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Rice Today

International Rice Research Institute
October-December 2006, Vol. 5, No. 4

International Rice Congress 2006
9-13 October

Perspectives on IR8
The rice that changed the world

Life, death, and rice at a time of war

Making rice waterproof

Farming for conservation

Rice in harm's way

Bold new vision
Lessons of the past help IRRI chart the way forward

ISSN 1655-5422

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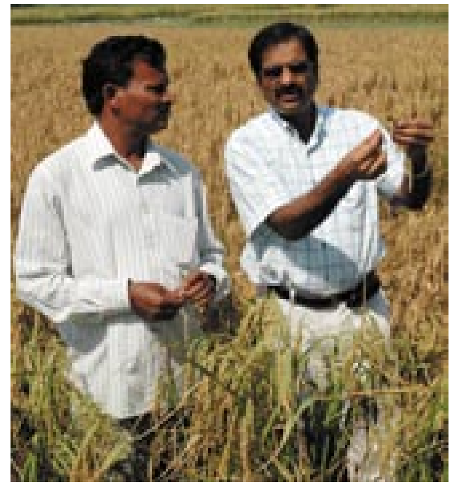

On the cover: An Indian farmer with a bumper IR8 harvest in 1967 (see pages 34-38).

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Rice Today is published by the International Rice Research Institute (IRRI), the world's leading international rice research and training center. Based in the Philippines and with offices in 14 other countries, IRRI is an autonomous, nonprofit institution focused on improving the well-being of present and future generations of rice farmers and consumers, particularly those with low incomes, while preserving natural resources. IRRI is one of 15 centers funded through the Consultative Group on International Agricultural Research (CGIAR), an association of public and private donor agencies. For more information, visit the CGIAR Web site (www.cgiar.org).

…But what has IRRI done for the world lately?

It was 40 years ago this 28 November that the International Rice Research Institute (IRRI) released a rice variety, under the name IR8. Some years later, the analogy was made that "IR8 was to tropical rice what the Model T Ford was to automobiles … a rugged variety that could go almost anywhere." In this issue (pages 34-38), former IRRI editor Tom Hargrove and former IRRI rice breeder Ronnie Coffman recount the fascinating story of the breeding of this variety that drastically changed the world food situation and initiated what is today called the Green Revolution.

Of course, this was four decades ago. As IRRI is rapidly approaching its 50th anniversary in 2010, some skeptics are asking, "But what has IRRI done for the world lately and has the Institute, perhaps, outlived its usefulness?" To answer that question, one need look no further than the 10 August 2006 issue of the prestigious journal *Nature* and pages 28-31 in this *Rice Today*. IRRI researchers, along with colleagues from the University of California (Riverside and Davis), have discovered a gene that confers submergence tolerance in rice. Rice breeders are already developing new varieties that can withstand severe flooding and have the potential to offer relief to millions of poor rice farmers around the world who must deal regularly with flooding in their fields.

If this and other recent successes—such as the breeding of rice with elevated iron content, which can help fight debilitating nutritional deficiencies—don't appease the critics, perhaps IRRI's plans for the future will. Unquestionably, IRRI's bold new Strategic Plan 2007-2015 spells out compelling reasons for the Institute's continued presence on the world stage beyond its 50th anniversary (see *Bringing hope, improving lives* on pages 10-15).

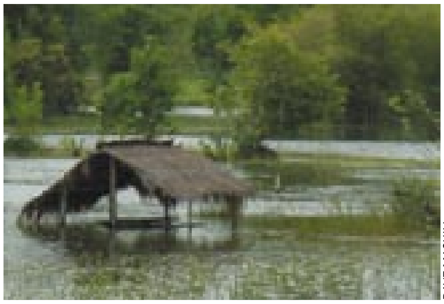
The world has changed enormously since IRRI developed its last strategic plan a decade ago. Recent scientific discoveries—particularly in genetics and genomics—have opened up new opportunities to achieve impact that would have been difficult if not impossible as recently as the turn of the century. A reduction in poverty and sustainability of the rice production environment, through the use of modern technology and the latest communication tools, are at the heart of IRRI's innovative Plan.

As part of the IRRI History Project, which is an element of our preparations for the 50th anniversary, I am collecting oral histories from IRRI "pioneers." One prevailing theme across more than a dozen interviews made at the recent IRRI Alumni Reunion (see page 9) was that their "IRRI experience" ranks ahead of anything else in their careers—either before or after their time at the Institute.

Dr. Nyle Brady, a spry octogenarian and IRRI's third director general (1973-81), summed up everyone's feelings when he stated: "I felt I was involved with a group of men and women who wanted to improve the lives of people. They were not there just to do research and write journal papers. They were there to solve problems." After observing IRRI now for more than 24 years myself, I could not agree more. This commitment of the IRRI staff was true in Dr. Brady's time, it is true now, and it will continue to be true as we carry out our new Plan in the decade to come.

Gene Hettel
Contributing editor

Flood-proof rice



DAVE MACKILL

A gene that enables rice to survive complete submergence has been identified by a team of researchers from the International Rice Research Institute (IRRI) and the University of California's Davis and Riverside campuses. The discovery allows for the development of new rice varieties that can withstand flooding, and that could offer relief to millions of poor rice farmers around the world. Flooding in Southeast Asia alone costs farmers an estimated US$1 billion each year.

Although rice thrives in standing water, like all crops it will die if completely submerged for more than a few days. The development and cultivation of the new varieties are expected to increase food security for 70 million of the world's poorest people. The study appeared in the 10 August issue of the journal *Nature*.

For more information, see *From genes to farmers' fields* on pages 28-31.

A more powerful and efficient engine for rice

A major international scientific effort was launched in July to develop and use a radical new approach to boost rice production and avoid potential rice shortages, or even future famine. Knowledge generated by the recent sequencing of the rice genome is offering new insights into the possibility of completely reconfiguring what's known as the engine of rice production, the plant's photosynthetic system.

IRRI crop ecologist John Sheehy, convener of a workshop on *C_4 Rice – Supercharging the Rice Engine*, held at IRRI on 17-21 July, said, "The photosynthetic process is the engine of growth for the rice plant. If we can improve that, the whole plant benefits."

To meet this challenge, scientists at the workshop focused on enhancing the rice plant's photosynthetic efficiency, or what's known scientifically as converting rice from a C_3 plant to a C_4 plant, where the "C" refers to the carbon captured by photosynthesis for growth. To do this, C_4 plants—such as maize—use solar energy more effectively for growth.

The experts at the workshop suggested that it will probably take another 3–4 years to achieve the proof-of-concept needed, and another 10–15 years after that before the first C_4 varieties would be available.

International rice industry to gather in India

The international rice industry is preparing to meet in India at a time of unprecedented change for the food that feeds almost half the planet.

Held every 4 years, the International Rice Congress (IRC) will bring together all aspects of the rice industry with a special focus on the latest research, science, and technology. Hosted by the Indian Ministry of Agriculture and co-sponsored by the Indian Council for Agricultural Research (ICAR) and IRRI, the IRC will be held in Delhi on 9-13 October and include three main events—the 26th International Rice Research Conference, the 2nd International Rice Commerce Conference, and the 2nd International Rice Technology and Cultural Exhibition.

According to Mangala Rai, secretary of India's Department of Agricultural Research and Education and ICAR director general, "The IRC2006 aims to provide a common platform for sharing knowledge and expertise on research, extension, production, processing, trade, consumption, and related activities with stakeholders."

GM rice turmoil

Small amounts of a genetically modified rice variety not approved for sale were detected in U.S. commercial supplies in August. The long-grain "LibertyLink" rice, developed by Bayer CropScience and known as LLRICE 601, possesses bacterial DNA that makes the rice plants resistant to the herbicide glufosinate. Two other strains of rice that produce the same transgenic protein as LLRICE 601 have previously been approved for sale. The U.S. Food and Drug Administration issued a statement declaring that "the presence of this bioengineered rice variety in the food and feed supply poses no food or feed safety concerns."

The discovery has hit the U.S. rice industry, with Japan banning imports of U.S. long-grain rice and Europe accepting only shipments that have been verified free of LLRICE 601 following a U.S. Department of Agriculture-approved test. Since the 18 August announcement of the contamination, prices for U.S. rice have dropped. Bayer is facing lawsuits from three U.S. rice-farming groups seeking damages to compensate farmers for falling prices.

PARK HYUNG-GEUN, RDA

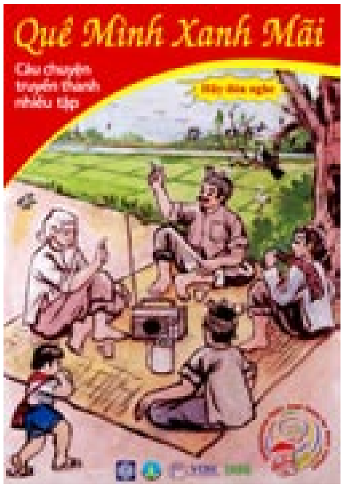
KOREAN AGRICULTURE CELEBRATES: Korea's Rural Development Administration (RDA) celebrates its 100th birthday this year. Established in 1906 in Suwon, the agency—then known as the Experiment Station for Agricultural Encouragement—has led Korea's modern agricultural research as well as disseminated technology and educated farmers. About 1,000 people participated in a 30 August–3 September celebration, *Korean agriculture—100 years and beyond*. Korean Minister of Agriculture and Forestry His Excellency Hong-Soo Park (*left*) and RDA Administrator In-Sik Kim (*right*) are seen here inspecting high-yielding rice cultivars developed by the RDA's National Institute of Crop Science. For more on the RDA, see *Donors corner* on page 47.

A greener rice industry

IRRI is working with the member countries of the Association of South East Asian Nations (ASEAN) to develop a series of five environmental indicators for rice production in the region. The indicators will focus on production, biodiversity, pollution, land degradation, and water.

When implemented, the indicators will allow each country to monitor and compare the environmental impact of its rice production with that of its neighbors, and either correct any problems or improve on existing practices. The project, launched in Hanoi on World Environment Day on June 2, will be the first to monitor the impact of agricultural production on such a large regional basis.

Also on 2 June, IRRI, in collaboration with the Ministry of Agriculture and Rural Development (MARD) of Vietnam and the World Bank, formally launched the Environmental Radio Soap Opera for Rural Vietnam. The new radio soap opera, Quê Mình Xanh Mãi (Forever Green Homeland), is aired on radio stations the Voice of Ho Chi Minh and the Voice of Can Tho. The 105 episodes feature daily struggles, joys, and loves in rural life, with environmental issues carefully weaved into the dialogue.



The project highlights the use of traditional communication media to educate farmers on environmental conservation principles and promote messages on issues such as pesticide and fertilizer use, pollution control, straw burning, water conservation, wildlife preservation, soil health, and natural biological controls.

Rice domesticated at least twice

The two subspecies of modern cultivated rice—*Oryza sativa* indica and *Oryza sativa* japonica—were domesticated independently in different parts of Asia. According to Barbara Schaal, a biology professor at Washington University in St. Louis, and her colleagues, indica arose south of the Himalayas in eastern India, Myanmar, or Thailand, and japonica was domesticated independently from a different wild rice gene pool in southern China.

Their report, "Phylogeography of Asian wild rice, *Oryza rufipogon*, reveals multiple independent domestications of cultivated rice, *Oryza sativa*," was published in the 20 June issue of the *Proceedings of the National Academy of Sciences*.

The domestication of rice from its wild ancestor *Oryza rufipogon* is thought to have started about 9,000 years ago, somewhere within an area spanning eastern India, Indochina, and parts of southern China. Schaal and her colleagues, Jason Londo, Yu-Chung Chiang, Kuo-Hsiang Hung, and Tzen-Yuh Chiang, looked at three genes shared by *O. rufipogon* and *O. sativa* and compared the genetic variation therein.

Vietnam export plan

The Vietnamese Ministry of Agriculture and Rural Development has released a 5-year development strategy aimed at producing at least 36 million tons of rice per year, with a minimum 4 million tons for export. Vietnam will develop several rice-exporting regions, including large areas in the Mekong and Red River deltas. The country will also invest in irrigation projects and storage facilities and encourage more efficient production methods. In 2006, Vietnam expects to harvest 38–39 million tons of paddy rice, 5 million tons of which are earmarked for export.

BRIEFLY

Bangladesh training online

The Bangladesh Rice Research Institute has launched a 3-day Web-based training course on *aman* (wet-season) rice production. Initially, extension workers from some 100 upazilas (subdistricts) will take the course, whose development was supported by the European Commission-funded Food Security for Sustainable Household Livelihoods (FoSHoL; www.foshol.org) project.

Salt-tolerant rice

Indian scientists have discovered a gene that allows rice to grow in extremely salty conditions. The researchers, from the Bose Institute's Centre for Plant Molecular and Cellular Genetics in Kolkata, cloned the gene from a wild rice variety that grows in the Sunderbans mangrove delta. They have transferred the gene into modern rice varieties as well as mustard and are testing the saline-resistant crops on an experimental farm. The team is awaiting U.S. and European patents.

Rice price to double?

The global rice price is likely to double within 2 years, according to Stephan Wrobel, chief executive officer at Diapason Commodities Management in Switzerland. According to a 14 August Bloomberg report, as major rice-producing countries such as China and Vietnam dig up their paddies to make room for urban developments, production will drop and prices will rise. Indeed, recent reports have suggested that increased demand in Asia is currently pushing prices upward.

Name change for IPGRI

From 1 December 2006, the International Plant Genetic Resources Institute will change its name to Bioversity International to better reflect the institute's strategy, which focuses on improving people's lives through biodiversity research.

Malaysia to curb imports

Malaysia plans to restructure its agricultural agencies to increase efficiency

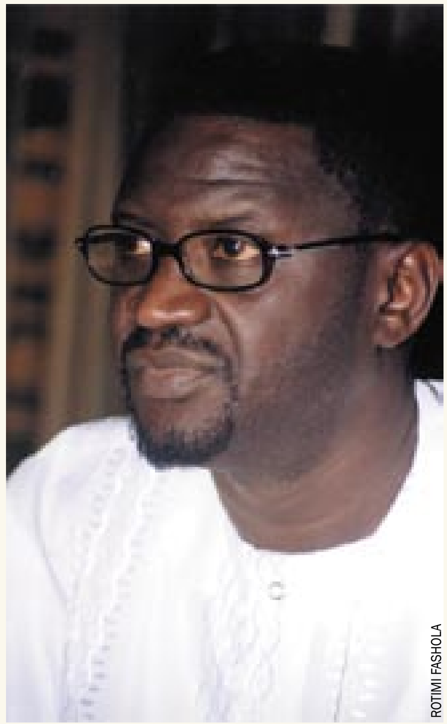
African rice news

New Africa rice leader

Papa Abdoulaye Seck of Senegal (*pictured right*) will succeed Kanayo Nwanze, whose second and final term ends in November, as director general of the Africa Rice Center (WARDA). His Excellency Adamu Bello, Honorable Minister for Agriculture and Natural Resources of the Federal Republic of Nigeria, in his capacity as the chair of the WARDA Council of Ministers, made the announcement at an extraordinary session of the WARDA Council on 22 June 2006 in Abuja, Nigeria.

At the time of the announcement, Dr. Seck was director general of the Senegal Agricultural Research Institute and adviser to the prime minister of Senegal. A member of the executive committee of the West and Central African Council for Research and Development and of the Global Forum on Agricultural Research, he also served as chair of the Forum for Agricultural Research in Africa.

Dr. Seck said, "One of my cherished dreams has been fulfilled: to be in a strategic position to serve Africa better.... My work at WARDA will be built on the pillars of transparency, equity, scientific excellence, strengthening of the national agricultural research systems, and an open-door policy towards all partners."



ROTIMI FASHOLA

Growing rice demand

The demand for rice in Africa, which accounts for 20% of world rice imports, is growing at around 6% per year. About 20 million farmers in sub-Saharan Africa grow rice, while about 100 million people depend on it for their livelihood, People's Daily Online reported. In 2004, some 13.2 million tons of rice were produced locally, while 5.9 million tons were imported from elsewhere, costing the sub-Saharan African region some US$1.2 billion.

Nigeria rice import ban

Nigeria's decision to ban rice imports from 2007 has been met with both enthusiasm and skepticism. Mike Ejemba, former secretary to the Presidential Rice Initiative Committee, warned that the government may be fined by the World Trade Organization (WTO) or have WTO benefits withdrawn. "If Nigeria is found guilty, she would lose substantial revenue in millions of dollars as penalty and legal bills," he said.

However, in an article entitled *Nigeria: the rice penalty*, published in *This Day* in Lagos on 28 July, writer Tayo Agunbiade hailed the move as part of an attempt to revive rice production for both local and international consumption and a positive step toward reforming and diversifying the nation's economy.

"Nigeria's ban on the importation of rice should in no way attract a fine or withdrawal of WTO benefits. On the contrary, the nation should be commended for taking a bold step towards addressing some of its domestic problems such as unemployment, and poverty, as well as promoting agricultural development and diversifying the foreign exchange earner base," Agunbiade said.

For a wrap-up of the recent Africa Rice Congress in Tanzania, see Putting rice on the African agenda *on pages 16-17.*

and productivity as well as upgrade drainage and irrigation systems in commercial paddy fields. The country aims to increase its rice production and reduce its imported-food bills. By 2009, all local paddy farmers will be required to plant high-yielding rice varieties. Malaysia, which imports from Thailand and Vietnam, had set a target to meet 90% of the local demand for rice in the next 5 years, up from the current 72%.

Rice as food aid

Rice made up 17% of global cereal food aid deliveries in 2005, according to a World Food Program report. Global cereal food aid deliveries totaled 7.1 million tons, which accounts for 86% of all food aid delivered. In 2005, slightly more rice food aid—1.2 million tons—was delivered than in 2004, but less than the 1.4 million tons delivered in 2002 and 2003.

Global food supplies at risk?

Climate change may put global food supplies at risk because rising carbon dioxide levels are unlikely to boost yields enough to compensate for factors such as higher ozone levels and drier conditions, according to a University of Illinois study published in *Science* magazine. The researchers used open-field tests to study how the world's main staples—corn, rice, sorghum, soybeans, and wheat—would grow under conditions projected for 2050. Results showed that crop yields were about half those drawn from similar earlier experiments conducted in enclosed test conditions.

Rice News Worldwide

IRRI
Rice News Worldwide

IRRI's Rice News Worldwide site provides links to a comprehensive list of the latest rice news stories. See for yourself at http://ricenews.irri.org.

Achievements

IRRI

HANK BEACHELL briefs visiting philanthropist John D. Rockefeller III on IR8 in 1967.

Henry "Hank" Beachell, one of IRRI's pioneer plant breeders who worked in the 1960s on the first high-yielding modern rice variety, IR8 (see *Breeding history* on pages 34-38), celebrated his 100th birthday on 21 September. Dr. Beachell, who joined IRRI in 1963, shared the 1996 World Food Prize with former IRRI senior breeder Gurdev Khush. According to his World Food Prize biography, "The economic magnitude of his achievement is in the multibillion dollar category; beyond this, billions of people are now better fed, enjoy better health, and have increased life expectancy, thanks to Dr. Beachell and his unexpected and exemplary efforts in rice breeding."

M.A. Salam, chief scientific officer and head of the Plant Breeding Division at the Bangladesh Rice Research Institute in Gazipur, has won the Senadhira Rice Research Award for 2006. Dr. Salam was honored for his outstanding contributions to the development of varieties for the rainfed lowlands of Bangladesh. The award honors the late Sri Lankan scientist **Dharmawansa Senadhira**, one of IRRI's most successful rice breeders, who tragically died in a traffic accident in Bangladesh in 1998.

Keijiro Otsuka, chair of IRRI's Board of Trustees, has been named president-elect of the International Association of Agricultural Economists. He is set to begin the role at the association's Beijing Conference in 2009.

Philippine National Scientist and IRRI consultant **Gelia Castillo** received an Honorary Doctor of Science (Rural Sociology) degree, *honoris causa*, from De La Salle University in Manila on 17 June. The university recognized Dr. Castillo's "outstanding contributions as a rural sociologist, and of her being the first social scientist to raise the level of research as a tool for development studies."

Deputy Director General for Operations and Support Services **William Padolina** has been appointed editor-in-chief of the prestigious *Philippine Journal of Science*, a technical journal on natural sciences, engineering, mathematics, and social sciences.

IRRI entomologist **K.L. Heong** was appointed adjunct professor of the Fujian Agriculture and Forestry University (FAFU) on 13 August. Dr. Heong—pictured (*below left*) receiving the appointment certificate from FAFU Vice President and Fujian Academy of Agricultural Sciences President **You Minsheng**, with the Wuyi Shan (mountains) in the background—was also announced winner of the Academy of Sciences for the Developing World Prize in Agricultural Sciences 2006.

FAFU

Glenn Gregorio and **Dante Adorada** of IRRI's Plant Breeding, Genetics, and Biotechnology Division, and **Cristina Sison**, former IRRI nutritionist, shared the 2006 Philippine Agriculture and Resources Research Foundation, Inc. Research and Development Award (research category) with **Angelita del Mundo** and **Angelina Felix** of the University of the Philippines Los Baños College of Human Ecology, **Jere Haas** of Cornell University, and **John Beard** and **Laura Murray-Kolb** of Pennsylvania State University, USA. Their winning paper was entitled *Rice biofortification as a viable approach towards improved human nutrition*.

Scientists **Roland Buresh** and **Mirasol Pampolino** of IRRI's Crop and Environmental Sciences Division received awards from the Philippine Society of Soil Science and Technology, 1-2 June 2006, during the 9th Annual Meeting and Scientific Symposium of the society at Central Luzon State University.

