Rice Today

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International Rice Research Institute

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IRRI researchers' agronomy challenge

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Tiny Uruguay yields big

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NEW

Rice fables

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About the cover. IRRI's head of research tried his hand at planting rice using the recommended practices and tools of the Institute.

Rice Today is published by The Rice Trader Inc. (TRT) in association with the International Rice Research Institute (IRRI).

TRT, for 22 years, has brought subscribers crucial, up-to-the-minute information on rice trade through its weekly publication, *The Rice Trader.* Acknowledged as the only source of confidential information about the rice market, this weekly summary of market data analysis has helped both the leading commercial rice companies and regional government officials make informed decisions, which are critical in today's market.

IRRI is the world's leading international rice research and training center. Based in the Philippines and with offices located in major rice-growing 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. It is one of the 15 nonprofit international research centers that are members of the CGIAR (www.cgiar.org).

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Expanding the world of rice

We are pleased to announce that the *Rice Today* editorial board held its first meeting in May this year via conference call and this was hosted by The Rice Trader at its Americas conference in Miami. The board shared some great ideas about making *Rice Today* even better. We are truly grateful for everyone's contributions and for their ongoing contributions in the future. The entire team is looking forward to implementing these ideas over the coming issues—so, stay tuned for even more great content!

In this issue, we head to Sri Lanka and discover the extent of its weedy rice problem and efforts to combat it. Then, in our country highlight, we visit Cambodia to hear about rice production and research there, including a heart-warming reminder of how the International Rice Genebank repatriated "lost" rice seeds from traditional rice varieties following the country's internal strife.

One interesting feature story we have is how African farmers have become desperate in warding off queleas—birds that feed on rice and cause significant yield losses—and how some seemingly simple techniques can fight this major problem in Senegal.

From Africa to South America, we have an incredible story of how the tiny country of Uruguay can produce so much rice, perhaps something that countries working on increasing their rice production can take notes from.

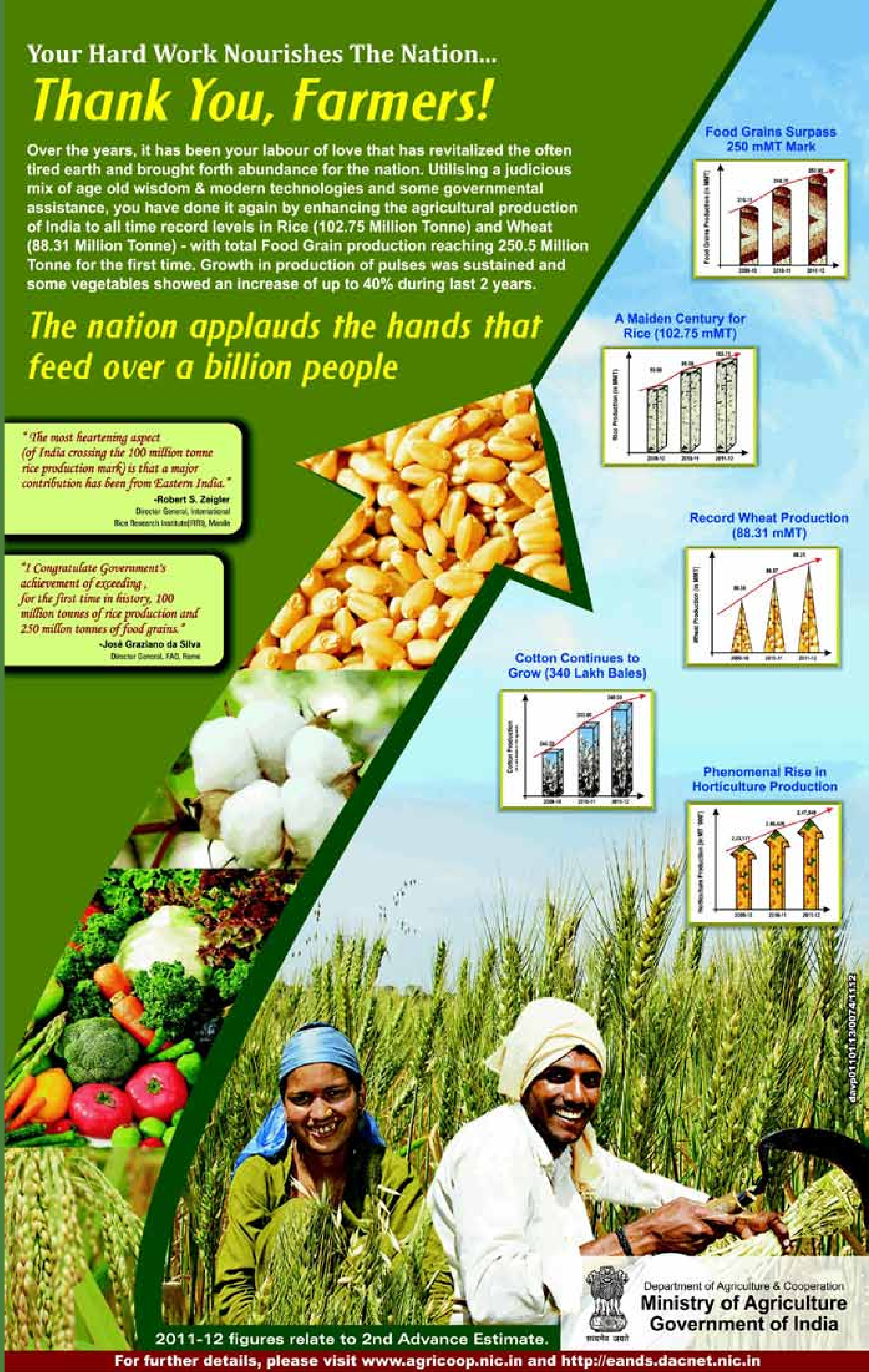
We are also privileged to have Dr. Yuan Longping, the Father of Hybrid Rice, answer some questions about success in life, hybrid rice's potential to boost rice yields, and China's position as the top user of hybrid rice. In response to the ongoing popularity of our articles about rice art and culture—thanks to our readers who enjoy learning about all aspects of rice—we have our first rice fable. Folk legends and fables shed light on the history of rice in different cultures, and, by publishing such stories, we help preserve them in this modern age.

For those who want to see scientists get all muddy and to learn the practical art of growing rice, you'll love the IRRI Agronomy Challenge feature. Earlier this year, IRRI's Deputy Director General for Research (and *Rice Today* editorial board member) Achim Dobermann and Experiment Station Head Leigh Vial tried their hand at growing rice and we feature their exploits in this issue.

Finally, don't overlook our news section this issue! We have hot-off-the-press news about how collective action to control rodents in Vietnam has delivered farmers a 20% pay raise. Also, we now know the true nature of the glycemic index of rice, which will help rice consumers wisely choose the type of rice they eat. We also have news from the Philippines about a microfinance bank using a nutrient management tool to help the bank provide fertilizer microloans to rice farmers.

Happy reading!

Sophie Clayton
Rice Today associate publisher


Your Hard Work Nourishes The Nation...
Thank You, Farmers!
Over the years, it has been your labour of love that has revitalized the often tired earth and brought forth abundance for the nation. Utilising a judicious mix of age old wisdom & modern technologies and some governmental assistance, you have done it again by enhancing the agricultural production of India to all time record levels in Rice (102.75 Million Tonne) and Wheat (88.31 Million Tonne) - with total Food Grain production reaching 250.5 Million Tonne for the first time. Growth in production of pulses was sustained and some vegetables showed an increase of up to 40% during last 2 years.
The nation applauds the hands that feed over a billion people
"The most heartening aspect (of India crossing the 100 million tonne rice production mark) is that a major contribution has been from Eastern India."
-Robert S. Zeigler
Director General, International Rice Research Institute(IRRI), Manila
"I Congratulate Government's achievement of exceeding, for the first time in history, 100 million tonnes of rice production and 250 millon tonnes of food grains."
-José Graziano da Silva
Director General, FAO, Rome
Food Grains Surpass 250 mMT Mark
A Maiden Century for Rice (102.75 mMT)
Record Wheat Production (88.31 mMT)
Cotton Continues to Grow (340 Lakh Bales)
Phenomenal Rise in Horticulture Production
2011-12 figures relate to 2nd Advance Estimate.
Department of Agriculture & Cooperation
Ministry of Agriculture
Government of India
For further details, please visit www.agricoop.nic.in and http://eands.dacnet.nic.in

Collective action boosts rice farmers' pay in Vietnam

Rice farmers from two districts in Vietnam have successfully carried out a community action plan to thwart rodent damage to their crops—reducing damage caused by the pests and giving them a 20% boost in income.

Every year, Vietnam loses 10% of its rice production to rats, and, in years of rat outbreaks, this rises to 20–30%.

"Farmers in many rice-growing countries see rats as one of their top three pests," says IRRI rodent expert Grant Singleton.

Vietnamese farmers who worked together to implement ecologically sustainable rodent management produced 10–14% more rice and got 20% higher income.

Rats cause hardship and food insecurity to farmers by eating grains or parts of the rice crop; spoiling grain through their droppings; bringing diseases to humans, poultry, or livestock; destroying personal possessions; or, sometimes in extreme cases, biting humans in their sleep.

"The key to outsmarting rodents is ecologically based rodent management, but, to be effective, it should be implemented strategically with community participation or collective action," says Dr. Singleton.

In a three-year project, Dr. Singleton and his team worked with the village cooperatives and people's committees of Binh Luc and Kim Bang (two districts of Ha Nam Province in Vietnam).

Ecologically based rodent management uses knowledge about when and where rats breed, and other ecological and biological information, to control rodents effectively without relying on rodenticides.

Farmer An Van Lai, who was involved in practicing such management, notes that, before the project, they felt hopeless about controlling rats. He indicated that even when they knew that the rodenticide was not good, they believed they had no choice but to use it.

The community adopted practices such as synchronized community planting, timely community rat control campaigns, smart trapping systems, hunting of female rats, and proper sanitation of fields.


IRRI

FIELD RATS infesting rice plants can be thwarted with a community action plan based on ecology.

With community action at the early stage of the crop, the farmers found that they could effectively manage the rodent population.

The rodent management community project resulted in 93% less rodent damage in rice areas, a 10–14% increase in rice yields, 20% higher economic returns, and 50% less rodenticide use.

"Using electrocution as a way to get rid of rats has also stopped," says Dr. Nguyen Huu Huan, deputy director general of Vietnam's Plant Protection Department.

Work on ecologically based rodent management is also under way in Bangladesh, Indonesia, Laos, and the Philippines.

Rice research in Africa: a strong case for investment

Excited by the work of Africa Rice Center (AfricaRice) and its partners on the development of new stress-tolerant and climate-resilient technologies for major rice production systems in Africa, AfricaRice Board Chair Peter Matlon stated, "We believe that rice research in Africa provides a strong case for investment."

The work includes marker-assisted selection for tolerance of important yield-limiting and yield-reducing stresses, such as salinity, drought, cold, iron toxicity, rice yellow mottle virus, and rice blast. Component technologies are also used to increase labor, nutrient, and water productivities to close yield gaps, and reduce risks in farmers' fields. Several of these technological options are already being tested with farmers' participation.

AfricaRice's product-oriented, 10-year strategic plan presents a clear vision of success to help Africa achieve almost 90% self-sufficiency in rice by 2020. The Board described this plan as "a compelling and convincing agenda for realizing Africa's tremendous rice potential."

"AfricaRice can achieve its mission only through strong national agricultural research systems and strategic partnerships worldwide in order to bring the best efforts of rice science to bear on the immense challenge of food security faced by Africa," said AfricaRice Director General Papa Abdoulaye Seck.

Study serves up healthy choice of rice

Rice consumers concerned about reports that rice is linked to diabetes can rest assured that rice can be part of a healthy diet, with scientists finding that the glycemic index (GI) of rice varies a lot from one type of rice to another, with most varieties scoring a low to medium GI.

The findings of the research, which analyzed 235 types of rice from around the world, is good news because it not only means rice can be part of a healthy diet for the average consumer, but it also means people with diabetes, or at risk of diabetes, can select the right rice to help maintain a healthy, low-GI diet.

The study found that the GI of rice ranges from a low of 48 to a high of 92, with an average of 64.

The research team from the International Rice Research Institute (IRRI) and Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) Food Futures Flagship also identified the key gene that determines the GI of rice, an important achievement that offers rice breeders the opportunity to develop varieties with different GI levels to meet consumer needs. Future development of low-GI rice would also enable food manufacturers to develop new, low-GI food products based on rice.

Dr. Melissa Fitzgerald, who led the IRRI team, said that GI is a measure of the relative ability of carbohydrates in foods to raise blood sugar levels after eating.

"Understanding that different types of rice have different GI values allows rice consumers to make informed choices about the sort of rice they want to eat," she said. "Rice varieties such as India's most widely grown rice variety, Swarna, have a low GI and varieties such as Doongara from Australia and Basmati have a medium GI."

IRRI

MORE THAN 3 billion rice consumers can rest assured rice can be part of a healthy, low-GI diet.

Understanding that different types of rice have different GI values allows rice consumers to make informed choices about the sort of rice they want to eat.

Dr. Tony Bird, CSIRO Food Futures Flagship researcher, said that low-GI diets offer a range of health benefits: "Low-GI diets can reduce the likelihood of developing type 2 diabetes, and are also useful for helping diabetics better manage their condition.

"This is good news for diabetics and people at risk of diabetes who are trying to control their condition through diet, as it means they can select the right rice to help maintain a healthy, low-GI diet," he added.

Low-GI foods are those measured 55 and less, medium-GI foods are those measured between 56 and 69, while high-GI foods measure 70 and above.

When food is measured to have a high GI, it means it is easily digested and absorbed by the body, which often results in fluctuations in blood sugar levels that can increase the chances of getting diabetes, and make management of type 2 diabetes difficult.

Conversely, foods with low GI are those that have slow digestion and absorption rates in the body, causing a gradual and sustained release of sugar into the blood, which has been proven beneficial to health, including reducing the chances of developing diabetes.

Eating rice with other foods can help reduce the overall GI of a meal and, when combined with regular exercise, can reduce the chances of getting diabetes. In addition, people who exercise need more carbohydrates in their diet and can take advantage of low-GI foods for sustained activity.

Rice plays a strong role in global food security. Being the staple for about 3.5 billion people, it is important to maximize the nutritional value of rice. Low-GI rice will have a particularly important role in the diets of people who derive the bulk of their calories from rice and who cannot afford to eat rice with other foods to help keep the GI of their diet low. Low-GI rice could help to keep diabetes at bay in these communities.

This is the first of several studies the group plans to carry out based on investigating the role of rice in mitigating chronic diseases such as type 2 diabetes.

More carbon dioxide could threaten rice

In a study published in the journal *PLoS ONE*, scientists showed that rice grown in chambers with elevated carbon dioxide more readily cross-pollinates.

"Most of the time, rice is self-pollinating," said Lew Ziska, a plant physiologist at the United States Department of Agriculture (USDA), and lead scientist in the study.

Using growth chambers, the scientists set the concentration of carbon settings: 300 parts per million (what it was at the end of the 19th century), 400 ppm (what it is now), and 600 ppm (what it is projected to be by the end of this century).

They placed in chambers the same ratio of Clearfield rice (a cultivated rice that is resistant to herbicides) to wild rice (sometimes called "red rice") as is usually found on farms in the American South.

ISAGANI SERRANO

WILD RICE produces more flowers at higher CO_2, which could increase cross-pollination.

The results showed for the first time that carbon dioxide concentration can affect gene flow between plants. The study did not prove that this was happening in nature as greenhouse gases increase, only that it is possible.

