Reinventing r

Photos by Brad Collis

The International Rice Research Institute is developing high-yielding 'super rices' and urging Asian farmers to protect biological diversity by swapping chemicals for integrated pest management, a move that has brought remarkable success in the Philippines. Brad Collis heralds the Green-Green Revolution.

From a vine-wrapped lookout above wind-ruffled ricefields, Sesinando Masajo serves his visitors strong, black coffee and regales them with an extraordinary vision: a future in which farmer and insect live in peace.

Masajo uses no pesticides on his 28-hectare rice farm. He believes all animals must be preserved, no matter how harmful a 'pest' might be perceived, because any reduction in biodiversity ultimately will damage the quality of human life.

The sentiment itself is not new, but Masajo is an influential disciple. In the 26 years since he last used a chemical pesticide, he has become the highest-yielding rice farmer in the Philippines. This arguably makes him one of Asia's most successful rice producers.

Masajo's average yield of 9.6 tonnes a hectare is three times the Philippines and Asia average. He attributes his success to the priority he has placed on nurturing the biological vigour of the growing environment.

His results, plus the added credence of an agricultural science degree obtained before returning to the family's Laguna Province rice farm in 1972, have caused a mini revolution. All of the district's 501 rice farmers have abandoned pesticides.

Scientists at the International Rice Research Institute (IRRI) at Los Banos, south of Manila, hope the changing practices in Laguna Province will be emulated by Asia's 200 million rice producers. The institute is trying to make Asian rice production environmentally sustainable in the face of rising populations and declining land and water resources. This means stepping up its research and extension services to repeat the 1960s 'Green Revolution' with a turn-of-the-century 'Green-Green Revolution'.

Sesinando Masajo's approach epitomises the integrated pest management (IPM) principles promoted by IRRI. These involve pushing, wherever possible, the replacement of pesticides and herbicides with agronomic, biological and genetic advances.

High-yielding new plant type (NPT) rices, or 'super rices' with inbuilt pest-resistance are being developed at the institute, but probably won't be ready for release to farmers in the Philippines for another five years. And it may be two decades before scientists in other rice-producing countries of Asia and Africa modify the new rices to suit local conditions, especially areas that don't have irrigation. In the meantime, farmers are being urged to protect biological diversity by cutting their pesticide dependence.

The potential for yield losses caused by pests remains a threat if chemical pesticides are not replaced with other control systems. So biological control, such as that practised by Masajo, has become fundamental for sustainable rice production.

Masajo's argument, and the basis of his crop management, is that pesticides are unnecessary. His experience is that insects control insects; that natural predators emerge before an insect population begins to cause any economic damage.

'Chemical company representatives take delight in inspecting my crops and telling me how many insects they find. I say, "so what",' Masajo says.

'Yes, there are insects in my crops. Yes, there is some visible damage to foliage. But this doesn't translate automatically to an economic cost; to a detrimental impact on yield. Wherever there are insect pests there are natural enemies – unless you have interfered by using chemicals.

'The trouble for a lot of farmers, especially in Asia, is that they have been told insects are bad. It's taken a long time for farmers in this district to relax when they see rice-plant insects, because for years we've had the big companies telling us we must use pesticides.'

Masajo says the psychological hurdle for farmers is the presence of a large number of insects eating into a crop during the first few weeks after planting because natural predators, particularly spiders, have been reduced during land preparation.

'The first generation of pests multiplies quickly,' Masajo says. 'This is when the farmer sees the most damage, so will quickly apply a pesticide. But if you wait, say four to six weeks after planting, the natural enemies catch up, reducing the pest numbers. The rice plant recovers and the yield is ultimately unaffected.'

Before taking over the family's 2.5-hectare farm in 1972, Masajo worked on a corporate rice farm where the practice was to spray pesticides three to five times during each crop cycle. 'I used to notice that each time the chemical was sprayed, the numbers of insects pests actually seemed to increase,' he says.

Soon after returning to his home farm, Masajo decided to stop using chemicals and see what happened. The result was that predators, particularly spiders, were no longer killed. This meant he could focus on his overall rice production system, leaving pest control to other insects. As yields climbed and costs fell, the family farm started to expand and today is large for an Asian family farm.

'Now none of the farmers in Laguna uses pesticides and we pride ourselves on producing the best rice in the Philippines,' Masajo says. 'We also live without fear of poisoning our children.'

Scientists first faced the challenge of doubling rice yields in Asia 30 years ago. That they did is an extraordinary effort which staved off famine and allowed the Asian economic miracle to begin.