Keeping up with IRRI staff

Noel Magor, former IRRI representative in Bangladesh, is returning to the Institute's Philippine headquarters to head the Training Center. He is scheduled to begin on 3 October. Interim Training Center Head **David Shires** will return to his position as a curriculum adviser and trainer.

Former IRRI Operations Management Head **Joe Rickman** moved to Mozambique in September to head the new IRRI Africa office. Another Australian, **Terry Jacobsen**, arrived in August to take over as the new head of operations management.

Gary Atlin, senior scientist in Plant Breeding, Genetics, and Biotechnology (PBGB), leaves IRRI to take up a position at IRRI's sister institute in Mexico, the International Maize and Wheat Improvement Center.

Senior IRRI agronomist **Vethaiya Balasubramanian** has retired and plans to return to India, where he will teach at Tamil Nadu Agricultural University (see *The quiet achiever* on pages 32-33).

Jill Cairns, formerly a postdoctoral fellow in the Crop and Environmental Sciences Division, has been appointed international research fellow, working on drought tolerance in rice.

Agricultural economist **Kei Kajisa** joined the Social Sciences Division.

2006 IRRI reunion brings together past, present, and future

More than 150 people (former and present staff and families) attended the 2006 IRRI Alumni Reunion on the campus of the University of California-Davis in Davis, California, 23-25 June. The program encouraged great fellowship through a barrio fiesta on Friday evening and a Saturday scientific symposium, followed by a tour of rice fields and farms in this region of California, which is the second-largest rice-producing state in the U.S. after Arkansas.

FORMER directors general Klaus Lampe (*left*) and Nyle Brady contributed their recollections for the IRRI History Project.

During the fiesta, Davis Mayor Ruth Asmundson (who had visited IRRI earlier in 2006 and is a Los Baños native) made honorary citizens of all the IRRI alumni in attendance. During the Saturday symposium, Duncan Macintosh, IRRI spokesperson and head of Visitors and Information Services, brought the group up to date on IRRI's new strategic plan and recent events and discussed how the large IRRI alumni contingent in the U.S. can keep in better touch with the Institute.

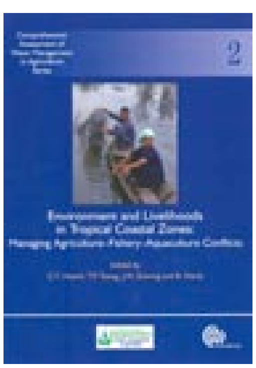
As part of the IRRI History Project, which is an element of preparations for the 50th anniversary, Gene Hettel, head of IRRI's Communication and Publications Services, interviewed (on video tape) IRRI pioneers in attendance, including former directors general Nyle Brady (1973-81) and Klaus Lampe (1988-95). IRRI history was a running theme throughout the event and historical material, including photos and video footage shown there, can now be seen at www.irri.org/about/history.asp.

AURORA HETTEL (2)

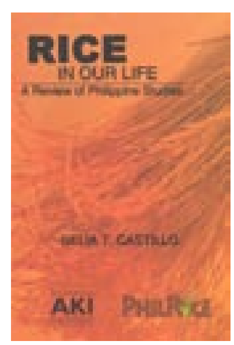
JUST BEFORE the IRRI reunion, on 22 June 2006 in Sacramento, California, Gene Hettel, head of IRRI's Communication and Publications Services, presented to Mrs. Liz Havener a 1/4-size duplicate plaque of the original that names the auditorium in IRRI's Chandler Hall in memory of Robert Havener, who served as interim director general in 1998 and who passed away in August 2005.

Books

Environment and Livelihoods in Tropical Coastal Zones: Managing Agriculture-Fishery-Aquaculture Conflicts (edited by C.T. Hoanh, T.P. Tuong, J.W. Gowing, and B. Hardy; co-published by CAB International, International Water Management Institute [IWMI], and IRRI; 309 pages). This book focuses on the challenges people face in managing agricultural crops, aquaculture, fisheries, and related ecosystems in inland areas of coastal zones in the tropics of Asia, Africa, Australia, and South America. These challenges can create conflicts in the use of natural resources between different stakeholders. Through many case studies, the authors discuss the nature of the conflicts and identify what is known and not known about how to manage them. For example, some case studies relate to the trade-offs between enhancing agricultural production by constructing embankments to keep out saline water and maintaining not only the variety of rural livelihoods but also brackish aquatic biodiversity. Other case studies provide the lessons learned from the conversion of mangrove forests to shrimp farms. For a copy, go to www.cabi-publishing.org.



Rice in Our Life: A Review of Philippine Studies (by Gelia T. Castillo; co-published by De La Salle University's Angelo King Institute for Economic and Business Studies and the Philippine Rice Research Institute; 182 pages). According to the *Philippine Daily Inquirer*, Dr. Castillo, eminent rural sociologist and Philippine National Scientist, has written "what's probably the most lucid summary of scientific studies, over the past 30 years, on a cereal that can make or break presidents." In a delightful prose style, she highlights the remarkable changes in the past three decades in the Philippine rice economy and society. For example, she writes, "The integrity of rice science deserves to be respected so the culture of rice will rise above the culture of politics. Whether rich or poor, in a very unequal society like ours, rice is the one thing we have in common." She points out that rice farming now relies more on hired labor than on family labor. Rice-farming households are increasingly less reliant on rice farming for household income, which indicates that some members of those households are earning income from other sources. Purchasing information: contact Dr. Ponciano Intal, Jr., De La Salle University, 10th Floor, DLSU-CSB-Angelo King International Center, Arellano Avenue corner Estrada St., Malate, Manila 1004, Philippines.



Bringing hope, improving lives

by Jay Maclean and Gene Hettel

Rice feeds roughly half the planet's population and approximately three-quarters of a billion of the world's poorest people depend on the staple to survive. A carefully focused agenda for continued research on this vital crop is as important as ever.

ARIEL JAVELLANA

PETER FREDENBURG

If all goes as planned, in 2010—while the International Rice Research Institute (IRRI) is celebrating its 50th anniversary—the initiatives spelled out in the Institute's new Strategic Plan (the Plan) will already be starting to have impact. IRRI titled the Plan *Bringing hope, improving lives*, as that is precisely what the Institute hopes to do for rice producers and consumers around the world.

The Plan, to be officially unveiled by IRRI Director General Robert Zeigler during International Rice Congress 2006 in New Delhi on 9 October, is also designed to enable IRRI to do its part in helping partners and nations across the globe to reach the United Nations Millennium Development Goals (MDGs) by 2015.

Developing the Plan took nearly 12 months. IRRI consulted widely among its partners and stakeholders and sought expert guidance throughout. Says Dr. Zeigler, "During these deliberations, we concluded that the MDGs related to hunger, poverty, environmental sustainability, and nutrition and health formed a sound basis and direction for IRRI's future activities. So, we developed five strategic goals (see page 12) and seven research programs (see page 11) to achieve them to reflect this thinking."

Achieving IRRI's first goal—*Reduce poverty through improved and diversified rice-based systems*—will take the Institute beyond its traditional focus on rice production (increasing productivity or "filling the rice bowl"), which required an emphasis on favorable irrigated areas, to "filling the purse," a major effort to improve farmers' incomes in unfavorable rainfed areas. Nevertheless, rice supplies will need to remain plentiful to provide reliable food that even the poorest can afford. In Southeast Asia, South Asia, and sub-Saharan Africa, rice consumption in 2015 is projected to be, respectively, 9 million tons (11%), 14.9 million tons (13%), and 6.8 million tons (52%) above 2005 levels (for more details, see *Rice facts* on pages 48-49).

"This means relatively less research emphasis for IRRI on yield gains for irrigated rice—for which there is now strong capacity among the national agricultural research and extension systems (NARES), particularly in Asia," says Ren Wang, IRRI's deputy director general for research. "Instead, IRRI's focus on intensive production systems will shift more to sustainability. In addition, by targeting the MDG on eliminating extreme hunger and poverty as our first strategic goal, we are opening profound new opportunities for IRRI to improve the economic and social well-being of poor rice consumers and farmers."

"Rainfed areas coincide to a large extent with regions of severe and extensive poverty where rice is the principal source of staple food, employment, and income for the rural population," says Mahabub Hossain, interim leader of the new program on *Raising productivity in rainfed environments: attacking the roots of poverty* (see map on page 13).

Up to now, success has been limited in increasing productivity in rainfed rice ecosystems—home to 80 million farmers on 60 million hectares. Rice yields in these ecosystems remain low at 1.0 to 2.5 tons per hectare and tend to be variable due to erratic monsoons. Poor people in these ecosystems often lack the capacity to acquire food, even at lower prices, because of poor harvests and limited employment opportunities elsewhere.

Recent research successes have underscored the potential for improvements in the rainfed area. For example, a team of researchers from IRRI and the University of California have identified a gene that helps rice survive prolonged flooding, and which will allow breeders to develop new submergence-tolerant rice varieties (see *From genes to farmers' fields* on pages 28-31).

IRRI's new programs

1. Raising productivity in rainfed environments: attacking the roots of poverty
2. Sustaining productivity in intensive rice-based systems: rice and the environment
3. East and Southern Africa: rice for rural incomes and an affordable urban staple
4. Rice and human health: overcoming the consequences of poverty
5. Rice genetic diversity and discovery: meeting the needs of future generations for rice genetic resources
6. Information and communication: convening a global rice research community
7. Rice policy support and impact assessment for rice research

"Our primary objective will be to enhance household food security and income in these rainfed areas of Asia," says Dr. Hossain. "With rapid advances in genetics and genomics, the chances of developing high-yielding, drought- and flood-tolerant varieties for the rainfed system—and, consequently, helping farmers to diversify their farming systems and thus their income—are much greater now than ever before."

Sub-Saharan Africa is now one of the world's major poverty zones and

AILEEN RONDILLA

The relationship between IRRI's new strategic goals and the Millennium Development Goals

IRRI strategic goals	Millennium Development Goals 1	2	3	4	5	6	7	8
Goal 1: Reduce poverty through improved and diversified rice-based systems	Direct	Direct	Indirect	Indirect	Indirect	Indirect	Indirect	Indirect
Goal 2: Ensure that rice production is sustainable and stable, has minimal negative environmental impact, and can cope with climate change	Indirect	Indirect	Indirect				Direct	Indirect
Goal 3: Improve the nutrition and health of poor rice consumers and rice farmers	Indirect		Indirect	Direct	Direct	Direct		Indirect
Goal 4: Provide equitable access to information and knowledge on rice and help develop the next generation of rice scientists	Indirect	Indirect	Direct	Indirect	Indirect	Indirect	Indirect	Direct
Goal 5: Provide rice scientists and producers with the genetic information and material they need to develop improved technologies and enhance rice production	Direct			Indirect	Indirect		Direct	Indirect

Direct: A direct contribution toward achieving the MDGs
Indirect: An indirect contribution toward achieving the MDGs

The United Nations Millennium Development Goals

The goals provide a focus for global efforts to meet the needs of the world's poorest people. IRRI's new strategic plan ensures the Institute will do its part in achieving them.

1. **Eradicate extreme poverty and hunger**
2. **Achieve universal primary education**
3. **Promote gender equality and empower women**
4. **Reduce child mortality**
5. **Improve maternal health**
6. **Combat HIV/AIDS, malaria, and other diseases**
7. **Ensure environmental sustainability**
8. **Develop a global partnership for development**

Goal 1 targets this vast region as well.

"About 130 million people in East and Southern Africa (ESA) live in extreme poverty and more than 85% of these depend on agriculture," says Joseph Rickman, interim leader of the new program on *East and Southern Africa: rice for rural incomes and an affordable urban staple*. A large number of these people are rice consumers and many are small rice producers. A significant investment in agriculture is critical to eradicate hunger and poverty in ESA.

"Rural poverty in ESA could be significantly reduced if the efficiency of local rice production were improved in the key rice-growing areas of Kenya, Mozambique, Tanzania, and Uganda," says Rickman. "Our research agenda here will also focus on enhancing small farmers' access and linkage to markets. We will collaborate closely with the Africa Rice Center (WARDA), the national programs, and advanced research institutes to capitalize on both the existing knowledge within the countries and the available international expertise."

It is critical that the stability and productivity of rice agroecosystems in Asia and Africa not be taken for granted and that their use by future generations not be jeopardized. "That is why our second goal is to *Ensure that rice production is sustainable and stable, has minimal negative environmental impact, and can cope with climate change*," says Dr. Zeigler.

Rice-growing areas are among the world's most enduring, environmentally sound, and productive agroecosystems, and increased rice production in recent decades has had a significant impact on poverty reduction.

"Rice ecosystems provide basic commodities and regulatory services, including nutrient and water cycling, and biological control to reduce pest and disease outbreaks," says David Johnson, interim leader of the new program *Sustaining productivity in intensive rice-based systems: rice and the environment*. Poor people often depend on these "ecosystem services" to provide their needs as they are often without infrastructure to obtain clean water, food, and fuel. Environmental sustainability and ecosystem services are threatened,

IRRI has staff based in 14 countries

- The Philippines (headquarters)
- Bangladesh
- Cambodia
- China
- India
- Indonesia
- Korea
- Lao PDR
- Myanmar
- Nepal
- Nigeria (IRRI–Africa Rice Center liaison)
- Mozambique
- Thailand
- Vietnam

however, by the loss of biodiversity, climate change, and inappropriate management systems often due to land, water, or labor shortages.

"Strategies are urgently needed to preserve the natural resource base while improving productivity in rice agroecosystems in the face of changing physical and socioeconomic environments," says Dr. Johnson. "IRRI will focus on land management, biodiversity, water availability and productivity, and the impact of climate change to develop and promote technologies and options to sustain rice-producing environments."


IRRI

Nutritional deficiencies, especially in women and children in both Asia and Africa, often go hand in hand with extreme poverty because poverty is a major factor limiting diversity in the diet. "Hence, our third goal is to *Improve the nutrition and health of poor rice consumers and rice farmers*," says Dr. Zeigler. Reliance on a single staple, such as polished rice, does not provide the requisite suite of minerals and vitamins necessary for healthy growth and development and leads to widespread nutritional deficiency in many of the 1.2 billion people in Asia and sub-Saharan Africa living in extreme poverty.

Gerard Barry is the interim leader of the new program *Rice and human health: overcoming the consequences of poverty*, which will bring together the multiple rice biofortification projects (including the HarvestPlus Challenge Program—see *Breeding for nutrition* on pages 24-26 of *Rice Today* Vol. 2, No. 2) and other health-related efforts that already investigate germplasm, farm practices, and policy options.

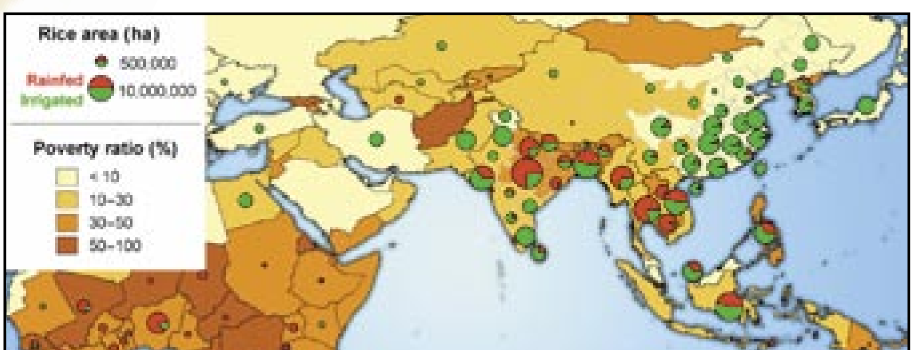
Underpinning maximum success in meeting many of the MDGs is the need to solve the widespread problems of health and nutrition that debilitate people and hinder economic growth. Poor nutrition is manifested in invisible nutritional deficiencies (hidden hunger) and in malnutrition (visible hunger). "In addition," says Dr. Barry, "poor health in the context of rice cultivation may be related to chronic and infectious diseases from water and from vectors such as rodents and mosquitoes, as well as illness attributed to the improper handling of farm chemicals."

For much of the work in this program, the delivery chain includes partners in NARES for the co-development and deployment of germplasm (seeds and the genetic material they contain) and agricultural practices. However, IRRI will greatly expand its interactions with the public health sector in developing countries, for both policy and delivery effectiveness.

"This process has already begun in the Golden Rice Network for India and the Philippines and this will serve as a model for other products," explains Dr. Barry. "The existing structures in the Golden Rice Network and in HarvestPlus have already brought together many of the relevant national and regional institutions needed for impact."

Developments that will affect all of the efforts mentioned so far are the rapidly increasing availability and affordability of information and communication technology, such as the Internet, mobile phones, and powerful computers. These new technologies have created important opportunities to allow people with common interests to form communities, communicate, and collaborate.

"They have also raised new obligations for IRRI to curate, exchange, and share not only its own body of information, data,



POVERTY AND RICE distribution and irrigation by country, and subdivisions for China and India. The size of the pie diagram is scaled (not linear) to the total rice area in a country. There is a clear relationship between the prevalence of rainfed rice and the level of poverty.

ARIEL JAVELLANA

and experience but also that of the world's knowledge about rice in all its forms," says Dr. Zeigler. "This will not only enhance global rice research efforts but also empower developing-country rice scientists with state-of-the-art information and knowledge and their associated tools. So, our fourth goal is to *Provide equitable access to information and knowledge on rice and help develop the next generation of rice scientists*."

According to Graham McLaren, interim leader of the new program *Information and communication: convening a global rice research community*, this effort will build on many global investments in information and technology within and outside IRRI's parent organization, the Consultative Group on International Agricultural Research (CGIAR).

"Through this program, we are formally attempting to consolidate all IRRI research and development on information and communication technology for rice science and extension under a single coordinated activity," says Dr. McLaren. "We plan to place bioinformatics and communication tools directly in the hands of crop scientists, extension agents, and farmers to deliver impact through two major pathways, which will enhance the capacity of IRRI's six other research programs to deliver impact more effectively.

"The first pathway is Internet dissemination via a World Rice Community Portal of restructured and cross-linked information on crop science and extension. The second pathway is direct engagement of science and extension communities using current communication technologies, both new, such as Web portals, videoconferencing, and cell phones, and traditional, such as radio and television."

Another ingredient in the mix that will continue to contribute to the impact of IRRI's research agenda is the rice germplasm it has assembled over nearly half a century. "IRRI now maintains, on behalf of humanity, the world's most complete and diverse collection of rice germplasm," says Dr. Zeigler, "and this leads to our fifth and final goal, to *Provide rice scientists and producers with the genetic information and material they need to develop improved technologies and enhance rice production*."

According to Hei Leung, interim leader of the new program *Rice genetic diversity and discovery: meeting the needs of future generations for rice genetic resources*, there are still significant gaps in IRRI's germplasm collection and, despite the advanced state of knowledge of the rice genome, information is scant on what diversity of genes exists within the rice gene pool, what these genes do, and how they may help meet the needs of rice producers and users. Meanwhile, genetic erosion in the field continues.

"We expect a greater demand for specific genetic resources to address production and environmental problems in the future," says Dr. Leung. "This will translate into a greater demand for the genetic knowledge and tools that are needed to identify and use resources that meet specific needs."

Through genomics (the science of discovering genetic structure, variation, and function, and the interrelationships among these), genetic knowledge can now be integrated across species, leading to accelerated discovery of gene functions. Furthermore, genome-wide analysis has the potential to reveal new insights about genetic pathways, and create new opportunities to meet both anticipated and unforeseen challenges.

"Bringing together germplasm conservation, diversity analysis, and gene discovery under this single program," says Dr. Leung, "presents a unique opportunity to maximize the utility of conserved and customized germplasm. This program will offer a comprehensive, well-documented germplasm base, a public research platform to enable gene identification, and genetic knowledge for priority traits. Building on the investments and achievements made in germplasm characterization, functional genomics, and bioinformatics, IRRI is poised to play a major role in gene function discovery, applications of genetic knowledge, and conservation and sharing of genetic resources."

The last new program, which will be critical to achieving the five Plan goals, is *Rice policy support and impact assessment for rice research*. According to Dr. Zeigler, the impact of rice research on poverty reduction and environmental sustainability depends on policies and appropriate technologies that address farmers' livelihood needs.

"To effectively set research priorities, we must understand the broad trends in socioeconomic and policy environments that affect the economics of rice production," he says. "This involves analyzing trends in rice production and consumption at national and subnational levels and shifts in comparative advantages in rice production relative to other crops across regions and ecosystems."

According to interim program leader Sushil Pandey, IRRI aims to provide sound advice to policymakers, research managers, and donors regarding research priorities and the design of agricultural interventions through policy analyses, livelihood studies, and impact assessments focused on rice-based systems of Asia.

"By making regional comparisons of rice economies and associated livelihoods, the program will help produce a global view of the drivers of change and their impacts," says Dr. Pandey. "In addition, we will develop research approaches and tools that will have wider application for policy research and impact analysis." We will also closely partner with NARES to help build their capacity for broader socioeconomic and policy analyses of the agricultural sector. NARES, sister CGIAR centers, and advanced research institutes will all have key collaborative roles in the program."

JON NASO/THE STAR-LEDGER

IRRI's new Frontier Projects

Drought and productivity in unfavorable rice environments

Recent IRRI research has shown that the drought tolerance trait is strongly influenced by genes and gene networks with large effects. This project will scale up their detection, analysis, and delivery for use in marker-aided breeding. By incorporating genes for this trait from rice and other species into widely grown rice varieties, technologies can be developed with national agricultural research systems and provided to farmers to enhance and stabilize their rice yields and income. (See *Diagnosing drought* on page 32 of *Rice Today* Vol. 5, No. 3.)