> **The results showed for the first time that carbon dioxide concentration can affect the gene flow between plants.**

The number of flowers produced by the wild rice at the highest carbon dioxide concentrations was double the production at 300 ppm, a far greater increase than in domestic rice. The wild rice also produced flowers 8 days earlier, which apparently increased cross-pollination.

The plant produced was less nutritious, didn't look as good, and the seeds were more fragile.

Steve Linscombe, senior rice breeder and director of the Rice Research Station at Louisiana State University, cautioned that the results of the experiment were limited. Carbon dioxide in the air could be important, he said, because "anything that increases gene flow is important. But, it is just another variable among many."

The USDA scientists tested only one variety of wild rice and one variety of cultivated rice under restricted conditions. It was not possible to tell from the study what is happening in nature or what would happen with different species of rice or different temperatures.

"There is a huge baseline of weedy rice in nature," Linscombe said. He added that, historically, wild rice has continually crossed with cultivated rice with no proven threat to cultivated rice.

Source: www.insidescience.org

Rice farmers to get fertilizer microloans

In a pilot test, BPI Globe BanKO Inc., a microfinance bank in the Philippines, will provide microloans to a group of Filipino farmers for fertilizers based on the recommendations of Nutrient Manager for Rice—a Web tool and phone application that accurately determines rice crop fertilizer needs.

"Linking technologies developed from research with microfinance services that a farmer can easily access is a promising approach for helping farming households and boosting food production in the country," said IRRI's Dr. Roland Buresh, who led the development of Nutrient Manager for Rice.

New GRiSP director

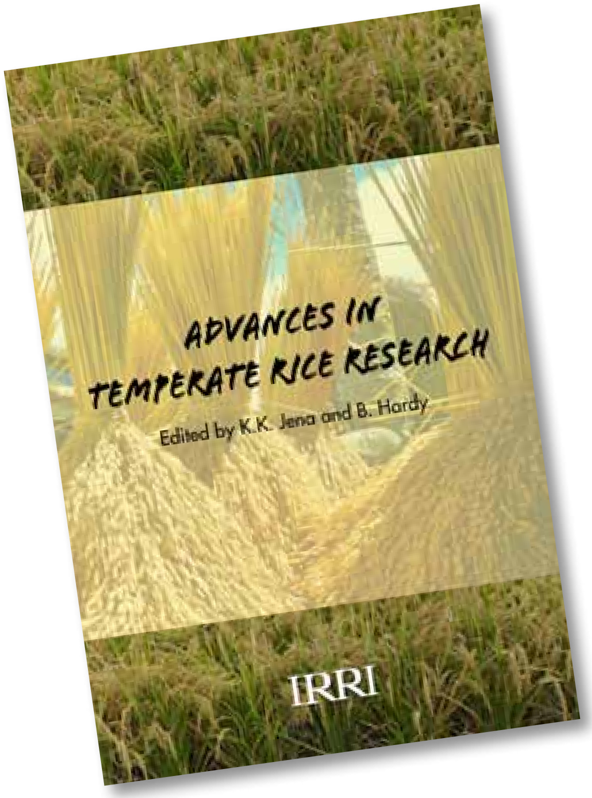
Dr. Bas Bouman, current head of IRRI's Crop and Environmental Sciences Division, has been named the new director of the Global Rice Science Partnership (GRiSP) effective on 1 September 2012.

In his new role, Bas will provide strategic and operational leadership for GRiSP—the CGIAR Research Program for Rice.

He will also provide strategic guidance, develop effective implementation mechanisms, and build outstanding teams to implement the GRiSP strategy and work plan.

CHRIS QUINTANA

DR. BAS A. Bouman, a senior water scientist and newly appointed GRiSP director.



Advances in Temperate Rice Research

Edited by K.K. Jena and B. Hardy

This book is a compilation of research on improving temperate rice in countries from all over the world. It is a publication of the Temperate Rice Research Consortium, which was established by the International Rice Research Institute, in cooperation with the Rural Development Administration of the Republic of Korea.

Methodologies for Root Drought Studies in Rice

Edited by H.E. Shashidhar, Amelia Henry, and Bill Hardy

This manual focuses on describing the relatively high-throughput, low-cost, and precise root phenotyping techniques that have been developed for drought studies in rice and adopted by researchers across the world. This publication looks into the huge potential of rice for root traits that can be effective for drought resistance.

For more information, please contact a.caballero@irri.org.

SELECTED TRAINING COURSES AT IRRI

Course title	Date	Venue	Target participants	Course fee (US$)
Advanced Indica Transformation Course	3-8 September	IRRI, Philippines	Tissue culturists, breeders, physiologists, and agronomists who work on varietal improvement using novel methods such as genetic engineering	3,000
Personal Skills for Professional Development	25-28 September	New Dehli, India	Postdoctoral fellows and early career scientists	2,000
Rice: Postproduction to Market Training Course	22 October-2 November	IRRI, Philippines	Personnel involved in postproduction activities	2,550
Molecular Breeding Course	12-23 November	IRRI, Philippines	Scientists and researchers	1,700
Project Management	12-16 November	New Delhi, India	Postdoctoral fellows and early career scientists	1,250

For inquiries, contact IRRITraining@irri.org, m.maghuyop@irri.org, or a.aquino@irri.org. Phone: (63-2) 580-5600 ext 2538 or +639178639317; fax: (63-2) 580-5699, 891-1292, or 845-0606; mailing address: The IRRI Training Center, DAPO Box 7777, Metro Manila, Philippines (Attention: TC Course Coordinator); Web site: www.training.irri.org.

Note: Fees and schedules are subject to change without prior notice.

H. CHANDANA VAYASIRI (3)

Weeding out a rice impostor

by **Paula Bianca Ferrer**

With 15–20% of its rice produced annually above self-sufficiency levels, Sri Lanka seems to overcome many of its rice production challenges except for one fierce field enemy—weedy rice

For many years, rice has been an important part of Sri Lankan culture and it is also the country's invaluable and most accessible food source. On average, each Sri Lankan consumes 115 kilograms per year. Despite the country's flourishing rice industry, a field enemy has been taking farmers' paddies by storm.

This enemy is weedy rice. It resembles cultivated rice, except for some characteristics.

Some weedy rice species bear a scrawny awn that starts to develop after only 2–3 seasons and these awns appear in the stages just before the grains start to appear; others have grains that come off easily when touched but most weedy rice species don't mature uniformly in the field.

"To date, we have identified more than 1,500 types of weedy rice," says Anurudhika S.K. Abeysekara, a weed expert from the Rice Research and Development Institute (RRDI) in Sri Lanka.

"The first time I saw weedy rice was in 1992, but, back then, it was not a problem," shares Ms. Abeysekara. "At that time, we had identified only 7–8 types of weedy rice. Then, in the early 2000s, we noticed that the problem started to worsen."

A rice impostor

In 2005, a local TV station reported that farmer D. Rajapakse claimed to have found a "miracle rice variety" that could produce 120–150 panicles. (Panicles are the flowering part of the rice plant where grains are formed.) Regular rice has only 3–10 panicles depending on the cultural method used, making the "newly found rice" appear to have much higher yield potential.

"That media report surprised me because I've never heard of a rice variety that could produce as many as 150 panicles, so some RRDI staff and I visited the farmer to see the crop ourselves," says Ms. Abeysekara.

"Indeed, it was no miracle rice variety—just weedy rice," she adds. "So, we had the media report corrected. And then we advised the farmers to pull out any weedy rice in their fields."

The grains of weedy rice have poor eating quality and fall to the ground easily. Also, weedy rice has lower yield after the first and second seasons.

Since its grains easily fall to the ground, weedy rice has no trouble multiplying itself in the soil. Therefore, it may take 3–4 years of weeding and good land preparation to clear the land thoroughly.

Field recovery

Farmer D. Rajapakse spent 5 long years removing weedy rice from his field. He tried many approaches to clear his land of weedy rice.

Initially, he tried seed broadcasting; then, he also used a drum seeder, transplanting, and parachute sowing among other techniques.

"Transplanting," he says, "was costly because the labor wage rate was 600–700 Sri Lankan rupees (US$4–5)." For Mr. Rajapakse, parachute sowing was the best among all the approaches he tried.

"A clean source of seed is very important to avoid re-planting weedy rice plants for the next season," says Dr. Nimal Dissanayake, RRDI director and national coordinator for the International Rice Research Institute (IRRI) activities in Sri Lanka.

No lost cause

"We can stop this weedy rice problem but we have to educate the people first," says P.V. Hemachandra, RRDI rice breeder. "Many farmers don't like to pull out weedy rice from their fields because they're thinking it's still rice.

"Moreover, farmers don't like to go into their fields during heading stage or grain-filling stage when they have a better chance of telling apart cultivated rice and weedy rice," he adds. "It is their traditional belief that going to the field at that time will ruin any developing grain."

"It's very difficult to convince them," narrates extension officer Dilhan Wickramasinghe. "Only 25% of the farmers follow our instructions but, with demonstrations, we can change their ideas or perceptions because they are able to see things for themselves."

"We carried out a total of 200 awareness programs in the previous years," cites Ms. Abeysekara.

"Awareness programs on weedy rice are relatively good even if our present extension system is limited," notes Swarna Herath, an assistant of Ms. Abeysekera in the weedy rice project. "But, because of media such as radio and TV, awareness is slowly building up."

"This weedy rice is really a green menace, but no miracle will easily remove it from farmers' fields—only practical community action and smarter strategies will do," says IRRI weed expert Dr. Bhagirath Chauhan.

In 2011, he conducted trials in different parts of Sri Lanka to study the effect of different crop establishment methods on weedy rice. Visually, results showed that weedy rice was less rampant when wet seeding was done with a drum seeder compared with broadcasting seeds.

He also introduced mechanical seeders in Sri Lanka so that farmers can plant rice much faster and easier, in rows. With this method, farmers can better spot weeds, especially those that closely resemble rice so they can be pulled out.

Dr. Chauhan also conducted a seminar and demonstration on mechanization with farmers in one district. "The chief engineer from Kandy said that although rice harvesting in Sri Lanka was already quite mechanized, seeding, on the other hand, was not, and that it was the first time mechanical seeders were brought to Sri Lanka," he shares.

PAULA BIANCA FERRER

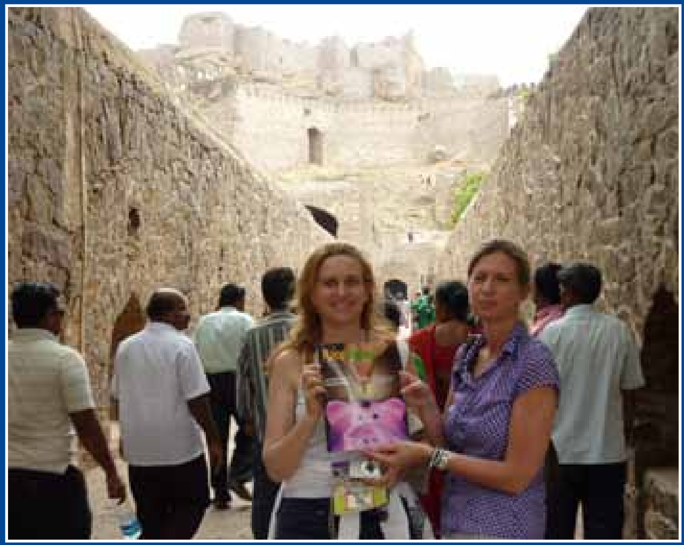
MS. SWARNA Herath (*left*) with a local RRDI farm worker inspects some rice plants in a field trial.

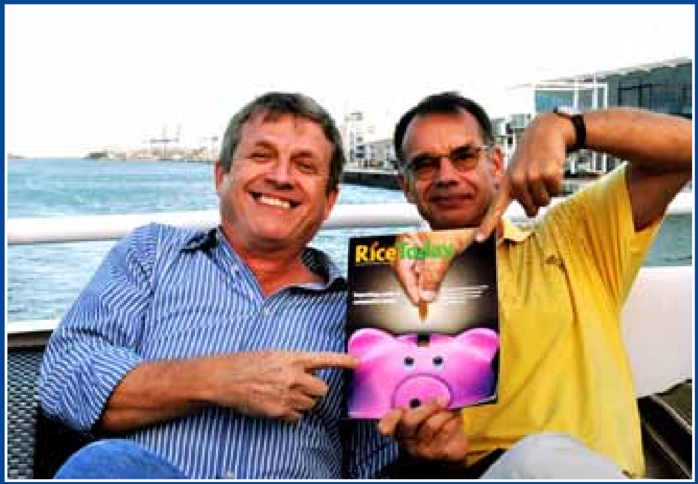
IRRI WEED expert Bhagirath Chauhan (*left*) and Ms. Anuru Abeysekara (*right*) examine a field infested with weedy rice.

Rice Today around the world

SUNNY AT THE BAY. *Rice Today* editor Lanie Reyes of the International Rice Research Institute smiles along the coast of the Bay of Bengal in Orissa State, India. The Bay of Bengal is the largest bay in the world.

SOUND ON A HILL. FAO staff members Carola Fabi and Rosalaura Romeo hold *Rice Today* before climbing the 91-meter granite hill in Golkonda Fort in Hyderabad, India. Golkonda is known for its acoustical system, by which a hand clap sounded at the fort's main gate can be heard at the citadel located on the hill.





RICE IN MIAMI. Dr. Bas Bouman (*right*), newly named director of the Global Rice Science Partnership (GRiSP), the CGIAR Research Program on Rice, and Duncan Macintosh, director of IRRI's Development Office, hang out on a corner of a yacht with *Rice Today* after attending the TRT Americas rice conference in Miami.

GOLD, EMERALD, AND PURPLE. *Rice Today* editor Aileen Macalintal of The Rice Trader holds her copy of *Rice Today* at the Temple of the Emerald Buddha in Bangkok during Songkran—Thailand's New Year celebration held every April.

Lesson plan: SAVE WATER

by **Rona Niña Mae Rojas**

Students in the Philippines learn how to save water in planting rice

Students troop to the middle of a rice field. With the sun at their backs, they listen carefully as someone tells them about the rice crops planted in the field. This is how they are introduced to a type of rice variety that could withstand an environment with less water. Eventually, these agricultural students from a Philippine state college will learn more as they get to visit the field more often.

Such a scene is a picture of an outdoor lecture about water-saving technologies such as the aerobic rice technology and the alternate wetting and drying irrigation method that are used in rice production.

The aerobic rice technology involves growing a rice variety using less water than the regular amount. The aerobic rice variety produces high yields and is best adopted in rainfed and upland areas—land that is generally productive only during the rainy season and is left idle in the dry season.

Alternate wetting and drying is practiced by alternately flooding rice fields and allowing them to dry for a few days. With this technology, no losses in crop harvest were shown when compared to fields using continuous flooding methods and, in general, it can reduce water use by 15–30%. In some irrigated production systems in the country, the use of alternate wetting and drying helped reduce tension among farmers because they are assured that water is sufficient for all of them. Moreover, their farming costs decreased, which meant some savings in money.

The International Rice Research Institute (IRRI), through the Irrigated Rice Research Consortium (IRRC), introduced these technologies to help farmers cope with limited water resources for rice production. Both technologies have favorable results in reducing water requirements and decreasing input costs.

With these technologies benefiting farmers, it is only fitting that the knowledge and practices be passed on to a new generation of young agriculturists.