Right: Sesinando Masajo and his son, Joseph, use a flame thrower to control rats in their crop. Above: Masajo's average yield of 9.6 tonnes a hectare is three times the Philippines and Asia average. He attributes his success to the priority he has placed on nurturing the biological vigour of the growing environment.

It was done by transforming the traditional rice plant: reducing its height from 1.5 metres to under a metre to help the stalks carry more grain. This change also reduced the growing period from 160 to 110 days, allowing two to three irrigated crops a year. From 1967 to 1992, rice yields across Asia doubled. In some countries, such as Indonesia, they trebled.

But scientists today say it pales against the challenge facing them now. Despite the dramatic lift in production, almost no Asian rice is traded. Little is left after domestic consumption. In fact, the threat of famine has never been far behind Asia's fleeting economic heels.

The demand for rice continues to increase due to unabated population growth. It's expected that the world's rice harvest must increase from 560 million

Spiders: the ultimate biological pest control in rice crops.

A revolutionary vision

THE International Rice Research Institute (IRRI) is an autonomous, non-profit agricultural research and training centre, whose purpose is to sustainably increase total food production from rice-based farming systems. It was established in 1960 by the Ford and Rockefeller foundations in cooperation with the Government of the Philippines.

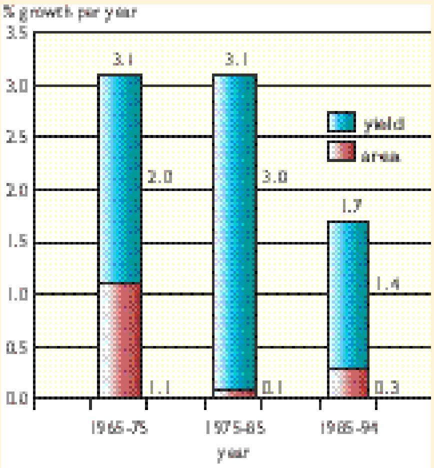
Most of IRRI's research is done together with national agricultural research and development institutions, farming communities and other organisations that share its goals. Its research centre includes laboratories and training facilities at a 252-hectare experimental farm on the campus of the University of the Philippines Los Banos, about 60 km south of Manila.

IRRI developed the first semi-dwarf breeding lines for rice in the mid-1960s. The high yields and rapid farmer adoption of the new grain varieties triggered the Green Revolution. National agricultural programs worked in cooperation with IRRI to intensify rice production. The IRRI rices were soon followed by dozens, then hundreds, of semi-dwarfs developed by scientists in national programs.

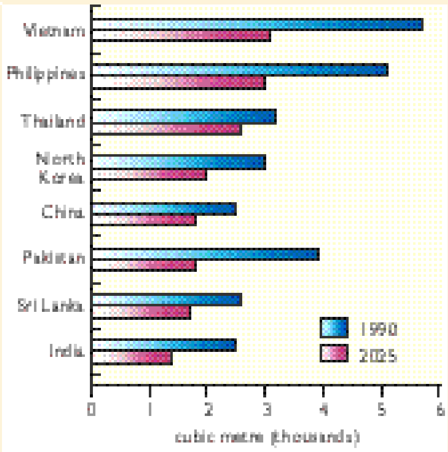
By 1991-93, total rice production in South and South-East Asia had increased by 120% since the start of IRRI's research, while the land planted to rice had increased by only 21%.

Rice surpluses and low prices in recent years have given an impression that the world's food production problems are solved. But prime ricelands are under pressure. Resource-poor farmers and the rural landless in Asia are being forced to till highly erodible and marginal lands, or to migrate to urban areas in search of livelihood, often leading to even more poverty.

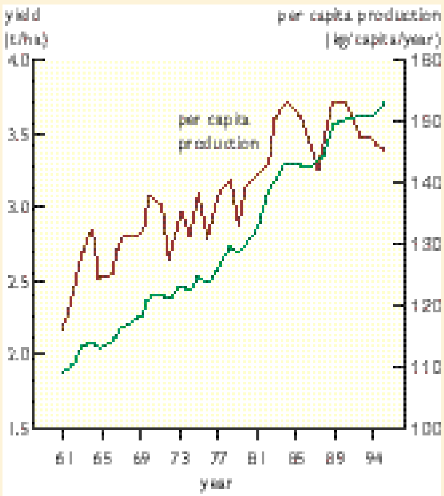
IRRI was established as the prototype for a world network of 16 non-profit international agricultural, forestry, and fishery research centres supported by the Consultative Group of International Agricultural Research.



