Hidden Hunger: Biofortified Crops to the Rescue

Plant breeders and nutritional scientists are boosting micronutrients in food crops to enrich diets and reduce malnutrition in developing countries.

BY MARISSA FESSENDEN '09
In 1997, the children of Bangladesh were suffering from a disease never before seen in that part of the world. There was no Bengali word for the deformities that were bending the backs and bowing the legs of their children.

The disease was rickets, a softening of the bones that results in gross deformities. Rickets is normally associated with lack of sunlight and accompanying vitamin D deficiency. Cornell scientists were puzzled to see a high rate of this disease in sun-drenched Bangladesh. One of the scientists was Ross Welch, adjunct professor of crop and soil sciences and researcher at the USDA–ARS lab at Cornell. Welch and the other researchers thought that the rickets were caused by a lack of calcium rather than lack of vitamin D. The children of Bangladesh were eating only rice, staving off hunger but suffering from malnutrition.

Known as “hidden hunger,” malnutrition affects more than 3 billion people in developing countries. Using plant breeding and nutritional science to grow plants that will provide the needed nutrients, Cornell researchers and the international research program HarvestPlus are leaders in biofortification.

“The problem isn’t that there isn’t enough food,” says Leon Kochian, a professor of plant biology and director of the USDA–ARS lab. “The Green Revolution addressed the caloric needs of the people but tended to push agriculture toward a monoculture. Instead of eating legumes and other diverse foods of the traditional food system, people began to rely on a single cereal crop like rice. This decreased the varied diet.”

Plenty of Carbs but Not Enough Nutrients

The Green Revolution brought sweeping agricultural changes. Starting in Mexico in the 1940s and spreading to India and Asia by the 1970s, farmers in developing countries began to adopt new technologies and methods that dramatically increased yields of staple food crops. India saw annual wheat production rise from 10 million tons in the 1960s to 73 million in 2006. The Green Revolution was heralded as a huge success, reducing famine and poverty in the developing world.

“In Bangladesh, no one over the age of 25 has rickets,” Welch says. “I attribute that health problem to the loss of edible legume seeds in the diet of the poor. Legumes are much richer in calcium than the cereal crops that replaced them.”

According to Welch, there are more than 30 million deaths each year from malnutrition, or about one death per second from both overt deficiencies as well as chronic malnutrition. The problem is on the rise, from 30 percent suffering before the Green Revolution to more than 50 percent now.

“The current problems are unforeseen consequences of the Green Revolution, which stressed three crops—rice, corn, and wheat,” Welch explains. “The staples provided two nutrients—carbohydrates and a little protein—but people need a minimum of 42 nutrients, and if you are missing even one of these nutrients, you become sick.”

Micronutrients are the minerals and vitamins needed in only small amounts to maintain a healthy diet. As malnutrition rises, HarvestPlus scientists have identified iron, zinc, and vitamin A as three key micronutrients that are often deficient. In the United States, micronutrient malnutrition is a rarity because food is fortified during processing. Iron, folic acid, thiamin, riboflavin, and niacin are added to flour; iron and many other micronutrients are added to baby formula; and vitamins A and D are added to milk.

“We’ve been fortifying food in this country for 60 years now,” says Dennis Miller,
PhD ’78, professor of food science and nutrition at Cornell. “This works very well in places like the U.S., where we have good centralized processing, good technology, and very good monitoring of the food supply. In developing countries it is very difficult to regulate the nutrients in the food. They don’t have the centralized processing facilities that we do. If they have any at all, it may be at a village level.”

Ten years ago, Howdy Bouis, an economist at the International Food Policy Research Institute, became a pioneer in the then unnamed field of biofortification.

Welch says, “He wanted to know, ‘Can plants fortify themselves?’” Inspired by Welch’s work with zinc in wheat, Bouis founded HarvestPlus in 2004. The program, one of three pioneer programs under the Consultative Group for International Agricultural Research, is now a global leader in developing biofortified crops. Supported by grants from the Bill and Melinda Gates Foundation, USAID, and other donors, HarvestPlus works with more than 200 agricultural and nutrition scientists around the world.

Edward Buckler, a USDA–ARS research geneticist in Cornell’s Institute for Genomic Diversity and an adjunct associate professor in the Department of Plant Breeding and Genetics, dissects the complex pathways that lead to beta-carotene, a precursor to vitamin A in maize.