Rice goes to school

Dr. Junel Soriano, an agricultural engineer and professor at the Bulacan Agricultural State College (BASC) in the Philippines who once worked in the National Irrigation Administration, proposed the integration of water-saving technologies in selected courses in undergraduate and graduate academic programs on agriculture. The idea was deemed sound and was approved by the BASC council.

Thus, Dr. Soriano was able to include technologies such as aerobic rice and alternate

BULACAN AGRICULTURAL STATE COLLEGE

DR. JUNEL Soriano, professor at the Bulacan Agricultural State College, Philippines, teaches his students about the principles and benefits of water-saving technologies.

BULACAN AGRICULTURAL STATE COLLEGE (2)

DR. JUNEL Soriano (*second from left*), together with farmers and technical staff from the Department of Agriculture regional office, visit a site demonstrating the use of water-saving technologies.

wetting and drying and they are now integrated in the curriculum.

In La Union Province, Don Mariano Marcos Memorial State University (DMMMSU) students conduct field and laboratory activities in aerobic rice production systems to complete their course requirements.

Now, Dr. Soriano is working closely with Dr. Marina Sabado, a professor of agriculture in DMMMSU, to present a proposal to the university's academic council to fully and officially integrate water-saving technologies into the school curriculum.

More benefits

The collaboration of state universities and colleges with IRRI and government institutions in conducting research and dissemination activities on water-saving technologies reaped unintended rewards.

BASC was allocated more funds because its Aerobic Rice Research, Development, and Extension Program caught the attention of more institutions and agencies that wanted to be involved in the research, development, and extension of aerobic rice.

"With more funds, we were able to improve the facilities of the College and hire more staff that the whole College can benefit from," says Dr. Soriano.

The availability of additional resources also meant a re-energized atmosphere for research.

A unified approach

DMMMSU and BASC have influenced other state colleges and universities such as Isabela State University (ISU) in following their path in water-saving technology research, development, and extension. ISU developed its own program on aerobic rice technology, formulated a road map for the Cagayan Valley region, and has now implemented projects in Isabela Province and in some parts of the region.

Dr. Soriano and Dr. Sabado aim to continuously develop the technologies and get students more involved in research. They acknowledge the need to determine what aspects of the technologies need more research. Any new development would be included in the schools' instructional and extension materials.

In fact, BASC now has projects in eight other provinces to continue its research on water-saving technologies and has demonstrated the benefits to students and farmers as well. "Soon," says Dr. Soriano, "students will be able to learn more on the use of mechanical tools for the different operations and practices in the technologies, organic farming practices for aerobic rice technology, and weed management."

Another teaching tool being developed, in coordination with the IRRC, is a video documentation of farmers practicing alternate wetting and drying and aerobic rice technology. These videos will showcase the success stories of farmers from the different provinces.

"We will work with other state colleges and universities in creating a solid and unified proposal to fully integrate water-saving technologies in academe, especially in instruction," says Dr. Soriano. "The IRRC plays a strong role by providing technical and financial support."

Meanwhile, schools like DMMMSU, BASC, and ISU will continue toward their goal of educating their students—the future agriculturists—on the different ways to save water, a resource so valuable in today's food production.

DEPARTMENT OF Agriculture technical staff and local officials from Lanao del Norte (in southern Philippines), where the Bulacan Agricultural State College has a project for water-saving techonologies, take part in a field demonstration of aerobic rice technology.

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ISAGANI SERRANO

Knee-deep in mud

by **Leah Baroña-Cruz**

IRRI's head of research takes the plunge into the hard, dirty business of growing rice to see things better from the farmer's side

Rice research has helped many countries feed their people, but its successes account for only a small part of the rich rice production toolbox that the International Rice Research Institute has helped put together.

Achim Dobermann, IRRI's head of research, has always wondered the following about the methods and technologies developed by scientists: Why don't rice farmers use these more?

This question influences the direction rice research might take in the future, and Achim needed an answer urgently.

So, instead of poring over journals and talking with yet more experts, he decided to go on a quest to satisfy his curiosity. He took this challenge to the field.

Achim enlisted the help of a young rice farmer from Australia, Leigh Vial. Leigh currently heads the Experiment Station at the International Rice Research Institute (IRRI). Together, they attempted to produce a rice crop using IRRI's recommended best practices and tools for the prevailing field conditions and climate.

The two set aside a 25 × 100-meter field—a quarter of a hectare—on IRRI's Experiment Station and, in January 2012, started preparing the land for a dry-season crop in a 4-month experiment they called the *IRRI Agronomy Challenge*.

Land preparation

Before planting starts, the soil needs to be prepared. Dry soil tillage was no longer possible because of early rains, so the field had to be plowed as farmers normally do—with standing water in the field.

To level the land, Achim and Leigh opted to use a tractor equipped with a laser leveler instead of maneuvering a carabao (water buffalo) and a wooden plank around. Laser technology is supposed to help level the land in the most precise way possible, all in less than half an hour.

A TRACTOR guided by a laser leveler was used to even out the land and prepare it for planting. It did a quick job, but not better than a buffalo and wooden plank might have.

CHRIS QUINTANA

It did, or at least they thought it did. After closer inspection, the two found that the soil was still uneven and needed a tiny bit of rework, and so they had to use the laser-leveling equipment a second time. It becomes a suspicion, at this point, that there are no shortcuts to an even field.

It was important for the land to be evenly flat, so that water is equally deep at all points. This helps the rice plants root out well to get a firm grip on the soil and mature at the same pace. When rice plants mature uniformly, weeds have much less chance to grow.

Which variety to plant?

For their little experiment, Achim and Leigh decided to use the IRRI-bred variety IRRI 154, which was released in 2010 in the Philippines as NSIC Rc 222 or Tubigan 18.

IRRI 154 is recommended primarily for irrigated lowland areas, but has also performed very well in rainfed areas in the Philippines.

Achim and Leigh intended to use direct seeding (as opposed to transplanting) with a drum seeder, a device with holes through which rice seeds fall when it rolls over the surface of the soil.

When they started, however, they found after a few attempts that they could not use a drum seeder on the plot they made. They ended up broadcast seeding, which Leigh claims is an art that they had previously admired only from a distance. Broadcast seeding is a method of planting in which seeds are released by hand with a quick flick of the wrist so that they land in an even sprinkling over the surface of the soil.

New isn't always best

A few days after seeding, Leigh was dismayed to find an uneven field: there were well-germinated seeds on 50–60% of the area, where water drained well; poorly germinated seeds where water failed to drain; and bare spots, where seeds died because it was too wet. This, despite laser-leveling technology!

The dead spots were seeded again almost a week later. "Rice has a habit of catching up when it comes to flowering and harvesting, so this should be okay," assured Leigh, who admitted that they were "seduced by technology" when it came to preparing the field.

"We looked to the laser-guided equipment, when, in hindsight, I think the smaller equipment invented here in the Philippines would have given us more level fields," he added. "High-tech isn't always better."

Nutrients and water

As a soil scientist, Achim knew that the soil on the paddy field was rich in organic matter (about 4%) and had good potassium content. Using the recommendations of *Nutrient Manager* (a site-specific nutrient management tool on the Web, on

ISAGANI SERRANO (5)

THE AGRONOMY Challenge brought together the expertise of several IRRI scientists, among them Finbarr Horgan, entomologist (1), Grant Singleton, rodent expert (2), and Martin Gummert, postharvest specialist (3).

ACHIM AND Leigh assess their first season's crop and what they would do differently next time.

CHRIS QUINTANA (2)

mobile phones, and on smartphones) and his own assessment of the soil, he decided to apply NPK (14-14-14) about 2 weeks after sowing, and urea twice, at about 4 and 6 weeks after sowing.

Achim applied NPK, despite sufficient potassium in the soil, because this fertilizer usually comes only in a 14-14-14 package in the Philippines and doing so will be a closer simulation of what most Filipino farmers do.

After fertilizer application, the field needed to have some water on it to help the rice plants take up nutrients better.

There's a sticky part to water use, though: although a good layer of water will enhance nutrient uptake and prevent weeds from growing, it also provides a "highway" for golden apple snails to move across the field. These snails could cut off the young seedlings, and so a fine balance in water use was crucial.

An IRRI-recommended best practice, alternate wetting and drying (AWD), was used. With AWD, the field is irrigated with less water (so that snails can't move around so much) but more frequently (so that weeds don't thrive). This strategy also cuts water use by 15–30%. "But it does increase the risk of weed re-infestation," said Leigh. "No such thing as free lunch."

Insects and rats

Because the crop was growing in uneven patches across the field, Achim and Leigh were anxious about insect pests taking advantage, especially when they found some leaf damage.

They sought the expertise of Finbarr Horgan, IRRI entomologist, and Nancy Castilla, IRRI plant pathologist, and eventually decided not to use any insecticide, as many of the bugs they found turned out to be helpful insects.

They also found that perennial grasses had encroached on the field from the bunds. These were taken out by hand weeding quite quickly, which removed the need for herbicides.

By late tillering stage, the bald spots on the field had filled up a bit, as Leigh had hoped. Nancy and her team, however, found that 8.5% of the crop had been damaged by rats and 25% by whorl maggots. The maggot damage was higher than normal, but Nancy's team concluded that the extent of leaf damage at that stage would not cause a significant yield loss.

The rat damage, however, was a different story. Achim and Leigh had earlier consulted IRRI's rodent expert, Grant Singleton, on the likelihood that rats, or birds, could have caused the bare spots. At this point, there was no question. They found that the rats were very quickly eating the plants into frighteningly bare patches in the crop. Thanks to swift action by IRRI farm staff, the rat problem was stemmed.

Leaf color

The greenness of the leaves of the rice plants, which tells us whether the plants have taken up enough nitrogen for their needs, was a bit lighter than desired. Achim decided to apply a small amount of additional nitrogen (20 kg per hectare) to help the plants catch up and enhance grain filling.

"It's been 63 days, and by this time, all major crop management decisions have been made," Achim said. "There's not much more we can do but wait."

Harvest

Even the harvest was not something clean-cut in the whole cropping formula, as it turned out. Achim and Leigh were guided by Martin Gummert, IRRI engineer and postharvest specialist, on the matter.

Timing was important at this point, and, in Achim and Leigh's experiment, a sudden downpour shortly before the scheduled harvest caused lodging of the rice plants, increasingly affecting a portion of the rice crop. "Lodging" is a term used to describe the way vegetation tips over or gets flattened by heavy rains.

IRRI's Thai combine harvester was the equipment of choice, as the harvest had to be done quickly to save the grains. With the crop heavily lodged, even the combine did not make harvest any simpler.

The team eventually harvested 1,310 kilograms of grain from the 1/4-hectare field, which translated into a grain yield of 5.24 tons per hectare—about a ton more than the average rice yield in the Philippines, but almost 2 tons less than expected in this experiment.

"About 600 kilograms of rice per hectare was lost in the harvest process," reports Leigh. "But as this was a real-world exercise, we cannot count this loss as yield—any more than a farmer can!"

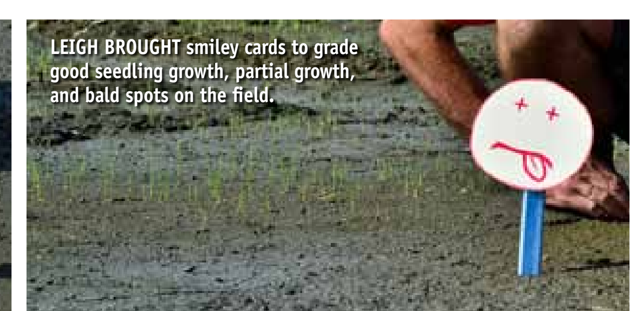
The balance sheet

"The good news is, we made a profit," Leigh said. "Not a good one. But a profit."

Yield projections for the experiment were made with the simulation tool ORYZA2000. Using 20 years (1992-2012) of yield data, theoretical yield was 10.6 tons per hectare. When weather data for dry-season 2012 were used, however, the projected yield went down to 8.7 tons per hectare—the difference due to generally poor weather this year.

Achim and Leigh estimated yield at harvest to be 5.9 tons per hectare, but actual yield—even using the combine harvester—was 5.24 tons per hectare.

"The combine was not made for this situation," Leigh said, referring to the lodged rice crop. "We can indulge ourselves in all sorts of statistical assumptions, but we could have done more with a better-adjusted machine."



LEIGH BROUGHT smiley cards to grade good seedling growth, partial growth, and bald spots on the field.

Achim and Leigh made a net profit of US$84 on the 1/4-hectare farm, which translated to a profit of $336 per hectare—not far from what many rice farmers make in similar production situations, according to Achim.

Among the costs incurred on the farm, irrigation took the biggest share ($525) since IRRI uses groundwater. On a real farm, where irrigation might be partly or fully subsidized by the government, the profit would have been higher.

It is worth noting that no insecticides or fungicides were used during the season, so Achim and Leigh saved some amount from that.

A necessary exercise

The *IRRI Agronomy Challenge* might be considered an "experiment of experiments," as it puts to the test IRRI's prescriptions for rice production that are, in turn, the result of decades of research.

"Some advice, such as that found in the *Rice Knowledge Bank*, provides a good assessment of a problem but does not offer a clear 'actionable' solution'," Achim said. Hence, the many hours that he and Leigh spent monitoring, deliberating, and agonizing over decisions during the season.

"Mostly agonizing," Achim said.

"Not to mention arguing," reminded Leigh.

Many of the glitches they encountered at the start were brought about by rains that came too early in the year, as this was supposed to be a dry-season crop. But, this draws attention to just how much more intricately climate change must be weaved into rice breeding and research.

"There's an opportunity cost to having spent so much time figuring out what to do next, but it could not have been much worse on a real farm than Leigh and I had it," Achim said. "It was our first crop. Next time, we'll do better."

That things did not turn out quite as expected does not necessarily mean IRRI's prescriptions were wrong, but that they need to be refined further. This also tells us that the assumptions made in rice research can use some precision checks as well.

The *Agronomy Challenge* is IRRI's brave first venture into a communication experiment that involved publicly available video documentation of every phase of the cropping season, supplemented by a blog (http://snipurl.com/achim-blog) that Achim and Leigh maintain.

Already, Achim is laying down the premises for the "second season" of what seems like IRRI's first reality show that will take place in the dry season of 2013. "Next time, it will involve more people, with more diverse disciplines," he concluded. "We could all learn a thing or two from the experience."

The *IRRI Agronomy Challenge* continues to be a source of excitement and hope, because laboratory and farm have found yet another way to rendezvous.

The IRRI Agronomy Challenge was documented at every stage. Go to this link (http://snipurl.com/agronomy_challenge) to view 18 videos taken throughout the cropping season, including Achim and Leigh's wrap-up session.

What's cooking?

Thiebou dieune: Senegal's rice and fish dish

R. RAMAN, AFRICARICE

by **Mariama Dieng**

Among the rice dishes prepared in Senegal, a country situated in West Africa, the most popular is *Thiebou dieune* (pronounced "chebu jen"), which is a richly flavored combination of fresh fish, rice, and vegetables. *Thieb*, in local Wolof language, means rice, while *dieune* means fish.

This dish requires 30–40 minutes of preparation and about an hour and a half of cooking time.

For this recipe, a wide variety of vegetables and fish can be used, making *Thiebou dieune* a versatile and healthy dish. Broken rice is preferred because it seems to better absorb the sauce and is more pleasing to the taste than long-grain rice.

Mrs. Dieng is a Senegalese national who lives with her husband and two children in Cotonou, Benin. She holds a bachelor's degree in management assistance and works in Corporate Services at the Africa Rice Center (AfricaRice). When she's not busy at work, she loves cooking big meals for friends and family.