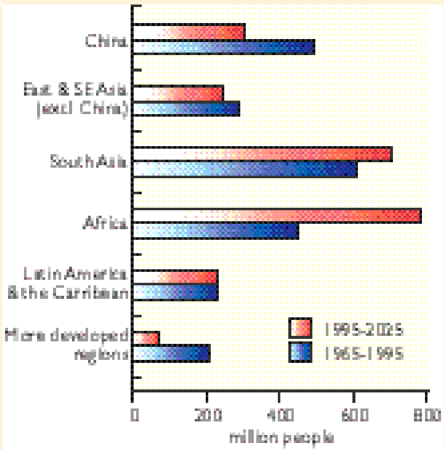
Sources of growth in world rice production, 1965-94.



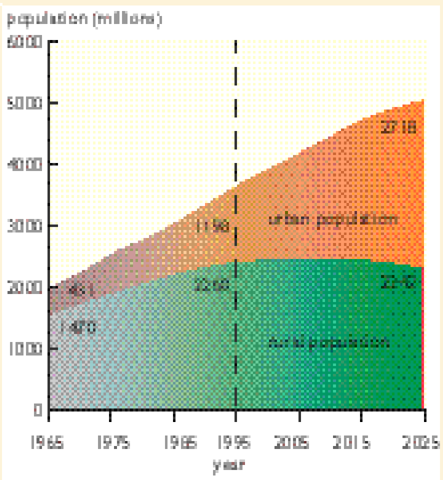
Projected change in per capita water resources.



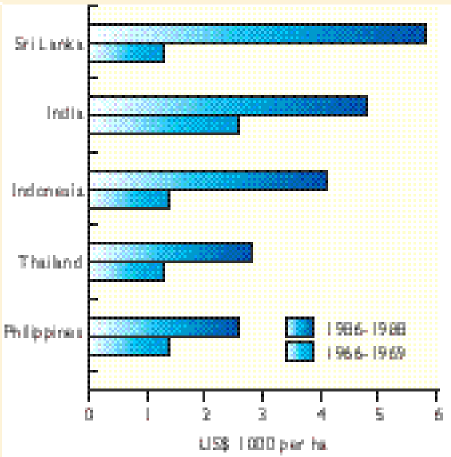
Growth in rice yield and per capita rice production in Asia.



Projected increase in population in the next three decades compared with increase in the past three decades.



Projection of population and urbanisation in Asia.



Real capital cost for construction of new irrigation systems.

tonnes to at least 880 million tonnes by 2025, and it all has to come from existing, or even less, cultivated land.

Rice land being consumed by urban growth cannot simply be replaced by clearing more forests or expanding into marginal areas. Countries such as the Philippines don't have much forest left.

And there are other harsh realities. Global fresh water supplies are barely half what they were 20 years ago, and according to the United Nations, consumption is doubling every two decades.

Earlier this year the UN reported that a quarter of the world's 5.9 billion people had no access to clean drinking water and that water shortages were emerging as the most serious threat to world peace. The developing world will be adding another 2.31 billion people in the next three decades, compared with an increase of 2.12 billion in the previous three (see graphs).

Thus the 'Green-Green Revolution' now challenging scientists at IRRI is to lift yields with less land and water without chemical pesticides and herbicides, to protect the biotic resource base from which all food must come.

This quest to keep food, water, population and environmental sustainability in balance now rests on a single ambition: a whole new rice plant, structurally and genetically far removed from traditional varieties that have sustained humans for the past few thousand years. The natural plant that evolved with the strength to support up to 800 grains is being re-engineered to produce 2000 grains and to be strong enough to carry the load.

The new rice plant will also need to be drought-resistant and pest-resistant, and have the capacity to genetically outcompete weeds. In countries such as Bangladesh it will be modified further to be flood-tolerant. In all cases, its aroma, taste and nutritional composition will be enhanced or stabilised. In 30 to 50 years, the temperature-sensitive rice plant will also need to tolerate higher temperatures because of global warming.

IRRI's deputy director for research, Australian scientist Dr Ken Fischer, says plant breeders will have to push biological systems to new limits if rice production – in South-East Asia, South America and much of Africa – is to keep pace with population growth.

It's a race against time, with the first reports of drought-induced famine already coming out of countries such as Indonesia and the Philippines this year.

'Yields must be lifted from an average of four tonnes a hectare to more than 12 t/ha,' Fisher says. 'To achieve this we're redesigning the whole plant from the bottom up. It will have increased photosynthetic capacity and will need to put more of this increased energy into grain production, instead of biomass. The existing plant has 40 to 50 tillers (stems) of which 30 are productive. The new plant will have 20 to 30 tillers and all will be productive.'

