, and exploitation of groundwater in the intensive rice bowls of Asia, will likely result in resource degradation, environmental pollution, and adverse effects on human health (IRRI 2003b).

Rice researchers have developed yield-increasing technologies for favorable environments, which have led to a massive growth in rice production through the Green Revolution. Had the yield of rice remained at its pre-Green Revolution level of 1.9 t/ha, current production would have required more than double the current rice land area. Such an expansion of rice area would have most certainly led to high environmental costs. In addition, yield improvements through better rice technologies in marginal areas have contributed directly to a decrease in intensification pressure in these environments.

A strategy for the future would be to further strengthen the two-pronged approach of increasing productivity in favorable environments while developing rice technologies that have minimal adverse effects on the resource base of fragile environments (IRRI 2003b). This will involve the use of new integrative approaches that take into account resource flows, interactions, and trade-offs in the use of land, labor, water, and capital across the landscape for assuring farmer livelihood and resource conservation. It will be important to conduct comprehensive analyses of farmers' livelihood strategies in the fragile environments and how these interact with the use of land resources to underpin our efforts at developing suitable technologies.

Breaking out of the poverty trap

We can better get our point across on the challenge to alleviate poverty if we use an example that provides a human face. Look at the dilemma of Mr. Sucipto, a subsistence farmer on the rainfed lowland plains of central Java in Indonesia. He uses most of his one-quarter- ton harvest from his direct-seeded wet-season crop on his small farm to feed a large extended family. He would sell more rice if his yields were higher, but he has a lot of mouths to feed.

How can Mr. Sucipto and his family—and millions like them—break out of their poverty trap? First, we have to understand that they are in this "trap" due mainly to the small size of their farms, which has—up to now—not allowed them to produce much beyond their families' needs! But remember, Mr. Sucipto would most likely not even be adequately feeding his family if it were not for the Green Revolution—certainly an important accomplishment. However, even though Mr. Sucipto and legions like him are not starving, they are still extremely poor!

Economist Timmer points out that, with staple cereal prices at all-time lows in world markets, a dynamic agriculture in Asia will depend on diversification into commodities with better demand prospects, such as fruits, vegetables, and a variety of livestock products (Timmer 2003). To accomplish this, we need to make rice production even more efficient to free up resources so that many small farmers, like Mr. Sucipto, can indeed consider diversifying their farms—or perhaps, if they choose, use the additional resources to start or enhance full-time nonfarm livelihoods!

IRRI economist David Dawe points out that, throughout history, every country that has become wealthy has gotten most of its population out of agriculture—without exception! So, we need to get some people out of rice farming—and still keep rice prices cheap to assure household food security for the hundreds of millions of rural and urban poor who will still be eating the staple. To accomplish this, we need the emergence of a new breed of rice farmer in Asia who could take advantage of a more efficient, productive, and profitable rice industry made possible by the exciting new technologies being developed by rice research.

One last point before we move on to the array and the importance of those new technologies. In this presentation, we have used the terms national food security and household food security. You might ask, what is the difference? Dr. Dawe defines national food security, which was achieved for many Asian nations by the Green Revolution with its new seed-fertilizer technologies, as the ability of a country to, in some sense, either produce or import enough grain or food to meet the average needs of its population. However, a country can achieve national food security and obviously still have a large part of its population poor and not enjoying what we call household food security, which is—as defined by Dr. Dawe—providing poor families with enough income to buy the food that they need. So, with household food security, a family can lead a healthy, active life with no worry about where the next meal is coming from.

Technological Innovation Is Essential for Progress

We think it is safe to say that most everyone agrees that technological innovation is essential for human progress. Indeed, it has been at the heart of development over the centuries. From early farmers' selection of seeds to the Green Revolution, from the first use of penicillin to the widespread use of vaccines, and from the printing press to the computer, people have devised tools for raising agricultural productivity, improving health, and facilitating learning and communication.

Building human capacities and economic growth are integrally linked with technological innovation. You simply can't have one without the other. Technological innovation is a means to human development because of its impact on economic growth through the productivity gains it generates. And conversely, human development is an important means to the development of new technologies!

We agree with the assessment of the United Nations Development Programme (UNDP 2001)—as articulated in its *2001 Human Development Report*—that technology deserves more attention than ever! Certainly, as technological breakthroughs of the past have improved human health and nutrition, expanded knowledge, and stimulated economic growth—the genetic, molecular, and digital wonders we are seeing today will only accelerate how we can use technology to alleviate, if not eradicate, poverty and to meet the challenges posed by water scarcity, land degradation, and other problems.