Ingredients

- 1 large fish (about 2 kg, preferably a grouper or any other white fish), rinsed and cut into 4 large chunks
- 250 grams tomato concentrate
- 1 cup peanut or vegetable oil
- 1 kg rice (Senegalese prefer to use broken rice for this recipe, but you can use normal rice)
- 100 grams dried fish such as stockfish, rinsed
- 200 grams carrots, peeled
- 200 grams cassava, peeled
- 1 small cabbage cut in quarters
- 4 okra (optional)
- 4 sweet potatoes, peeled
- 2 eggplants with their stems removed and cut in half
- 4 small turnips, peeled
- 1 onion
- 1 clove garlic
- 3 green chili peppers
- 1 bunch fresh parsley
- 1 small green bell pepper
- 1 Jumbo cube (if not available, substitute it with a fish- or shrimp-flavored Maggi cube)
- Salt to taste
- 1 tablespoon black pepper

Preparation

1. Deseed and cut the bell pepper in half. Slice the onion and finely chop the parsley. Peel the garlic clove and cut it into two pieces.
2. Make a paste by grinding together the parsley, half of the chili pepper, a half tablespoon of the black pepper, and half of the garlic clove with a mortar and pestle or in a grinder. Add a pinch of salt.
3. Using a knife, make a slit in each chunk of fish, but be careful not to cut all the way through. Stuff the slits with this paste.
4. Heat 2–3 inches of oil in a large pan and fry the fish for 3–4 minutes on both sides. Remove the fish and set aside.
5. In the same pan, fry half of the sliced onion and half of the bell pepper and chili pepper. Add the tomato concentrate (dilute it with a little water), let it simmer for 2–3 minutes, pour 1 liter of water on it, and add salt. Boil the mixture for 5 minutes.
6. Add all the vegetables and the rinsed dried fish along with the remaining chili peppers, then cover and simmer on low heat for 30 minutes.
7. Grind together the remaining black pepper, garlic, and onion, and the remaining half of the bell pepper with the Jumbo cube.
8. Pour this paste into the pan and add the fried fish. Reduce the heat and then simmer for another 15 minutes.
9. Remove the fish pieces and all the vegetables with a little sauce. Leave the rest of the sauce in the pan.
10. Wash the rice and half-cook it (preferably using a steamer). Remove the half-cooked rice from the steamer and stir it in the pan with the remaining sauce. Cook it for 15 minutes (stir every 5 minutes).
11. Spoon the cooked rice onto a large serving platter, arrange the fish and vegetables over the rice, and garnish with lemon wedges.

Serves 4–5.

Bon appétit!

Watch Mrs. Dieng demonstrate how to prepare this delicious dish in a 6:05-minute video on YouTube at http://youtu.be/Ra0X0CzYCqk.

URUGUAY:

A small country, big in rice

Photos and story by **Neil Palmer**

NEL GARCIA

If you were asked to name some of the outstanding rice producers of the world, you might say China, India, or the United States.

You'd be forgiven for not thinking of Uruguay.

But, this small, temperate country on the east coast of South America's "southern cone" is now firmly on the rice radar. From relative obscurity half a century ago, it now has the third-highest rice productivity in the world—an average of 8 tons per hectare of dry paddy rice in the last 5 years—thanks to a unique system that, in recent years, has triggered 25% gains in productivity.

Given the need to produce an estimated 116 million additional tons of rice by 2035 to meet the growing global demand, rice producers can learn from Uruguay's rice revolution. With this in mind, Global Rice Science Partnership (GRiSP)[1] representatives from around 20 countries spent a week in Uruguay to learn about its success in rice production.

The Uruguayan way

In Uruguay, only 580 rice farmers are cultivating some 180,000 hectares of irrigated rice. Around 95% is exported, with key markets in Iran, Iraq, Brazil, and Peru.

The key features of the rice sector are vertical integration and transparency among farmers, millers, researchers, and the government.

BRANDED URUGUAYAN rice is loaded at the SAMAN rice mill near Treinta y Tres.

[1] GRiSP is the CGIAR Research Program on Rice.

SACKS OF Uruguayan rice at the SAMAN rice mill near Treinta y Tres, are waiting to be shipped to markets abroad.

This well-integrated structure means complete and up-to-date information on every rice export, well-defined rules on rice quality standards, active participation of farmers and millers in research goals, and the farmer-miller relationship duly signed in a production contract every year, which includes a private agreement on farmer rice price.

Organized through the Rice Farmers' Association (ACA in Spanish), rice producers sell their rice directly to local mills, which process it for export.

The mills lend farmers up to 70% of the credit required for investments in machinery and other inputs, and coordinate a collective insurance scheme with farmers to protect them against crop losses due to hail damage.

The mills work closely with international traders and feed information to rice breeders at Uruguay's National Agricultural Research Institution (INIA by its Spanish acronym) to ensure that breeding priorities are in line with market demand.

What drives Uruguay's rice technology?

Farmers pay a tax of 0.4% of their annual income from rice production to fund future rice research at INIA. As co-founders of the Latin American Fund for Irrigated Rice (FLAR by its Spanish acronym) in 1995, INIA and ACA have helped to ensure that rice producers in Uruguay are able to get the most advanced technologies as soon as they are delivered by international centers.

Three locally released varieties cover more than 90% of the rice grown in the country. One of these, El Paso 144—an indica variety introduced in the 1980s—accounts for two-thirds of the area planted. It was selected from a population developed by Peter Jennings during his time in the rice program of the International Center for Tropical Agriculture (CIAT). The other two are INIA Olimar (indica 20%) and INIA Tacuarí (tropical japonica 15%).

Uruguay has no publicly funded extension system, so the mills or private consultants provide the farmers with agronomists to advise on the use of fertilizer, herbicide, and pesticide, as well as to supply clean, certified rice seed and to help to guarantee the best possible harvest.

The rice crop itself is rotated with pastures, usually in a 5-year cycle with two seasons of rice and three of pastures.

Based on a calendar of precise sowing times, the rice is "direct-seeded" using minimum tillage and no-till planters. This planting system allows seeding in October, which ensures high solar radiation at flowering and reduces the risk of cold damage at the reproductive stage. The pastures—normally a mix of grasses and legumes—are direct-seeded by plane immediately after the rice harvest. Roughly half of the water for irrigation comes from reservoirs that are specially constructed to collect the country's abundant rainwater.

Although the costs of production are high in Uruguay—around US$1,800 per hectare—so are the quality and quantity of rice produced—1.3 million tons per year.

Mercifully free of middlemen, Uruguay's integrated approach to rice production helps reduce uncertainty for all involved, providing a stability that allows the system as a whole to thrive.

Rice is branded "Uruguayan," fostering a sense of solidarity across the sector in the face of fierce regional competition from neighboring Brazil and Argentina, as well as the United States and Thailand, among others in the international market.

"Uruguay is a unique case of a rice agribusiness sector based on exports that can sustain itself in the international market without any subsidy or government protection," explained Gonzalo Zorrilla, FLAR executive officer. "This integration of the rice chain has been the driving force for the impressive competitiveness achieved in the past four decades."

A lesson for the rest of the world?

Can we pick a lesson or two from Uruguay's rice production and apply it to the paddy fields in Asia where 120 million rice farmers have an average area of 0.5–2 hectares and a very limited access to inputs? For Bas Bouman, who is shortly to take up the position of director of GRiSP, the answer is a resounding yes.

"I think elements of the Uruguayan system really could work in parts of the Mekong Delta," he explained. "In Vietnam's An Giang Province, for example, the government has a vision to develop a high-quality rice sector to supply niche markets. Here, I could definitely see one or more large mills joining together with large groups of farmers to produce high-value rice in a system based on trust and transparency.

"While most of the rice in Asia is consumed by the very poor, there is a rapidly growing middle class buying high-quality branded rice from supermarkets. Introducing something like the Uruguayan system at a smaller, local level could help them take advantage of this."

For Dr. Bouman, there are also larger-scale opportunities.

"It's possible that rice production in Myanmar could benefit from the experience of Uruguay. I consider it a 'virgin territory' because the existing system is relatively undeveloped and comes with no 'baggage.' Up until World War II, Myanmar was a major rice exporter in the region—the environment is perfect for rice production in many parts of the country. If it continues to open up, it could be a great opportunity to introduce a Uruguayan-style rice system from scratch."

Although Uruguay's rice system is indeed unique with its strong focus on integration and agronomy, its success could make it something of a game-changer for rice research, thus helping to benefit the rice world beyond its borders.

GONZALO ZORRILLA, director of the Latin American Fund for Irrigated Rice (*right*), guides GRiSP delegates around the rice fields of eastern Uruguay.

INCOMING GRiSP director Bas Bouman talks to Joe Tohmé of the International Center for Tropical Agriculture during a field visit to Agropecuaria del Este, a rice farm near Treinta y Tres.

GRiSP DELEGATES, including Achim Dobermann of the International Rice Research Institute (*left*), receive a guided tour around the experimental rice fields of INIA, the Uruguayan national agricultural research program, by Pedro Blanco, INIA´s senior rice breeder.

BREEDING PLOTS at the Paso de la Laguna Rice Research Station of INIA show advanced material under yield evaluations.

Neil Palmer (CIAT)

After heavy rains, drainage channels carry water away from rice paddies near Vergara, close to Uruguay's eastern border with Brazil. Agronomists from the National Rice Millers Association (SAMAN in Spanish) regularly fly over the rice fields to assess the progress of the season's crop. (This photo was taken from a small aircraft, 150 meters above the ground.)

Global watch: Asia and the Americas

by **V. Subramanian**

In the Americas, farmers are expected to continue to move away from rice because of better returns in soy, wheat, and maize, but the Indian monsoon and Thailand's record stocks are set to shape the trends in global rice trade

Ever since Thailand supported its farmers through a mortgage program and India started exporting its surplus nonbasmati rice again, much has changed in the global rice trade. Any market development in the future may rely strongly on this. Other key issues also came into focus during the 6th Rice Americas conference of The Rice Trader (TRT) in Miami.

An important theme in the event was the falling rice output in key export regions, such as the United States and MERCOSUR (the Southern Cone Common Market, which pertains to Argentina, Brazil, Paraguay, and Uruguay in this report).

When TRT CEO Jeremy Zwinger kicked off the proceedings, he looked not just at the underperforming U.S. and South American crop but also at what the global economy was facing: economic crises, risks, and volatility.

DELEGATES OF the 6th TRT Rice Americas board a boat at the Miami Beach Marina for some fun and networking activities.

THE RICE TRADER (3)

A confusing storm

Mr. Zwinger tackled long-term market drivers, which he compared to a "confusing storm." These are the growing population and the long-term trend of the U.S. dollar, which recovered during the euro-zone debt crisis. He said that, despite the weak global economy, rising oil and energy prices in the long term were also vital ingredients in the cost of rice production.

Mr. Zwinger also described global rice stocks as recovering but with some risks, considering that these current stocks were 22% lower than those 10 years ago.

Fellow panelists Jaime Clendenin, head of the Rice Desk, Bunge, and Ramiro Velásquez, CEO of Global Commodities Inc., agreed with this idea and added that more risk and volatility can be expected.

The panel also agreed that the rice market looks susceptible to sharp movements largely due to the tight supply in the Americas. Mr. Velásquez suggested that low supplies in North, South, and Central America could see more Asian rice coming their way, especially if importers from the Americas reject higher prices from the U.S. and if South American exports are lower.

Weather watch

The Indian monsoon plays a key role in shaping Asian exports that dominate current markets; hence, it is important to keep an eye on the weather.

This September, the current La Niña cycle may switch to El Niño, according to Dr. S. Elwynn Taylor, agronomist and extension climatologist at Iowa State University.

This switch could affect large rice-producing regions across Southeast Asia and even Australia. Consequently, El Niño's higher temperatures and lower precipitation could lead to a poor monsoon. Dr. Taylor mentioned a 70% chance of a poor Indian monsoon. He stated, however, that this 70% chance was possible only if La Niña directly became El Niño.

RICE TECHNOLOGY leader (RiceCo) John Leeper receives his *TRT market achievement award* from CEO Jeremy Zwinger.

Health of the economy

Another interesting topic in the event was the current and future world economy.

Mike Dwyer, director of global policy analysis of the Foreign Agricultural Service at the U.S. Department of Agriculture, presented key economic points (see *8 driving forces in global agriculture, Rice Today*, Vol. 11, No. 2). He said that, in 10 years, agricultural commodity prices will remain high and this will boost long-term farm profitability and invite more investments in research and production.

Notably, today's euro-zone debt crisis has an important role in the way it has tempered the fall of the dollar and global demand. Hence, agricultural prices are lower. Indeed, the health of the global economy significantly affects prices and future trends in agriculture.

Asia's rice giants

As the conference closed, the Brazilian real was beginning to show some early signs of weakness. This fired more discussions on how Uruguay's, Argentina's, and Paraguay's exports to Brazil might be affected by a weaker currency.

As the last speaker in the conference, I talked about the role of the biggest players in global rice trade while zooming in on Asian markets.

First, India. India's long-term role in exports is expected to have an impact on price trends. With the Indian rupee looking especially weak, Indian rice may cost less in dollars—much lower than it already is, thereby taking away the market share of other export origins.

Then, Thailand. How will the country dispose of its record stocks? This is a million-dollar question. Thailand's decision on some 15 million tons of rice stocks poses challenges to the global market. African buyers have already been turning to cheaper Indian offers, as India's return to nonbasmati rice exports has, for now, helped ease concerns over how the Thai rice policy will shape market prices in 2012.

All in all, Thailand and India are the major influences on global rice market sentiment and trends.

TRT CEO Jeremy Zwinger (*right to left*) joins Meryl Kennedy (Planters Rice Mill), Jorge Alberto Vara, and Juan Pablo Gómez de la Fuente (both from the Ministry of Production, Work, and Tourism of Corrientes, Argentina).

COUNTRY HIGHLIGHT:

IRRI in Cambodia

Compiled by **Ma. Lizbeth Baroña-Edra**

Cambodia's resurgence in the 1990s, following a couple of troubling decades of war and internal strife, was a transformation that saw its economy rise hand in hand with productivity in its agricultural sector.

Cambodia's economy is now largely driven by agriculture—a sector that is dominated by rice. According to a 2011 International Food Policy Research Institute (IFPRI) report, between 2000 and 2008, when the country's agricultural sector consistently grew at an average of 5.6% every year, the country's economy was also registering an impressive 9.8% growth.

Rice in Cambodia

Rice-based farming has existed in Cambodia for around 2,000 years. Eighty percent of its farmers grow rice, which is planted on about 80% of the total cultivated land in the country.

Back in the game

After a 30-year hiatus, Cambodia's exports were reinvigorated to an estimated 800,000-ton increase from the early 2000s to 2010. This was after Cambodia's rice production increased steadily by 9% annually in that decade. This change came as its government paid special attention to rice after recognizing its strong role in the agricultural sector, which employs more than half of Cambodia's labor force.

The government is prioritizing yield improvement through intensification, and the country has opportunities to dedicate more land to rice production and improve irrigation.

Rice renaissance in Cambodia

The International Rice Research Institute (IRRI) played a key role in Cambodia's rice renaissance. After the Khmer Rouge regime of the late 1970s, the country lost almost all its traditional rice varieties because farmers were unable to plant rice; thus, they resorted to eating their rice seed instead of sowing it.

IRRI, which has in its International Rice Genebank duplicates of 766 traditional Cambodian rice varieties, replenished this lost rice by multiplying the conserved rice and repatriating it back to Cambodia between 1981 and 1990.