Some 5000 litres of water is needed produce one kilogram of rice under traditional paddy field production. The 'super rice' will be developed initially for irrigated regions, but further modifications will enable it to perform in drier conditions

Tales of a cultural staple

IN HUMID and sub-humid Asia, rice is the principal staple food and the single most important source of employment and income for the rural people. Rice is more important to the economy and people at lower income levels, and hence is an important intervention point for agricultural development and the alleviation of poverty.

In countries with an annual per capita income of US$500 or less, rice accounts for 20-30% of the gross domestic product, 30-50% of the agricultural value added and 50-80% of the calories consumed by the people. Nearly 150 million households in Asia depend on rice cultivation for their livelihood.

The urban poor and the rural landless, the most vulnerable groups with regard to food security, spend 50-70% of their incomes on rice. Therefore, most Asian governments regard rice as a strategically important commodity, and maintaining stability in rice prices is a key political objective.

Rice is mentioned in all the scriptures of Asia's ancient civilizations. Its cultivation was considered as basis of the social order and played a major role in Asia's religions and customs. The Japanese did not think in terms of breakfast, lunch and dinner; the three meals they served were asa gohan (morning rice), hiru gohan (afternoon rice), and ban gohan (evening rice). In Thailand, rice was considered to be the gift of the fruitful womb of the goddess Mae Phosop.

In China and Bangladesh, a polite way of greeting a visitor was: 'Have you eaten your rice today?' To have a steady job is still referred to in China by the phrase 'to have an iron rice bowl' and to be unemployed is 'to have broken the rice bowl'. Many other customs related to rice have evolved in the thousands of years of rice cultivation and consumption.

The significance of rice in prosperous Asian countries may have diminished somewhat over the past few decades, but not entirely. Today, even in the modern world of the Japanese automobile industry, rice remains a symbol of success. The word Toyota means beautiful ricefield, and Honda means main ricefield.

Source: IRRI

School's in for farmers of the future

CELSO MALABAYABAS grew up on a rice farm on the Philippine island of Mindoro. Upon leaving school he left its muddy fields to become a librarian and for the past 16 years has worked for a large oil company in the Middle East.

But earlier this year, he was once more knee-deep in mud, wrestling with a mechanised tiller and spending hours in a classroom, learning to become a modern rice farmer. He had decided to return to the Philippines to take over management of his father-in-law's 14-hectare rice farm – a heavy responsibility for someone raised on a 0.8 hectare farm.

Malabayabas says he's looking forward to working with the land again, but is acutely aware of the wider responsibilities of his country's and Asia's rice farmers to achieve higher production with minimal environmental impact. So he signed on for IRRI's rice production course, designed to introduce scientists, extension officers and aid workers to rice and its production and culture, and to expose farmers to modern methods and thinking.

This year's course was also attended by local representatives from the Bayer chemical company. They were sent to 'check out' integrated pest management, a threat to pesticide sales.

Peci Lyons, an agricultural economics graduate from Melbourne University, was there to study new production techniques and to ascertain how to cost-effectively incorporate them into extension services. Farmers in some countries can't afford mechanical implements. They use village labour and the ever-reliable caribou (water buffalo). Lyons works with the Cambodia-IRRI-Australia project which has been restoring rice production in Cambodia's ravaged hinterland.

Dux of this year's course was Akihiko Kamoshita, a young Japanese scientist who had come for some practical experience on applying science to production systems. He has been part of the general scientific effort to make rice more drought tolerant.

Top: Knee-deep in mud. Celso Malabayabas, aware of the need for sustainable rice production, joined students from Japan and Australia at IRRI's rice production school.

Above: The course is designed to introduce scientists, extension officers and aid workers to rice and its production and culture, and to expose farmers to modern methods and thinking.

and increasingly on rain-fed land as irrigated land disappears under burgeoning cities.

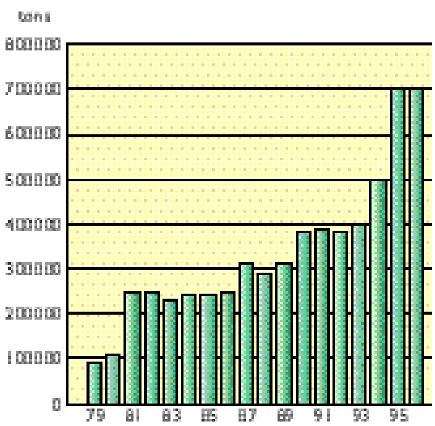
Much of the new plant is being constructed using genes gathered from rice already growing under harsh conditions in regions such as West Africa. IRRI has the genetic traits of more than 85 000 varieties in its germplasm bank and through its Genetics Resources Centre (GRC) is involved in a five-year project to safeguard and preserve the biodiversity of the rice genepool.