“In Sub-Saharan Africa and Latin America, there are large numbers of people who don’t get enough vitamin A,” Buckler says, “There, 60 to 70 percent of their calories are from direct consumption of maize.” After going through the thousands of genes that make up the maize genome, Buckler’s lab found a gene variant that conferred a three- to four-fold increase in beta-carotene.

“It takes five years of breeding to introduce the gene variant and put it in the proper genetic background,” Buckler points out. “Beta-carotene, or provitamin A, is a nutritional trait, but farmers are concerned about yield and drought resistance, so we need a maize variety that integrates all of these qualities.”

Genetically screening thousands of maize varieties suited for growth around the world is expensive. Fortunately, the International Wheat and Maize Improvement Center, based in Mexico, developed a five-cent molecular assay using PCR (polymerase chain reaction), a simple technique that can make millions of copies of the provitamin A gene. With this tool, researchers around the world are easily able to identify the gene in any variety of maize they need.

Bring on the Plant Breeders

After breeding the biofortified crop, nutritionists like Dennis Miller step in to make sure the nutrients from the plant are available for consumption. Miller works on iron-biofortified beans.

Iron is essential for carrying oxygen in the blood, making up the active part of hemoglobin. “When iron stores have been depleted and the demand for more iron is not met, you become anemic,” Miller explains. “Anemia has consequences. Kids who are anemic have impaired cognitive development. In severely anemic women, childbirth can be fatal. Anemia can be reversed easily, but the cognitive development in children is permanent.”
Kochian says that plants tightly regulate their uptake of iron from the soil. The chemical reactivity of iron makes it essential to living systems, but too much iron can be toxic. Bioavailability, or ease of uptake, is more important than the total amount of iron. “If you can increase the availability, then you don’t need to increase the content,” Kochian points out.

Miller’s nutritional studies with pigs show that consuming a high-iron bean increases iron in the bloodstream. This is promising enough that Jere Haas, the Nancy Schlegel Meinig Professor of Maternal and Child Nutrition in the College of Human Ecology’s Division of Nutritional Sciences, hopes to take the biofortified beans to southern Mexico to conduct a nutrition study with schoolchildren. If the beans improve the iron levels of those children, then the next step is to get the improved seeds to farmers.

The greatest biofortification success story so far is that of sweet potatoes in Africa. Traditionally, African farmers have grown white-fleshed sweet potatoes because they keep better and the texture is firmer. Unfortunately, the white flesh has no beta-carotene, and children were going blind as a result of vitamin A deficiency.

“In Mozambique, they were able to convince people to switch to orange-fleshed sweet potatoes and show improvement in children’s vitamin A,” Miller says. Some breeding was needed to improve the orange sweet potatoes’ shelf life and disease resistance, but orange-fleshed sweet potatoes are on the market now.

The story is similar to that of golden rice. Golden rice is a genetically modified organism (GMO) with a higher beta-carotene content than normal white rice, which has essentially none. But there is concern that people will be reluctant to adopt a yellow version of their traditional white rice, and that because the golden rice is a GMO, many governments have been reluctant to promote or even approve the more nutritious variety. (The GMO debate has not affected development of high-iron beans, provitamin A maize, or the biofortified sweet potatoes because they are grown through traditional breeding practices.)

“It takes educating parents,” Miller says. “If you tell a parent that this food will prevent blindness in their children, that is a powerful message, and I think people will change.”

To help people around the world escape the hidden hunger of malnutrition, researchers, seed companies, and politicians must work together.

“Everyone is worried about population growth,” says Welch, “but you need to put nutritional needs up front. Many children who suffer from micronutrient malnutrition can never reach their genetic potential for intelligence, they can’t get a good education, they can’t get the better jobs, and they marry early. It is a vicious cycle. If you want to stop that, you must put nutrition up front and break the cycle.”

In a HarvestPlus pilot project, Ugandan women grow orange-fleshed sweet potato that is higher in Vitamin A content.

Jere Haas in the Division of Nutritional Sciences hopes to bring iron-biofortified beans to schoolchildren in southern Mexico. If the beans increase the children’s iron levels, the improved seeds will be given to farmers.