Biotechnology safeguards the rice supply

Food for the world

Rice is the staple food of the majority of humanity. But this crop is facing a crisis: climate change and pests are making life tough for the plants. A growing world population needs this high-quality foodstuff, however. Researchers working for Bayer CropScience are using state-of-the-art molecular biology methods and breeding new, high-yield varieties while at the same time making the plants more resistant to disease, drought and flooding.

It is the most important cereal on earth: around 600 million tons of rice are harvested each year around the world. But rice production can already barely keep pace with consumption. The rice yield in Asia has been around four tons per hectare since the mid-1990s. That is too little for too many people; the annual rice harvest needs to be over 780 million tons, around 30 percent above today's level, if the world's food supplies are to be secured until the year 2020. What's more, the global rice reserves are currently lower than they have ever been before. Rice-growers face an enormous task: they have to make more out of less, because the amount of land they have to farm cannot be enlarged. So the challenge is to produce larger volumes of better-quality food from the limited acreage available.

Rice is not the only crop that could be in short supply in the future. The Food and Agriculture Organization of the United Nations (FAO) believes that the entire agricultural sector needs to double its output by the middle of the century. In 2008 it called on "the international community, including the private sector, to decisively step up investment in science and technology for food and agriculture."

This call has not fallen on deaf ears at Bayer CropScience's Plant Biotechnology Innovation Center in the Belgian town of Ghent. The scientists working here have long been developing crops that could one day meet humanity's growing demand. "Rice has a special role to play here," explains Dr. Alain Sailland, Head of Rice Research at Bayer CropScience in Ghent. "That is because it is the main staple food in Asia in particular." It is especially important to achieve secure food supplies in Asia, as more than half of the world's population lives in this region, and the population figures are still rising dramatically.

Boosting harvest yields of rice fields by 20 percent

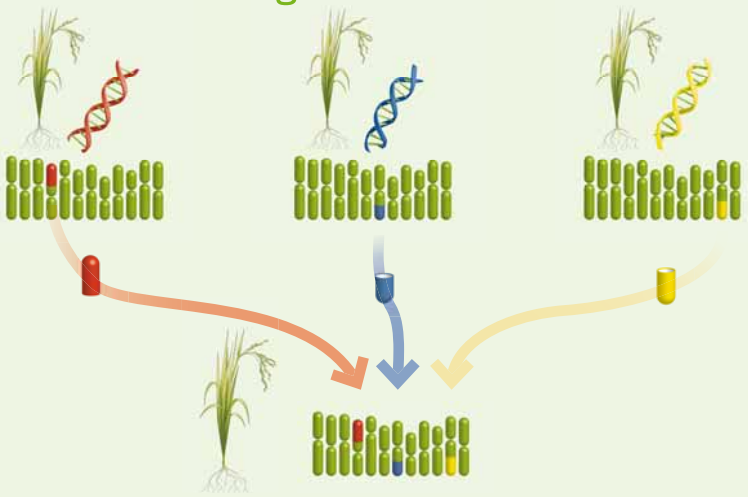
Bayer CropScience's researchers in Ghent are investigating new rice varieties to keep hunger at bay in China, India and Bangladesh. Their aim: "We want to increase rice yields by 15 to 20 percent. And that should be possible in the foreseeable future," comments Sailland. With the help of a dedicated team of molecular biologists, the Belgian researcher is trying to get the most out of the many different rice plants that are currently in cultivation. But that alone is not enough. "We also want to improve the quality," says Sailland. As part of a joint venture with the Israeli crop biotechnology firm Evogene, he and his colleagues have been granted exclusive rights to work with numerous new genes in rice. Some of these may one day help to boost the yields of rice-growers dramatically.

The Ghent plant scientists are not only interested in higher yields, however, although Sailland does describe this as their main priority. They also want to introduce traits into rice that will make them more resistant to the consequences of climate change. "We are currently working on a number of projects. One of them is looking into ways of protecting rice against the harmful effects of flooding. And we are trying to make the rice tolerant to salinated soil." Sailland's team is also working to produce rice plants that are resistant to pests and diseases.

In addition to targeted changes to the genetic material of rice by means of genetic engineering, Bayer's scientists have for the past few years also

Rice specialists: rice feeds a large part of the population in Thailand. Workers (photo left) prepare the seedlings for mats that will later be loaded onto seedling machines and then planted. New generations of rice lines are tested in the International Rice Research Center (photo right).

How protection against disease is introduced into genetic material



Bayer's research scientists have bred different genes from separate rice varieties into new varieties of hybrid rice that are resistant to biotic or abiotic stresses. For example, a new hybrid very tolerant to bacterial leaf blight has been developed using marker-assisted selection. MAS helped the experts identify those plants which had the targeted genes embedded in their genetic material. The diagram shows the twelve rice chromosomes and the pyramiding of three genes that improve the agronomic performance of the new hybrid.

had access to the latest form of plant breeding: marker-assisted selection (MAS) or smart breeding as it is also called. Sailland has set up a working group to continue developing this and other innovative techniques for Bayer so that they can be used not only by researchers working on rice but also by scientists involved in other projects, such as the cotton research headed by the U.S. expert Linda Trolinder (see also "Cotton with less thirst," page 78). "MAS helps us dramatically speed up the process of breeding plants with desirable characteristics," comments Dr. Stephan Brunner, who is overseeing three of Bayer CropScience's rice research projects. "We can now complete development work after six years, whereas it used to take at least eight."