IRRI and Cambodia's relationship, however, can be traced back a decade earlier. Six Cambodian scientists were trained at IRRI between 1960 and 1973, and IRRI had collected traditional rice varieties for conservation in the country.

By 1985, the Cambodian government, through the Cambodian Ministry of Agriculture, Forestry, and Fisheries, asked IRRI to assist the country in developing its rice research system. Progress in research and institutional development soon occurred, and eventually improved rice-based farming systems in Cambodia. An IRRI mission to Cambodia in January 1986 identified potential areas of cooperation and aid, and a memorandum of understanding for collaboration was signed between the two partners in July of the same year.

A significant collaboration between IRRI and Cambodia lasted 15 years (1987-2002). The Australian Agency for International Development financially supported this collaborative effort, known as the "Cambodia-IRRI-Australia Project," and nine IRRI staff members were posted in Cambodia to work on this project.

This relationship was further strengthened in 2000 when Cambodian Prime Minister Samdech Hun Sen visited IRRI headquarters in the Philippines, and in 2007 when the country's agriculture minister presented the Royal Government of Cambodia's Sahametrei Medal to former IRRI Directors General M.S. Swaminathan and Ronald Cantrell, to recognize IRRI's contributions in reviving and developing the country's rice research system.

Current work

Today, IRRI and Cambodia have embarked on different rice research programs involving breeding, varietal trials, integrated pest management, agricultural engineering, postharvest and mechanization, farming systems, training, and infrastructure support.

IRRI's postharvest experts have been working with Cambodian partners in capacity building for researchers and farmer intermediaries to overcome high postharvest losses and the lack of postharvest experts in the country. Also, through the Irrigated Rice Research Consortium, innovation platforms are developed to bring together stakeholders in research and extension to make sure that more people adopt sustainable technologies.

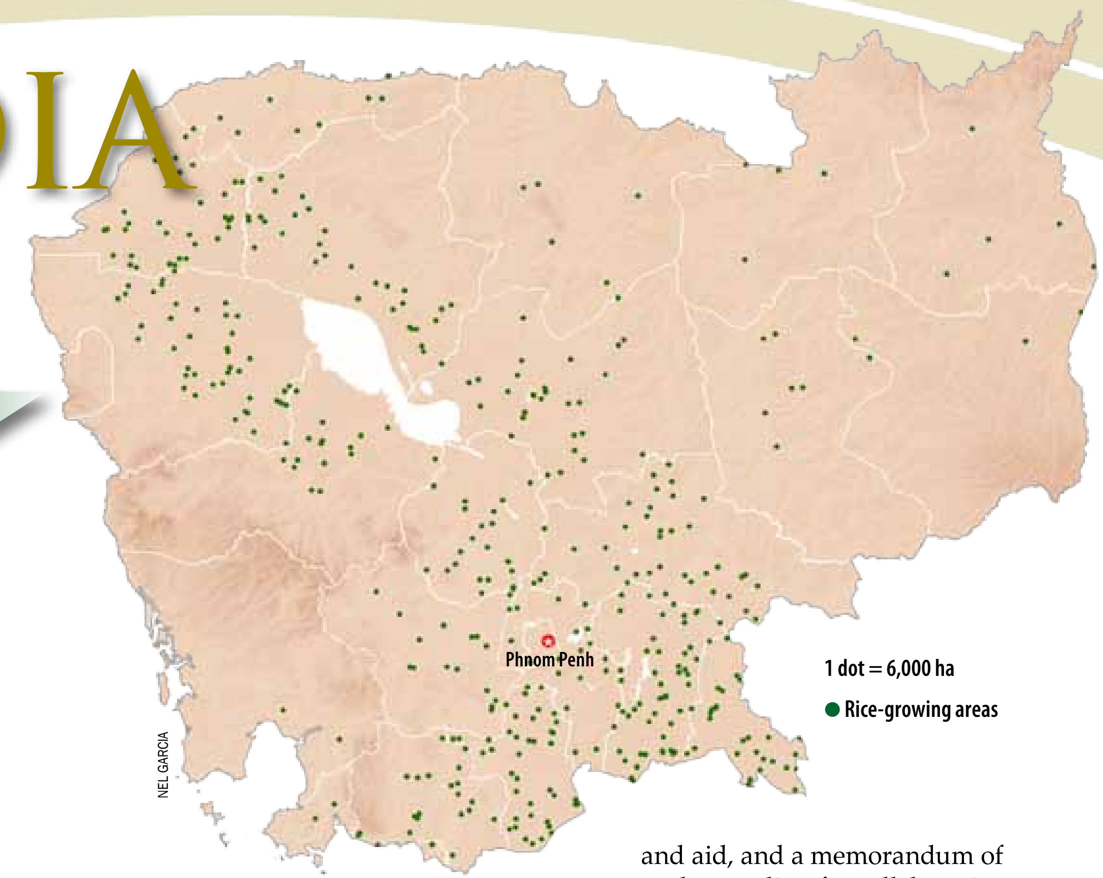
Another IRRI project in Cambodia is the Green Super Rice project, which aims to develop "green super rice" varieties that are adapted to difficult growing conditions, such as drought and low inputs, no pesticide, and less fertilizer. Moreover, these varieties can grow fast to out-compete weeds, thus reducing the need for herbicides.

The Consortium for Unfavorable Rice Environments also leads research activities together with local government units and nongovernment organizations to disseminate technologies that help improve the production and livelihood of Cambodian rice farmers, especially those whose lands are less suited to rice production.

IRRI works closely with the country in supporting its next generation of rice experts. As of May 2012, 257 scholars and trainees from Cambodia had gone through IRRI's training courses and graduate study research work.

Continually working together with Cambodia through various rice-related projects and programs, IRRI hopes to further contribute significantly to the development of Cambodia's rice industry as the country aims to become one of the largest rice-exporting countries in the world.

View related video clips on IRRI in Cambodia at http://snipurl.com/irri-cambodia.



NEL GARCIA

Cambodia: fast facts

Population:	14.9 million
Total rice production:	8.4 million tons
Area planted to rice:	2.7 million ha

Source: U.S. Department of Agriculture, World Rice Statistics, and cia.gov

USE OF a combine harvester helps farmers harvest the crop on time, with less labor, and at less cost.

TRINA LEAH MENDOZA (2)

WITH AN improved granary, farmers' grains are protected from rain, insects, birds, and rats.

Rice feels the heat

by **Alice Laborte, Andrew Nelson, Krishna Jagadish, Jorrel Aunario, Adam Sparks, Changrong Ye,** and **Ed Redoña**

Heat waves are expected to be more intense and frequent in the future, which could jeopardize more rice areas.

Rice thrives in hot and dry to humid climates. However, extreme heat episodes can irreversibly damage rice yield, grain quality, and plant processes such as germination and fertilization.

Rice is highly susceptible to heat stress, particularly during the reproductive and ripening stages. Extremely high temperatures, even for a few hours, during flowering can cause complete sterility, while high temperatures during ripening can lead to reduced grain filling and poor milling quality (i.e., more broken grains). And, in combination with other constraints such as lack of water, canopy temperatures can increase even further.

Unfortunately, hot days and warmer nights have increased recently. Higher nighttime temperatures, in particular, have reduced rice yields—by as much as 10% for every 1 °C increase in minimum temperature.[1] In 2003, heat stress affected about 3 million hectares of rice, resulting in losses of 5.18 million tons in the Yangtze River Valley in China.[2] In 2010, extreme nighttime air temperatures adversely affected the milling quality of rice grown in Arkansas in the U.S.[3]

Changing cropping systems and management are strategies to meet the increasing demand for rice in areas prone to heat stress. This means that farmers may need to adjust planting dates, change crop rotations, and use varieties with shorter maturity to avoid high-temperature periods. Researchers therefore seek to introduce new rice varieties with improved heat tolerance.

To identify hotspots for daytime and nighttime heat stress, we compared daily maximum and minimum temperatures during critical rice growth stages from 1983 to 2011[4] against temperature thresholds obtained from published literature (Fig. 1).

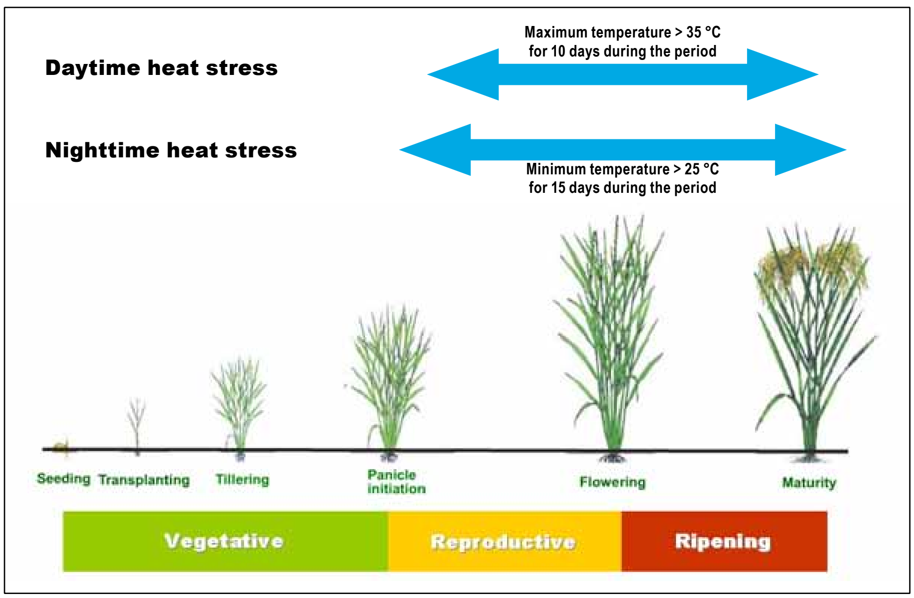
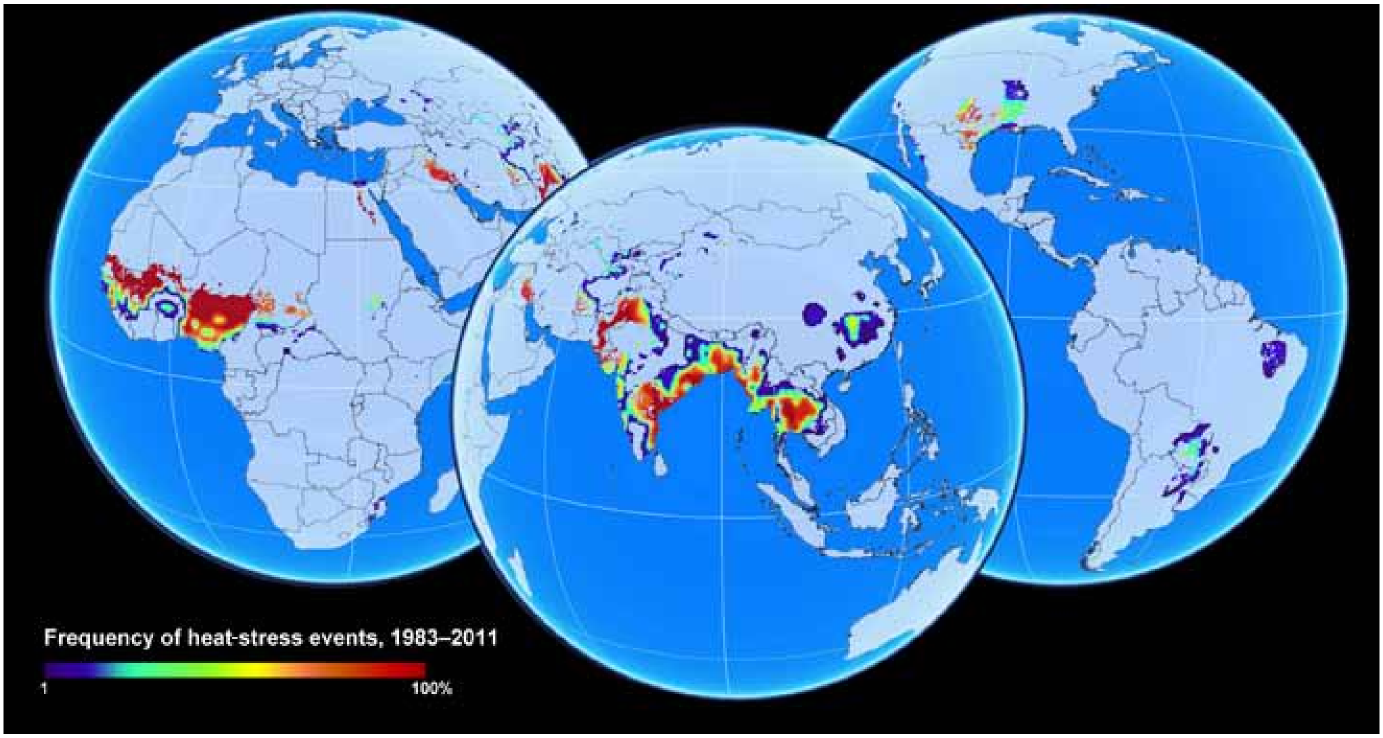


Fig. 1. Temperature thresholds at critical growth stages of rice.

[1] Peng S, Huang J, Sheehy JE, Laza RC, Visperas RM, Zhong X, Centeno GS, Khush GS, Cassman KG. 2004. Rice yields decline with higher night temperature from global warming. Proc. Natl. Acad. Sci. USA 101:9971-9975.
[2] Tian X, Luo H, Zhou H, Wu C. 2009. Research on heat stress of rice in China: progress and prospect. Chin. Agric. Sci. Bull. 25:166-168.
[3] Lanning SB, Siebenmorgen TJ, Counce PA, Ambardekar AA, Mauromoustakos A. 2011. Extreme nighttime air temperatures in 2010 impact rice chalkiness and milling quality. Field Crops Res. 124:132–136.
[4] Daily temperature from NASA Prediction of Worldwide Energy Resource (POWER, http://power.larc.nasa.gov/) corrected using station data (Sparks A, unpublished data).