This extensive project began in 1994 and is sponsored by the Swiss Agency for Development and Cooperation (SDC). Its goal is to collect and preserve the genetic resources of the Earth's cultivated rice and wild species before they disappear. The three components of the project involve field collection of germplasm, on-farm conservation, and national staff training-genebank development in the 20 participating countries.

Scientists searching for vanishing rice species in remote parts of Asia, Africa and South America, have encountered all kinds of hazards, from charging elephants to snakes, leeches, murky swamps, political unrest, raging storms, mountains and wild rivers. But according to IRRI germplasm specialist Dr Bao-Rong Lu, such 'minor' irritants can be quickly forgotten when a rare discovery is made, such as a population of *Oryza rufipogon* found after an arduous two-day search in Bangladesh.

However, as more improved varieties make their way into farmers' fields, low-yielding traditional varieties of the main cultivated *Oryza* species are being abandoned. Alarming genetic erosion is also occurring in the 22 wild *Oryza* species.

'The paradox is that plant breeders have been too successful,' says GRC chief, Dr Michael Jackson. 'Farmers have been so quick to switch to the new varieties they've stopped growing the traditional varieties that we need as a genetic resource.'



Cambodian dry season rice production

Jackson says more than 100 000 samples of rice from across Asia, South America and Africa have been collected from an estimated 120 000 varieties in existence. In 1997, 15 160 previously uncollected seed samples of unique populations (14 018 cultivated, 1142 wild) were rescued ahead of oblivion, mostly from Laos, a country that was previously closed. Jackson's team is hoping to be able to announce it has the earth's complete rice collection by the year 2000.

After they've been identified and catalogued, the collected seeds are dried slowly for four weeks, then sealed in aluminium packets. The active collection, from which researchers and breeders can order samples, is stored in a vault at Los Banos in the Philippines at 2°C.

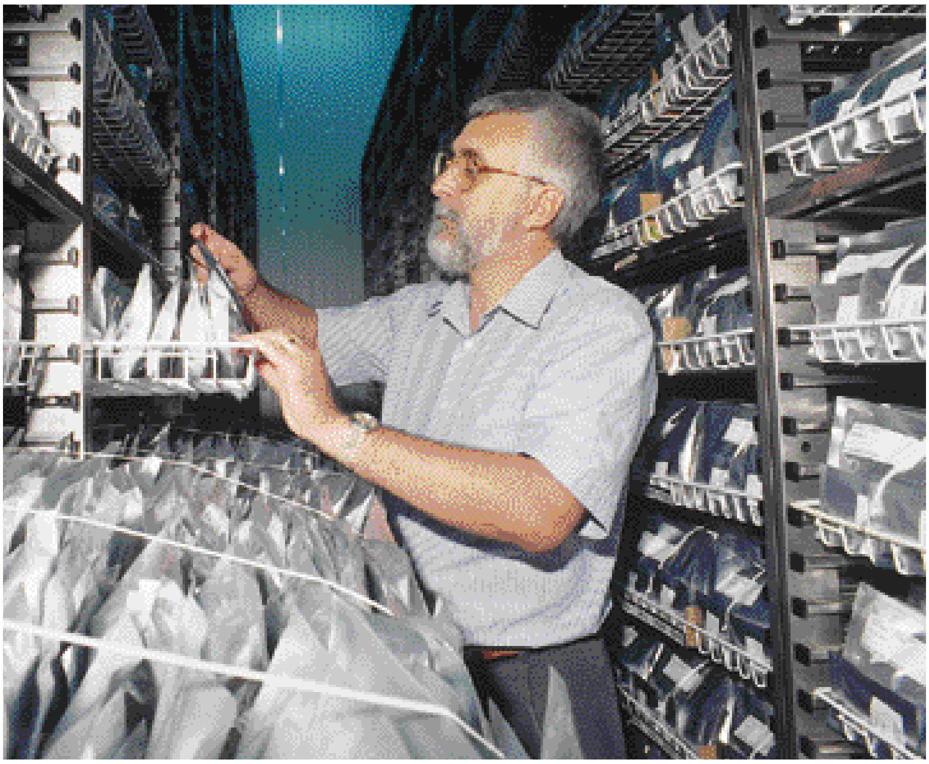
A duplicate of the active collection – the permanent collection – is stored at minus 20°C in a neighbouring vault. The seeds in this vault have a storage life of at least 100 years. For security reasons, this collection is duplicated in the United States.

The presence of the germplasm bank has already demonstrated its value in the aftermath of the drawn-out war in Cambodia. Rice production there had almost stopped, through rural communities being forcibly moved and later their land littered with anti-personnel mines.

