PROTECTING RICE, PROTECTING PEOPLE

Rice is a staple for half the world population, but also a major source of arsenic in food. 2013 TWAS Prize Winner Zhu Yong-Guan is combining multiple strategies to obtain safe rice for all.

by **Cristina Serra**

Rice feeds half of the world population: It is nutrient-dense and a good source of energy. Arsenic is a chemical element naturally occurring in water and soil, but it is also released by human activities such as mining and coal-burning.

Unfortunately, rice and arsenic establish a dangerous relationship. Arsenic pollutes the soil and becomes easily available to rice, and rice absorbs large amounts of this pollutant through the roots, storing it in its grains.

Zhu Yong-Guan, a professor of environmental sciences at the Institute of Urban Environment at the Chinese Academy of Sciences (CAS) in Beijing, is studying the biochemical pathways that bring arsenic into rice tissues. His aim is to avoid such storage and make healthier, safer rice for consumers.

"Arsenic in food, and particularly in rice, poses health risks to global population, equal to if not more than arsenic intake from water", points out Zhu, who presented his research at the 25th TWAS General Meeting in Oman.

Zhu is also a 2013 TWAS Prize Winner in Agricultural Sciences, and an influential voice in arsenic pollution worldwide. A member of CAS, he holds a PhD in environmental science from the Imperial College in London. He is now focusing on the biogeochemical mechanisms that make rice a dominant source of inorganic (and toxic) arsenic to people.

▲ Zhu Yong-Guan

▼ From left: a sampling of rice grains (Photo: IRRI Images); asian rice. (Photo: Jeevan Jose/ Wikimedia Commons)

SERIAL ACCUMULATOR

Rice is a very efficient accumulator of metals and nutrients from the soil, and silicon is one element that rice needs to grow and overcome physical and chemical stress.

Unfortunately, one of the chemical forms that arsenic takes in the soil closely resembles silicon, and rice makes little distinction between the two.

"On average, Chinese people eat around 200 grammes of rice per day", observes Zhu. "And even if the amount of arsenic that people take in through their diet is not lethal, it may have severe effects on the human metabolism."

Growing evidence suggests that short-term exposure to arsenic triggers gastrointestinal problems, and lesions of hands and feet. When ingested through food, it increases the risk of skin, bladder and kidney cancer.

"We need to look for effective measures to avoid massive exposure to arsenic"

Zhu Yong-Guan

▲ Cambodian farmers planting rice. (Brad Collis/ Wikimedia Commons)

"We need to look for effective measures to avoid massive exposure to arsenic", observes Zhu. "The good news is that we have several weapons available."

COMBINING STRATEGIES

Keeping arsenic out of rice is not easy. It enters through the roots, ascends the plant and gets embedded in shoots, leaves and grains. The husk and the bran, the two outer layers of rice grains, are especially prone to accumulating arsenic.

Due to complex interactions occurring within the plant-soil-environmental microbes system, integrated approaches are needed.

One strategy encourages farmers to use silicon fertilisers, which are less aggressive and reduce the arsenic uptake by competing with this substance. A second option is growing rice under non-flooding conditions, where arsenic is less bioavailable.

But Zhu and colleagues have better targets. One is to coax the activity of microbes that live in the rhizosphere (a narrow region of soil influenced by root secretions and soil microbes), forcing them to shield rice from arsenic.

Zhu explains that in the DNA of soil microbes sits a gene that codes for a protein (an enzyme called methyltransferase) that adds a chemical group to specific molecules, thus converting inorganic arsenic into a less dangerous organic molecule.

"We can stimulate the microbial activity by feeding soil bacteria with organic matter to make them more active, in turn boosting the protein activity. Or we can use genetic engineering and add more copies of the same gene inside bacteria. In doing so, microbes produce larger amounts of the same protein from multiple genes", he adds.

Working in close collaboration with chemists, biologists and soil engineers from the US (Barry Rosen) and UK (Andy Meharg), Zhu's team came up with another modification on the rice plant itself.

They genetically modified the rice genome by inserting a gene from a bacterium called *Rhodopseudomonas palustris*. The resulting transgenic plants are able to transform arsenic into a volatile gas, thus reducing the amount of toxic compound inside the tissues.

FUTURE PLANS

A parallel project Zhu is expanding targets iron in the soil. "We are studying how to use another group of soil bacteria that trigger the oxidation of ferrous iron, resulting in the precipitation of iron oxides in the soil and on rice roots. Iron oxides, in turn, sequester arsenic from soil solution acting as a shield, thus preventing arsenic from entering the roots", he says.

Which of these strategies holds promise in clearing arsenic from rice? "The more we learn about arsenic and rice," Zhu concludes, "the more we realize that the rice-soil-bacteria system is way too complex, thus requiring multidisciplinary approaches."

Finding ways to solve this problem is becoming more urgent: Women are subjected to arsenic exposure also during pregnancy, and children who consume rice regularly have increased concentrations of arsenic in their urine. Says Zhu: "Protecting them means protecting our future." ◘