Climate change and sustainability

Climate change brings new problems for the sustainability of rice production. Further, changes in air quality and composition, acid rain, and Asian "brown" clouds will produce a new bio-climate for food production systems. Rice cultivation is often viewed as a contributor to climate change through the production of greenhouse gases. Given the essential role of rice in the food system, solutions must be sought that not only minimize the impact of rice production on the environment but also sustain productivity and environmental quality. Strong science will decipher the causes and effects involved, improve germplasm adaptation to expected future climatic conditions, and mitigate the negative effect of agriculture on climate. (See *Climate change initiative ramps up* on page 5 of *Rice Today* Vol. 5, No. 3.)

A much more productive and efficient rice plant

Plants like maize and sorghum have a more efficient photosynthetic mechanism (called C_4) for converting energy to biomass than rice (a so-called C_3 plant). C_4 plants are also more efficient in nitrogen and water use, and are generally more tolerant of high temperatures. Genomic sciences and comparative biology may be able to break the yield ceiling of rice and enhance its water- and nitrogen-use efficiency by changing the photosynthetic mechanism in rice to that of the more efficient plants. IRRI has formed a C_4 rice consortium of scientists from both advanced research institutes and developing countries to chart and conduct research to develop a C_4 rice plant. (See *A more powerful and efficient engine for rice* on page 5.)

IRRI has a 46-year history of investing in visionary "frontier" research—research that, when successful, has revolutionized agriculture. The original frontier project was none other than the incorporation of semidwarf genes to create the modern high-yielding varieties that began with the release of IR8 40 years ago and spurred the Green Revolution in rice. (See *Breeding history* on pages 34-38.)

Three new Frontier Projects, involving work on drought tolerance, climate change, and producing a more productive and efficient rice plant (see *IRRI's new Frontier Projects*, above), are intended to accentuate the Institute's commitment to achieving its new goals. Says Dr. Wang, "They will constitute novel and focused research on problems of strategic importance to future rice production and the environment. The projects will be undertaken by multi-institutional, international research teams, and we expect that significant portions of the research will be conducted at collaborating institutions in both developed and developing countries."

Jay Maclean is a freelance writer and information specialist with more than 30 years' experience in agriculture and fisheries.

Complete details of IRRI's exciting Strategic Plan 2007-2015, Bringing hope, improving lives, are available online in pdf format at www.irri.org/bringinghope/improvinglives.pdf. Hard copies are available upon request from the office of IRRI's Director for Program Planning and Communications at dppc-irri@cgiar.org or DAPO Box 7777, Metro Manila, Philippines. IRRI's Medium-Term Plan, 2007-09, which provides details on the seven research programs for the first 3-year period of the Strategic Plan, is available online at www.irri.org/mtp2007-09.

PARTICIPANTS at the Africa Rice Congress included (*front*) Josephine Maseruka, a journalist from New Vision, Uganda; (*second row, left to right*) Mpoko Bokanga from the African Agricultural Technology Foundation, Kenya, and rice breeder Susan McCouch from Cornell University, USA; (*third row, left to right*) Yousouf Dembele, Leonard Ouedraogo, Thio Bouma, and Ibrahim Ouedraogo, all from the Institut de l'environnement et des recherches agricoles, Burkina Faso.

PAPA ABDOULAYE SECK (*left*), who is set to become director general of WARDA in November 2006, prepares to speak while WARDA entomologist Francis Nwilene (*center*) and IRRI agronomist Vethaiya Balasubramanian assist.

ROTIMI FASHOLA (3)

Putting rice on the African agenda

by Savitri Mohapatra

The recent Africa Rice Congress in Tanzania helped chart the course for the future of the rice industry in sub-Saharan Africa

Rice was one of the cornerstones of the Asian Green Revolution. Will it play a similar role in sub-Saharan Africa (SSA)? Participants at the Africa Rice Congress in Dar es Salaam, Tanzania, on 31 July–4 August 2006, urged African governments to recognize the strategic role of rice and urgently put in place policies and infrastructure to transform the rice sector in the region.

The first of its kind in SSA, the Congress brought together more than 200 participants, including national and international rice scientists, policymakers, economists, international nongovernmental organizations, representatives from rice networks in West and East Africa, farmers' associations, the private sector, the donor community, and media. The main purpose of the Congress was to chart the way forward for rice research and development in SSA.

Rice is of significant importance to food security in many African countries. Although per capita rice consumption in some Asian nations is declining, it is growing rapidly in most countries in SSA. Annual demand for rice in SSA is increasing by 6% per year, fueled by rapid population growth and changes in consumer preferences.

VICKY NTETEMA, BBC Bureau Chief in Dar es Salaam, Tanzania, interviews a Tanzanian rice farmer during the Africa Rice Congress.

Although rice production in SSA rose from 6.2 million tons of paddy (unhulled) rice in 1980 to 12.6 million tons in 2005, it has not been able to keep pace with increasing demand. As a result, the quantity of rice imported yearly by the region increased from 2.5 million tons in 1980 to 7.2 million tons in 2005. Rice imports cover more than 45% of SSA's consumption and represent a third of world rice imports.

Since only 4–6% of world rice output is subject to trade, Aliou Diagne, impact assessment economist from the Africa Rice Center (WARDA), cautioned that SSA would be ill advised to rely on this relatively "thin" world rice market for its growing rice demand. "SSA should urgently review its rice import policy to avoid a crisis in the near future," he said at the Congress.

Dr. Diagne emphasized the need for African smallholder farmers to get a more level playing field to access markets, inputs, and credit. "While SSA's 36 million farmers scrape a living out of rice farming in a liberalized market, Asian and American rice farmers are highly supported by their governments," he said.

Confirming the vital need for government support to the rice sector, World Food Prize Laureate and former International Rice Research Institute (IRRI) principal breeder Gurdev Khush said that the development of high-yielding varieties alone could not have provided the boost in rice production that led to India's Green Revolution in the 1960s.

"It was a combination of success factors that included the government's decision to support its rice farmers by providing a fertilizer subsidy, price support, and a ready market, in addition to irrigation, roads, and machinery," said Dr. Khush.

The Congress participants acclaimed the achievements of WARDA's partnership-based research, especially its New Rice for Africa (NERICA) varieties. "We are just witnessing the beginning of the NERICA revolution in Africa," stated Keijiro Otsuka, chair of IRRI's Board of Trustees. Discussions began on the development of next-generation NERICAs.

The need to strengthen the capacity of human resources of the whole range of rice stakeholders—from researchers to extension workers, farmers, and processors—was underscored.

A Committee of Eminent Persons comprising mainly the keynote speakers at the Congress provided overall guidance to the discussions on some of the critical issues relating to rice research and development in SSA.

The committee included Dr. Khush; Ruth Oniang'o, member of parliament, Kenya; Eric Tollens, Catholic University of Leuven, Belgium; Susan McCouch, Cornell University, USA; Marco Quinones, Africa director of Sasakawa-Global 2000; Toshiyuki Wakatsuki, Kinki University, Japan; Prof. Otsuka; Oumar Niangado, Syngenta Foundation, Mali; Mpoko Bokanga, African Agricultural Technology Foundation, Kenya; Kallunde Sibuga, Sokoine University, Tanzania; and Richard Musangi, Kenya.

The Congress was organized by WARDA, in association with the West and Central Africa Rice Research and Development Network and the East and Central Africa Rice Research Network, under the aegis of the Tanzanian Ministry of Agriculture, Food, and Cooperatives. Sponsors were the U.S. Agency for International Development, the Canadian Fund for Africa, the Sasakawa Africa Association, the West and Central African Council for Agricultural Research and Development, the Association for Strengthening Agricultural Research in Eastern and Central Africa, the European Union, and the Rockefeller Foundation.

The first Congressional Honor was bestowed on Kanayo F. Nwanze, in recognition of his outstanding contribution to rice research and development in Africa during his term as WARDA director general from 1996 to 2006.

Savitri Mohapatra is head of communications at the Africa Rice Center (WARDA).

Resolutions of the first Africa Rice Congress

- Given that Africa has to import almost 50% of the rice it needs and that demand is increasing at the rate of 6% per year, rice should be one of the cornerstones of a Green Revolution for Africa that anticipates the needs of future populations.
- Transform the low level of available scientific expertise in sub-Saharan Africa, where there are only 83 scientists per million people, compared with 1,100 scientists per million in industrialized countries and 785 per million in Asia. The Congress resolves that for the Green Revolution to succeed in Africa, a new capacity-building program focusing on the development of a multidisciplinary cadre of scientists and extensionists is urgently needed.
- To accelerate farmer adoption of New Rice for Africa (NERICA) varieties and other improved technologies, concerted actions by a broad partnership including governments, research institutions, the private sector, and local, regional, international, and nongovernmental organizations are needed. The Congress recognizes the value of micro-financing and participatory learning as powerful means both for technology dissemination and for developing appropriate infrastructure to improve access to seeds, fertilizer, mechanization, and market systems.
- The Congress is deeply appreciative of the support and hospitality of the government of the United Republic of Tanzania. It recognizes the role played by the Africa Rice Center (WARDA), not only in African agriculture and, therefore, in the continent's economic growth but also in providing leadership in rice science and development. Desirous, therefore, of the necessity for the Center to continue to provide such leadership in rice development in Africa, the Congress resolves and urges all stakeholders to maintain the Center's identity, as previously resolved by the WARDA Council of Ministers in September 2005 and the National Experts Committee in June 2006, and to strengthen its capacity for the welfare of African rice farmers.

Conserving the future

Story and photos by Adam Barclay

APPROPRIATE MACHINERY—such as these drill seeders—is key to the conservation agriculture approach. Equipment like this allows farmers to reduce seed and fertilizer waste, seed through existing crop residue, and incorporate residue into the soil.

As India's rice-wheat belt grapples with declining soil health and water tables, a vanguard of young, innovative farmers and researchers is leading a new approach that could hold the key to reversing the region's waning productivity

You've been farming for 20 years. You do things as your father did them, and his father before him. Then, one day, a scientist visits your farm. You discuss the problems that have been getting worse for the past few years. Productivity is declining and you need more fertilizer to get the same yields. You both agree that something different needs to be done. Together, you decide on a new approach.

Despite some skepticism, you allocate a significant portion of your land to a trial. But, early in the season, this experiment is looking disastrous. Your crop looks terrible. Your neighbors tell you you're crazy and laugh at you. You seriously consider plowing the whole field under.

Now jump ahead to harvest time. That same plot of land is now admired by your neighbors as one of the best in the area. The other farmers are lining up to try the same thing in their fields next season. On top of that, you've saved money and helped the environment.

Conservation agriculture, as this new approach is known, is still young. We won't know for a few years yet whether it lives up to its promise.

Right now, though, that promise is exciting. And, make no mistake—conservation agriculture could be very important indeed. This isn't about niche farming to supplement the way things have always been done. This is about feeding a nation.

Agriculture in India is currently at a crossroads. In many areas—especially on the most productive farms in the rice-wheat belt of the Indo-Gangetic Plains in the country's northwest—decades of conventional farming have begun to take their toll. Years of the intensive irrigation required to grow rice have sucked the water table down, and it is dropping further each year.

On top of this, the combination of flooding the fields and the ever-increasing use of inputs, such as fertilizer, has led to sick and deteriorating soil. The situation is simply unsustainable.

"This is one of the biggest problems, although we don't see that yet," says J.K. Ladha, International Rice Research Institute (IRRI) representative to India and IRRI's Rice-Wheat Coordinator. "Right now, productivity is maintained because farmers are putting in more chemical inputs. But I think it's just a matter of time—five, ten years down the road—and we'll really start to see the visible effects of land degradation."

If that isn't disheartening enough, you can add another problem to the mix. Fewer and fewer of India's young want to farm. Growing up watching their parents work their fingers to the bone, often for little reward, has dissuaded a generation that sees a brighter future in India's burgeoning urban economy. And, often, they have the understanding and support of their parents.

"Both my sons want to get out of farming," explains Akhtar, a 45-year-old farmer from Kalugarhi village in the northwestern state of Uttar Pradesh. "My land is so small, I don't make profits—I can't fulfill my children's needs. I want them to get out. I'm not against children staying on the farm. But my land will be divided between my children—more fragmentation. This is already a problem. We should look for alternatives."

But what are the alternatives? In the next few years, scientists and farmers will discover whether conservation agriculture is one of

DR. JAT points to an experimental field at the Project Directorate for Cropping Systems Research in Modipuram, Uttar Pradesh. The field is part of an experiment on tillage and residue management in the rice-wheat cropping system. A field worker (*left*) at the Central Soil Salinity Research Institute in Karnal, Haryana, helps load just-harvested rice. Dr. Ladha (*top, at right*) talks to Uttar Pradesh farmer Akhtar Khan about the progress of his conservation agriculture trials.

FARMERS INSPECT a seed drill at a Central Soil Salinity Research Institute field day in October 2005 at the institute headquarters in Karnal, Haryana.

them. In India's rice-wheat belt, conservation agriculture holds great potential as part of an urgent and necessary change in the way people think about agriculture. That potential is currently being assessed in an Asian Development Bank-sponsored project, *Enhancing farmers' income and livelihoods through integrated crop and resource management in the rice-wheat system in South Asia*. The project, which is managed by IRRI under the leadership of Dr. Ladha, falls under the umbrella of the Rice-Wheat Consortium for the Indo-Gangetic Plains. Collaborating institutes include the International Maize and Wheat Improvement Center along with the national agricultural research and extension systems of India, Bangladesh, Nepal, and Pakistan.

One of the keys to its success is not only that it maintains or increases productivity but also that it is economically viable. If it cannot help farmers increase their incomes, it is doomed from the start. Several characteristics of conservation agriculture—such as zero-tillage and direct seeding—are likely to save farmers money (for more information on direct seeding, see *The direct approach* on pages 12-18 of *Rice Today* Vol. 5, No. 2) and, so far, farmers have achieved yields as high as or higher than those obtained by the conventional practice of transplanting seedlings into flooded fields (see table *below* for a description of conservation agriculture principles).

Any gains from conservation agriculture will be limited if only a few scattered farmers become converts—true success will mean wide-scale adoption across the rice-wheat belt. But, with any technology, good potential is no guarantee of success. More than 20 years ago, S.K. Sharma, director of the Project Directorate for Cropping Systems Research (PDCSR) in Modipuram, Uttar Pradesh, was heralding the benefits of direct-seeded rice, but it was never taken up in farmers' fields.

"There were concerns about weed management in direct-seeded rice, but now several technologies allow effective control of weeds," says Dr. Sharma. "Further, people said you need more water for direct-seeded rice. This is a myth! By using direct-seeded rice, farmers cut water use."

Yashpal Saharawat, a soil scientist based at the IRRI-India office in Delhi, points out the grave importance of such water savings. "In India, farmers are using underground water very fast. Currently, in Haryana's Karnal region, for example, the water table is dropping at around 1 meter per year. But farmers using direct seeding in this region are reducing their water use by around 25%."

When Dr. Sharma first championed direct seeding, it was in some ways ahead of its time. The ideas were good but the machine technologies that would make it attractive to farmers were not available. That is no longer the case. Recent advances in machinery, along with growing shortages of labor and water and concerted research and technology dissemination efforts, mean the time is ripe for a fresh approach.

According to R.K. Gupta, the regional facilitator of the Rice-Wheat Consortium, machinery has a key role to play if conservation agriculture is to succeed on a wide scale.

"Recently developed machines allow more precise seeding," explains Dr. Gupta. "Seeders are now available that can meter the seed rate and simultaneously apply fertilizer. Such precision allows farmers to reduce the amount of seed and fertilizer they use and so save money."

The new seeders can also plow through the residue of the previous crop. The rotor disk drill, for example, can seed through up to 7 tons per hectare of loose residue. This offers two significant advantages. First, it allows farmers to leave their fields untilled, resulting in a big savings of labor.

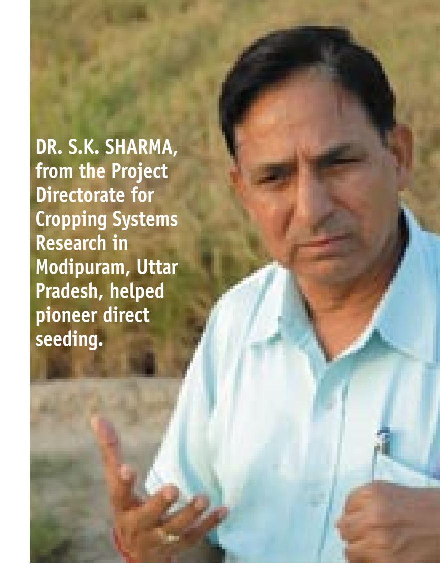
M.L. Jat, senior agronomist at PDCSR, says that through reduced labor—using traditional methods, farmers plow at least 10 times—zero-tillage alone can save farmers 3,000 rupees (US$65) per acre (0.4 hectare). Yields are more or less the same as for conventional tillage, but even where they are slightly less, farmers win economically.

The second big advantage of zero-tillage is that farmers can leave the residue of the preceding crop in the field. That residue can then act as mulch, providing the soil with moisture and nutrients, and suppressing weed growth. And, as a double bonus, farmers no longer need to burn the residue, a practice that can harm the environment as well as soil and human health.

"We've developed some very good machines that can actually pick up the straw and then, after drilling the seed and putting fertilizer into place, throw the straw back for mulch," says Dr. Ladha. "If those machines become popular, then we are really into the conservation agriculture concept."

One of the reasons for tilling the land is to ensure that the soil is moist enough for germination. So why is zero-tillage, combined with direct seeding, now possible? The answer, again, lies in the availability of appropriate machinery. Older seed drills opened large furrows of 7.5–10 cm. If you used these to direct-seed an untilled field, the seeds would quickly dry out. The new, precise machines leave much smaller furrows, thereby eliminating this risk.

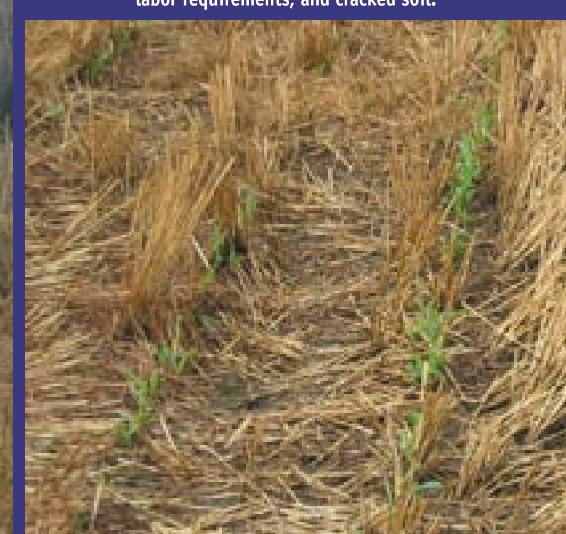
"Presently, we have around 2 million hectares under zero-tillage in



DR. S.K. SHARMA, from the Project Directorate for Cropping Systems Research in Modipuram, Uttar Pradesh, helped pioneer direct seeding.

Potential benefits of key conservation agriculture technologies.

Conservation agriculture technologies	Potential benefits relative to transplanted rice
Laser leveler	Cuts water use; fewer bunds and irrigation channels; better soil nutrient distribution; less leaching of nitrates into groundwater; more efficient tractor use (reduced diesel consumption); increased area for cultivation.
Zero-tillage	Less labor required; soil physical structure is maintained (reduced nutrient loss, soil health maintained); less water required; avoids large cracks in soil after dry periods; can keep previous crop's residue in field for mulch (if appropriate drill seeder is used for seeding); subsoil layer is not compacted by tractors (compacted subsoil impedes root growth).
Crop residue mulch	Increases soil water-holding capacity, increases soil quality, reduces weed pressure, avoids burning.
Dry seeding	Less water required; less labor required (especially at peak transplanting time); postharvest condition of field is better for succeeding crop; deeper root growth (meaning better tolerance of dry conditions, better access to soil nutrients).
Drill seeder	Precise seeding (reduced seed rate); applies fertilizer and/or herbicide simultaneously with seed (increased input efficiency); seeds through previous crop's residue; incorporates previous crop's residue into soil (adds to soil fertility).
Green manure (*Sesbania*)	Fast early growth suppresses weeds; after herbicide treatment, it acts as mulch (reduces evaporative water loss; adds soil organic matter plus nutrients—especially nitrogen—to the soil).
Crop diversification (raised seedbeds, intercropping)	Two to three crops grow simultaneously (e.g., rice, chickpea, pigeon pea, maize); increased income; increased nutritional security.



IRRI-INDIA OFFICE

IRRI-INDIA OFFICE

A COMMON SIGHT: smoldering piles of rice straw (*left*) pouring carbon dioxide into the air and reducing soil organic content. This is one of the practices that Drs. Saharawat (*left*) and Gathala want to end. With machinery that can sow seeds through crop residue, leaving the stubble alone is a much more attractive option—as can be seen *below*, where rice seedlings are growing through wheat straw. *Right*, Drs. Saharawat and Gathala crouch in a rice field that has been dry-seeded after zero-tillage, thus reducing water use, labor requirements, and cracked soil.