As the land was gradually made safe again, it was discovered that the country's store of seed had gone. Food shortages had forced farmers to eat their rice seed and the main source of many traditional varieties

Above: IRRI deputy director for research, Dr Ken Fischer, says plant breeders will have to push biological systems to new limits if rice production in South-East Asia, South America and much of Africa is to keep pace with population growth.

Below: IRRI has the genetic traits of more than 85 000 varieties in its germplasm bank and through its Genetics Resources Centre is involved in project to safeguard and preserve the biodiversity of the rice genepool. GRC chief, Dr Michael Jackson, says farmers have stopped growing the traditional varieties needed as a genetic resource.



Managing the social cost of technological change

AS TALK of a Green-Green Revolution gathers momentum, efforts are being made to avoid the sociological costs that came with the first new rice varieties and production technologies in the 1960s and 1970s.

Dr Thelma Paris, a senior associate scientist at IRRI, is responsible for ensuring the next generation of technological change – biotechnology, plant breeding and advances in farm management – also has a positive social impact.

Paris says that aside from the agronomic and economic gains made after the release of the first high-yielding rice, IR8, there were some costly consequences. With 36% of rice grown under rain-fed conditions, many rural people saw the Green Revolution as only benefiting farmers wealthy enough to afford irrigation infrastructure.

Rice yields have remained low in rain-fed lowlands and uplands, at two tonnes a hectare against 5 t/ha for irrigated systems. Addressing this imbalance will be IRRI's next research priority.

Paris is supported by the head of IRRI's social sciences division, Dr Mahabub Hossain, who is encouraging fellow scientists to take up the challenge of breeding high-yielding rice varieties that can survive the stresses of rain-reliant farming. This is where poverty and food shortages are ever-present.

The other social and economic division created by the Green Revolution was the displacement of women, who lost their traditional roles such as planting and weeding to machines and chemicals.

'People think of farmers as being men, but 60 to 80% of the work in rice production was done by women,' Paris says. It created a Catch-22 situation. The introduction of chemicals and mechanisation took from their shoulders an over-burden. They didn't particularly like planting, weeding, harvesting, husking and the pitifully low wages, but without those roles they were displaced socially and economically.

'What scientists have to realise is that technology is not neutral if the tasks it replaces are gender specific,' Paris says.

She says the Green-Green Revolution will provide the opportunity for women to regain a role in rice production by giving them the key role in the introduction of integrated pest management (IPM).

IPM, an ecological approach to pest management, has become a priority at IRRI in the past 10 years. 'IPM is going to be a key aspect of the new production systems being developed and we are tailoring the training and extension courses to make women the agents of this change,' Paris says.

'IPM is knowledge-based, rather than labour-based, which puts women in a good position to take control of the change. If women are convinced they don't have to use pesticides and that the money saved can be better spent on health and education for their children, the men will take their lead.'

Paris says a concerted effort has been made to involve women wherever on-farm experiments have been set up to demonstrate IPM and to ensure that wherever IPM incorporates women's traditional roles, they are put in charge.

'For example, women have been responsible for on-farm seed storage, so it's women we are training in the new methods for improved seed storage and management,' she says. 'The cleaner and better stored the seeds, the higher the yields, and the knowledge to achieve this will be with farm women.

'We're also looking for ways to take the drudgery out of traditional women's roles, such as hand-pounding husks. Most of the new mechanisation has been for the work men did, such as ploughing.'

Paris took the matter to IRRI's agricultural engineers, who have developed a portable micro-mill: 'It means women still have their traditional role, but the mill gets the job done much faster, giving them more time for other activities. Some are also using the mills to establish businesses; contracting to do the work for other farmers.'

Dr Thelma Paris says the Green-Green Revolution will provide the opportunity for women to regain a role in rice production.

Rice farmer Reynaldo Honra and his son, Reysan. IRRI is working to ensure the next generation of technological change has a positive social impact.

was lost. Fortunately, despite the war raging at the time, IRRI collectors gathered a large bank of Cambodia rice germplasm in December 1972 and January 1973.

Between 1981 and 1990, IRRI reintroduced 766 traditional Cambodian rice varieties, helping to transform Cambodia from being rice deficient, to exporting a surplus by 1995 (see graph on page 17).

A further promising sign was that improvements to the seed that went back enabled the 1996 harvest to match the previous peak production in 1969 of 3.3 million tonnes, on half a million hectares less land.

IRRI senior plant breeder, Dr Gurdev Khush, began searching through the world's rice gene bank in 1988 for material with which to begin the latest rice plant 'redesign', which began its breeding phase two years later.