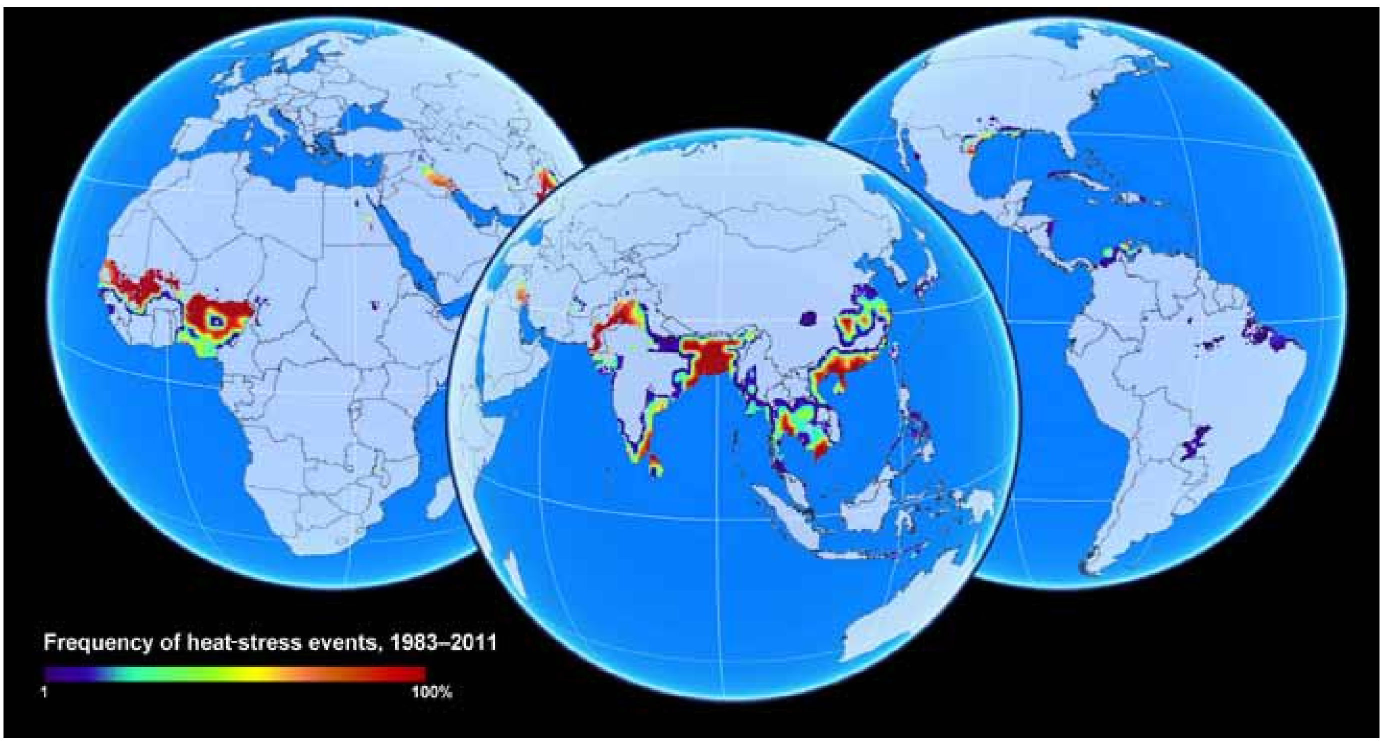


Fig. 2. Hotspots of heat stress on rice and frequency of occurrence: daytime (*top*) and nighttime (*bottom*).

Our preliminary analysis shows that many rice areas in mainland Asia and parts of western Africa have been experiencing frequent heat stress events over the past three decades (Fig. 2).

Spatial assessments of rice areas that are vulnerable to heat stress are important for planning and targeting appropriate adaptation and mitigation strategies to ensure food security.

Dr. Laborte, Dr. Sparks, and Dr. Ye are postdoctoral fellows; Dr. Jagadish is a plant pathologist; Mr. Aunario is a specialist on geospatial programming; and Dr. Redoña is a plant breeder, all working at IRRI.

From tiger shrimp to rice

by Savitri Mohapatra

A rice breeder from The Gambia looks back at his humble roots and first love with the beauty and diversity of nature

R. RAMAN, AFRICARICE (2)

Reminiscing about his early years, Baboucarr Manneh said that his first experience with research was a few months after high school in 1988. He served as a hatchery assistant in an aquaculture lab where he looked after the development of tiger shrimp larvae.

Dr. Manneh liked this experience so much that he applied for an honors program in marine biology. "But, as fate would have it, I ended up getting a scholarship to study general agriculture and eventually studied plant breeding and biotechnology—with a focus on rice," he said.

Since seafood and rice are especially popular in The Gambia—the smallest country on mainland Africa—it is not surprising that Dr. Manneh's research experience encompassed both, albeit at different stages of his career.

A lover of nature and science

Born to a farming family in a small village called Sukuta, Dr. Manneh has always been fascinated with the beauty and diversity of nature. Quite aptly, his favorite subjects were biology, chemistry, and agriculture. "It was my desire to apply an understanding of biological processes to improve living systems that drove me to study biotechnology," he said.

His farming roots helped him understand that science is not only a tool to uncover the mysteries of nature but that it also provides a powerful means of helping people and improving their lives. His profession as an agricultural scientist gave him an opportunity to help farmers through research.

For Dr. Manneh, working with farmers is both enjoyable and humbling. He is most touched when farmers genuinely appreciate the efforts of scientists and extension workers to improve their livelihoods. "They are often willing to offer their last chicken to a visiting agricultural officer," he remarked. "Therefore, no amount of effort is too much when we are trying to assist such appreciative people."

A serious worker

After finishing his bachelor of science degree, Dr. Manneh joined the National Agricultural Research Institute (NARI)—The Gambia's main agricultural research institute—first as an assistant research officer in the Agricultural Engineering Unit and then in the Socioeconomics Unit. Part of his work was to help develop and evaluate postharvest equipment for rice and coarse grains and to conduct socioeconomic surveys on the adoption of improved agricultural technologies.

Since Dr. Manneh was keen to continue his studies, he was granted a study leave by NARI to follow a master's program at Wageningen University in the Netherlands, specializing in crop breeding. On his return, he was appointed head of the Cereals Research Program at NARI and became a manager for the Sapu Agricultural Station—the biggest regional agricultural station in the country.

Dr. Manneh was very serious and hard-working and we were sure that he was going to succeed in his career," said Dr. Samuel Bruce-Oliver, who was heading NARI at that time. "We were also impressed with his skills in managing the Sapu station, which hosts more than a hundred research and extension staff with their families as well as other government officials and R&D partners."

Thanks to NARI's help, Dr. Manneh was able to pursue advanced studies on genetic, physiological, and modeling approaches toward salinity tolerance and low-nitrogen supply in rice when he was awarded a PhD sandwich fellowship by Wageningen University in 1998. He conducted his PhD research with awards from the Netherlands Organization for Scientific Research and the International Foundation for Science.

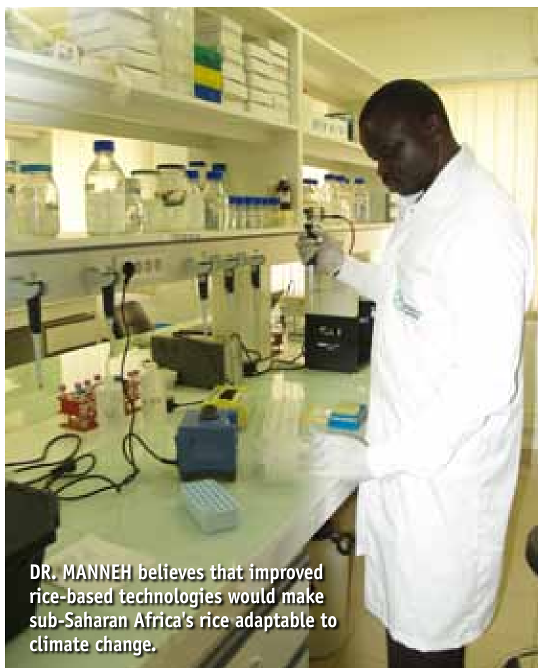
Rising through the ranks

Dr. Manneh continued to be associated with NARI, where he rose to become a director of research and advisor to the Minister of Agriculture on seed and biotechnology issues.

In 2005, he joined the Africa Rice Center (AfricaRice) as a postdoctoral fellow in the Biotechnology Unit in Cotonou, Benin, where he worked closely with his team on using marker-assisted selection and conventional breeding approaches to develop drought-tolerant rice.

Drought stress causes substantial crop losses yearly in Africa, and AfricaRice is involved in developing drought-tolerant rice varieties that produce stable yields in rainfed systems in Africa.

The threat of climate change is aggravating the drought problem. "One of the most viable options to enable farmers to adapt to climate change is the use of rice varieties with good drought tolerance," Dr. Manneh said.



DR. MANNEH believes that improved rice-based technologies would make sub-Saharan Africa's rice adaptable to climate change.

After joining the Center as a postdoc, Dr. Manneh has since risen to the post of principal scientist and he is now an irrigated lowland breeder based at the Sahel regional station in Saint Louis, Senegal. Since arriving at the station in 2008, he has helped broaden irrigated lowland breeding activities there to cover breeding for high yield potential and adaptation to environmental stresses such as temperature extremes, salinity, and flooding, using both conventional and molecular breeding approaches.

An advocate for partnership

Dr. Manneh is a strong advocate for partnership. "No single research or development institution has the resources to tackle the challenges faced in converting Africa from a net food importer to a net food exporter," he observed. Hence, his unit has established strong collaboration with international agricultural research centers and with local and regional universities to foster research and contribute to building the capacity of Africa's next generation of plant breeders.

In view of his work experience, Dr. Manneh was the natural choice to lead the coordination of the AfricaRice component of the project "Stress-Tolerant Rice for Africa and South Asia (STRASA)." Launched in 2008, the project focuses on tolerance of five major abiotic stresses—drought, submergence, salinity, iron toxicity, and low temperature.

With funding by the Bill & Melinda Gates Foundation to the International Rice Research Institute (IRRI), STRASA involves AfricaRice and the national programs of 18 countries in sub-Saharan Africa. The project is now in its second phase.

Dr. Takashi Kumashiro, leader of the Genetic Diversity and Improvement Program at AfricaRice, spoke highly of Dr. Manneh's efficient management of this project component, which involves collaboration across continents and time zones. "He has a very sound background in all areas of plant breeding, including molecular biology."

Dr. Manneh is convinced that the availability of improved rice-based technologies, especially stress-tolerant varieties, would make sub-Saharan Africa's important food and cash crop adaptable to climate change.

"When farmers are certain that the varieties they are planting are capable of tolerating stresses, they will invest more resources, time, and energy into their fields," he said. "This in turn can help increase rice production and ultimately improve farmers' livelihoods."

by **Savitri Mohapatra**

Trouble from the sky

Best agricultural practices may be the best scarecrows for Africa's nemesis in rice fields

R. RAMAN (4)

Mrs. Aguénou from Benin might not have seen Alfred Hitchcock's terrifying movie *The Birds*, which shows masses of ordinary birds mysteriously attacking people, but she is ready to do anything, including going to voodoo priests, to get rid of the flock of ravenous red-billed quelea birds that invade her rice fields every year.

Queleas—often referred to as "feathered locusts"—are probably the most destructive birds in the world. In Africa, they have been a granivorous pest for thousands of years, as seen from the images in pyramids showing farmers using whips to scare them off.

"These birds can easily wipe out the whole rice crop and they are very difficult to manage because they move quickly from one area to the next," Mrs. Aguénou said.

Birds feeding on ripening grain are known to be very damaging to rice and, in Africa, they are considered a major pest because small farmers have few options to manage them.

Traditionally, women, along with their children, run up and down in the field, shouting, waving, clapping hands, throwing stones, and sometimes trying to scare the birds off with rattles and drums. In some places, farmers use large nets to catch birds or sound cannons and scarecrows.

In Uganda, for example, the news of children missing school to chase birds off their parents' rice farms evoked so much negative reaction among the public that the government had to set up a commission to solve the problem with birds.

Farmers are right

Farmers in Senegal and Mali attribute 10–15% crop loss to birds. Annual surveys over several years in the Senegal River Valley, a key rice belt in West Africa, show that farmers consider weeds and birds as the two most important pests in irrigated rice production.

The Global Rice Science Partnership (GRiSP), the CGIAR Research Program on Rice, confirmed this. GRiSP identifies birds as the second most important biotic constraint in African rice production after weeds, based on farmer surveys in 20 African countries.

"However, there are limited recent and accurate estimates of the rice crop losses inflicted by birds and their temporal and spatial variability," observed Africe Rice Center (AfricaRice) economist Matty Demont. Thus, information on the extent of damage is urgently needed to guide future R&D priority setting.

Since bird-inflicted losses are a major obstacle to the development of intensive rice production in the Senegal River Valley, Dr. Demont recently studied the use of a damage abatement framework.

The damage abatement framework is based on the idea that some agricultural inputs, such as bird-scaring efforts, are not yield-enhancing, but they abate yield losses. According to Dr. Demont, this is probably the first study providing detailed estimates of bird damage in irrigated rice production.

The study indicated that birds cause more than US$9 million in losses in the Senegal River Valley per year—with an annual bird damage of 13.2% of potential rice yield during the wet seasons from 2003 to 2007.

This analysis was complemented by a survey to check the reliability of the estimates using the damage abatement approach. The estimates were found consistent with farmers' perceived bird-inflicted crop losses, averaging 15%. However, the study also indicated that losses reach $18.6 million when pressure from birds is highest.

"Moreover, farmers indicated that, at high bird pressure, traditional bird-scaring methods are not effective," said Dr. Demont. "This suggests that monitoring, controlling bird populations by applying avicides on a large scale, and insurance measures against massive invasions are urgent."

The bird and weed nexus

In an AfricaRice survey near Saint Louis, Senegal, farmers said that, if they managed their weeds in their rice fields, they would have fewer bird attacks. "It's not the rice that attracts the birds at first; it's the weeds that bring the birds to the fields," they said.

AfricaRice weed scientist Dr. Jonne Rodenburg found out that the farmers were right. His experiments showed that weed-free fields discouraged birds. Weedy fields attracted birds because they fed on weed seeds, found shelter in the weeds, and perched on the weeds to eat the rice.

Combining methods

In general, birds can be kept away from rice fields by following good agricultural practices. In addition to keeping fields weed-free, planting early-maturing rice varieties, experimenting with different planting times, and avoiding open water in the middle of rice fields are recommended to farmers.

Also, the removal of nesting, perching, and roosting sites around the field can reduce the number of birds. Reflective ribbons or used video/cassette tapes and nets have been found to be effective, too. However, birds quickly get used to such methods. Therefore, farmers are advised to combine the techniques.

Sometimes broad-spectrum poisons are used to kill destructive birds. However, aside from damaging the environment and human health, these also kill birds that do not eat grain.

Alternatives to these harmful pesticides, such as bio-repellents for birds, are now increasingly being promoted across many countries in Africa. In addition, scientists are continuously working with farmers to help develop environment-friendly tools to protect rice crops from birds.

However, Dr. Demont points out that, if one farmer scares birds from his field, these birds only move to adjacent fields. "Unless all farmers regionally coordinate their bird control practices, damage will only be shifted among farmers."

His study recommends that policymakers treat regional bird control as a public good. "This can be seen as an important step towards increasing domestic rice production as well as ensuring that children go to school instead of chasing birds," he concluded.

Cosmic rice

by **V. Sankaran Nair** and **Alaric Francis Santiaguel**

Long ago, farmers turned to the stars to determine when to plant and harvest rice

In southern Travancore, Kerala State in India, many ancestral homes are located close to large stretches of erstwhile paddy fields. Families living in these homes used to cultivate rice.

Today, the paddy fields are gone. Massive fields in Thiruvananthapuram, the capital of Kerala, have been slowly but steadily turned into sprawling estates, to meet the ever-increasing demand for living space. Many traditional houses have been demolished. Along with them, all rice-based rituals have become a part of the nostalgic memories of the elders.

A spiritual bridge to the stars

One of the rituals can still be found in and around the capital: the tradition of worshipping antlers or a sculpture of a deer's head. These antlers are housed in shrines called *thekkathu*, which stand on the southeastern corner of houses. Neither questioning the practice nor knowing its actual meaning, those who continue this tradition have no immediate explanation for the worshiping done for generations.

Antler worship is also practiced on Bali island, in Java, Indonesia, more than 4,500 km east of Kerala. One can find thousands of shrines carrying antlers.

Antler worship is related to plowing by way of language. The Malayalam (a major southern Indian language) and the Balinese words for plow (*nangol* and *tengala,* respectively) are correlated with the constellation *Makayiram* (antler or antelope's head).[1]

Westerners know *Makayiram* as Orion, the hunter. This constellation, located on the celestial equator, is one of the most conspicuous and most recognizable cosmic patterns in the night sky.

According to the *Aitareya Brahmana,* an ancient Indian collection of sacred hymns, the three stars on the head of Orion (Lambda Orionis or the Meissa Ring) formed one of the Hindu lunar stations known as "the antelope's head."