SAMAR SINGH (*with microphone*), senior agronomist at the International Maize and Wheat Improvement Center-India Office, talks to farmers at the Central Soil Salinity Research Institute field day in October 2005. One of Dr. Singh's research areas is the co-planting of *Sesbania* with rice to suppress weed growth, act as mulch, and provide extra nitrogen.

the Indo-Gangetic Plains of India," says Dr. Jat. "This is after 3 or 4 years. We have a total of 10 million hectares under the rice-wheat cropping system in this region. I expect that, in the coming years, the whole area will go under conservation agriculture practices, including zero-tillage."

Another aspect of conservation agriculture that is gaining favor is planting the legume *Sesbania* simultaneously with rice. After 25–30 days, farmers spray their crop with a herbicide that kills the *Sesbania* along with other broadleaf weeds, but doesn't affect the rice plants. The quick-growing *Sesbania* initially suppresses weed growth—often enough for farmers to perform one less hand weeding, thus saving 1,500 rupees ($32). Then, after spraying, the *Sesbania* leaves act as mulch, further suppressing weed growth, reducing evaporative water loss, and providing around 15 kg per hectare of nitrogen.

One challenge, though, is providing equitable access to machinery, as many farmers can't afford their own seeders. A single machine, however, can service several farms. Currently, groups of farmers share machines or rent them from larger farmers. The same system is gaining momentum with laser land levelers.

According to Dr. Jat, laser leveling, which was first promoted four years ago on just a few hectares, has now been adopted on more than 3,000 hectares. By ensuring a perfectly flat, horizontal field, the technology reduces the need for bunds and irrigation channels and can cut average water use by 20–25% as well as reduce labor requirements. Further, the resultant uniform application of water leads to uniform distribution of nutrients in the soil and the fewer bunds and channels mean a 4–5% increase in cultivated land. Also, an undulating field leads to an accumulation of nitrogen fertilizer in low-lying areas, increasing the chance of nitrates polluting the groundwater.

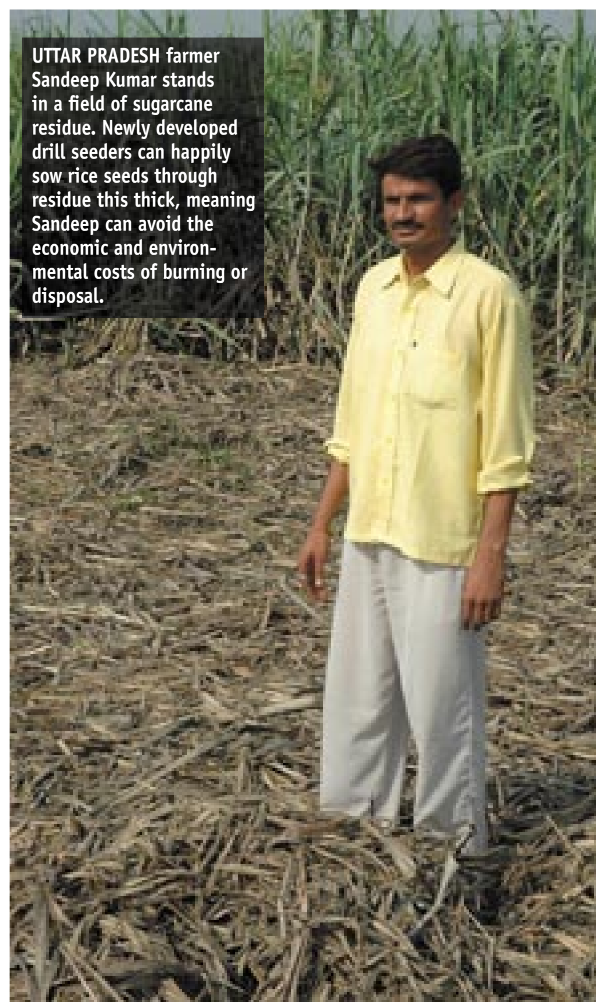
"It's such an attractive technology; farmers really like to have it, and it's really an entry point," adds Dr. Ladha. "Once you've leveled the land, zero-tillage becomes easy, water management becomes easy, and weed management becomes easy."

A major part of the reason for the success of machinery adoption by farmers in this region is the consultation with farmers. "We consider our farmers as research partners rather than research clients—and there is a big difference between a partner and a client," explains Dr. Jat.

But all the machinery in the world is no good if no farmers are around to use it. So, in the face of the exodus from the farm to the city, who will produce India's food? Fortunately, there is light on the horizon. A new breed of farmers is emerging from India's agricultural communities. Young and innovative, they believe in science, they are open to new crop management systems and technologies, and they contradict the idea that farming is some sort of hell from which to escape.

"Older farmers often see farming as merely a livelihood," says M.K. Gathala, an IRRI agronomist based in Modipuram. "These young farmers see it as a business. They understand the market, they're aware of issues like water and soil health. If they have a problem, they'll go to the scientists and the private sector; they won't wait for someone to come to them."

Sandeep Kumar, a 25-year-old farmer from Lalpur village in Modipuram, typifies the new breed.



UTTAR PRADESH farmer Sandeep Kumar stands in a field of sugarcane residue. Newly developed drill seeders can happily sow rice seeds through residue this thick, meaning Sandeep can avoid the economic and environmental costs of burning or disposal.

Changing a mindset

The families of Akhtar Khan and Pradeep Singh have farmed near Kalugarhi village in Modipuram, Uttar Pradesh, for generations. Both 45 years old, they first tried conservation agriculture in the 2005 season, each dedicating 1 acre (0.4 hectare) to direct-seeded, zero-tilled rice. Akhtar recalls the initial skepticism of his neighbors.

"This was a complete shift, moving from puddling," he says. "My neighbors said, 'You're crazy!' Now, some of them are also trying it. The price of diesel [used to pump water] has gone up like crazy; zero-tilled rice saves water and therefore saves money."

It hasn't been all smooth sailing, though. Pradeep explains that they encountered some early challenges.

"Weed management is one problem," he says. "I feel the problem is worse in zero-tilled versus tilled land. I can overcome this, but I have to put in more herbicides. But I won't give up. These problems can be solved."

In addition, the first zero-tilled seeds did not germinate as well as hoped, although this is improving as the farmers optimize settings—such as seed depth—on the drill seeder.

IRRI's J.K. Ladha emphasizes that early problems are to be expected: "Whenever you bring in new technology, it's never a clean sweep. Never. There are always problems you have to solve."

Both Pradeep and Akhtar, who have two and four children, respectively, are concerned about the next generation.

"Farming is becoming less attractive," says Pradeep. "The younger generation wants to get out. We have seen benefits from conservation agriculture, but not yet on a larger scale. We don't know if this will work on a large scale. But the involvement of international centers gives us hope and confidence. Having the scientists come is having a very positive impact on our children, too."

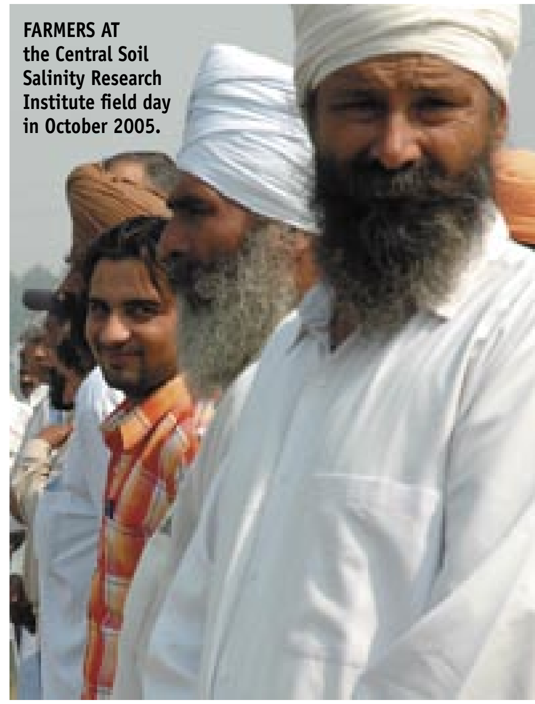
Part of the solution, suggests Pradeep, lies in changing the way farmers think about farming.

"Our fathers and forefathers were stubborn," he says. "They wouldn't listen to anybody about new technologies. But, because of our education, we're ready to change that mindset."

And, in the face of farming's trials and tribulations—the rising costs, the declining soil health, the backbreaking work—Pradeep and Akhtar remain philosophical.

"One of my children has left the farm already; the second is trying to get out," says Pradeep. "His father is trying to keep him here! I have 30-odd years of experience and I can't pass this on to my children—this is deeply frustrating. But, sitting here, people think the outside world has no problems. But it's full of problems. I'm happy. I want to stay here. At least I have time in the evenings to sit with my wife."

FARMERS PRADEEP SINGH (*center*) and Akhtar Khan (*left*) contemplate change with Drs. Ladha (*arms raised*) and Jat (*right*).



FARMERS AT the Central Soil Salinity Research Institute field day in October 2005.

"We have a group of young, educated farmers," explains Sandeep. "We're saving a lot of money and water. We want to adopt conservation agriculture as a whole. Our natural resources are being degraded; we need to sustain them. I hope this whole area will go for these technologies. We were the first farmers to adopt. At first, the district administration didn't believe, but after I showed them that mine was the best field in the area, they believed. Last year there was one field—mine. Next year, there will be 50! Next year, I want to plant other crops using conservation agriculture principles and technologies."

If a major shift is to take place, much more is needed than to merely disseminate technology and train people to use it.

"What is required is a change in mindset that prompts farmers to understand that good farm management is essential," says Dr. Gupta.

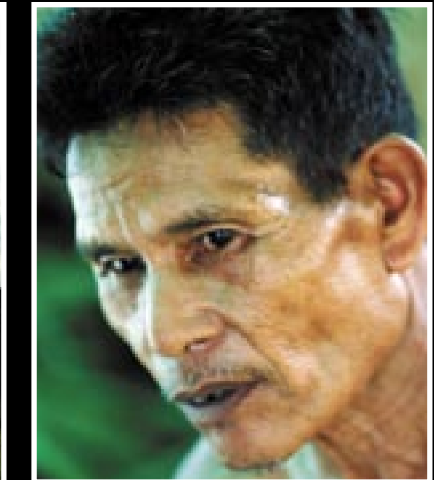
Younger, scientifically knowledgeable, innovative farmers will lead the next generation; having them on board the conservation agriculture bandwagon is crucial.

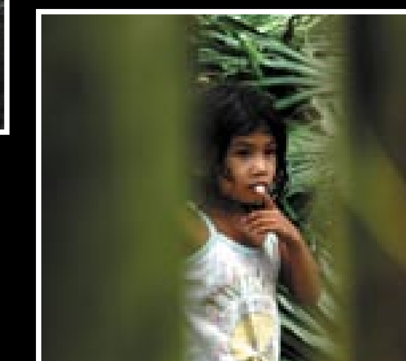
The next few years will reveal whether conservation agriculture takes hold and lives up to its early promise. The signs are good, though, and it is indisputable that something needs to change. The farmers who have tried it for themselves are enthusiastic—and it is these pioneers who will ultimately lead the way. Time and again, when asked about their early experiences, one common answer emerged: "My neighbors laughed and said I was crazy. Now they want to do the same as me."

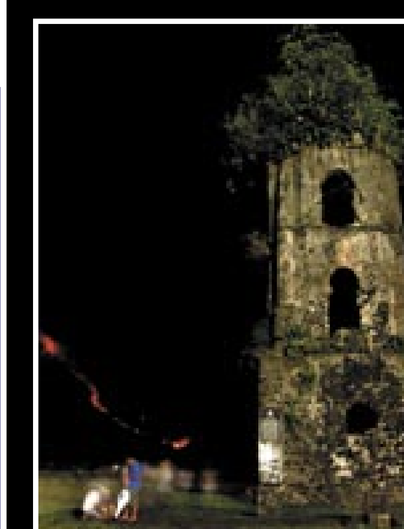
RICE
in harm's way

On 24-28 July 2006, intrepid IRRI photographers Ariel Javellana and Jose Raymond Panaligan braved the area around the base of Mayon volcano, in Bicol, Philippines (see map, *right*). Mayon, famous for its near-perfect conical shape, began showing increased volcanic activity in mid-July (see centerfold on pages 26-27). The activity continued throughout August and, as *Rice Today* went to press, the Philippine Institute of Volcanology and Seismology was maintaining an 8-km danger zone and recorded the volcano's status at alert level 4, "which corresponds to a high probability for a hazardous eruption."

Although a boon to our photographers, the volcano has the capacity to cause great hardship for the surrounding rice-farming communities. Aside from causing danger to life and limb, lava, ash falls, and pyroclastic flows—fast-moving mixtures of hot gas, rocks, and ash that travel quickly down the mountain—can also damage or destroy crops, housing, and infrastructure. Presented here are some images of Mayon volcano and the people who live in its shadow.







Clockwise from main photo (left): **Steaming lava on the mountainside in Barangay Tagas, Daraga, Albay Province; a woman protects herself from the sun—and ash—in Bonga Gully; 57-year-old rice farmer Sofroneo Rodriguez—whose farm was damaged in Mayon's 1984 eruption—sought refuge with his family in the Sitio Bical evacuation center; Rodriguez's granddaughter occupies herself at Sitio Bical; Rodriguez's son, who takes turns with other family members to return to the farm each night to guard against looters and thieves; lava creeps toward the bell tower of the old Cagsawa church—one of the only structures remaining above the lava that buried Cagsawa town in the 1814 Mayon eruption, which killed more than 1,000 people.**

Ariel Javellana

Rice fields at the edge of Mayon volcano's 8-km danger zone, near Legaspi City in the Philippines' Bicol Region, 27 July 2006.

JOSE RAYMOND PANALIGAN (2)

IRRI RESEARCHERS Abdelbagi Ismail (*left*), Sigrid Heuer (*second from right*), and Dave Mackill (*right*) examine a submergence-tolerance screening experiment in an IRRI greenhouse while associate scientist Alvaro Pamplona (*center*) and Gina Vergara look on. *Top left*, assistant scientists Jessica Rey (*left*) and Darlene Sanchez prepare DNA samples for analysis in the lab.

From genes to farmers' fields

by David Mackill

The practical application of gene discovery to develop submergence-tolerant rice will help farmers avoid the ravages of severe flooding

Rice is considered a semiaquatic plant, and it thrives in the wettest agricultural environments. However, most rice varieties will be heavily damaged and die if they remain underwater for more than 4 days. A few varieties—such as the traditional Indian variety FR13A—can tolerate 2 to 3 weeks of submergence and rapidly recover when the water subsides. This is important for the vast rainfed lowland areas of Asia where intermittent flooding causes frequent submergence. Estimated crop losses are around a billion dollars annually. Compounding the problem, submergence stress tends to be more common in areas where poverty is high. Rice production in these areas is highly variable due to flooding.

Relief may be at hand, though. Researchers at the International Rice Research Institute (IRRI) and the University of California (UC Riverside and Davis) have recently discovered a gene from FR13A that is responsible for that variety's strong tolerance of submergence. This gene belongs to a class of genes known as "ethylene response factors" or ERFs. The significance of the research—recently reported in the scientific journal *Nature*[1]—is that it provides new tools to develop rice varieties that combine high yields and tolerance of temporary submergence.

Submergence-tolerant varieties have been known for a long time, and submergence tolerance has been a breeding focus at IRRI since the early 1970s. In India, varieties like FR13A (FR stands for flood resistant) were selected from farmers' varieties as early as the 1940s and showed a high level of submergence tolerance compared with other varieties. FR13A and other tolerant varieties were crossed with high-yielding semidwarf varieties (which are shorter than most traditional varieties and thus resistant to damage from rain and wind), producing short varieties with tolerance of submergence. Despite continuing efforts by rice breeders, these varieties were not adopted by farmers because of unacceptable traits such as poor taste or inadequate adaptation to the location.

Work on the genetics of submergence tolerance began in the early 1990s. Graduate student Kenong Xu and I—then working for the Agricultural Research Service of the United States Department of Agriculture and UC Davis—used molecular markers (a molecular marker is a segment of DNA that is linked to a gene that controls an important trait and can easily be detected in the lab) to map a region of DNA on rice chromosome 9 that was responsible for most of the tolerance. We named the gene (or genes—at the time, we didn't know whether it was a single gene or several linked genes) *Sub1 (Submergence1)*. This began the search to pinpoint the genes responsible for submergence tolerance.

We were then joined by Pamela Ronald, an associate professor at UC Davis. Ten years of hard work by Dr. Xu plus a strong contribution from his wife, Xia Xu, would ultimately unravel the DNA sequence of the *Sub1* region. The group was joined by molecular biologists Julia Bailey-Serres and Takeshi Fukao at UC Riverside and Sigrid Heuer at IRRI, who helped analyze the genes in the *Sub1* region (see *Identifying the submergence-tolerance gene*, page 30). IRRI plant physiologist Abdelbagi Ismail and his team have been studying the mechanism of action of *Sub1* (see *The mechanics of submergence tolerance*, page 31) as well as management options for the new submergence-tolerant varieties.

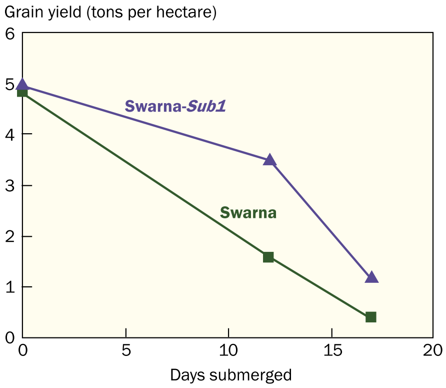
Parallel to the gene-hunting work is research using marker-assisted selection (see *On your mark, get set, select!* on pages 28-29 of *Rice Today* Vol. 3, No. 3) to develop new submergence-tolerant varieties by introducing *Sub1* into widely grown varieties. Using marker-assisted selection, breeders can selectively transfer a small chromosome fragment containing a beneficial gene or genes, while leaving the rest of the genes untouched. For example, the IRRI team has developed a version of the widely grown variety Swarna—grown on more than 5 million hectares in India and Bangladesh—that contains the chromosome segment containing the *Sub1* gene, while the genes in all other chromosomal regions are those of Swarna. This ensures that the submergence-tolerance trait is added without changing other desirable properties—such as high yield, acceptable taste, and good regional adaptation—of the recipient variety.

The IRRI group has produced submergence-tolerant versions of three widely grown rice varieties: Swarna and Samba Mahsuri from India, and IR64 from IRRI. Three more are near completion: Thadokkham 1 from Laos, CR1009 from India, and BR11 from Bangladesh—each currently grown widely in their respective countries. These new varieties do not show any differences from the originals except for the submergence tolerance. Experiments at IRRI showed that the *Sub1*-enhanced version of Swarna achieves the same yields as "regular" Swarna under normal shallow-water conditions (about 5 tons per hectare), but, when subjected to 12 days of submergence about 4 weeks after planting, followed by a return to shallow conditions, Swarna-*Sub1* has more than double the yield of Swarna

RICE FARMERS from Kaudikol village in the Indian state of Orissa wait for floodwaters to recede. This area experiences flooding as deep as 2.5 meters for up to 3 weeks each year.

GINA VERGARA

[1]Xu K, Xia X, Fukao T, Canlas P, Maghirang-Rodriguez R, Heuer S, Ismail AI, Bailey-Serres J, Ronald PC, Mackill DJ. 2006. *Sub1A* is an ethylene response factor-like gene that confers submergence tolerance to rice. *Nature* (10 August 2006)



YIELD VERSUS TIME submerged for "regular" Swarna and Swarna-*Sub1*. Plants were completely submerged 14 days after transplanting of 14-day-old seedlings in field plots at IRRI.

(3.5 tons per hectare versus 1.6 tons per hectare—see figure *above*). Swarna-*Sub1* was grown at research stations in India and Bangladesh in 2005 and is being tested in farmers' field experiments in 2006.

Dr. Mackill is the head of IRRI's Plant Breeding, Genetics, and Biotechnology Division

Funding for this study was provided by the U.S. Department of Agriculture, the U.S. Agency for International Development, and the German Federal Ministry for Economic Cooperation and Development.

Identifying the submergence-tolerance gene

by Sigrid Heuer

Marker-assisted selection can be implemented at different levels, like a map can be drawn at different scales or resolutions. That means, in molecular terms, that the higher the resolution of the genetic map the closer we are to the actual gene responsible for a particular trait—submergence tolerance in this case. Being very close to the responsible gene is important for our breeding approach. Because we are transferring tolerance to widely grown and well-adapted varieties, we don't want to change them in any way other than to make them submergence-tolerant. Close markers allow us to develop plants that carry only the tolerance gene, and that remain otherwise identical to the variety that farmers know and like. In the case of *Sub1*, we went down to the highest resolution possible by sequencing the DNA in the chromosomal region where we expected the submergence-tolerance gene to be located.

Within the *Sub1* region, we found several genes and needed to analyze all of them to determine the actual submergence-tolerance gene. By testing the expression of these genes and their response to submergence stress, we narrowed down the number of candidate genes to three. These three genes—*Sub1A*, *Sub1B*, and *Sub1C*—all belong to the same type of regulatory genes, known as ethylene response transcription factors (ERFs). Transcription factors can switch the expression of other genes on or off and therefore often have important regulatory functions.

We then discovered that some intolerant varieties have only two copies of these ERF genes (*Sub1A* is absent) and that tolerant rice varieties have *Sub1A* and *Sub1C* genes that have slightly different sequences than the same genes in intolerant varieties. This pointed to *Sub1A* as the major determinant of submergence tolerance. However, we needed more evidence. We therefore tested whether or not *Sub1A* could confer tolerance of submergence to previously intolerant plants. To do this, our partners at the University of California, Davis, introduced the tolerant form of the *Sub1A* gene into the intolerant rice variety Liaogeng and, indeed, the plants produced were submergence-tolerant. These plants now provide a very useful tool to study the function of the *Sub1A* gene in detail.