We have no doubt whatsoever that technology will play a crucial role in helping a substantial percentage of the poor people, who currently till millions of tiny rice farms in Asia, break out of the poverty trap that we mentioned earlier. We base this conviction on what Green Revolution technology has already accomplished in rice over the last 25 years on the continent.

Certainly, increased production and lower prices of rice across Asia have been the most important results of the higher yields that rice research and new farming technologies have made possible. Around 1,000 modern varieties—approximately half the number released in 12 countries of South and Southeast Asia over the last 40 years—are linked to IRRI germplasm—a large impact indeed! Modern varieties and the resultant increase in production have increased the overall availability of rice and also helped to reduce world market rice prices by 80% over the last 20 years. Poor and well-to-do farmers alike have benefited directly through more efficient production that has led to lower unit costs and increased profits. Poor consumers have benefited indirectly through lower prices. This has brought national food security to China and India, not to mention Indonesia and other countries. However, further increases in output and even lower prices continue to be needed for many poor families to realize the household food security that we mentioned earlier.

Now we would like to discuss some of the technologies IRRI and its partners are using to meet the challenges of the 21st century—some are already benefiting farmers while others promise results in the near (less than 5 years) and distant (within 5-15 years) future.

Dawn of tropical hybrid rice in Asia

After more than 20 years of research, we are truly at the dawn of having tropical hybrid rice available as an option for many Asian farmers. By exploiting the phenomenon of hybrid vigor (FAO 2003a), hybrid rice varieties yield about 1-1.5 tons per hectare higher (15-20%) than the best semidwarf inbred varieties grown under irrigated conditions. The vigorous and more active root system of hybrid varieties also enables them to tolerate moderate stresses caused by salinity and drought due to limited irrigation water.

This technology has already demonstrated great potential to increase rice production in China, where 15 million hectares (50% of the total rice area) are planted to hybrid rice varieties (Virmani et al 2003). In tropical Asia, hybrids have started showing their potential in India, Vietnam, the Philippines, Bangladesh, and Indonesia, where about 1 million hectares total were planted to hybrid rice varieties in 2003 (S.S. Virmani, IRRI, 2003, personal communication).

This technology clearly helps rice farmers to increase their yields, productivity, and profitability by using less land and water and enables them to opt for crop diversification to increase their income. An associated seed production technology has helped to develop a seed industry in Asia, which in turn has contributed to increased rural employment opportunities.

Within the next few years, hybrid rice area in tropical Asia should increase significantly due to the efforts of countries such as the Philippines, which has an ambitious hybrid rice program that is targeting its farmers to be growing 600,000 hectares by 2005 (Aguiba 2003).

New plant type—foundation for higher-yielding rice plants

Parallel to the development of hybrid rice, IRRI and colleagues in national research programs have achieved another important success—the new plant type (NPT). With the NPT, the objective is to increase both the total biomass and the harvest index of the plant, which we hope will increase yield potential by about 20% over the current modern varieties. In yield trials, the top-performing tropical NPT line has produced 10.2 tons per hectare, which is very close to the best yields of any post-Green Revolution varieties.

NPT lines have been distributed via nurseries of the International Network for the Genetic Evaluation of Rice to interested countries. National program researchers are now evaluating—under local conditions—these very best lines. Three NPT varieties are outyielding popular modern varieties in farmers' fields by 1 ton per hectare in China.

The evidence accumulated by IRRI suggests that the yield barrier of 10 tons per hectare is probably a fundamental obstacle rooted in the bioenergetics of 100-day rice crops growing in the tropics. That is why it needs a radical solution and we believe that the NPTs will have a major part to play in breaking this yield barrier. The NPTs have many properties—mechanical strength to support higher yields and high leaf nitrogen content for building higher grain yields—that could make them part of the foundation of the higher-yielding lines of the future. The improved NPT lines have equal contributions from both the indica and japonica subspecies. This has resulted in a significant increase in genetic diversity of the elite breeding lines from IRRI. The NPT lines will be valuable parents for achieving higher heterosis in hybrid rice varieties.

Transferring C_4 maize genes to C_3 rice to save water and fertilizer

Leaving no stone unturned in the quest for a higher yield potential in rice, we are looking at the link among photosynthesis, yield, and radiation-use efficiency—or RUE. Some scientists have concluded that the upper yield limit of rice with its conventional photosynthetic pathway will go only halfway to the goal of increasing rice yield by 50% by 2050. Improved crop photosynthesis would then seem essential. One proposal for increasing rice's RUE is to incorporate the high C_4 photosynthetic capacity of a crop such as maize into rice, which is a less photosynthetically efficient C_3 cereal (Sheehy et al 2000).