Smart breeding only came onto the scene about ten years ago, but it is slowly but surely replacing conventional breeding throughout the world. This is because scientists using MAS no longer have to rely on assessing the external appearance of a plant to ascertain whether it has inherited a particular property, and if so how strongly. Says Brunner: "We use the plants' genetic material directly to validate our experiments – and this is unambiguous and therefore much more informative than previous methods." Bayer's biotechnology experts have already added thousands of genetic markers to their database. Each marker stands for a unique gene sequence. This section equates to a particular property of the rice plant from which it was taken: for example, because a nearby gene has undergone a slight change at one point, making it unable to function, or has taken over a different task in the plant's metabolism. Many of the markers were taken from documents in the public domain, but Bayer's experts have themselves discovered a large number.

Using markers to search for the resistance gene

Researchers can use markers to quickly and accurately assess the genetic material of rice: they use biochemical methods to investigate the marker-specific regions of the genetic substance. Analysis of the tests – comparable with the analysis of a fingerprint – shows the scientists where the desired gene occurs in the genetic material. This allows breeders to recognize the "genotype" immediately. They then know what variety of rice they are dealing with, and whether the plant really has absorbed the desired property into its genetic material in the purest possible form.

Sailland explains what this means in practice. "For instance, if we want to find out whether a plant is resistant to a bacterium, we no longer have to infect it with the disease and see whether it survives." Thanks to smart breeding, the only thing the scientists need to do is use a marker to look for the gene that is responsible for resistance. They can even test whether the same plant is immune to various diseases. That was impossible with conventional breeding. "After all, you cannot expose a plant to three diseases at the same time, the results would not be clear," comments the rice specialist.

In their search for optimized rice varieties, Sailland and his team cross genetically varied parent plants and then use MAS to pick out the variety that combines as many desirable traits as possible. The first rice variety developed through smart breeding was launched on the market in 2008: Arize™ Dhani is resistant to bacterial leaf blight, a dangerous infection that can destroy

Stress test: in the Innovation Center in Ghent (photo left), Dr. Alain Sailland tests high-yield, stress-tolerant rice varieties. To this end, stress factors such as extreme light conditions or flooding for several days are simulated to test how the performance of the cereal can be increased.

entire harvests. It is designed specifically for the Indian weather conditions. The Ghent researchers are now developing new variants that are adapted to different environmental conditions and pathogen types, so as to open up new markets.

But that's not all: one rice variety that is unappetizing to the insects which caused Biblical plagues is at an advanced stage of development: Sailland's team has bred a trait into the plants that makes them much less attractive to Nilaparvata lugens. These locusts often swarm in Asia and strip entire fields bare. "We don't know why the insects don't like our rice – but that doesn't really matter," says Brunner. "The main thing is that once again the new breeding method has been shown to be effective."

For example, another variant from Bayer's breeding program can survive for ten days under water, when normal rice plants would suffocate. The gene responsible for this resistance to flooding was first discovered by scientists working at the publicly funded International Rice Research Institute (IRRI) in Los Baños in the Philippines and at the University of California in Davis, USA. It is triggered by lack of oxygen, stimulating the plant to produce a protein that adjusts its metabolism to cope with these life-threatening conditions. "This resistance is important for coastal areas that are frequently flooded," says Dr. Achim Dobermann, Director of the IRRI. After all, floods like this will probably occur more often in future as a result of climate change.

International rice research network

To strengthen their research work, the Ghent-based scientists decided to initiate a research collaboration with the IRRI. Bayer is also planning cooperation on an even broader front with the IRRI in the future. Three entire projects are scheduled for joint development right from the start. Bayer and the IRRI also joined forces with several other partners all over the world to set up the Hybrid Rice Research and Development Consortium (HRDC) a year ago. The aim of this body is to develop more important hybrid rice varieties to meet the growing needs of the world's population.

Interview

"Rice is the most important staple foodstuff"

research **spoke to Dr. Achim Dobermann, Deputy Director General of the International Rice Research Institute (IRRI) in Los Baños, Philippines, about rice research.**

Why is it so important to find new rice varieties?

We are constantly racing against the world's population growth. About half of the increased production that will be needed in the future must come from optimized varieties, and the rest from better growing techniques.

How important is rice as a foodstuff?

About half of the world's population depends on rice as its staple food. Rice provides about 20 percent of direct human calorie intake worldwide. Rice consumption exceeds 100 kilograms per capita annually in many Asian countries. Rice also provides food security and so boosts political stability, as nearly all of a country's crop is consumed by its domestic market. Only seven percent is exported.

What are the priorities among the properties of rice that need to be optimized?

Increasing the yield potential is still the main focus, especially as very little progress has been made in this area for the past thirty years. Stress resistance, better nutrient uptake and optimized grain quality are also important.

What contribution does your institute, the IRRI, make to this?

We manage the world's largest rice gene bank, containing around 110,000 varieties, we work on all aspects of improving rice production systems, we provide critical information, and we train scientists and agricultural professionals. The advantage we have is that we are publicly funded and our results are therefore available to all. We can help farmers with things like new cultivation methods or irrigation systems.

www.irri.org

The website of the International Rice Research Institute (IRRI) in the Philippines contains a great deal of information about modern rice breeding.