Our partners in UC Riverside have compared the expression of genes in rice plants with and without the *Sub1* locus and we have learned a lot about the genes that are regulated by *Sub1*. In the future, we also need

I WILL SURVIVE: the one remaining live plant comes from a line derived from Swarna-*Sub1*'s submergence-tolerant parent variety, FR13A. This is part of a new experiment to identify novel submergence-tolerance genes.

SIGRID HEUER

DAVE MACKILL

POPULAR RICE VARIETIES containing the submergence-tolerance gene will be much more likely to survive floods like this one in Cambodia.

to study the genes that regulate *Sub1*.

We already know that when tolerant varieties are submerged, *Sub1A* is induced and *Sub1C* is suppressed. Interestingly, when intolerant varieties are submerged, we see the opposite: *Sub1A* is hardly detectable and *Sub1C* expression is high. It therefore seems that a balance of *Sub1A* and *Sub1C* expression is important for tolerance (in addition to differences in the sequence). We now want to identify the genes that determine when and to what extent *Sub1A* and *Sub1C* are expressed.

The identification of tolerance genes and their interaction with other genes is important because it helps us to better understand the underlying mechanisms and the regulation of stress tolerance. Certain genes probably have important functions in other stresses as well, such as drought or salinity. Intimate knowledge of the genetics behind tolerance of, or susceptibility to, these stresses might one day allow breeders to develop multi-stress-resistant rice varieties by adding to established varieties a few key regulatory genes. *Sub1A* will surely be one of these.

Dr. Heuer is a molecular biologist in IRRI's Plant Breeding, Genetics, and Biotechnology Division.

AN IRRI FIELD experiment to evaluate Swarna (*left*) and Swarna-*Sub1* (*right*), which carries the submergence-tolerance gene. Fourteen-day-old seedlings were transplanted in the field and, 14 days later, submerged for 12 days. Shown here 60 days after transplanting, Swarna-*Sub1* is doing well while few Swarna plants have survived.

SUDHANSHU SINGH

The mechanics of submergence tolerance

by Gina Vergara and Abdelbagi Ismail

A submerged rice plant faces several problems ranging from inadequate growth to damage and death. For example, low light levels inhibit photosynthesis, slower gas exchange results in lower carbon dioxide intake for photosynthesis and lower oxygen intake for respiration, and gases trapped in the water, such as ethylene, promote plant elongation and chlorosis (yellowing or discoloration of the normally green parts of the plant), with a consequent loss of photosynthetic area. Therefore, our research team examined the mechanics that allow rice plants with the *Sub1* genes to tolerate submergence.

The Indian variety FR13A can survive submergence because of some key physiological traits that emerge when the plant is underwater. FR13A maintains a higher carbohydrate supply in its shoots before submergence and does not greatly elongate, meaning it conserves energy that can then be used for survival. It also experiences slower carbohydrate depletion and higher rates of alcoholic fermentation as a way of providing energy for maintenance processes in the absence of oxygen underwater. And, when submerged, FR13A maintains higher chlorophyll levels—allowing relatively better photosynthesis during submergence and also after the water recedes to resume its growth and recovery—than intolerant varieties.

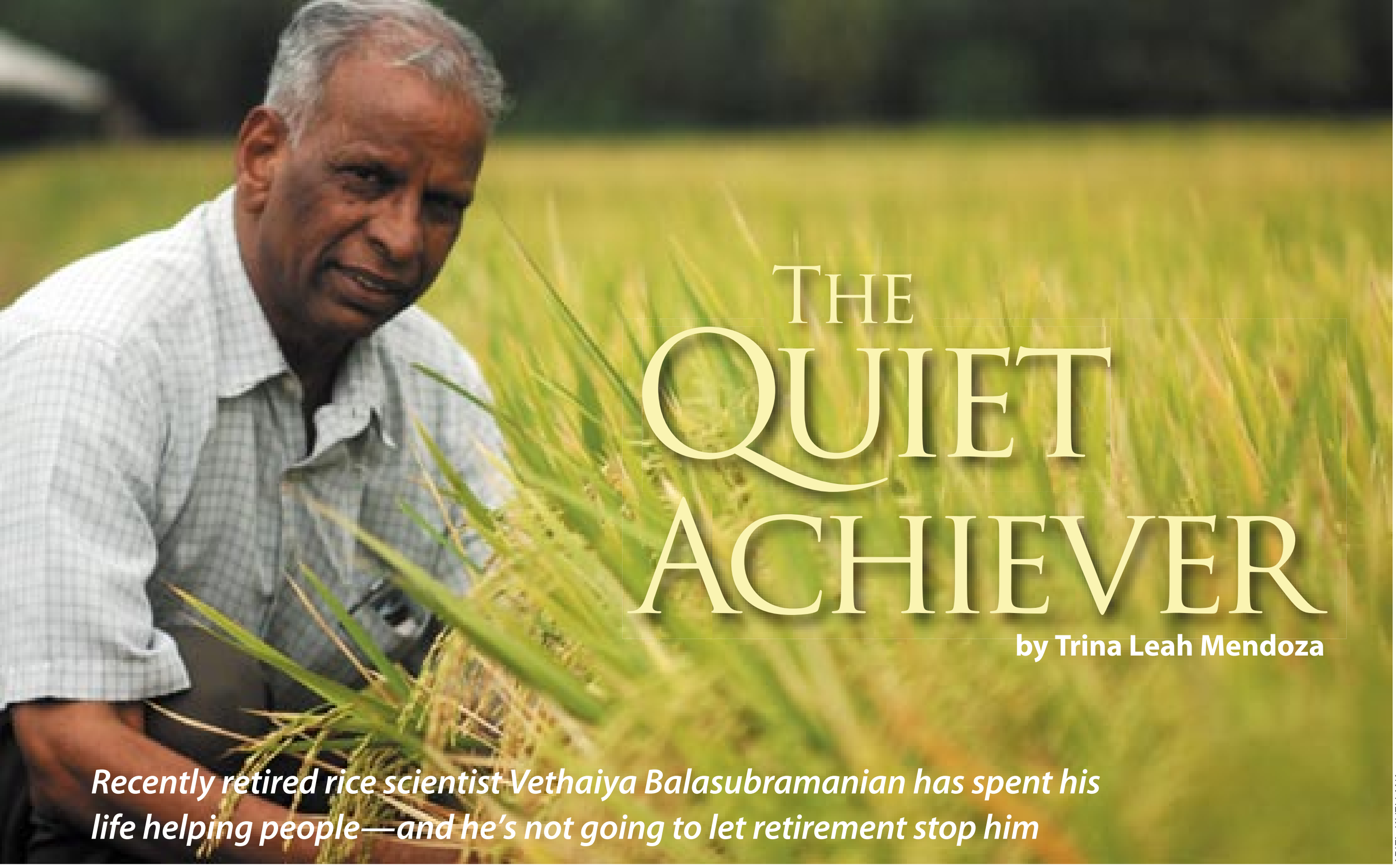
As survival strategies, maintenance of higher carbohydrate levels before and during submergence and minimization of both elongation growth and chlorosis had the most striking effects. To demonstrate this, our team inhibited the synthesis of ethylene—which reduces its chance of affecting a submerged plant's survival—in submerged conditions. This resulted in an improved survival rate for submergence-intolerant varieties but not for submergence-tolerant varieties such as FR13A. This suggested that *Sub1* reduces a plant's sensitivity to ethylene and therefore reduces elongation and chlorophyll degradation under submerged conditions. This increases the chance of survival in two ways. First, less energy is wasted on elongation. Second, the plant needs intact chlorophyll to generate more energy during submergence and to resume active growth during recovery from submergence.

More supporting evidence comes from data comparing the performance of Swarna and newly developed Swarna-*Sub1*. Under submerged conditions, Swarna more than doubled its length, elongating by as much as 150%. The submergence-intolerant check variety, IR42, almost tripled its length, elongating by 180%. Swarna-*Sub1*, however, less than doubled in length, with significantly reduced elongation of only 55%. This is comparable with FR13A, which showed 52% elongation.

How did this translate into an ability to survive tolerance? The results were impressive—70% and 80% of, respectively, Swarna-*Sub1* and FR13A plants survived. This compares with a mere 8% of IR42 and 21% of "regular" Swarna plants.

Because of Swarna's short stature, and because *Sub1* further inhibits elongation during flooding, Swarna-*Sub1* is unsuitable in areas prone to flashfloods where water tends to stay in the field at a depth greater than 30 cm. For such conditions, IRRI is developing taller *Sub1* varieties. Swarna-*Sub1* is better suited to areas where floodwater recedes to shallower depths following submergence.

Dr. Vergara is a postdoctoral fellow and Dr. Ismail is a senior plant physiologist in IRRI's Crop and Environmental Sciences Division.



The Quiet Achiever

by Trina Leah Mendoza

Recently retired rice scientist Vethaiya Balasubramanian has spent his life helping people—and he's not going to let retirement stop him

ARIEL JAVELLANA

If you turn on the TV or flip open a magazine, it's not uncommon to see a Hollywood star, a famous athlete, or a high-profile socialite in some far-flung region, mingling with the poor, assisting at medical clinics, or handing out care packages. Perhaps these celebrities genuinely want to help. Or perhaps their agents convinced them that some positive publicity would help boost their profile. Far from these stage-managed, filmed, and photographed excursions, however, you will find far less famous people doing work that often goes unrecognized but probably achieves far more.

Vethaiya Balasubramanian, recently retired senior agronomist at the International Rice Research Institute (IRRI), is one such person. Serving as IRRI Africa coordinator since 2005, Dr. Bala, as he's known to his colleagues, was involved in setting up rice research and development programs in eastern, central, and southern Africa. He also worked in the training and delivery of IRRI technologies in both Asia and Africa.

Dr. Bala first stepped aboard IRRI in 1991 as chief of the IRRI-Madagascar project, advising and training staff on soil and resource management, and rice-based cropping systems. As IRRI's Crop Resources Management Network coordinator from 1994 to 2001, he helped the Institute's partner countries source, evaluate, and adapt promising crop resources and management technologies.

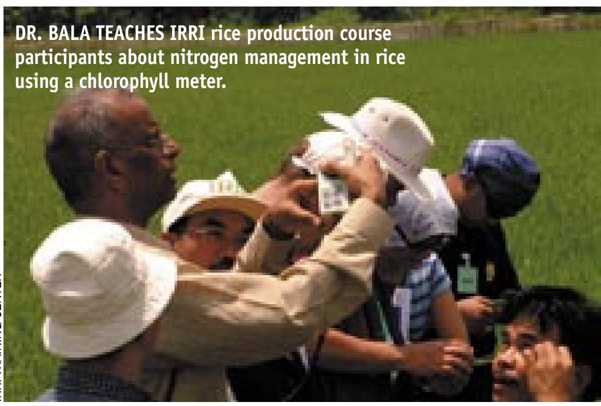
The foundations for Dr. Bala's impressive career were laid in his native India. After earning his bachelor's degree in agriculture and master's degree in soil science and agricultural chemistry at India's Tamil Nadu Agricultural University, he took his Ph.D. in agronomy and soil science at the University of Hawaii, USA. His next step was a big one—saying goodbye to the U.S., he ventured into one of the globe's poorest regions, spending his next 16 years in the African countries of Nigeria, Rwanda, Ghana, Cameroon, and Madagascar.

"I lived in small villages with no water or electricity," recalls Dr. Bala. We collected rainwater to quench our thirst and cook our food. We used kerosene refrigerators with a lamp at the bottom. I lived like that in Rwanda for five years."

And although development in Africa still has a long way to go, Dr. Bala believes that advances in other regions have helped.

"The governments and scientists in Africa are more fortunate now because they can use the latest technologies. They don't have to go through long periods of research because the technologies are available elsewhere, like in Asia, and can be used and modified."

IRRI's stimulating scientific atmosphere has been a source



DR. BALA TEACHES IRRI rice production course participants about nitrogen management in rice using a chlorophyll meter.

IRRI TRAINING CENTER

of great satisfaction for Dr. Bala, and has given him the chance to share his 4 decades of accumulated knowledge. In the 5 years before his retirement, he was heavily involved with the Institute's Training Center, co-presenting the rice production course and a workshop on scientific writing and presentation skills for young scientists.

"I really want to share what I know, and all the technologies, all the information, all the skills that I have," he says. "I want to transfer my knowledge to developing countries' scientists so they can, in turn, train farmers and help them produce more food and better their livelihoods. If we can't produce more food to feed the poor, there's going to be a lot more conflict and problems in the world."

In Dr. Bala's 15 years at IRRI, he cites the leaf color chart—a simple piece of technology developed in collaboration with the Philippine Rice Research Institute and used for fertilizer management (see *Chart hit for N sync* on page 33 of *Rice Today* Vol. 3, No. 4)—as one of the most successful developments for rice.

"We have more than one million charts distributed all over Asia and in a few countries in Africa and Latin America," he says.

Dr. Bala considers integrated crop management another IRRI success story. This approach brings together technologies to provide farmers with a basket of options that offer solutions to a wide array of problems. The strategy, he says, is doing very well, particularly in Vietnam, Indonesia, and southern India. He mentions direct seeding and drum seeding as booming technologies that IRRI has helped develop and disseminate (see *Drumming up success* on pages 22-27 of *Rice Today* Vol. 4, No. 2, and *The direct approach* on pages 12-18 of *Rice Today* Vol. 5, No. 2, respectively).

Dr. Bala also helped pioneer the modified mat nursery, which is now being adopted in several countries (see *Making mats matter*, *right*).

When Dr. Bala returns to his hometown in Voimedu, India—the date is set for October 2006—it isn't to slow down. He plans to teach at

BALASUBRAMANIAN PERSONAL ARCHIVES

A 29-YEAR-OLD Dr. Bala, then an East-West Center Fellow studying for his Ph.D. at the University of Hawaii, forgoes rice for bananas during a cultural exchange and exploration tour in 1970.

Tamil Nadu Agricultural University and, starting with his own village, has taken on IRRI's goal to reduce poverty and hunger. Dr. Bala's *Revive Your Village* project will establish—with his own money—a "village knowledge center" in his hometown, which will serve as a play area for preschool children, a reading room and lending library, a computer room, a preventive health advisory clinic, and a training hall.

"I want to improve the education and training facilities in rural areas and remove the gap between the skills and capabilities of rural and urban children," Dr. Bala explains. "From my village, I want to develop a model that can be duplicated all over India and in other countries as well."

Dr. Bala knows he has a long way to go, but it is his way of giving back to his country—his thanks for the opportunities he has had. He feels blessed to have had the chance to spend his life helping people in need.

"When I look back, I'm really proud that I had the strength and courage to work in extreme conditions with different groups of people," he says. "For each country, each university, and each institute I've worked with, I feel that I've really done something for them. They're happy to see me when I go back and visit. That is really satisfying."

Trina Mendoza is a communication specialist with the Irrigated Rice Research Consortium.

Making mats matter

IRRI TRAINING CENTER

Producing young and robust rice seedlings is a challenge for rice farmers everywhere. To help meet this challenge, scientists from IRRI and the Tamil Nadu Agricultural University in India have developed an improved method of crop establishment: growing seedlings in a modified mat nursery.

The technology establishes seedlings in a layer of soil mix arranged on a firm surface. It also uses less land and requires fewer seeds and inputs, such as fertilizer and water, reducing nursery costs by up to 50%.

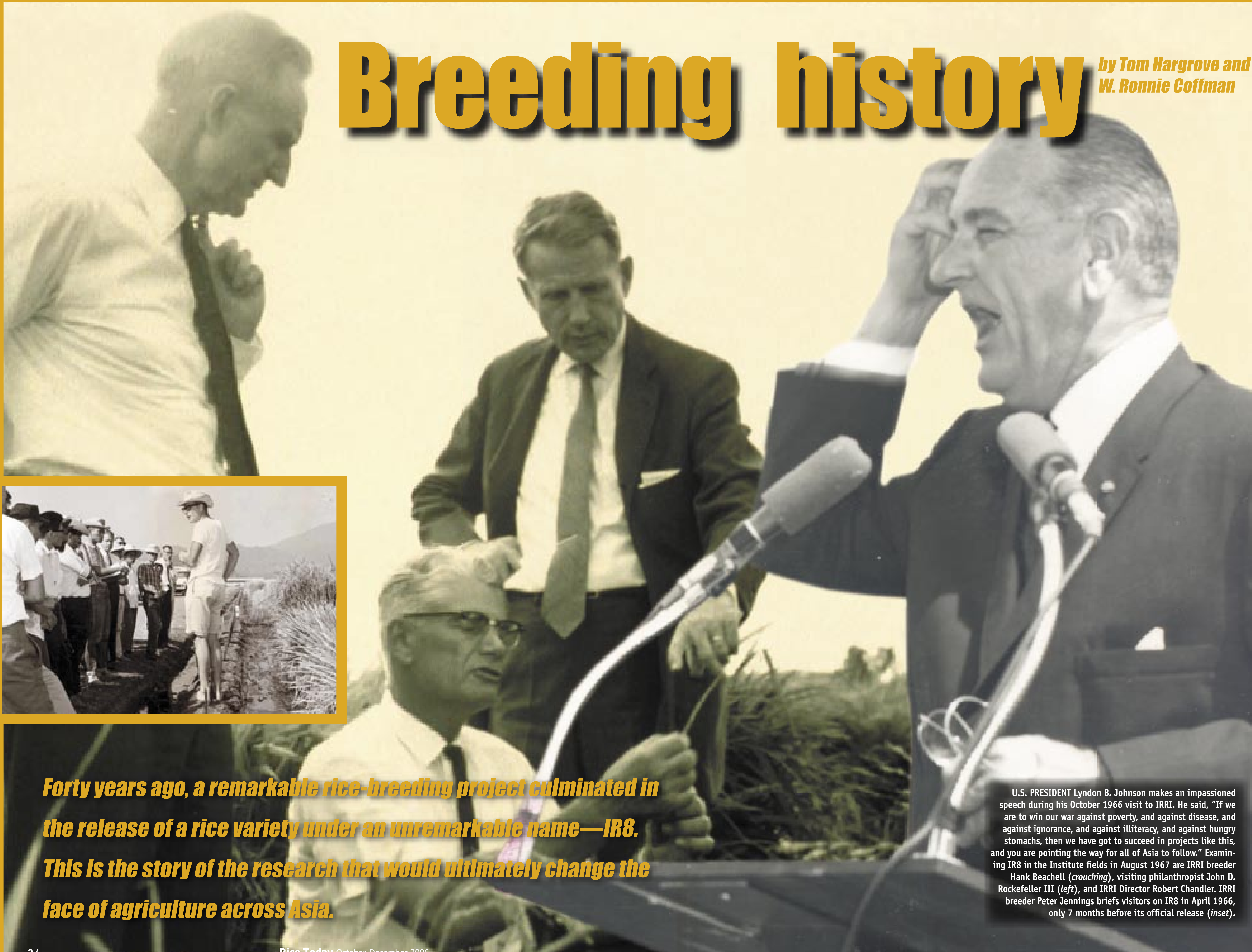
The key is the modified mat nursery's soil mixture, which is composed of seven parts soil, two parts well-decomposed chicken manure, and one part charred rice hulls. The mix is poured into a wooden frame laid on top of banana leaves or plastic sheeting, which prevents the roots from penetrating into the soil, making it easier to pull seedlings out and thus minimizing root damage.

Pregerminated seeds are sown uniformly, sprinkled with soil, and patted gently to embed them at about 2–3 cm into the soil bed. They are then watered and covered with banana leaves or plastic. The nursery is watered twice a day for 5 days, and kept covered for the first 4 days to protect the seedlings from either drying up or getting washed away by heavy rains. On the fifth day, the cover is removed, and the nursery is flooded to a 1-cm water level around the beds. After 15–20 days, the seedlings reach the four-leaf stage—which favors quick establishment in the field and rapid growth—and are ready for transplanting. This is much quicker than the 25–35 days required for traditional wet-bed nurseries.

The technology has already been adopted in southern India, and was recently introduced in Myanmar, Nepal, Bangladesh, East Timor, and the Philippines. One major advantage of the method is that it can be applied in all countries and on all soil types, as long as the soil is kept moist. In areas where modified mat nurseries have been successfully implemented, they have produced robust, fast-growing seedlings, an additional 20–40% yield, and about US$100–250 additional income per season for farmers.

Breeding history

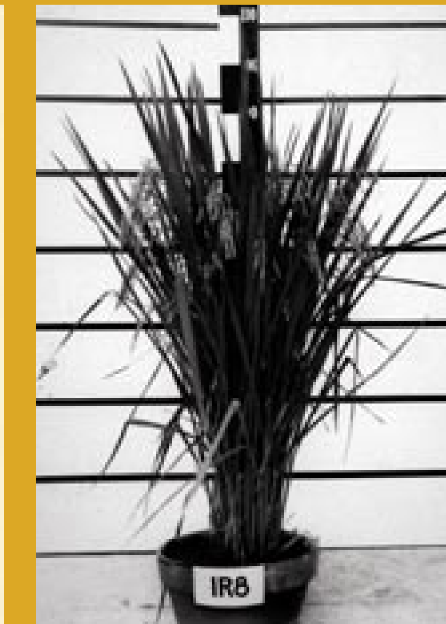
by Tom Hargrove and W. Ronnie Coffman



Forty years ago, a remarkable rice-breeding project culminated in the release of a rice variety under an unremarkable name—IR8. This is the story of the research that would ultimately change the face of agriculture across Asia.