Rice and the cosmic plow

Many practices are tied to *Makayiram* or Orion throughout the ancient world.

The Javanese viewed the stars in Orion's belt (Alnitak, Alnilam, and Mintaka) and three of the four outer stars, Rigel, Saiph, and Bellatrix, excluding Betelgeuse, as a plow and they named the constellation *Bintang Weluku* after their traditional plow, *weluku*.

The rice farmers in Java believed that Orion regulated the different seasonal activities in rice farming. Over the years, the Javanese observed the celestial upright plow at both predawn and sunset. The start of the new agricultural year is marked by the first appearance of "the plow" during the summer solstice (20 to 22 June, depending on the year). Its subsequent rise in the sunset sky was considered to be the time for women to sow the paddy in the nursery and for men to plow the fields.

In Jogyakarta in Central Java, ritual practitioners placed paddy rice on their palm while facing east at dusk. They raise their arm straight toward the belt of Orion. Planting season begins when the position of the stars is high enough so that an angle of the arm causes the grains to roll down from an open palm.[2]

The rice stars

Before the Chinese introduced methods for determining a lunar calendar, early Japanese farmers also relied on Orion's belt, which they called *Mitsu Boshi*, for signs of when to plant their crops.[3] The farmers, however, viewed the three stars of *Mitsu Boshi* not as a belt but as a fulcrum, with Alnilam as the center balancing Mintaka (representing the yield of millet) and Alnitak (the yield of rice).

Across Japan, *Mitsu Boshi* rises in a vertical position. As it moves across the sky in the fall, Alnitak appears to be higher than Mintaka. This is known as *Komeinya Boshi* (rice stars), the time to harvest rice and plant millet. As the constellation is seen setting in the west in late spring, Almitak begins to dip lower and lower than Mintaka and becomes *Komeinya Boshi* (millet stars), the time to harvest millet and plant rice.

NASA (2)

BEFORE THE use of calendars became popular, farmers observed the night skies and relied on the positions of the stars to mark the planting and harvesting of rice.

SANKARAN NAIR (2)

THE TRADITION of worshiping antlers in small shrines, practiced in Kerala in India and Bali in Indonesia, is associated with the constellation *Makayiram* (antler or antelope's head). Ancient rice farmers believed that *Makayiram* (also known as Orion) regulated the different seasonal activities associated with lowland rice cultivation.

The astrology of rice farming

Aside from Orion, early farmers relied on other star formations as well. In the constellation of Taurus, Pleiades (or the Seven Sisters) often served as important calendar markers for many cultures around the world.

The Maloh people in West Kalimantan, Indonesia, used the stars for their cue when clearing, felling, burning, and planting of rice was to take place. The planting season would begin when ritual practitioners looked up to gaze at Pleiades and the hats on their heads fell off.[4]

On the other hand, *muzhakkol* (measuring scale), a Verdic constellation in *Dhanu* (Sagittarius), indicates the time for treading the wheel previous to sowing. To clear a rice field of water, preparatory to sowing, is *chakram chavittuka*. The word *kalappaichakram,* in Tamil, denotes a diagram in astrology in the form of a plow to determine the best day for plowing.[5]

As the use of calendars spread, they provided farmers with more precise methods to determine when to plant and harvest rice and other crops. But, before that, though separated by incomprehensible distances, farmers looked up at the night sky and sought the guidance of the stars.

Dr. Nair is an academic and Indologist whose book Rice and Culture *(in Malayalam language), published by the State Institute of Languages in Kerala, argues that rice cultivation originated in India. His ensuing book on the* History of Ploughing Ceremonies *brings forth more evidence on this hypothesis.*

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[3] Renshaw S, Ihara S. October 1999. Yowatashi Boshi: Stars that Pass in the Night, Japan's Cultural Heritage Reflected in the Star Lore of Orion. www2.gol.com/users/stever/orion.htm.

[4] Isler, op. cit., p. 6
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Maung Khin buries his treasure

by **Alice Stilwell**

"It's such a busy life," young farmer Maung Khin thought, wishing he had time for a little fun. His lean body was used to planting, weeding, and harvesting. He checked the mud banks around each field and mended them when the rains were heavy, or when crabs burrowed into them, or when the hot sun cracked the caked earth. He also scooped water from the canal to make sure the rice crop had plenty of water. Sometimes, he scared birds away from the ripening harvest.

U Nu, Maung Khin's father, also worked hard, yet money was not plentiful.

"We work very hard, but seem to have few pleasures," Maung Khin said to his father wistfully. "Maybe, if I go to the city, we can become rich."

U Nu was hurt and upset, for Maung Khin was his only son, but he understood.

"If you want, go to the city," he replied. "I wish you health and wealth."

U Nu gave his son a few silver coins he had saved. Maung Khin packed up. "The city is large, and work there will also be hard," his father said. "In case we do not see each other again, just remember, the earth bears golden fruit, and only buried treasure is worthwhile."

Looking fondly at his son, U Nu added, "I wish you well."

Maung Khin started toward Mandalay. Expectation coursed through his veins; even the name of the big city seemed exciting.

It was several days' walk to the city. Maung strode along the dusty roads, his head held high.

Maung Khin imagined what lay ahead—Mandalay, riches, good times, all heady thoughts for a farm boy.

As he reached the city, his excitement rose. The mighty Irrawaddy ran lazily through the city. "What a big river," he marveled.

He had never seen such large buildings and magnificent pagodas, so tall they seemed to reach for the sky. He gaped at the broad streets lined with riotous red flame trees and delighted in the prosperity and wealth around him. He savored the aroma from small eating houses and looked longingly at stores, which lined every street and offered all sorts of colorful wares he had never seen before.

"Soon I will be just like them, wearing bright clothes, and buying whatever I want," he thought. "What a wonderful place."

He spent one of his silver coins to eat the best meal he had ever had, and then snoozed under a shady flame tree. When Maung Khin awoke, he stretched and shook his head, throwing off the vestiges of sleep.

"Now, I will find a job and I'll be rich in no time," he said.

Maung Khin soon worked as a servant of a wealthy merchant. In the merchant's house, he saw affluence. His master's garden abounded in orchids and roses and he saw the master and his friends spending hours of leisure. Although his master was rich, Maung Khin's wage was small. He saved nothing.

Months, then years, went by.

"Father was right," he mused. Money is not easy to come by, even in Mandalay." Sometimes, his thoughts returned to the simple village life and the rice fields.

One day, a stranger came to his master's house. "I am looking for Maung Khin, the son of U Nu from the village of Mawlu," he announced to the man who greeted him at the door.

His uncle found Maung Khin in the servant's quarters. "I'm sorry to bring you sad news," he said. "Your father died a few days back. His end was peaceful but, before he died, he asked me to find you here in Mandalay and to tell you he had left a large bag of treasure for you at home. It can wait there until you return."

How Maung Khin wished he could have seen his father again before he died.

"My old father remembered me on his deathbed, even though it has been many years since I was home," he thought. "Now, he is at peace with Buddha."

From then on, life in the big city seemed even more difficult.

So, Maung Khin decided to go back to Mawlu.

"How did my father come by this treasure?" he thought on his way back. "We were always poor and my father's house was so small."

Reaching the village, he went to his uncle's place. They greeted each other warmly and sat down to chat. They drank tea and nibbled at sweet palm jaggery.

"The sack of treasure your father left you," his uncle went on, "he made only one condition. That you bury it!"

Maung Khin was stunned.

"This is madness," he blurted out. "My father leaves me treasure, but says I must bury it? How does that make sense?"

His uncle was of no help and soon went off to sleep. After some time, Maung Khin lay down on his own sleeping mat. Though tired from the long walk, he lay awake recalling the times spent working with his father, and the words, "I looked at only buried treasure is worthwhile."

Next morning, Maung Khin greeted his uncle.

"If it is my father's wish that I bury his treasure," he said. "Then, it must be. I must do as he asked."

His uncle then gave him a large sack, bulging and heavy. Maung Khin was eager to open it. His hand shook as he bent to untie the rope, a thin strip of bamboo, now hardened and dry. When at last the sack fell free, he looked inside.

"What's this?" he said, standing up. "Has there been a mistake? This is not treasure. It's rice."

Maung Khin gaped in disbelief. Then his father's words became clear. He went out to the fields to prepare the soil for burying his treasure.

Maung Khin became a successful and prosperous rice farmer, but before every planting he recalled his father's words, "Only buried treasure is worthwhile."

Ms. Stilwell is a writer based in Hobart, Australia. This story, originally published in 1959, is part of her forthcoming book, Rice—a grain with many stories, *a collection of 28 legends about rice and the many customs associated with this amazing grain.*

Hybrids head for the tropics

by **Alaric Francis Santiaguel** and **Lovely Merlicel Quipot**

Hybrid rice could play an important role in food security, especially in poor countries in the tropics, where population is soaring and agricultural areas shrinking

CHRIS QUINTANA

MESTISO 32, a tropical hybrid rice variety.

ISAGANI SERRANO

NELSON AMÉZQUITA, agricultural engineer at Fedearroz, Colombia; Fangming Xie, hybrid rice breeder at IRRI; and Edgar Torres, rice breeder at CIAT-FLAR (left to right), inspect rice in IRRI's breeding plots for potential hybrid varieties that are suitable in Latin American conditions.

Hybrid rice has the potential to produce up to 30% more yield than the best-performing modern inbred varieties, thanks to hybrid vigor or heterosis.

In 2011, the media reported that, on a test plot in Hunan, China, an output of 13.9 tons per hectare had been achieved—potentially setting a new world record. Such is the potential of hybrid rice varieties to feed the world and its ever-growing population.

Heterosis for the tropics

Success in temperate hybrid rice accelerated research and development in tropical hybrid rice. This can be attributed to the Hybrid Rice Development Consortium (HRDC).

The International Rice Research Institute (IRRI) took the lead in developing the technology for tropical rice-growing countries, and now several hybrids from the public and private sector are released and commercialized in India, the Philippines, Vietnam, Bangladesh, and Indonesia.

Breaking the limits

The HRDC continues to push the yield potential of tropical hybrid rice. In 2011, the Consortium released three IRRI-bred tropical hybrids in the Philippines: Mestiso 30, Mestiso 31, and Mestiso 32.

"These varieties have an average yield of 6.93 tons per hectare," said Fangming Xie, hybrid rice breeder at IRRI and HRDC coordinator. "This is 6.5% higher than the average yield of 11 other Philippine hybrid varieties released in 2011."

New research on tropical hybrid rice is also under way, including increasing hybrid seed production; disease resistance; stress, drought, and flood tolerance; and better grain quality, among others.

Latin hybrids

Halfway across the globe, the International Center for Tropical Agriculture (CIAT) is also exploring hybrid rice technology as a new approach to increase rice productivity in Latin America.

CIAT field-tested its first 19 experimental hybrids from basic germplasm from IRRI. The Center is looking for hybrids with high heterosis, resistance to diseases, good grain quality, and high suitability for the tropical conditions of many Latin American countries.

"The results show some hybrids, such as CT23057H, with good potential to be commercial products," said Edgar Torres, plant breeder with CIAT's Rice Program and the Latin American Fund for Irrigated Rice (FLAR).

"More trials are being conducted by FLAR partners in Brazil, Argentina, Uruguay, Colombia, Panama, Nicaragua, Costa Rica, and the Dominican Republic," he added.

Widening the network

The HRDC not only strengthens its hybrid rice research and development at IRRI but also focuses on its collaboration and network with private and public partners, thus expanding research areas with more products and bringing new resources, as well as valuable experience, to the hybrid rice community. In 2011, the HRDC had a total of 59 partners, up from only 38 in 2008.

"The hybrid rice products developed by the HRDC, including more than 3,500 IRRI hybrid rice breeding germplasm accessions and hybrid rice parents, have been shared with Consortium members and the international hybrid rice community," Dr. Xie reported. "This partnership enhances the steady stream of innovation and improves product accessibility and commercial use ultimately by rice farmers."

Dr. Torres acknowledges the importance of sharing in making tropical hybrid rice a commercial reality. "The increased germplasm interchange with the HRDC has enabled us to produce hybrids with higher yield and good grain quality," said Dr. Torres. "The collaboration effort between IRRI and CIAT is targeting the development of new technology relevant for the rice farmers in Latin America."

The future of tropical hybrids

The international hybrid rice community has grown rapidly in just 3 years. Where does it go from here? Dr. Yuan Longping, the "Father of Hybrid Rice," is determined to develop a super high-yielding hybrid rice that could bring average yields to 15 tons per hectare by 2020 (see related story *Q&A with the Father of Hybrid Rice* on page 42-43).

In time, through the sharing of germplasm, knowledge, and experience, researchers working on tropical hybrid rice could shoot for the same.

Q&A with the Father of Hybrid Rice

Rice scientists hold one of the toughest jobs in the world as they are in constant search of ways to overcome global starvation. One of their achievements is hybrid rice, a type of rice that can significantly increase a farmer's yield per hectare.

In this issue of *Rice Today*, we get to know the thoughts of this scientific breakthrough's pioneer—the Father of Hybrid Rice—Professor Longping Yuan. Here, he talks about what he thinks about how hybrid rice outyields ordinary rice, how China became the largest user of this agricultural innovation, how it feels to be named after celestial bodies, what can encourage youth to study agriculture, which countries can be self-sufficient by growing hybrid rice, and why China is the second-largest economy in the world.

THE FATHER of hybrid rice says that increases in grain production because of planting hybrid rice are key to strengthening China as the world's second-largest economy.

CHINA NATIONAL HYBRID RICE RESEARCH & DEVELOPMENT CENTER©

How does it feel being named the "Father of Hybrid Rice" and having four asteroids and one college in China named after you?

I have received many awards and prizes in and outside China and I take these honors as a high recognition to encourage me to pursue new heights in developing hybrid rice. My friends and colleagues say, "Credits made Prof. Yuan more modest rather than being a conceited person."

What encouraged you to be a rice scientist?

Well, rice is the most important food crop in China; it feeds more than 60% of our people. In addition, my working place, Hunan Province, is the number-one rice-producing province in terms of total production and planting area in China.

Also, I happened to be working on a natural hybrid rice plant, which had very significant heterosis, or hybrid vigor, in a farmer's field in 1962. This discovery inspired me to start a research project on developing hybrid rice.

In one sentence or two, how would you define hybrid rice?

Hybrid rice is created by crossing two genetically distinct rice lines to produce hybrid seed, which has hybrid vigor (heterosis) and is used for commercial production.

Since hybrid rice is a little more costly to cultivate than ordinary rice, does it cater only to farmers with better financial condition? How can this be a viable option for cash-poor subsistence farmers?

Though the price of hybrid seed is higher, the seed rate for planting hybrids is very low—it is only 15 kilograms per hectare. So, the seed cost per hectare is not high. Even poor farmers can afford it because most Chinese rice farmers have a very small paddy—about 0.3 hectare per family.

At the end of the day, will the hybrid rice farmer profit more than a farmer planting ordinary rice? How?

In China, generally, hybrid rice outyields ordinary rice by 1.35 tons per hectare. Planting super hybrid varieties gives a yield advantage of 2 tons per hectare.

How did China become the largest user of hybrid rice in terms of percentage of rice production?

Because of three major factors. First, at the onset of hybrid rice (the late 1970s), in order to promote planting it commercially, the government made some favorable policies such as providing seeds to farmers free of charge and seed companies were tax-free and even subsidized by the government. Second, in the 1980s, a perfect seed production system was established, in which (1) provincial seed companies were in charge of producing foundation seed, (2) prefecture seed companies were responsible for A line, a rice line that cannot produce viable pollen multiplication, and (3) county seed companies produced F_1 hybrid seed. This system not only guaranteed seed quality but also speeded up extension of hybrid rice.