Making the photosynthetic pathway of rice resemble that of maize would require a long-term genetic engineering project (10-15 years) to introduce genes for enzymes of the C_4 pathway and for leaf anatomy. If accomplished, the benefits would be enormous across the rice ecosystem spectrum. A C_4 rice plant would yield the same as a C_3 with half the transpirational water loss. It would also require significantly less N fertilizer, thus providing for a cleaner environment. In irrigated rice, yield potentials would rise significantly, enabling poor farmers to produce enough additional income to break out of that poverty trap.

In drought-prone ecosystems (rainfed lowland and upland rice), yields could be maintained or increased with less water and less fertilizer, especially when coupled with the predicted rising atmospheric concentration of carbon dioxide that is associated with future world climate change. Farmers living at the margins in these ecosystems would see improvements in yield and yield stability. It would be a revolution in rice farming.

Molecular breeding for dealing with complex traits

We have had great success in backcross breeding for simply-inherited traits. There are also tremendous amounts of "hidden" genetic diversity for many complex traits, particularly for yield and abiotic stress tolerances, in the primary gene pool of rice—much of which will be more easily "found" with the wealth of information coming out of the sequencing of the rice genome (Cantrell and Reeves 2002). The new International Network for Rice Molecular Breeding (INRMB)—devised by Zhikang Li, IRRI molecular geneticist who is based at the Chinese Academy of Agricultural Sciences—is attempting to fully exploit the genetic diversity in the germplasm collections preserved in rice gene banks by integrating gene discovery and allele mining with rice improvement.

The INRMB has a comprehensive strategy involving marker-aided and backcross breeding and improved phenotypic selection. We believe this strategy will contribute to discovering and exploiting the hidden diversity. Currently, large-scale gene/QTL discovery, allele mining (see next section), and marker-aided pyramiding of complex traits are in progress in China and at IRRI. By sharing this information and materials with participating national agricultural research and extension systems (NARES), the network will aid in the development of elite rice varieties in a shorter time than could be achieved through more conventional breeding approaches.

Allele mining for efficient use of natural variation

Regarding allele mining, we have set up an operation at IRRI's International Rice Genebank (Leung et al 2002). The bank contains more than 102,000 distinct accessions that carry a wide range of untapped traits for variety improvement. With the rice genome sequence available, we can begin to identify important loci after which we'll screen the genebank collection for novel alleles at those loci to find traits, for example, related to disease resistance. Here, the challenge is to find genes and mechanisms to provide broad-spectrum resistance to rice pathogens, such as blast and bacterial blight. This will benefit farmers by avoiding the boom and bust cycle caused by disease epidemics. Some promising results should be coming soon. For example, in the fight against blast, we have put together five known defense genes in a rice cultivar from China, and we are getting good resistance across locations, presumably because of resistance to multiple races of the pathogen.

Meeting the water crisis head-on with aerobic rice

To meet the water crisis head-on, valuable gains can be achieved by growing rice with less water. Traditionally, producing 1 kilogram of rice requires from 3,000 to 5,000 liters of freshwater. We need to develop a fundamental approach to reduce rice's water requirement significantly below this level. Why not create an "aerobic rice" that could be treated like other irrigated crops?

Although certainly easier said than done, we are confident that—within the next 4-5 years—we'll be able to develop an "aerobic" rice plant for the Asian tropics that grows similarly to rice plants being grown in irrigated upland rice fields in Brazil. An Aerobic Rice Working Group, involving breeders, physiologists, and water and soil scientists, are striving to overcome the many difficulties in taking rice out of its natural environment. By developing a completely new management system, the new aerobic rice should be able to yield 6 to 7 tons per hectare using only half the water!

Aerobic rice will also help close the yield gap in marginal rainfed environments as well. Our first results in the Philippines suggest that aerobic rice outperforms lowland rice under rainfed conditions. We hope to make similar inroads in the rainfed uplands.

Developing resilient varieties for drought-prone environments

In addition to aerobic rice, we are enhancing drought tolerance on other fronts. Our molecular geneticists and physiologists are producing an enormous amount of information—to develop resilient rice varieties for drought-prone environments. Over the next few years, we expect significant progress in our understanding of the genetic basis of variation in drought tolerance among rice varieties. We have developed novel introgression lines between drought-susceptible lowland cultivars and low-yielding but drought-tolerant upland varieties. We are using genomics and bioinformatics tools to identify the exact genes that confer this tolerance. Breeders will then use markers to locate these genes to improve drought tolerance in agronomically adapted varieties. We expect multiple genes and alleles to be important in different stress scenarios.