U.S. PRESIDENT Lyndon B. Johnson makes an impassioned speech during his October 1966 visit to IRRI. He said, "If we are to win our war against poverty, and against disease, and against ignorance, and against illiteracy, and against hungry stomachs, then we have got to succeed in projects like this, and you are pointing the way for all of Asia to follow." Examining IR8 in the Institute fields in August 1967 are IRRI breeder Hank Beachell (*crouching*), visiting philanthropist John D. Rockefeller III (*left*), and IRRI Director Robert Chandler. IRRI breeder Peter Jennings briefs visitors on IR8 in April 1966, only 7 months before its official release (*inset*).

URBITO ONGLEO (3)



IRRI

Asia was desperate for food after World War II. Only massive shipments of U.S. grain prevented famine.

Rice was, and is, Asia's lifeblood. That's why the Ford and Rockefeller foundations pooled resources and, in 1960, established a modern research center to focus on the world's most important crop: the International Rice Research Institute (IRRI), based in Los Baños, Philippines.

Robert Chandler, IRRI's first director, assembled a team with a mission: to develop a high-yielding rice variety.

IRRI scientists knew that the architecture of the tropical rice plant was the main constraint to yield increases. Traditional rice varieties are tall, with long, weak stems. When a farmer fertilizes a tall plant, it "lodges," or falls over. Photosynthesis ceases, and grain rots in the water, or rats eat it.

A short, nonlodging rice plant that would convert nutrients to grain and hold the panicle (the terminal shoot of the rice plant that produces grain) upright—a dwarf or semidwarf—was needed to accelerate rice production.

IRRI didn't invent the dwarf concept. Scientists had already established it in other crops. Dwarf sorghum was already available. And semidwarf rice varieties


THE TALL Peta variety, one of IR8's parents, towers over its more resilient offspring. Because of its shorter, stouter stature, IR8 was less prone to lodging (falling over), which caused severe yield losses in the taller traditional varieties.

IRRI

had already been developed and released in mainland China, largely unknown to the rest of the world.

More significant, in 1946, S.C. Salmon, a geneticist with General Douglas MacArthur's Occupation Army in Japan, had sent seeds of Norin 10, a dwarf wheat variety that he found in a Japanese agricultural experiment station, to Orville Vogel at Washington State University. Within a few years, Dr. Vogel had developed Gaines, a semidwarf wheat variety that spread rapidly across the U.S. Pacific Northwest. Vogel sent seeds with the Norin 10 dwarfing gene to Norman Borlaug of the Rockefeller Foundation wheat program in Mexico. Dr. Borlaug used those seeds to breed semidwarf wheat varieties. The most successful was 8156—given that name for Dr. Borlaug's 8,156th cross. 8156 yielded bountifully and made Mexico self-sufficient in wheat production by the mid-1960s. Seeds of 8156 spread to Pakistan, where it was called "MexiPak," then to Turkey, Iran, and India.

In 1949, the Food and Agriculture Organization of the United Nations established the International Rice Commission, which commissioned an indica-japonica hybridization project based in Cuttack, India. Its mission was to cross the short japonica, or temperate, rice with taller indica, or tropical, varieties, to develop short-statured varieties with higher yield potential. Shorter rice varieties such as ADT 27 and Mahsuri, selected from the japonica × indica crosses, were widely planted across the Indian subcontinent in the 1960s.

Meanwhile, U.S. rice breeders were irradiating seeds of tall U.S. varieties, hoping to induce a short-statured mutant. Among those pioneers were Nelson Jodan of Louisiana State University's rice research center in Crowley, Louisiana, and Henry ("Hank") Beachell of the Texas A&M University rice research center near Beaumont, Texas. But their selections had high sterility and were not successful.

In 1957, the Rockefeller Foundation sent Peter Jennings, a young plant pathologist, to Arkansas, Texas, and Louisiana to learn about rice in order to develop new rice varieties for Latin America. The Rockefeller Foundation then sent Dr. Jennings to Mexico and Colombia.

Dr. Jennings and Sterling Wortman, later to become IRRI's associate director, traveled across Asia in 1960, looking at rice varieties, meeting rice scientists, and interviewing prospective trainees and staff. "Be on the lookout for a dwarf rice," Dr. Beachell recalls advising them. Dr. Beachell visited the fledgling IRRI as a consultant in 1962, then returned to Beaumont.

In India, Drs. Jennings and Wortman encountered Taichung Native 1 (TN1), a Taiwanese variety that was probably the first widely grown semidwarf variety in the tropics. TN1 yielded far better than tall varieties, but was highly susceptible to major disease and insect pests.

Dr. Jennings joined IRRI as head of the Varietal Improvement Department in 1961. Among the germplasm assembled at that time was Dee-geo-woo-gen (DGWG) from China, a parent of TN1, and clearly its source of dwarfism. But at that time the nature of inheritance of DGWG's short stature was unknown.

Dr. Chandler described DGWG as "a high-yielding, heavy-tillering, short-statured variety from Taiwan."

Dr. Jennings and Akiro Tanaka, hired from Japan as IRRI's first plant physiologist, conceptualized the semidwarf rice plant and systematically studied the causes, and effects, of lodging during IRRI's first 3 years. In his 1982 book, *An adventure in applied science: a history of the International Rice Research Institute*, Dr. Chandler wrote about lodging research:

> *By supporting tall varieties such as Peta and MTU-15 with bamboo sticks, Jennings found that tall varieties yielded essentially as well as did lodging-resistant varieties. Moreover, the lodging-susceptible varieties, when supported, responded well to nitrogen applications, whereas the unsupported plants showed a decided negative response. … This proved beyond doubt that lodging per se was the primary cause of low yields when traditional tropical varieties were subjected to modern management methods.*

Dr. Chandler made several references to IRRI's breeding objectives in the first IRRI Annual Report (1961-62). The section "Varietal Improvement" almost gives a blueprint for the


AFTER A BUMPER crop in his first season growing IR8, Indian farmer K.N. Ganesan was so moved by the new variety that he named his second son in its honor—IR-ettu in Tamil, and signed as Irettu. Here, father and son stand in a field of a different variety, IR50, in 1983.

GENE HETTEL

variety, yet to be developed, that several years later would turn rice production on its head:

> *It would seem that the following plant type might be useful in the near future throughout much of the tropics—a combination of short, stiff culms bearing erect, moderately sized, dark-green leaves; responsiveness in yield to fertilizer; mid-season maturity and in most cases, photoperiod sensitivity to permit double cropping practices. These objectives are being pursued […] with both indica by indica and indica by japonica hybridization.*

Not much was known about the genetics of tropical rice varieties at the time, so IRRI hired a geneticist—Te Tzu Chang, from Taiwan—in its first group of scientists. Dr. Chang began studying the inheritance of plant height.

Jennings made 38 crosses in late 1962; 11 of them included the dwarf parent DGWG, TN1, or I-geo-tze (IGT)—another dwarf from Taiwan.

The eighth IRRI cross—from which IR8 was eventually selected—was of Peta, a tall, vigorous variety from Indonesia, and DGWG. From that cross, 130 seeds were formed. Those seeds were planted in pots in IRRI's screenhouse and produced the first, or F_1, generation of plants. All were tall.

Seeds from the F_1 plants were sown in the field, and produced about 10,000 second-generation (F_2) plants that segregated by height in a ratio of three talls to one dwarf. Dr. Jennings immediately recognized this as a Mendelian ratio—named after Gregor Mendel, who became known as the father of genetics for his 19th-century research into the inheritance of traits in pea plants. This was a key result—it meant that dwarfism in DGWG was controlled by a single gene and was therefore simply inherited, making the job of developing a commercially usable semidwarf variety immeasurably easier.

Dr. Jennings immediately brought Drs. Chandler and Wortman to the field to see the segregating plants. He then cabled the good news to Dr. Beachell in Texas. "That's when we knew we had it [meaning that DGWG could be used to breed an improved semidwarf variety]," Dr. Beachell recalled years later.

With this discovery, Dr. Jennings persuaded Drs. Chandler and Wortman to exchange a cytogenetics position in the Varietal Improvement program for a second breeder to help with the increase in field work that would obviously come. They agreed, and Dr. Jennings suggested Dr. Beachell, who arrived in 1963.

Tall, late-maturing plants from the Peta-DGWG cross were discarded, and only short, early-maturing plants were saved. Seeds were "bulked" and planted in a nursery where they could be screened for susceptibility to the rice blast fungus. In 1963, Dr. Jennings departed IRRI for study leave, leaving the material in the hands of newly arrived Dr. Beachell. From the third (F_3) generation, Dr. Beachell selected 298 of the best individual plants. Seeds from each plant were sown as individual "pedigree rows"—the fourth (F_4) generation.

From row 288, a single plant—the third one—was selected and designated IR8-288-3. Its seeds, the F_5 or fifth generation, were grown to produce the basic IR8-288-3 seed stock.

IR8-288-3—which was eventually named as variety IR8—was a semidwarf rice, about 120 cm tall with strong stems that held the plant upright, even when heavily fertilized. It was also nonsensitive to photoperiod, or daylength, scientists would later learn. That meant it could be grown in many latitudes, at any time of the year.

"The seed [of IR8] was uniform enough for trials in other countries, but a couple of years later Dr. Beachell devoted considerable effort to producing an extremely pure strain that would serve as a uniform seed source of IR8 for the future," Dr. Chandler wrote.

Meanwhile, seeds of IR8-288-3 and other promising lines were being sent for testing by national rice programs across Asia.

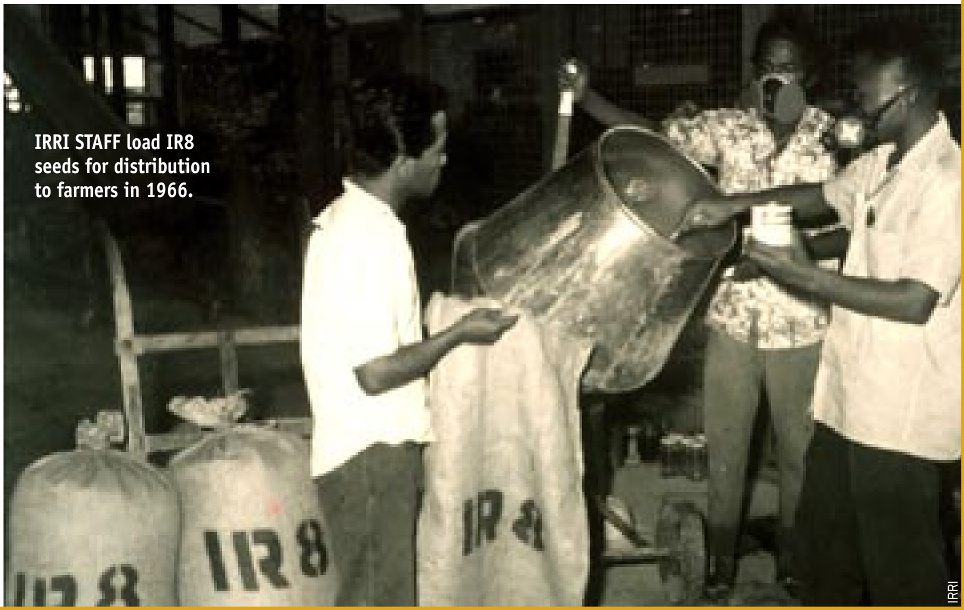
"IRRI's policy was free access to all of our genetic material," Dr. Beachell said. "It was made available to the world."

In the 1966 dry season, S.K. De Datta, a young Indian agronomist who had joined IRRI in early 1964, examined the fertilizer response of IR8, along with other rice varieties. "We wanted to determine maximum yields under the best management possible," he said.

Dr. De Datta was amazed when he harvested the trials in May. IR8 averaged 9.4 tons per hectare, yielding as high as 10.3 tons per hectare in one trial. Average yields in the Philippines then were about 1 ton per hectare.

Dr. De Datta took his yield data to Dr. Jennings, then to Dr. Beachell. "Let's go see Bob [Chandler]," Dr. Beachell said.

But, at that moment, Dr.



IRRI STAFF load IR8 seeds for distribution to farmers in 1966.

IRRI

Chandler was chairing a seminar—the news would have to wait another hour. After what seemed much longer, Drs. Beachell and De Datta finally saw their director. Sensing the pair's excitement, Dr. Chandler suggested they move to his office.

Dr. De Datta showed his data, and Dr. Chandler was excited.

"The whole world will hear about this," Dr. Chandler said. "We're going to make history!" He then shook hands, congratulating Dr. Beachell for helping develop IR8 and Dr. De Datta for discovering and demonstrating the semidwarf's yield potential.

"The IR8 yield data were the most exciting thing that ever happened to me," Dr. De Datta later recalled.

Soon, similar reports of dramatic yield increases were coming to IRRI from across Asia, including 11-ton harvests in Pakistan.

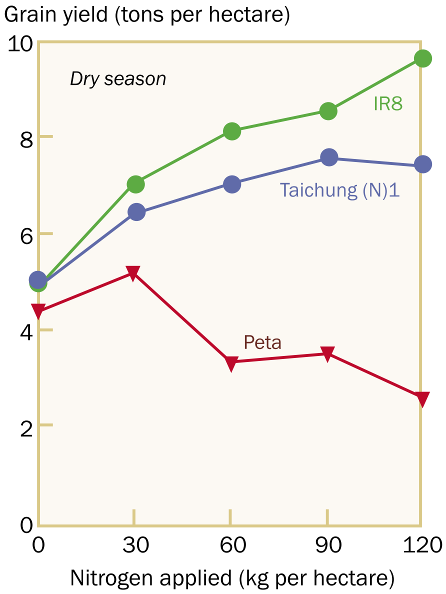
Dr. De Datta prepared his widely published "yield response" graph, showing how yields of IR8 rose with increased fertilization, while those of traditional varieties actually declined (see figure *above*).

Philippine President Ferdinand Marcos heard about the new rice, and flew to IRRI by helicopter on 3 June 1966. Dr. Jennings and others briefed the president by a plot of IR8 next to Peta, a tall, traditional variety.

Dr. De Datta recalls President Marcos's reaction: "Do you mean that little rice can out-produce our vigorous Philippine varieties?" the president asked. Dr. De Datta assured him that it could.

"*No kidding*?" Marcos responded.

President Marcos soon ordered that IR8 seeds be multiplied as rapidly as possible. Marcos's goal was to make the Philippines self-sufficient in rice production during his first term of office.



THE RESPONSE TO nitrogen fertizer of two semidwarf rice varieties—IR8 and Taichung Native 1—and of Peta, a tall, traditional variety, in the 1966 dry season on IRRI's experiment farm.

It was. During the last half of 1966 alone, 2,359 Philippine farmers came to IRRI by bus, on bicycle, and on foot, from 48 of the country's 56 provinces, to get seeds.

The new rice yielded bountifully, but had major disadvantages. Foremost was its bold, chalky grain, which distracted from its market appearance as polished rice. The grain also had high breakage during milling. And IR8 had high amylose content, which made it harden after cooling. (Dr. Beachell remembers a young Filipina saying, "I don't like IR8 because it scratches my throat.")

Dr. Beachell recalls the consensus view of the IRRI seed committee: "We needed to move as fast as possible. There was not enough rice to go around. We had to have something to alleviate the rice shortage. Enough rice was more important than grain quality.

"So, would we release the line as a variety, or wait to improve it? We knew IR8's limitations, but also knew we had the plant type. IR8 would be the prototype for future varieties. We decided to spread it."

The seed committee decided to formally name IR8-288-3 as IR8 on 14 November 1966. The news was released on 28 November.

Dr. Chandler later wrote:

> *He [Beachell], Jennings, and Chang made a fine team. When I was asked, some years later, who, among the three senior scientists in the Varietal Improvement Department, should receive the coveted John Scott Award for the creation of IR8, I replied that the prize should be split among the three: Jennings for selecting the parents and making the cross, Beachell for identifying IR8-288-3 from among the multitude of segregating lines, and Chang for having brought to the immediate attention of IRRI breeders at the start the value of the short-statured varieties from Taiwan such as Dee-geo-woo-gen, I-geo-tze, and Taichung Native 1.*

Pioneer rice scientists such as Drs. Jennings, Beachell, Chang, and De Datta, as well as others who played key roles in developing and testing IR8—such as Dr. Tanaka and another plant physiologist, Benito Vergara—proved Dr. Chandler right. IR8, and IRRI, did indeed "make history." IR8 changed the world food situation and initiated what is now called the Green Revolution in rice.

IR8 PICTURED next to its parents: Peta, a tall, vigorous variety from Indonesia, and the Taiwanese dwarf variety DGWG.

IRRI

Tom Hargrove, a former IRRI editor, is now coordinator, Information and Communications Unit at IFDC, an International Center for Soil Fertility and Agricultural Development in Alabama, USA (Tomhar66@swbell.net).

W. Ronnie Coffman, a former IRRI rice breeder, is now international professor of plant breeding and director of international programs, College of Agriculture and Life Sciences at Cornell University in New York, USA.

The author (*left*) with former Viet Cong political officer Tran Van Rang on the Xa No Canal in the lower Mekong Delta in 1988. Rang has just explained why he didn't have me killed 18 years previously, when he'd had the chance.

VO-TONG XUAN

I Remember Honda Rice

by Tom Hargrove

How the first Green Revolution rice variety—IR8—influenced life and death in the Mekong Delta during the Vietnam War

The Green Revolution in rice has been documented throughout much of Asia, but few think of Vietnam in the 1960s and '70s as a "Green Revolution country." That's because IR8 arrived at the height of a brutal war that overshadowed an agricultural transformation in the countryside. Rice means life itself in Vietnam, and was used both as a weapon and as a tool for peace. I have strong memories of the war: Huey choppers, mortars, ambushes, and needless deaths. But I also remember Honda Rice.

Tom Hargrove, August 2006

A VIETNAMESE family of five on a motorbike in 1974. Vietnamese farmers quickly dubbed IR8 "Lua Honda" (Honda Rice) because one good crop bought a new motorbike.

IRRI

4 June 1988, in Hau Giang Province, Vietnam (Chuong Thien Province during the war)

I'm stunned. I struggle for the right words, then simply ask, "Why didn't you kill me, Tu Rang?"

"Because you brought the new rice seeds, and our farmers needed them."

"But did you know I was a U.S. Army officer?"

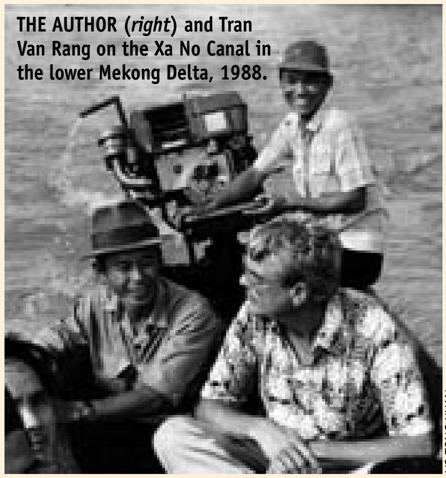
"Of course. Your civilian clothes didn't fool anyone."

The former Viet Cong—literally, Vietnam Communist, the common name for the National Liberation Front—and I look into each other's faces, something we never did in 1969-70. He's smiling, but he's hard—it shows. He's also telling the truth. I can sense it.

"I was less than a kilometer away whenever you traveled this canal in 1969," Tran Van Rang says. Today, Tu Rang is vice-chairman of the Vi Thanh People's Committee. But, two decades ago, he was the local Viet Cong political officer. I know that political officers held ultimate power in the Communist infrastructure—they gave orders to military commanders.

"You were entering *my* territory when you came here," Tu Rang continues. "The local farmers all supported the Revolutionary Forces, and reported on you.

"But I didn't have you killed because of the new rice seeds."



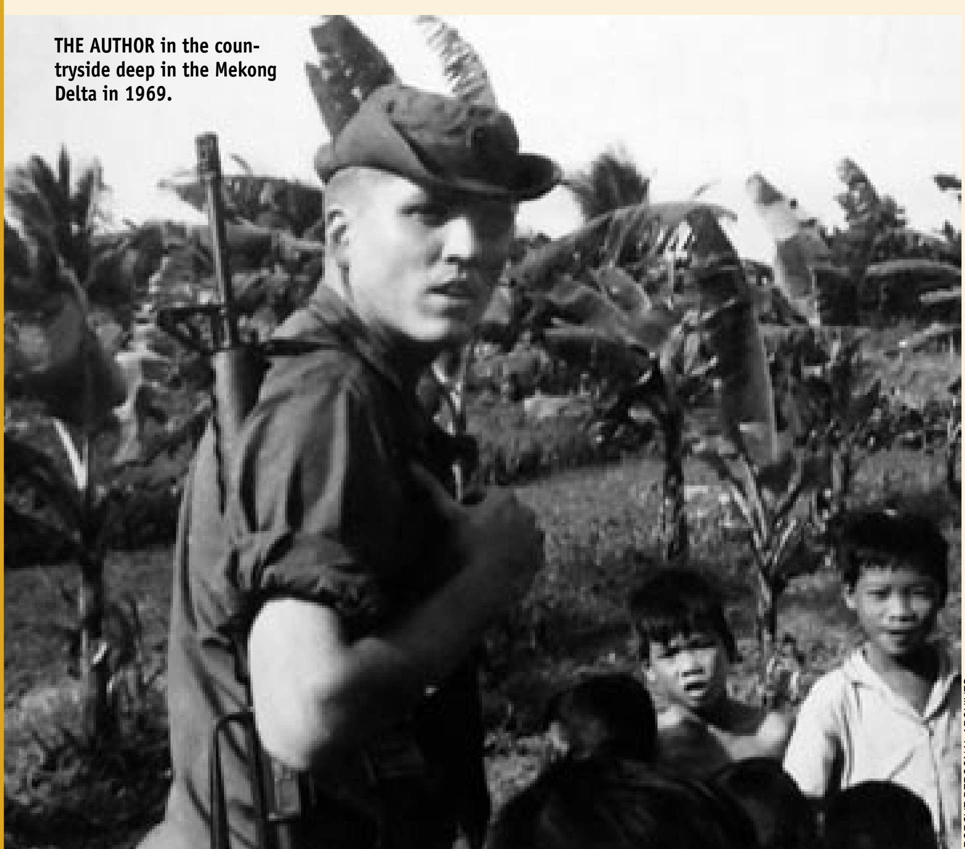
THE AUTHOR (*right*) **and Tran Van Rang on the Xa No Canal in the lower Mekong Delta, 1988.**

VO-TONG XUAN

This trip is getting heavy, I think, as our sampan cuts north through the muddy waters of the Xa No Canal.