Third, since the beginning of the 21st century, many private hybrid rice seed companies have emerged. Now, they are playing a major role in the development of hybrid rice.

Why are other countries slack in adopting hybrid rice?

Seed yield is low. Lines that are suitable to tropical areas are very few. One available line is IR58025A, but its outcrossing rate is poor.

Given its potential yield (20% more than ordinary rice), do you think hybrid rice can make some countries rice-sufficient? What countries have a potential to be self-sufficient because of hybrid rice?

To my knowledge, hybrid rice can make the following countries self-sufficient in rice: the Philippines, Bangladesh, Indonesia, East Timor, Malaysia, Madagascar, Liberia, and Guinea.

How about Africa? What role will hybrid rice play in rice production areas on this continent now and in the future?

Experiments have shown that hybrid rice varieties perform very well in Madagascar, Liberia, and Guinea. Their yield is two to four times higher than their local varieties. If a government takes strong measures to encourage farmers to plant hybrid rice and if private seed companies are involved, hybrid rice can be commercialized in the near future. Thus, rice production in these countries will have a quantum leap.

Who is the biggest winner in hybrid rice: the farmers who get a higher yield or the private companies that sell hybrid seeds? Why?

Seed production is a low-profit industry in China. For example, Long-Ping High Tec, the biggest hybrid rice seed company in China, sold about 50 million kilograms of hybrid seed, which covered 3 million hectares of planting area in 2010. The net profit was only about US$15 million. That is to say, 1 kilogram of seed earns only $0.30 and one commercial area of a hectare has only a $5 profit.

On average, rice farmers can get 500 kilograms more rice per family per year.

The biggest winner, I would say, is our state. The increase in grain production because of planting hybrid rice can feed 70 million more people annually. This is an important factor that has made China the second-largest economy in the world.

How do you see hybrid rice in the next 5 years?

The average yield will increase from 7.2 tons to 7.5 tons per hectare in China. The area under hybrid rice outside China will reach 6 million hectares.

Interest in agricultural education is generally dwindling. What do you think can encourage youth to pursue a career in agriculture?

I have visited several modernized agricultural museum gardens, which are very attractive to young city people. Moreover, agricultural college students in some provinces in China need not pay any tuition fee because the government gives grants to them.

Based on your life experiences, how would you advise others to attain success in life or in their chosen career?

My experience in attaining success can be summarized in four words: knowledge, perspiration, inspiration, and chance.

Rice self-sufficiency: the renewed mantra of domestic food security

by **Samarendu Mohanty**

The rice price spike in 2007-08 left a deep scar among many rice-consuming countries in Asia and Africa, where policymakers have since then been reluctant to depend on imported rice and have carried out various programs to achieve domestic food security through self-sufficiency.

Major rice-deficit Asian countries, such as the Philippines and Indonesia, have initiated a two-pronged approach to achieve rice self-sufficiency. On the one hand, various domestic programs have been rolled out to expand rice production. On the other hand, citizens have been urged to move away from rice to other staples.

Efforts to reduce rice consumption have been tried for years in Indonesia without much success; instead, its per capita consumption has continued to rise. Whether the Indonesian government can convince consumers to replace rice with other staples is yet to be seen. Just like Indonesia, the Philippine government is also urging its citizens to reduce rice consumption.

Many high-income importers, such as Malaysia and Brunei, are also keen to depend less on foreign rice. Rice-importing countries in sub-Saharan Africa (such as Nigeria and Ghana) are also trying to expand their domestic rice production and rely less on imported Asian rice.

Exporters such as India and Thailand have also taken strong measures to expand domestic rice production in the last few years. In India, the minimum support price (the price at which the government purchases crops from the farmers) for rice made a quantum leap from 2007-08 to 2011-12 by more than 75%, whereas it took from 1994 to 2006 for the minimum support price to increase by a similar proportion (Fig. 1). From September 2007 to September 2011, India kept its export ban on nonbasmati rice to make sure that enough rice was available for domestic food security. Recently, the Indian government announced a 16% increase in the minimum support price for paddy for 2012-13 from 1,080 to 1,250 rupees (US$20–23 at the current exchange rate) per quintal (100 kilograms) for a common variety of rice.

Similarly, the minimum guaranteed price for rice in Thailand (known as the mortgage price) has increased significantly in the last few years, with the latest hike in 2011 with the new Thai government raising the mortgage price for paddy to 15,000 baht ($471 at the current exchange rate) per ton, nearly 50% higher than the prevailing market price during that time.

Increased intervention: short-run effects

Greater support plus favorable weather in the major rice-growing countries in the last few years have resulted in nearly 4 million hectares of additional rice area and more than 45 million tons of paddy rice production being added globally from 2007-08 to 2011-12.

Global rice stocks leapfrogged by more than 30% from 75 to 100 million tons during this period. The Indian situation, in particular, has changed dramatically in the last few years. As of 1 June 2012, Indian rice procurement stocks had reached more than 32 million tons against a desired buffer of around 12 million tons (Fig. 2), despite India's export of around 4 million tons of nonbasmati rice since the removal of its export ban in September 2011.

Unlike India, Thailand's exports have been hampered by its mortgage scheme, which makes its rice noncompetitive in the global market. This has resulted in a record stock that is piling up in Thailand to the tune of 15 million tons of paddy rice (equivalent to 10 million tons of milled rice).

Overall, India's entry into nonbasmati rice has taken the market by storm and has transformed it from a seller's to a buyer's market. It seems

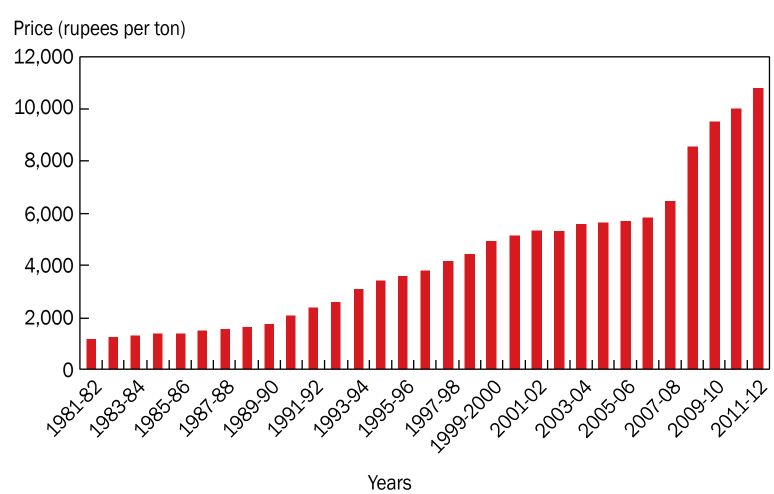

Fig. 1. Indian paddy minimum support price for a common variety of rice.
Source: IndiaStat.com

like there is plenty of rice to go around and threats to global food security seem to be a thing of the past.

Unlike India and Thailand, the top three rice-importing countries—Indonesia, Nigeria, and the Philippines—haven't fared well despite their efforts to expand their domestic production and reduce their dependence on imported rice. Since the 2007-08 rice crisis, rice production in these countries has moved sideways. This is reflected in the rise in Indonesian and Nigerian imports in the last few years (Fig. 3).

In the Philippines, however, imports have steadily declined, after reaching their peak of 2.6 million tons in 2008-09, to 1.5 million tons in 2011-12. This steady decline in rice imports has been partly possible because of drawing down the stocks from 4.7 million tons in 2008-09 to 1.8 million tons in 2011-12. Indonesia trends on the same path, where ending stocks have declined from 7 million tons to less than 5 million tons during the same period.

Self-sufficiency: long-run implications

Overall, higher government support and relaxation of India's export ban on nonbasmati rice appear to have eased the market situation and stabilized prices because of an adequate rice supply in the market. In fact, another good harvest this season could further lower the price.

However, in the long run, major rice-consuming countries that pursue self-sufficiency may be in danger. If these countries achieved self-sufficiency, import demand for rice would fall. This would push exporters, such as Thailand, Vietnam, and Pakistan, to cut back on their production to reduce exportable surplus and use their lands in planting other profitable crops.

The global rice market, which is relatively small compared with that of other major crops such as wheat, corn (maize), and soybeans, is likely to become even smaller if rice-consuming countries vigorously pursue self-sufficiency. A consequence of a smaller market is greater price volatility and, the smaller the market size, the more the prices have to move in response to any supply and demand shock.

In a year of low production, prices will rise rapidly; in a year of higher production, prices will fall rapidly with greater volatility. This is particularly worrisome since rice production can fluctuate greatly from year to year, at the whim of nature. And, if climate change predictions are realized, extreme weather conditions will be more frequent, leading to regular price spikes in the rice market. It may sound odd for someone to argue against the self-sufficiency policy pursued by many rice-importing countries after the 2007-08 rice crisis that caused riots and protests in different parts of the developing world.

What makes a strong case for importers to seek self-sufficiency is the current structure of the global market, where some of the big exporters are residual suppliers to the market because they are primarily growing rice for domestic food security and export is an afterthought to dispose of surplus rice. This is exactly what India did in October 2011—relaxing the export ban on nonbasmati rice after a lapse of nearly 4 years, primarily to tackle rising procurement stocks.

A strong global market is essential to achieve global food security for rice. This does not mean that countries should give up rice production and depend on foreign rice. Every country has the basic right to produce enough food for its citizens and this is particularly true for rice, a staple for the world's poorest of the poor. However, countries might be wiser to try to increase production by improving yield in a sustainable manner rather than pursuing self-sufficiency at any cost.

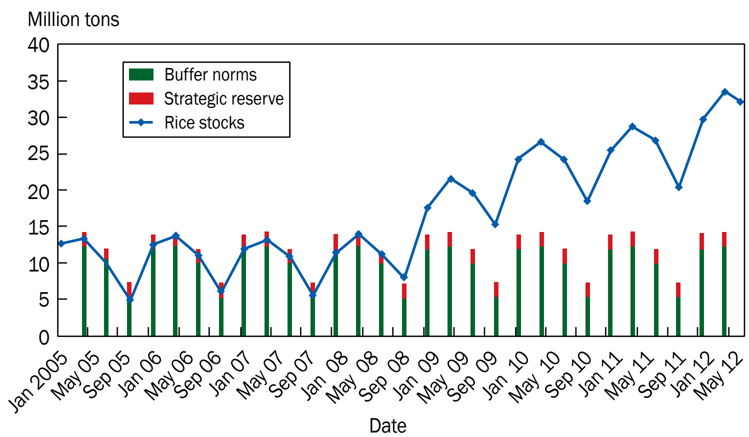

Fig. 2. Indian procurement stocks (actual vs buffer and strategic reserve).
Source: Food Corporation of India

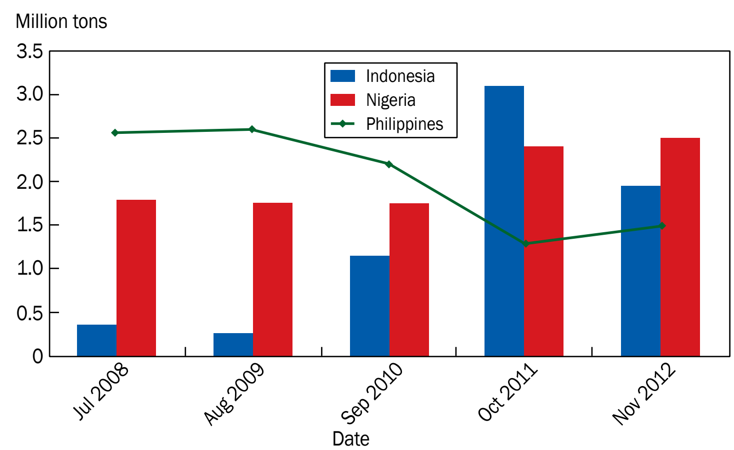

Fig. 3. Rice imports by top three rice importers.
Source: PSD, USDA (accessed on 2 June 2012)

Will Europe's perspective on GM crops shift?

by Emmanuel Guiderdoni

Although GM potato with modified starch and Bt maize are currently grown in Germany and Spain, respectively, nearly 15 years have passed since GM corn (maize) underwent its first attempt to be released in France in 1998.

Since then, unfortunately, no real science-based debate on genetically modified organisms (GMOs) has taken place in France. Moreover, dissemination of scientifically derived information for the general public has remained very poor. Even worse, public trust in the scientific expertise, notably on GMOs, has been lost during the last decade. A poll published in the newspaper *Le Monde* and the scientific magazine *La Recherche* in 2011 showed that, although French citizens still believe in science for improving their lives and notably their health, most of them no longer believe science experts, particularly GMO experts (58% of the respondents), even if 93% of the respondents feel sufficiently informed on genetic modification.

The politics of GMOs

Both left- and right-wing governments are either hostile or neutral regarding GM crops. Green party ministers generally participated in a left-wing government, while right-wing parties preferred to see green activists focusing on GM plants rather than on nuclear reactors. (This worked for some time until the Fukushima disaster.)

For example, the French ban on MON810 Bt corn is a consensus between right- and left-wing politicians although scientific authorities in France agreed with the European Food Safety Authority that GM corn is not risky to the environment. Because of this hostile climate for GM crops in Europe, most Europe-based biotech companies relocated to the U.S.

After GM testing was banned

In the early 2000s, all applied genetic engineering and field-testing activities gradually stopped. Thus, only methodological research has been pursued, but, with not as much enthusiasm and funding.

Facing this rather depressing situation, most French GMO specialists have been predisposed to "self-censorship" and have gradually shifted to other research fields. In France, public funding for applied research to develop GM innovations radically declined and testing them in fields has dropped to zero in the last decade. And, since the early 2000s, the European Commission has funded research consortia only to study the impacts of GM crops on the environment and to study the coexistence of GM and conventional crops. One had to wait for the launching of the 7th Framework (2009-13) for genetic engineering to be re-introduced as a potential technique in plant breeding. In France, government-funded agricultural research organizations such as the Institut National de la Recherche Agronomique (INRA) and Centre de cooperation Internationale en Recherche Agronomique pour le Développement (CIRAD) have a mandate to carry out research to assist the plant breeding effort of seed companies and technical institutes in France and national research programs in developing countries, respectively.

Now, the policy of public agricultural organizations on GM technology is to use transgenesis (the transfer of genes from one organism to another) as a laboratory tool to improve the research methodology. However, for applied research, genetic modification could be carried out only when no other conventional means to improve a breeding trait are available. These institutes have no program now that aims to release GM crops in the next 10 years.

A shift in perception of GMOs?

In the last 5 years, new genome modification technologies that can precisely change the genome at a predetermined site, without modifying the neighboring genetic context, have become commercially available for use. Recently, this has been successfully done in rice.[1]

Eventually, it will be difficult and sometimes almost impossible to discriminate the modifications obtained through these new methods compared with those using classical hybridization and mutagenesis or ways to induce the development of mutations in an organism.

The years to come will tell us whether these novel genome-editing technologies can shift public perception on GMOs, as well as the definition in the EU legislation and public investments in research on GMOs.

Dr. Guiderdoni has 28 years of experience in rice biotechnology research and is team leader and deputy director of the Genetic Improvement and Adaptation of Mediterranean and Tropical Plants Unit, Centre de coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) in Montpellier, France.

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[1] Li T, Liu B, Spalding MH, Weeks DP, Yang B. 2012. High-efficiency TALEN-based gene editing produces disease-resistant rice. Nat. Biotechnol. 305:390-392.

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