IRRI has developed a broad range of introgression stocks to be used for this gene discovery. Within the next few years, these products are expected to reveal key genes and superior alleles for breeders to use in improving yield under drought conditions. Recently, IRRI hosted a drought workshop during which invited specialists developed collaborative research agendas. Much of the new information on drought tolerance has been captured in a new IRRI book, *Breeding rice for drought-prone environments* (Fischer et al 2003).

Integrated pest management to protect the environment

Another technology that will maintain and even enhance yields while protecting the environment—and at the same time allow farmers to save their scarce and precious resources for other endeavors—involves integrated pest management. Hundreds of millions of farmers in Asia still overuse pesticides despite the emergence of viable alternative strategies for pest control. Not only do misapplied pesticides pollute the environment and threaten the health of farmers and their families, they set the stage for secondary pest infestations that can cause devastating crop losses (IRRI 2003c).

At IRRI, we've looked into patterns of insecticide use and found that spraying early in the crop cycle is unnecessary. Farmers often spray to eliminate visible leaf-feeding worms that don't cause yield loss. Worse—spraying disrupts the diverse ecology of the field, paving the way for pest infestations. So, our researchers came up with a way to motivate farmers to change their spraying practices.

A Vietnam study offers valuable lessons. We converted our findings into one simple rule: "Don't spray for the first 40 days." We launched a media campaign to deliver the message to farmers, stressing the cost savings and health benefits of reduced spraying. The result? In the test area of 21,000 households, after an 18-month interval, we recorded a 53% reduction in the number of insecticide applications—without affecting yields! Many farmers reduce input costs by US$30-50 per season—equal to a month's income in Vietnam. Underscoring the significance of this work, the project received the St. Andrews Prize for the Environment from Scotland's St. Andrews University in 2002 and the International Green Apple Environment Award from the U.K.-based Green Organization in 2003 (IRRI 2003c).

IRRI researchers and collaborators have achieved another notable IPM success in China's southwestern province of Yunnan. There—in what the *New York Times* called "one of the largest agricultural experiments ever (Yoon 2000)"—we found that intercropping rows of different varieties of rice can almost completely control devastating rice blast (Zhu et al 2000). Some farmers there were already using this technique, albeit in a haphazard way. We scientifically tested several variations of the concept and improved it.

Now we are disseminating our findings with confidence that the practice not only reduces farmers' reliance on chemical pesticides, thereby protecting the environment, but also improves yields and incomes to give farmers the options they need to break out of the poverty trap. Word-of-mouth is already leading to the technique's wide adoption in China.

Nutrient-use efficiency for intensive systems

New inroads into nutrient-use efficiency in intensive rice-farming systems will be making an impact soon. Collaborative research in the Irrigated Rice Research Consortium (www.irri.org/irrc/default.asp) has found that inefficient and unbalanced fertilizer use is widespread among Asia's rice farmers and millions of them may need to change their management practices and adopt new technologies to increase productivity and sustain the soil and water resource base. These changes promise substantial increases in their yields—and their incomes, which will, in turn, give them new options for the future!

An approach called site-specific nutrient management—or SSNM—is central to this effort. This tactic has been successfully tested over the last 6 years in more than 200 on-farm experiments across Asia. On average, farmers' yields and profits increased by 10 to 15% with improved nutrient management. We are simplifying and refining the concept together with researchers, extension personnel, and farmers in pilot villages in six Asian countries with supplemental support from the Potash and Phosphate Institute in Singapore.

We are disseminating information on SSNM through a comprehensive *Practical Guide* (Fairhurst and Witt 2002) and a new book that summarizes SSNM research conducted since 1994 (Dobermann et al 2004). We are also releasing training materials and software for a support system that is aiding farmers in making the right decisions regarding their nutrient applications.

Biofortification to boost rice's nutrient content

And finally, household food security is only truly achieved when—in addition to being available in sufficient quantity—the food is of ample quality as well. Although rice supplies adequate energy in the form of calories and is a good source of thiamine, riboflavin, and niacin (FAO 2003b), it is lacking as a source of vitamin A and other critical vitamins, iron, zinc, and other micronutrients and amino acids that are essential to human health, especially the health of children. We believe the nutrient content of rice can be improved substantially by using both traditional selective plant breeding and new biotechnology approaches.