New rice seeds. To me, they're one of the world's most powerful tools for peace. That's why I made the Green Revolution my profession.

But I learned about those seeds—especially IR8 or Honda Rice—here, in the midst of carnage. Had there been no war, rice wouldn't have become such a part of my life. Now I must face a new reality: those rice seeds probably *saved* my life.



THE AUTHOR in the countryside deep in the Mekong Delta in 1969.

HARGROVE PERSONAL ARCHIVES

The lower Mekong Delta is peaceful and beautiful now. But I remember it as ugly, dangerous, and one of the most tragic places on Earth. To me, this is still 1969-70. We've just passed Duc Long. I remember friends being killed in an ambush north of this village … in a sampan that I was supposed to have taken. Tu Rang must have ordered that ambush. I know I'm safe now, but I've never traveled this canal without an M-16 and bandolier of ammunition.

"Has any other American been here since the war?" I ask Dr. Vo-Tong Xuan, my host and vice-president of the University of Can Tho. Xuan, who is now the rector of Angiang University, in the Mekong Delta, had worked as a research fellow at the International Rice Research Institute (IRRI), where I'd worked since 1973.

"No, you're the first foreigner—of *any* nationality—to be in the lower Ca Mau Peninsula since the war ended in 1975."

I can do it only because I work with rice.

2006: looking back

Vietnam veterans and historians have recently queried me about the origin and history of the term Honda Rice in the war. Interesting, considering that the war ended 31 years ago. Or did it? Wars never really go away, for those who lived them.

War and rice. Anyone who wants to understand the war should know the role that rice played. I learned about rice as a young U.S. Army officer deep in Vietnam's heavily contested Mekong Delta at the height of the war, in 1969-70.

IRRI released the semidwarf IR8 to farmers in late 1966. Within a couple of years, it was the most widely grown rice variety ever known. IR8 launched the Green Revolution in Asian rice.

The Western press called IR8 the miracle rice. Its official name in Vietnam was Lua Than Nong, or "Rice of the Farming God."

But Vietnamese farmers quickly dubbed IR8 Lua Honda—or Honda Rice—because one good

HAVING TEA in the Ba Lien home in 1988 are the author (*second from left*), Ba Lien's granddaughter Huyen Xuan Dep (*center, holding baby*), and Ba Lien (*far right*).

VO-TONG XUAN

crop bought a new motorbike.

How did I get into rice in Vietnam? I was raised on a West Texas cotton farm. I received my B.S., a double degree in agricultural science and journalism—along with an Army officer commission—from Texas A&M University in 1966. I then finished an M.S. at Iowa State University and, in 1968, reported to Infantry Officers School at Ft. Benning, Georgia.

I arrived in Vietnam in June 1969 as a first lieutenant. The legendary John Paul Vann (made famous by the book and movie *A Bright Shining Lie*) ran the war in the Mekong Delta. Vann reviewed my records, saw my farm and educational background, and assigned me, as an adviser to the Vietnamese military and government, to Military Assistance Command-Vietnam (MAC-V) Team 73 in Vi Thanh in Chuong Thien Province, in Vietnam's southern Ca Mau Peninsula. Seventy percent of Chuong Thien's population was rice farmers.

Chuong Thien was an awful place for a dryland cotton farmer. The average elevation was less than 1 meter, and 97% of its land was covered by water—rice fields or swamp—during the 6-month monsoon season.

Chuong Thien was also a Viet Cong (VC) stronghold. The U.S. military constantly classified it as one of the two least secure South Vietnamese provinces. Putting it another way, Chuong Thien was one of the VC's two *most secure* provinces.

A dozen U.S. advisers were killed in Chuong Thien during my 1-year tour. Five were killed in sampans. These boats were our only transport, unless we could hitch a ride on helicopters, along the rivers and canals during 6 or 7 months of monsoon rain. No one survived a sampan ambush.

Our casualties may not seem high, but only 160 Americans were stationed in Chuong Thien, and only 30 or 40 advisers worked outside the small provincial HQ in Vi Thanh.

Chuong Thien was also the only Delta province with no civilian agricultural adviser, assigned by the U.S. Agency for International Development (USAID). The word was, none would go there. But no one asked if I *wanted* to go to Chuong Thien—the Army sent me.

U.S. President Lyndon B. Johnson, or LBJ, had visited IRRI in October 1966, accompanied by Philippine President Ferdinand Marcos. LBJ appreciated farmers, and went into the IRRI experiment fields to see IR8 (see main photo, pages 34-35). LBJ made a historic flight later that day, to Cam Ranh Bay, Vietnam, "to visit our boys over there." Johnson later pressured USAID to promote the hardy IR8 in Vietnam.

IR8 had arrived in Chuong Thien Province in 1968—a year before me. The first IR8 seeds were smuggled into Vietnam in 1967 by my colleague Jose Ona, a Filipino agronomist who had done his M.S. research at IRRI, then was hired as USAID rice agronomist for the Mekong Delta. A friend at IRRI had harvested the IR8 seeds from IRRI experimental plots, and given them to Ona.

Ona then set up IR8 demonstration plots in each province of the Mekong Delta. I feel safe in saying that no farm technology—anywhere—ever spread faster than IR8 seeds in the Delta, even at the height of the fighting.

A farmer named Ong Ba Lien planted the first Honda Rice seeds in Chuong Thien Province in late 1967. He was the best farmer in the region, and Ona and I later tested and demonstrated IR8 and IR5, another IRRI variety, on his farm. I felt not only welcome but, rarer in those days, *safe* on Ba Lien's farm, even though the area ranged from dangerous to suicidal for Americans.

When I arrived in 1969, farmers were already growing IR8 on almost 1,000 hectares across the province.

I was soon bringing IR8 seeds to farmers, who suffered as much as any people I've ever known, across Chuong Thien, a province that the war had torn brutally. We traveled mostly by sampan on brown-water canals and rivers with Vietnamese agricultural cadres and soldiers.

But sometimes by Huey helicopters. I could spot IR8 easily from choppers, because it reminded me of a "crew cut." IR8's short, stiff stems held it erect, while the tall traditional varieties fell over and lay flat. Thus, IR8 could convert nutrients to heavy heads of grain, and hold them upright.

That genetic trait made IR8 outyield any rice that tropical Asia had ever known. Farmers started harvesting 5 or 6 tons per hectare from fields where yields had stagnated at 1 or 1.5 tons for centuries. Traditional rice varieties took 160 to 200 days to mature, so farmers could grow only one crop per year using the monsoon rain. IR8 matured in about 130 days, so farmers could grow two crops per year. The new rice was also nonsensitive to daylength, so farmers anywhere could grow it, at any time of the year.

By mid-1970, IR8 was planted on about half of Chuong Thien's rice land, land that was scarred by bomb and artillery craters.

That's what made it tough to come to a personal peace with Vietnam. In my other role, as an Army officer, I called a lot of the bombs and artillery that left those scars, and sometimes killed or maimed farmers who were grateful for the IRRI seeds. War and peace. Working with both was hard.

The new rice seeds were the only good thing—other than wonderful Mekong Delta farm families—that I saw in the war.

To me, new seeds offer hope. Maybe that's why I made rice improvement—then later, overall international agricultural development—my profession after Vietnam.

But I learned about those seeds in a setting of death.

What did the Viet Cong think about IR8? In the first couple of years, the VC opposed IR8, calling it a plot of the "imperialistic Americans." But, in 1970, the VC

THE AUTHOR (*far right*) and Vietnamese staff at the Rice Research Station in My Tho, in the Mekong Delta in late 1974, a few months before Saigon fell.

HARGROVE PERSONAL ARCHIVES

IRRI

DESPITE THE TURMOIL of the war, IRRI maintained a presence in Vietnam. Here, the Institute's inaugural director, Robert Chandler, talks to trainees from the National Rice Production Training Center just outside Saigon in August 1969.

changed its position and issued a new directive. VC cadres were now to learn IR8 culture, and take the new seeds to contested or "liberated" (meaning VC-controlled) zones.

IR8 in North Vietnam

Information is scarce about how IR8 and other IRRI varieties spread in North Vietnam during the war. I've read that in 1968 or 1969, an Eastern European vessel—I believe it was Polish—purchased a shipload of IR8 seeds at Dhaka (then in East Pakistan) and quietly off-loaded the seeds at Haiphong, the main North Vietnamese port. From there, the seeds went to farmers in the Red River Delta.

A former high-ranking North Vietnamese agricultural official told me that IR8 reached North Vietnam in other ways. Some of the few North Vietnamese soldiers who went back north on the Ho Chi Minh Trail carried a kilo or two of IR8 seeds.

IR8 was called Nong Nghiep 8, or "Agriculture 8," in North Vietnam. But I'm sure the farmers weren't told that the high-yielding seeds were bred at an institute then funded entirely by the Ford and Rockefeller foundations, spawned by capitalism. Yet neither foundation intended for those seeds to be used for war.

Back to the Mekong Delta, two decades later

The Army discharged me in 1970. In early 1973, I joined IRRI, the source of those seeds that had impressed me so greatly. My family and I moved to the Philippines, and I spent the next 19 years following the world's rice crop.

In 1988, IRRI sent me to Vietnam to write about IRRI's impact there. It was my first return since the war ended in 1975. I probably could have returned to Vietnam years earlier, but I was afraid of how I might react, emotionally.

"Can we go look at the rice in the old Chuong Thien Province?" I asked my friend and host, Dr. Vo-Tong Xuan.

That led to the most emotional journey of my life. Soon after arrival in Vi Thanh, Tu Rang, Xuan, and I were traveling by sampan 8 kilometers up the Xa No Canal to visit Ong Ba Lien, the farmer who had planted the first IR8 in Chuong Thien.

I was never sure about Ba Lien's politics. I doubted that he had any. Honda Rice, or IR8, was the bond of our friendship.

Tu Rang speaks: "Of course, Ba Lien supported the National Liberation Front during the war. His two sons-in-law were Viet Cong colonels. One was a revolutionary hero. And his wife is my aunt, and helped us gather information on you."

"Ba Lien never told me *that,*" I reply.

"How *could* he?"

Tu Rang's words are numbing, but I knew that most farmers along the Xa No probably supported the VC, at least at night. I bear no animosity; I'm still alive.

We dock along the canal and follow the ex-VC to a familiar palm thatch home beneath coconut palms, surrounded by bougainvillea, in a grove of banana, papaya, and mangosteen. The house is so much smaller than I remember.

Ba Lien is in his seventies now, and his beard is scraggly and white, but I recognize him easily. We shake hands and embrace. We sit at a round table, where we had often shared simple meals of fish and rice. A crowd gathers, and someone pours green

THE AUTHOR (*tallest*) and Ong Ba Lien (*center, next to the author*) at the Ba Lien home. I had just given Ba Lien's granddaughter, Huyen Xuan Dep (*holding book*), a Vietnamese copy of *Field Problems of Tropical Rice*, an IRRI booklet that helps identify common pest and soil problems.

VO-TONG XUAN

tea. I talk about my family, IRRI … anything to hold back the emotion as Ba Lien throws me back in time.

"Do you remember Jose Ona, who brought the Honda Rice?" I ask. Xuan translates. "And how in 1970, Jose smuggled 2 kilograms of IR20 seeds from the Philippines?"

Those IR20 seeds—the first in all of Vietnam—were precious, because IR20 was IRRI's first improvement over IR8. Yields were slightly lower, but IR20 had better grain quality and resisted several insects and diseases without pesticides. Ona and I gave the IR20 seeds to Ba Lien in trust, because we knew he'd give them the care they deserved. Within a few years, IR20 had replaced IR8 across the Mekong Delta.

Yes, Ba Lien remembers the same things I remember—Honda Rice, Ona, IR20.

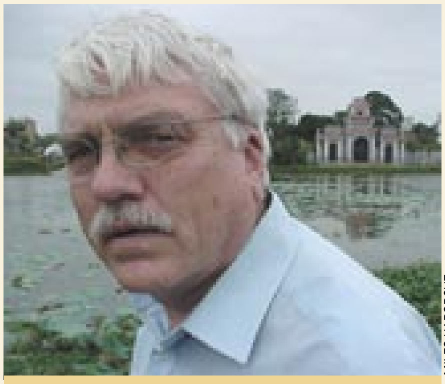
A shrill voice breaks my thoughts: "Uncle Tom! The tall American!" A young woman rushes through the crowd and grasps my shoulder. Xuan asks her to slow down, then translates.

"I remember you so well. I'm Huyen Xuan Dep, Ba Lien's grandaughter—the little girl you carried around the farm on your shoulders." She now balances her own baby on a hip.

All I can say is, "Yes, but I can't do that now." I can't talk anymore, so Ms. Dep and I walk outside to the concrete patio where Ba Lien dries rice.

I pull a copy of *Field Problems of Tropical Rice*, in Vietnamese, from my bag. I coordinated publication of the IRRI booklet, with 158 color photos to help farmers identify rice pests. I'm proud that Xuan and I raised the money to print 160,000 copies of the Vietnamese edition—enough to give one copy to every agricultural brigade in Vietnam.

Ms. Dep clutches at, then flips through, the booklet. She thrusts an open page at me. "This is our problem now!" It's thrip damage.



MILES HARGROVE

THE AUTHOR in 2003, during his fourth return to Vietnam since the war. This time, my son Miles and I were filming a documentary.

I introduce her to entomologist Nguyen Van Huynh, like Xuan, an IRRI alumnus. We all go to the field.

The rice looks bad, and Huynh confirms that thrips are the problem. IRRI variety IR13240, resists most pests, but not thrips. Huynh tells her how to save the crop, if she can get the chemicals.

We go back to the house. "What happened to the bomb shelter?" I ask. "It was in that corner."

"We don't need a bomb shelter anymore." I'd made a bad joke, and everyone knew it. But it was okay.

It's finally time to leave. About 30 Vietnamese have gathered at the canal to see us off. "We know it was hard for you to come here," Ms. Dep says, as tears streak her cheeks. "We are deeply moved that you remember us after all the years."

I should have taken *her* child for a ride around the farm on my shoulders, I think. But it's too late now.

A dozen Vietnamese are crying as we climb into the sampan for the trip back to Vi Thanh. Me too, I guess.

Much of this article is adapted from Hargrove's book A Dragon Lives Forever: War and Rice in Vietnam's Mekong Delta, *originally published by Random House/Ivy, now available from AuthorHouse.com.*

Thinking outside the box

GREG FANSLOW

JOSEF SETTELE, an ecologist from the Center for Environmental Research in Halle, Germany, comes to rice-growing Asia with a novel approach to large-scale environmental risk assessment.

by Greg Fanslow

As society accepts the reality of global climate change and begins to prepare for it, we need the tools to predict the risks we should expect

Climate change and human alterations of the landscape—for agriculture and housing, for example—are virtually certain to affect biodiversity and the stability of ecosystems. This is simply because, although certain species will be favored by changes, others will not. The simplicity, however, stops there.

It is relatively easy to test how something like increased temperature will affect an organism. We can isolate almost any organism, put it in a box, and observe how it responds to environmental changes we can simulate in a controlled setting, such as a laboratory. We might find, for example, that warming benefits this isolated organism. But what if warming also benefits a disease of this organism? What if temperatures become too warm for other organisms on which our hypothetical organism depends, such as its prey if it's a predator or a pollinator of its host plant if it's an herbivore? What if warming benefits a competitor even more?

Once we step outside the small hypothetical box that defines just one organism, or some isolated part of an ecosystem, and start to ask questions about how it will interact with other "boxes" in the environment, we're quickly inundated with uncertainty about how environmental change will reshape our world (see box).

Another challenging aspect to developing an understanding of interactions between components of a complex system is the matter of communication. The different scientific disciplines—which can be thought of as different boxes in which scientists work—have traditionally been viewed as distinct and have developed strikingly different languages. As a result, interdisciplinary collaboration tends to be rare because getting through language barriers with someone in a different discipline requires a lot of valuable time and energy for people that don't generally have a lot to spare.

When you want to understand

Calculating Complexity

Ecosystems are remarkably complex, which makes it exceedingly difficult to predict their behavior. If we are lucky, we may be able to understand how one species affects another species, but, in a relatively simple hypothetical system of 50 species, for example, each species potentially interacts with 49 other species. This gives us no less than 1,250 possible two-way interactions in a simple 50-species system. If you expand your frame of reference to larger areas with many more types of ecosystems, it's clear that even a large group of dedicated scientists couldn't study even a small percentage of the possible two-way interactions using traditional controlled experiments, much less the three- and four-way interactions that are often just as important.

processes in a very large scale system, but can't do experiments, modeling is a useful way to synthesize information gathered independently about components of a larger system. However, a model that combines too many different pieces of information becomes unwieldy and difficult to interpret because results can no longer be attributed to something happening in a particular part of the overall system.

Josef Settele, an ecologist from the Center for Environmental Research in Halle, Germany, thinks he has the right approach to understanding environmental risks over large areas. The European Union has given Dr. Settele more than 25 million Euros (US$32 million) to implement a project called ALARM (www.alarmproject.net), which has a scope matched only by the ambition of its acronym: Assessing LArge-scale environmental Risks for biodiversity with tested Methods.

The objective of the project is "to apply our best understanding of how organisms and ecosystems function and use new ways to assess large-scale environmental risks. Ultimately, we want to provide information that can be used to reduce negative impacts on humans and, in turn, minimize negative human impacts—both direct and indirect," says Settele.

After recently expanding its geographic reach by adding institutions and scientists from outside the European Union, ALARM will encompass a total of more than 250 scientists from 69 institutions in 33 countries, and will have a budget of more than 25 million Euros.

With the expansion of the project to Asia comes the need to tailor the ALARM approach for rice-growing systems and IRRI ecologist K.L. Heong has been enlisted to analyze long-term trends in the biodiversity of parasitic wasps. If the project continues to grow in the region, other rice scientists may be recruited as well.

Dr. Settele is no stranger to rice fields either. He began his ecology career in the 1980s as a graduate student with an insect ecology project in the Ifugao rice terraces in the Philippines. He has now returned to the rice fields of Asia to join International Rice Research Institute (IRRI) scientists in applying an approach he developed to predict the impacts of complex environmental changes on the ecosystems of Europe.

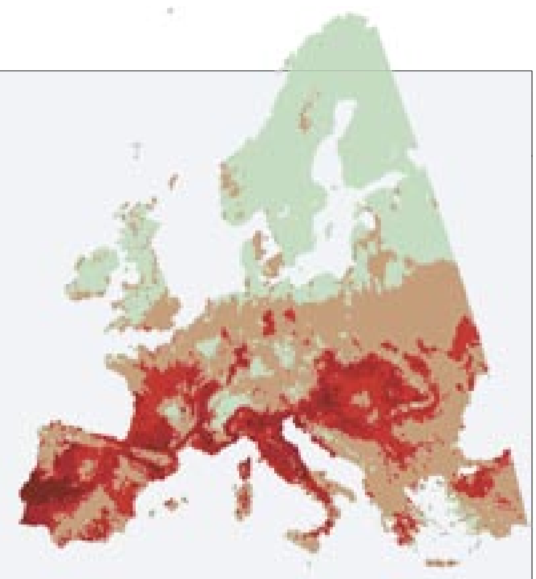
The feature of ALARM that sets it apart from overly complex modeling exercises is that it makes use of scientific narratives (or "stories") based on scientists' best understanding of the environmental systems they study. ALARM puts these narratives together to paint a larger picture of how something as large and complex as the environment of a continent will respond to different environmental driving forces.

Just as challenging as reaching an understanding of how environmental change will play out is translating that understanding into language that policymakers and the general public can understand.

To illustrate what he is trying to do through the ALARM project, Dr. Settele likes to contrast different forms of environmental storytelling. "Scientists tend to be reluctant to let a good story distract attention from the facts, while journalists or activists can often be faulted for ignoring facts for the sake of a good story," he says.