Khush also worked on the first of the modern rice varieties 30 years ago. 'With a plant called IR8 we had the capacity to lift yields from an average of two tonnes a hectare to 8 t/ha,' he says. 'IR72 took this to 10 t/ha. The next target I'm aiming for 12.5 t/ha.

'Essentially what we are doing is changing the plant's architecture so that it directs more energy to grain production and less to foliage. Before IR8 we had 70% biomass, 30% grain. We changed that to 50:50, but the new "super rice" will be 60% grain, 40% biomass.

'The approach we took was to conceptualise the ideal plant. For example, deciding how many tillers and stems it should have. We then searched through the germplasm bank for varieties with the traits we wanted, and put them into donor parents for crossing until we had them all in a single plant.'

Khush says he had the basic plant by 1995, and since then the work has concentrated on lifting grain quality and inserting genes that will confer disease and pest resistance.

One unforeseen obstacle, however, has been poor grain filling. This is preventing the plants from expressing their new yield potential. Khush and his colleagues are working to overcome this problem by modifying the new plant's vascular 'plumbing'.

Other work is on track. Resistance to tungro and brown planthopper is being incorporated and several lines with resistance to blast and bacterial blight have been selected from earlier crosses. Major strides have also been made in improving grain quality, using parents from Indonesia, the Philippines, Thailand and India.

Most of the changes introduced by Khush have been done through conventional breeding, but for stem strength, IRRI scientists have 'borrowed' the gene that

Changing nature. The plant on the left is tall traditional rice. In the centre is the first high-yield modern variety from the Green Revolution, and on the right is the new 'super rice' prototype.

gives maize its stem strength and put that into the new rice plant.

'Breeding is still the most effective method when you are seeking to transfer a large number of genetic traits,' Khush says. 'Genetic engineering is more suited to introducing single gene traits.'

Genetic engineering would be used to confer the new rice plant with resistance to insect pests, by inserting genes from the bacterium *Bacillus thuringiensis* (Bt). Bt genes that code for proteins toxic to insects have been transferred to several crop plants, including rice. But while Bt maize, potato and cotton plants are being grown commercially in several countries, the release of a Bt rice is being held up by the debate over whether Bt foods are safe for humans.

IRRI molecular biologist Dr John Bennett says *B. thuringiensis* is common in soils worldwide. But this hasn't stopped the arguments, mainly because there are two forms of Bt toxin. One is potentially harmful to humans, but is not associated with transgenic plants. Bennett is confident the controversy will abate once the community better understands biotechnology.

The toxins used in transgenic food crops are plant-produced Bt toxins called 'cry' toxins and they can be modified for specific results, such as to kill only unwanted insects. Also, these Bt toxins are only present in plant foliage, not the grain.

But laboratory tests have shown another strain of Bt toxins, called 'cyt' toxins, could be harmful to vertebrate animal cells. The genes controlling these toxins are different to, and separate from the *B. thuringiensis* bacterium used to confer insect pest resistance to plant foliage.

Some of the Bt toxin genes that have been transferred to rice make proteins that are highly effective against the major pest, stem borers. About 5% of Asia's potential rice yield is lost to stem borers alone. This is equivalent to 25 million tonnes, or almost all of the Bangladesh harvest which feeds 120 million people.

Another challenge for the IRRI scientists is to minimise, or reduce completely, methane emissions from rice fields.

Methane produced in millions of hectares of flooded paddies has contributed to the enhanced greenhouse effect. Fertiliser decomposing in soil that is anoxic (having low oxygen levels) due to long periods of submersion produces methane gas. The amount of methane emitted by rice paddies was decreasing because of increased chemical fertiliser use, but the process is slowly reverting as organic fertilisers are promoted as part of a more ecological approach to rice production.

IRRI's Dr Kong Luen Heong: using popular media to help change farmer's perceptions.

Learning with laughter in Vietnam

A POPULAR radio comedy in Vietnam's Long An Province in recent years has had rice farmers there in stitches. One farmer is trying to tell another that he doesn't need to spray for leaf folder, an insect with a ravenous appetite for young rice plants.

It's a big joke. Everybody knows you have to spray your crops to kill insects because . . . well because that's what everybody has been told for so long it's become a law of farming. But gradually, through the radio play's hilarity, the farmer who doesn't use insecticides manages to get across an irrefutable point. His yields are just as good, if not better, than everybody else's.

It took a while for the laughter to settle in Long An, but it did. And in the sober aftermath, farmers there are reassessing their use of chemicals. The radio play has been part of a trial by Dr Kong Luen Heong from the International Rice Research Institute to use popular media to change farmer's perceptions. Since the play's airing, the proportion of farmers who don't use any pesticides has risen from 1% to 32%.