IRRI is a major player in the CGIAR Challenge Program called Harvest Plus (www.harvestplus.org), which is seeking to reduce the effects of micronutrient malnutrition by harnessing the power of plant breeding to develop staple food crops that are rich in micronutrients, a process called biofortification. In this effort, rice will involve more scientists and research teams than any other crop. Swapan Datta, IRRI plant biotechnologist and the rice crop leader of Harvest Plus, has been active in research on enhancing micronutrient levels in rice through genetic engineering and leading the development at IRRI of tropical varieties of vitamin A-enriched Golden Rice (Datta et al 2003). It was only in early 2001 that the first seed samples were delivered to IRRI by Professor Ingo Potrykus, the German co-inventor of this genetically modified rice, which could save half a million children each year from irreversible blindness (Nash 2001).

Dr. Datta's team of scientists has bioengineered several Asian indica varieties with genes for beta-carotene biosynthesis. Selected lines—including genotypes of IR64—show expression of beta-carotene, the precursor of vitamin A (Datta et al 2003). Nonantibiotic and marker-free IR64 Golden Rice is now being evaluated in the IRRI greenhouse, which will be used for evaluating agronomic performance in 2004. Dr. Datta says that a long program of safety and bioavailability tests means that indica Golden Rice is still probably 4–6 years away from release to farmers.

Also, IRRI and its collaborators in Japan have introduced an iron-enhancing ferritin gene to indica rice in such a way that it expresses itself in the rice endosperm. Thus, after polishing, the rice grains contain three times more iron than usual (Vasconcelos et al 2003). Dr. Datta says this is the most significant increase in iron ever achieved in an indica rice variety and it could have significant benefits for the 3.5 billion people in the world who have iron-deficient diets.

The Roles of IRRI in the Genomics Era—Producing Knowledge Through New Technologies and Bringing the Benefits to the Poor

In conclusion, we want to point out that IRRI has special roles to play in bringing to the poor the benefits of many of the technologies we have just discussed. The sequencing of the rice genome, and then discovering the functions of individual genes and combining them to accelerate crop improvement, is revolutionizing rice science (Cantrell 2002). Our entry into this "Genomics Era" has fomented new interest in rice by the private sector. Critics fear that private ownership of portions of the rice genome will commercialize the crop in a way that subverts the right of farmers to grow the traditional varieties their ancestors developed over the millennia, as well as the improved varieties that publicly funded research institutions have bred and distributed as public goods over the past few decades. Insisting that rice must remain wholly within the public domain, they roundly condemn both private research and public-private research partnerships. But they are silent on the question of how cash-strapped public research institutions—such as IRRI—can maintain momentum without private-sector participation and the patents that corporations need to protect their investments. Wholly public ownership of the fruits of rice research would require steadfast commitment to public support for that research, which—sadly—is currently lacking (Cantrell 2002).

So, IRRI's roles as a producer of knowledge and a catalyst in technology development and transfer among various public institutions—and increasingly between the public and private sectors—are important as never before to assure strength in both sectors and that a balance is maintained (Leung et al 2002). For example, an approach we advocate is the formation of the International Rice Functional Genomics Consortium (www.iris.irri.org/IRFGC/) as a means to engage both developed and developing nations to contribute to the functional characterization of all agronomically important genes in rice. Active participation by developing countries will ensure access to the new science in the future.

As we have illustrated in this presentation, IRRI's key assets are a wealth of genetic resources and collective know-how across biological disciplines that are directly relevant to improving rice-based production systems, which will result in enhancing national and household food security and thus alleviating poverty across Asia and the Pacific. We have invested in research infrastructure to provide training and complementary support to our NARES research partners and have the technical expertise to be a strong research partner with advanced research institutions (ARIs).

IRRI has also adopted a policy on intellectual property rights that adheres to our principles and mission and, at the same time, allows us to collaborate widely with both the private and public sectors to bring in new science to benefit the poor. To capitalize on the advances being made in rice science research to which we devoted a large portion of this presentation, IRRI can serve as the unbiased "broker" between the rice improvement institutions in the developing world and the ARIs.

We are happy to use this forum—created by this FAO conference to celebrate the International Year of Rice—to get our important message across to this audience, which represents such a wide spectrum of interests. If you remember nothing else of what we've just discussed, please do remember how fittingly the IYR slogan "Rice Is Life" applies to Asia today and that, conversely, as we believe we have just illustrated, the Asia of the future has no life without rice.

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