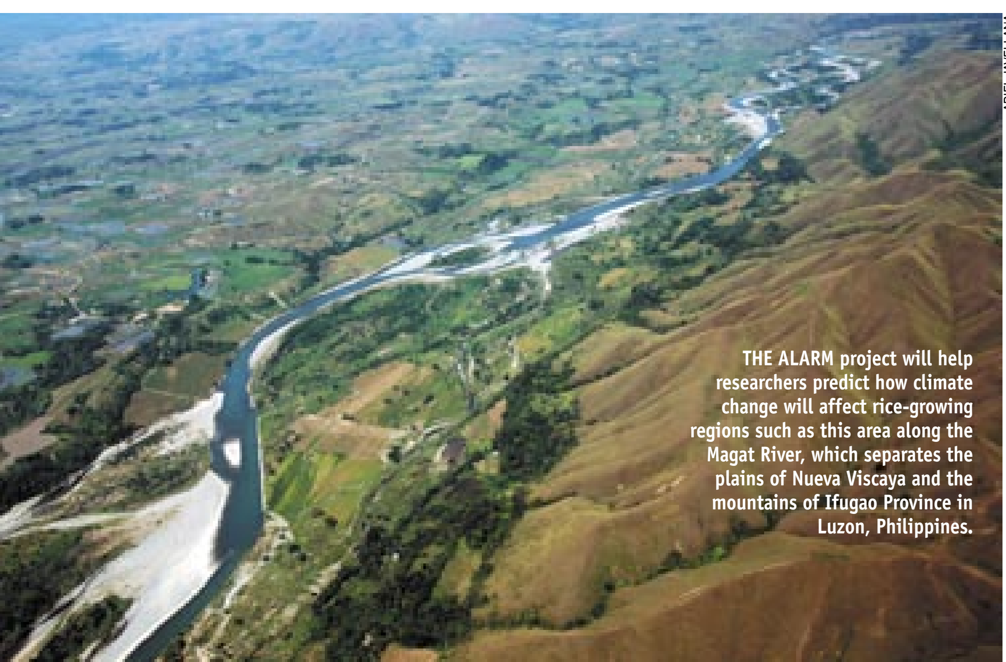
"The goal of ALARM is to find a compromise between these ways of telling environmental stories and treat stories as the envelopes to carry facts, and remember that facts are the basis of any good story."

Greg Fanslow is an environmental consultant at IRRI.



A MAP of Europe showing projected losses of areas that are environmentally suitable for amphibian species by the year 2050.[1] Colors represent a six-class scale where increasing intensities of red represent increasing degrees of species loss.

[1] Araújo MB, Thuiller W, Pearson RG. 2006. Climate warming and the decline of amphibians and reptiles in Europe. *Journal of Biogeography* (special issue: *Species distribution modelling: methods, challenges and applications*).



ARIEL JAVELLANA

THE ALARM project will help researchers predict how climate change will affect rice-growing regions such as this area along the Magat River, which separates the plains of Nueva Viscaya and the mountains of Ifugao Province in Luzon, Philippines.

Innovative research and extension are the key to agricultural development

by In-Sik Kim

RDA/SISA NEWS

MR. KIM is the administrator of Korea's Rural Development Administration.

The Rural Development Administration (RDA), which celebrated its 100th anniversary recently (see page 5), is the central government organization responsible for agricultural research and extension in Korea. Since 1906, RDA and its forerunner, the Experiment Station for Agricultural Encouragement, have developed new technologies and extended these for the development of rural areas and the agricultural sector.

RDA's efforts over the last 100 years have helped Korea achieve self-sufficiency in rice and other staple foods through dissemination and promotion of high-yielding cultivars and improved production technologies. RDA has also taken great steps to improve the rural environment and nurture new farmers.

Now, Korean agriculture faces an increasingly globalized agricultural sector. At the same time, the rural population and the relative economic importance of the Korean agricultural sector are decreasing. Against this backdrop, RDA is changing its research and extension system and accommodating Korean farmers who seek applied technologies that can help increase their income.

Amid the difficulties imposed by shifting domestic and international circumstances, the expectation of the Korean people for rural development and agriculture has not changed. To meet the population's demands, RDA announced on 9 May 2006 the *Innovation Program of RDA*.

Under the vision *Technology development and extension for competitive agriculture and cherished rural community*, RDA has set three goals: ensure agricultural competitiveness to help Korea reach a US$20,000 per capita gross national product, increase quality of life by enhancing the vitality of rural areas, and educate agricultural leaders to guide rural society.

To implement these goals, RDA has developed four basic courses for agricultural research and extension: address the bottleneck of agricultural technologies and apply on-the-spot research directly to farms, develop and extend technologies that lead to the formulation of a national policy for rural development, support agricultural industrialization in the form of biomedicine and other functional materials, and establish basic information and data (for example, soil surveys over Korea's total agricultural area and collection and analysis of genetic resources).

To support these four basic courses, RDA has developed seven policy projects: innovation of research and development at agricultural sites, customized extension services, customer-centered reorganization of RDA, a more competitive system among RDA staff, strengthened customer-centered service, progressive marketing techniques for new RDA-developed technologies, and improved laws and regulations for rural development and innovation.

Along with these initiatives, RDA is strengthening its efforts to reduce poverty, hunger, and malnutrition in developing countries. For example, RDA recently created five alumni associations consisting of RDA trainees from Indonesia, the Philippines, Sri Lanka, Thailand, and Vietnam. These alumni associations will help sustain the linkage and benefits between RDA and the trainees, and ensure the ongoing transfer of technologies from Korea to developing countries. Since the 1970s, RDA technology transfer training programs have trained more than 3,000 people from 111 countries, mostly in Asia and Africa, on rice production and rural development.

RDA collaborates closely with international organizations, international research centers under the Consultative Group on International Agricultural Research (CGIAR)—especially the International Rice Research Institute (IRRI)—and many national agricultural research and extension systems in Africa, Asia, and South America.

RDA has had particularly close partnership with IRRI since IRRI was established in 1960. This cooperation can be divided into three stages. The beginning stage (1962-76) saw IRRI support RDA by providing individual training for Korean scientists. It is widely acknowledged that Korea achieved rice self-sufficiency during the Green Revolution in the 1970s largely through IRRI's assistance. In the developing stage (1977-90), RDA co-supported collaborative projects. Now, we are in the mature stage (1991-present), during which RDA has donated funds to IRRI through the CGIAR. Throughout its partnership with IRRI, Korea's research and development capacity has continued to improve and is now highly regarded by world standards.

Now, it is time for RDA to find better ways to address world agricultural issues and the global problem of poverty. In this light, the recently opened IRRI-Korea Office—housed at RDA's National Institute of Crop Science in Suwon—can contribute not only to the strengthening of cooperation between RDA and IRRI but also to the continuing evolution of Korea as a world leader in japonica rice research.

Asia and sub-Saharan Africa: rice in numbers

This issue's *Rice facts* presents some key information on the rice situation in Asia and selected rice-producing countries in sub-Saharan Africa—where the International Rice Research Institute (IRRI) is stepping up its efforts to improve rice production and reduce poverty. For an outline of IRRI's new strategic plan and associated research agenda, see *Bringing hope, improving lives* on pages 10–15. The table also presents telling information on poverty and health in the listed countries.

- By 2015, the global rice-eating population is projected to consume over 50 million tons more than it did in 2005, with significant increases in South and Southeast Asia and sub-Saharan Africa.
- Most East Asian countries will reduce consumption, but it is unlikely there will be any surplus rice available for the world market from this region. The high cost of production there means that East Asian rice would be too expensive for the countries in need of more rice to obtain it. So, reduced consumption in East Asia is likely to lead to a reduction in rice area there as farmers switch to other high-value crops.
- Areas where rice is grown mostly under rainfed (rather than irrigated) conditions tend to correspond to low yields and extensive poverty and malnutrition.
- Despite Thailand being the world's largest rice exporter, average yields are the second lowest in Asia. This is largely because most rice is grown under rainfed conditions. However, relatively large farm sizes and the production for export of high-value varieties with superior grain quality mean that poverty is diminishing in many Thai rice areas.
- Although current rice consumption in Africa is lower than in Asia, sub-Saharan Africa's consumption will rise by around 50% by 2015—the greatest proportional increase worldwide. In this region, almost half of rice needs are met from imports. Nigeria is already the world's second-largest rice importer.
- Low African yields present both a challenge and a great opportunity. Since there is a large gap between actual and potential yield, a large percentage increase in yield and overall production is possible with the adoption of improved technology.
- A high proportion of the population in almost every listed country—with the exception of some in East Asia—suffers from serious health problems due to undernourishment and underweight. The proportion of the population living in poverty also remains very high.

This and a host of further information presented here clearly demonstrate that a continued, concerted rice research effort is essential if we are to help poor rice consumers and producers improve their lives.

Key Information on rice situation, poverty, health, and malnutrition

Region/country	Rice situation						Population[d] (million)		Rice consumption per capita[e] (kg/person/yr)		Rice consumption (000 t)		Increase in rice consumption (000 t) 2005-15	Indicators of poverty, health, and malnutrition			
	Area[a] (000 ha) 2003-05	Rainfed area[b] (%)	Yield[a], paddy (t/ha) 2003-05	Annual[a] production, paddy (000 t) 2003-05	Imports[c] (000 t) 2005	Exports[c] (000 t) 2005	2005	2015	2005	2015	2005	2015		Poverty ratio[f] (%)	Calorie intake[a] (Kcal/person/day) 2003	Under-nourished population[g] (% of total) 2000	Under-weight children below age 5[g] (%) 2000
East Asia[h]	**31497**	**7**	**6.19**	**194895**	**2143**	**856**	**1516.9**	**1596.4**	**79**	**73**	**120017**	**116597**	**-3420**				
China	28222	7	6.21	175394	609	656	1315.8	1393.0	82	75	107407	105059	-2348	10	2940	11	10
Japan	1691	0	6.31	10665	787	200	128.1	128.0	56	49	7170	6257	-904	0	2768	…[i]	4
Korea, DPR	586	33	4.05	2371	600	0	22.5	23.3	62	79	1402	1845	443	45	2178	36	28
Korea, Rep	999	0	6.47	6465	120	0	47.8	49.1	80	65	3829	3208	-621	4	3035	…	…
Southeast Asia[j]	**42927**	**58**	**3.77**	**162023**	**3630**	**12657**	**555.8**	**623.4**	**143**	**142**	**79482**	**88523**	**9041**				
Cambodia	2167	92	2.01	4360	76	5	14.1	17.1	152	178	2140	3035	895	34	2074	33	45
Indonesia	11734	46	4.55	53404	500	1	222.8	246.8	150	145	33437	35788	2351	27	2891	6	25
Lao PDR	756	86	3.20	2418	9	0	5.9	7.3	171	171	1015	1251	237	40	2338	22	40
Malaysia	663	35	3.35	2223	750	8	25.3	29.6	81	86	2059	2552	493	8	2867	0	20
Myanmar	6266	70	3.80	23782	18	150	50.5	55.0	206	206	10420	11307	887	25	2912	6	35
Philippines	4044	33	3.51	14204	1890	0	83.1	96.8	108	123	8990	11943	2952	34	2480	22	32
Thailand	9864	77	2.63	25966	1	7274	64.2	69.1	104	95	6707	6561	-146	10	2425	20	18
East Timor	20	100	3.27	65	5	0	0.9	1.5	71	63	68	93	26	42	2819	…	43
Vietnam	7412	45	4.80	35599	0	5174	84.2	95.0	177	169	14905	16050	1145	28	2617	19	34
South Asia	**58288**	**44**	**3.15**	**183790**	**896**	**7703**	**1453.5**	**1680.1**	**79**	**77**	**114345**	**129236**	**14891**				
Bangladesh	10731	45	3.62	38897	785	0	141.8	168.2	160	163	22647	27479	4832	36	2193	30	48
India	42667	46	3.05	130238	0	4795	1103.4	1260.4	76	73	84033	92039	8006	34	2473	21	47
Nepal	1537	51	2.79	4282	22	6	27.1	32.7	104	112	2832	3652	820	38	2483	17	48
Pakistan	2494	0	2.96	7387	0	2900	157.9	193.4	17	20	2720	3805	1085	32	2316	20	38
Sri Lanka	840	25	3.50	2942	50	2	20.7	22.3	92	91	1916	2022	106	22	2416	22	33
Sub-Saharan Africa[k]	**8349**	**84**	**1.48**	**12350**	**7202**	**105**	**751.3**	**934.3**	**17**	**21**	**13066**	**19904**	**6838**				
Congo, Dem Rep	417	100	0.76	315	21	0	57.5	78.0	4	8	230	624	394	68	1606	71	31
Côte d'Ivoire	471	94	2.30	1083	867	1	18.2	21.6	71	88	1292	1898	606	40	2644	14	21
Ghana	119	100	2.03	241	448	1	22.1	26.6	24	32	539	856	318	39	2680	13	25
Guinea	525	95	1.71	900	300	0	9.4	11.9	82	95	770	1125	355	40	2447	26	23
Liberia	120	100	0.89	107	108	2	3.3	4.4	42	74	139	324	185	31	1930	46	27
Madagascar	1222	60	2.42	2953	151	0	18.6	23.8	92	92	1715	2195	480	50	2056	37	40
Mali	420	79	2.03	852	42	0	13.5	18.1	50	68	675	1232	557	64	2237	29	33
Mozambique	179	100	1.08	193	263	0	19.8	23.5	9	12	187	282	95	70	2082	47	26
Nigeria	3646	85	0.96	3486	1777	0	131.5	160.9	26	30	3368	4828	1460	34	2714	9	31
Sierra Leone	210	72	1.26	265	19	0	5.5	6.9	76	97	419	670	251	68	1943	50	27
Tanzania	353	95	1.90	670	182	2	38.3	45.6	17	18	636	804	168	36	1975	44	29
World[l]	**151155**	**42**	**3.99**	**602993**	**28837**	**28837**	**6464.8**	**7219.4**	**55**	**54**	**354363**	**387753**	**33390**				

ha = hectares; t = metric tons; kcal = kilocalories; paddy = unhulled rice. [a] FAOSTAT © FAO Statistics Division 2 August 2006. [b] Estimated using data from World Rice Statistics and CORIFA of FAO. Countries with very low yield and for which data are not available are assigned as 100% rainfed. [c] 2005 import data for Cambodia, Laos, Myanmar, Thailand, East Timor, Vietnam, India, Nepal, Pakistan, Congo Dem Rep, Ghana, Liberia, Mali, Mozambique, Sierra Leone, Tanzania and 2005 export data for China, Japan, Thailand, Vietnam, Pakistan: USDA. [d] Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, *World Population Prospects: The 2004 Revision* and *World Urbanization Prospects: The 2003 Revision*, http://esa.un.org/unpp, 21 March 2005. [e] Estimated by analyzing the trend from time series data for 1990-2002. [f] World Development Indicators 2004. [g] FAO, 2004. *The State of Food Insecurity in the World*. Rome: FAO. [h] Includes all other East Asian countries. [i] ... data not available. [j] Includes all other Southeast Asian countries. [k] Includes all other African countries south of the Sahara. [l] World figures based on source except for rice consumption figures, which were based on estimates.

How many rice varieties are there?

Ruaraidh Sackville Hamilton

A common question but very difficult to answer. Depending on your definition of variety, the answer could be anything from zero to around 500,000 varieties of *Oryza sativa* (Asian cultivated rice). In the technical sense used by taxonomists (biologists who classify organisms into groups based on evolutionary relationships), descriptions have been published of 14 varieties, but most taxonomists now do not accept any of them as valid taxonomic varieties—so, in this sense, the answer is zero.

Cultivated varieties (abbreviated to "cultivars" to distinguish from the taxonomists' concept) are something different, but even then we count different numbers for different meanings. Many countries maintain an official list of recognized varieties released for cultivation by farmers. In countries with a legal system for protecting plant breeders' rights, these varieties may have been subjected to rigorous tests to demonstrate that they are novel, distinct from other varieties, uniform, and stable.

The International Rice Information System (IRIS; www.iris.irri.org) recognizes around 5,000 released varieties. The actual number may be greater than 5,000 because no one has systematically collated all countries' lists. It could also be less because the same genetic variety can be released in more than one country with different entries in IRIS, under the same or a different name.

If you include traditional varieties (also known as farmers' varieties or landraces), the number goes up markedly. The M.S. Swaminathan Research Foundation in India claims that India alone has 100,000 traditional varieties still in use by farmers around the country, and another 300,000 that have become extinct.

However, the task of counting them becomes very difficult. Traditional varieties predate legal systems of variety protection, and are named only for the farmer's own convenience, not for legal purposes. Therefore, counting one name does not mean one variety (just like naming people—many different people share the name "Sarah" even though they are unrelated). The same genetic entity may be known by different names in different communities, and the same name may be used for different genetic entities.

Depending on your definition of variety, the answer could be anything from zero to around 500,000 varieties of Asian cultivated rice.

In Laos, we have found 3,500 distinct names in use, but many of the names are just generic terms like "black rice" or "glutinous rice," each covering a multitude of different genetic entities. In a study of 95 samples of black rice from different parts of the country, we found no fewer than 45 distinct varieties—and they can be enormously distinct. For example, leaf color varies from uniformly almost black to variegated to normal green (a green-leaf variety can be called black rice if some other part is black, such as the grain or the husk). So, the 3,500 names in Laos could represent 10,000 or more distinct varieties.

Moreover, unlike modern varieties, traditional varieties are often genetically variable: plants of one variety differ within a field, from field to field, and from year to year. Therefore, even deciding whether or not two seed lots are sufficiently similar to be classified as the same variety is not a trivial task.

So, how do I get 500,000 as an upper limit? It's more or less a wild guess. India's 100,000 may be an overestimate, but, even if it is, it's probably not too wildly out. If the small Southeast Asian countries each have 10,000, India could easily have more than 50,000. Around 80 countries are rice producers. As a large country in the primary center of diversity of rice, it is not out of the question that India could have 10–20% of the worldwide total.

And how many varieties do we have safely conserved in the International Rice Genebank at the International Rice Research Institute? Right now, nowhere near the possible half-million total. The answer is around 100,000. This upper limit is simply the number of accessions that we keep and manage as separate entities. We have not yet begun the challenging task of classifying them into varieties or sorting out which ones, if any, are genetic duplicates.

Our priority now is to document and unravel this fantastic functional diversity of rice so that we can better conserve it and use it for sustainable development in the years to come.

Dr. Sackville Hamilton is the head of IRRI's T.T. Chang Genetic Resources Center.

WHAT A BOUNTIFUL HARVEST!

IRRN @30 1976 - 2006

International Rice Research Notes (IRRN) turns 30 this year. Since its birth in 1976, thousands of rice researchers have toiled in fields and laboratories to study the world's most important crop. Many have shared their findings with us. Meet the men and women who helped produce this bountiful harvest.

CONGRATULATIONS to the 2006 winners of the IRRN Best Article Awards

Crop management and physiology

Contribution of on-farm assessment of improved varieties and crop management to yield of deepwater rice

A. Ghosh and B.N. Singh, Central Rice Research Institute, Cuttack, India (December 2005)

Soil, nutrient, and water management

Arbuscular mycorrhizal fungi associated with upland rice in a rotational shifting cultivation system

S. Youpensuk and N. Yimyam, Graduate School, Saisamorn Lumyong, Biology Department, Faculty of Science, Chiang Mai University; B. Rerkasem, Agronomy Department, Chiang Mai University, Chiang Mai 50200, Thailand; and B. Dell, School of Biological Sciences and Biotechnology, Murdoch University, Perth 6150, Australia (December 2005)

Pest science and management

Endo- and ectoparasites of the Philippine rice field rat, *Rattus tanezumi* Temminck, on PhilRice farms

M.M. Antolin, R.C. Joshi, L.S. Sebastian, L.V. Marquez, and U.G. Duque, Philippine Rice Research Institute (PhilRice), Maligaya, Muñoz, Nueva Ecija 3119; and C.J. Domingo, College of Veterinary Science and Medicine, Central Luzon State University, Muñoz, Nueva Ecija 3120, Philippines (June 2006)

Genetic resources

Dhanrasi, a new lowland rice variety with *Oryza rufipogon* genes for improving yield potential and resistance to biotic stresses

T. Ram, Directorate of Rice Research, Rajendranagar (DRR), Hyderabad; N.D. Majumder, Indian Institute of Pulses Research, Kanpur; and B. Mishra, DRR, Rajendranagar, Hyderabad 500030, India (June 2006)

Agricultural engineering

Effect of hermetic storage in the super bag on seed quality and milled rice quality of different varieties in Bac Lieu, Vietnam

Diep Chan Ben, Department of Agriculture and Rural Development, Bac Lieu Province; Phan Van Liem and Nguyen Tam Dao, Bac Lieu Seed Center, Bac Lieu Province, Vietnam; M. Gummert and J.F. Rickman, IRRI (December 2006)

ASIA RICE FOUNDATION

In Asia, rice is culture, rice is life

"Harvesting rice"
1st Prize, Photo
Contest, 2004

Colored rice
wafers (kiping)
displayed at the
Pahiyas Festival,
Philippines

The Asia Rice Foundation is a regional organization that works for the betterment of rice in Asia.

The Asia Rice Foundation works with its member national rice foundations in five Asian countries—Bangladesh, China, Indonesia, Philippines, and Thailand—to undertake rice programs, projects, and activities relevant to the needs and constraints of the region. An affiliate chapter in the United States of America, ARF-USA, also helps support our programs.

We work with farmers to improve their well-being and to make rice farming a profitable and sustainable livelihood.

We work with the public, particularly youth, to provide rice knowledge that will enhance appreciation of the importance of rice to their culture, economy, and people's lives.

We work with scientists to help them do their jobs more efficiently and with greater relevance to the needs of rice consumers and producers.

We work with policymakers to provide them with unbiased information pertinent to the decisions they make that have great relevance to their respective countries' rice situations.

We work with business people to harmonize their interests with those of farmers and consumers.

The Asia Rice Foundation

You can help

What you do today can make a difference in Asia's tomorrow

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A young Thai farmer learning about rice production at Rice Camp 2006, IRRI