And the proportion of farmers who spray in the three early crop stages – seedling, tillering and booting – has fallen from 59%, 84% and 85% to 0.2%, 19% and 30%. Similarly, the proportion of farmers who now believe leaf folders cause economic losses has fallen from 70% to 25%.

Heong says that despite the success of the media trial in South Vietnam, the phase-out of pesticides is a delicate issue because they have to be replaced by changes in management to facilitate biological and other forms of control. The whole campaign could fail badly if farmers stopped using pesticides and suffered serious economic losses because they didn't make other adjustments. 'So we've been taking it steadily, inviting farmers to test for themselves the alternatives,' he says.

'We've invented a simple experiment in which we encourage them to set up a small plot in the backyard and not treat it with any chemicals. We then say, "don't look at the insects, just look at the final crop". In this way we're breaking down the perception that pesticides, by removing insects, give them an economic gain.'

Heong says the cheapness of pesticides has been another obstacle for scientists trying to phase them out. They only represent about 3% of production costs, so most farmers see the chemicals as a low-cost insurance. 'They feel reassured if they actually see worms dropping dead,' he says.

'Even so, the results of our campaign in Vietnam show that farmers will respond to a positive message. Gradually we're reducing the perceived benefit of spending any money on pesticides . . . and the real flow-on gains are in the environment. Most of the chemicals are organophosphates – World Health Organisation "category 1" toxins that are banned in countries such as Australia.'

Heong says the media campaign in Long An Province has been picked up by Vietnam's Ministry of Agriculture and Rural Development and being spread across the country.

'The onus is increasing on farmers to manage their organic inputs and change their water use,' says Dr Reiner Wassmann, a German scientist seconded from Fraunhofer Institute for Atmospheric Research to develop methane-control mechanisms in rice production.

Wassmann is researching the effects on intermittent drainage of paddies to aerate the soil, and the effects of different types of fertilisers and times of application.

'We find less methane is produced if the field is fertilised before flooding,' he says. 'Research also shows that composted organic fertiliser also results in less methane because the methane is consumed by the composting process.'

Wassmann says methane production also varies with soil types, with less methane emitted from Indian ricefields because of the sandier soil: 'So our research is now mainly focussing on the methane hot-spots: China, southern India, and Indonesia.'

But Wassmann points out that global warming has both negatives and positives. Increased levels of atmospheric carbon dioxide (the main greenhouse gas) will improve plant growth, but higher temperatures will lower yields. A 2°C increase in average daily temperatures would cut rice yields by 20%, and at 40°C, the plants become infertile.

Therefore the climate change work at IRRI has two purposes: to study rice production's contribution to greenhouse, and in turn the impact of global warming on rice production.

Research is also helping rice farmers to better cope with normal patterns of climate variability, such as periodic droughts caused by the notorious weather system, El Niño.

An English physicist, Dr John Sheehy, and a Philippine climate specialist, Dr Grace Conteno, are working to turn the world's vast array of theoretical climate models into prescriptive models for use by farmers.

'It might mean that where a farmer today has one or two crop choices, accurate long-range weather forecasts could give several,' Sheehy says. 'These would be based on what will grow best in his area and what market opportunities might be opened elsewhere because of adverse weather.'

Brad Collis visited IRRI with assistance from the Australian Centre for International Agricultural Research and the Crawford Fund.

A B S T R A C T

Scientists at the International Rice Research Institute in the Philippines are breeding high-yielding, disease-resistant 'super rices' for release to Asian farmers early next century. Rice yields across Asia doubled from 1967 to 1992, thanks to a reduction in stalk height which enabled the plant to carry more grain. But the world's rice harvest must increase from 560 million tonnes to at least to 880 million tonnes by 2025. The challenge now is to lift yields with less land and water, using integrated pest management principles that replace pesticides and herbicides with agronomic, biological and genetic advances. To help achieve this the 'super rices' will have increased photosynthetic capacity and will direct more energy into grain production, instead of biomass. IRRI is drawing on the resources of its germplasm bank, and using hardy genes gathered in regions such as West Africa. Other challenges are to reduce methane emissions from rice fields and to turn theoretical climate models into prescriptive models for use by farmers.

Keywords: **rice; integrated pest management; crop yield; plant breeding; rice varieties; genetic engineering; pest resistance; methane emissions; International Rice Research Institute.**

Dr Reiner Wassmann is studying both the contribution of rice production to the greenhouse effect, and the impact of global warming on rice production.