BIOFORTIFICATION

HARNESSING AGRICULTURAL TECHNOLOGY TO IMPROVE THE HEALTH OF THE POOR

Plant Breeding to Combat Micronutrient Deficiency

Imagine a new breed of ultra-nourishing crops capable of alleviating malnutrition in even the most hard-to-reach populations—crops such as rice loaded with iron, maize packed with zinc, and wheat strengthened with vitamin A. These staples would need no commercial fortification, and could be grown on family plots throughout the developing world.

Such crops are no longer imaginary. It is now possible to breed plants for increased vitamin and mineral content, making "biofortified™" crops one of the most promising new tools in the fight to end malnutrition and save lives.

Micronutrient Malnutrition: The Hidden Hunger

More than 840 million people do not have enough food to meet their basic daily energy needs. Far more—an estimated 3 billion—suffer the insidious effects of micronutrient deficiencies because they lack money to buy enough meat, fish, fruits, lentils, and vegetables. Women and children in Sub-Saharan Africa, South and Southeast Asia, Latin America and the Caribbean are especially at risk of disease, premature death, and impaired cognitive abilities because of diets poor in crucial nutrients, particularly iron, vitamin A, iodine, and zinc.

Current efforts to combat micronutrient malnutrition in the developing world focus on providing vitamin and mineral supplements for pregnant women and young children, and on fortifying foods through post-production processing. These approaches have accomplished much. In regions with adequate infrastructure and well-established markets for food processing and delivery, food fortification has greatly improved the micronutrient intake of vulnerable populations, particularly the urban poor.

Unfortunately, there are limits to commercial fortification and supplementation. In the poorest countries, consumption of commercially fortified foods is minimal. Furthermore, the recurrent costs associated with supplementation and commercial fortification are significant. By conservative estimates, providing vitamin A supplements and iron-fortified foods to one half of those in need would cost $100 million every year in South Asia alone.

BIOFORTIFICATION:
A New Paradigm for Agriculture and a Tool for Improved Human Health

The introduction of biofortified crops—varieties bred for increased mineral and vitamin content—would complement existing nutrition approaches by offering a sustainable and low-cost way to reach people with poor access to formal markets or health care systems. Biofortification can provide ongoing benefits throughout the developing world at a fraction of the recurring cost of either supplementation or post-production fortification.

The biofortification approach is backed by sound science. Research funded by Danish International Development Assistance (Danida) and coordinated by the International Food Policy Research Institute (IFPRI) has examined the feasibility of a plant breeding approach for improving the micronutrient content of staple crops and found that:

- substantial useful genetic variation exists in key staple crops;
- breeding programs can readily manage nutritional quality traits, which for some crops are highly heritable and simple to screen for;
- desired traits are sufficiently stable across a wide range of growing environments; and
- traits for high nutrient content can be combined with superior agronomic characteristics and high yields.

The ability of crop research to screen for and improve the nutrient content of staple crops has also been amply demonstrated by the Future Harvest international agricultural research institutes and their partners. Ability exists today to further improve and more widely disseminate these crucial varieties:

- Iron-rich rice (International Rice Research Institute, Philippines)
- Quality protein maize (International Maize and Wheat Improvement Center, Mexico)
- High-carotene sweet potato (International Potato Center, Peru)
- High-carotene cassava (International Center for Tropical Agriculture, Colombia)

Biofortified Crops for Improved Human Nutrition

It is time to move forward with a strong program to develop nutrient-rich crop varieties, demonstrate their impact on human nutrition, and distribute them to the people who need them most.

These tasks will be accomplished by a new international coalition bringing together an extraordinary range of knowledge and ability, including expertise in plant breeding, plant genomics, human nutrition, social behavior, and policy analysis. CIAT and IFPRI will coordinate the plant breeding, nutrition, crop dissemination, and policy analysis activities, which will be carried out at eight international agricultural research centers, numerous national agricultural research and extension institutions, and departments of plant science and human nutrition at universities in developing and developed countries. Nongovernmental organizations (NGOs) in developed and developing countries, farmer organizations, and private sector partnerships will strengthen the alliance and provide linkages to consumers.

Initial biofortification efforts will focus on six staple crops for which prebreeding feasibility studies have been completed: beans, cassava, maize, rice, sweet potatoes, and wheat. The project will also examine the potential for nutrient enhancement in 11 additional crops important in the diets of those suffering from micronutrient deficiencies: bananas, barley, cowpeas, groundnuts, lentils, millet, pigeon peas, plantains, potatoes, sorghum, and yams.

The objectives of the biofortification project are bold but realistic:

SHORT TERM (1-4 years)

- Determine nutritionally optimal breeding objectives.
- Screen CGIAR germplasm for high iron, zinc, and beta-carotene levels. Initiate crosses of high-yielding adapted germplasm for selected crops. Clarify genotype-by-environment interactions and cultural and food processing practices, and their effect on micronutrient content and bioavailability.
- Discern the genetics of high micronutrient levels, and identify markers available to facilitate the transfer of traits through conventional or novel means or both. Undertake in vitro and animal studies of the bioavailability of enhanced micronutrients in promising lines.
- Begin bioefficacy studies to determine biofortified crops' effect on micronutrient status of human subjects.
- Initiate study of trends in the dietary quality of poor people and the underlying factors driving these trends.
- Conduct benefit-cost analysis of plant breeding and of other food-based interventions to reduce micronutrient malnutrition.

FUTURE HARVEST

The Future Harvest℠ centers, located around th
scientists, and policymakers to help alleviate pover
resource base. The Future Harvest℠ centers are pri
tions, and regional and international organizatio
Agricultural Research (CGIAR).

MEDIUM TERM (5-7 years)

- Continue bioefficacy studies to determine how improved varieties affect the micronutrient status of human subjects in test sites in Africa, Asia, and Latin America.
- Initiate farmer participatory breeding.
- Adapt high-yielding, conventionally bred, micronutrient-dense lines for South Asia, East Africa, Central America, and Brazil.
- Release new conventionally biofortified varieties to farmers.
- Identify gene systems with potential for increasing nutritional value beyond traditional breeding methods.
- Produce transgenic lines at experimental level and screen for micronutrients. Test for compliance with biosafety regulations.
- Implement effective social marketing and communications to promote nutritionally improved varieties.
- Begin production and distribution of improved varieties.

LONG TERM (8-10 years)

- Scale up production and distribution of improved varieties.
- Undertake nutritional impact studies to identify factors affecting the adoption of biofortified crops, the impact on household resources, and the health effects on individuals.

Through the deployment of just six micronutrient-enhanced staple crops the biofortification approach could reach roughly 90 percent of the population at risk from micronutrient malnutrition in the developing world. Achieving these objectives will require a one-time investment of about $8 million per major staple crop over 10 years. These investments not only will generate returns in the billions of dollars, but also will improve the health and lives of billions of people.

AN INTERNATIONAL CONSORTIUM OF COLLABORATIVE PARTNERS

Collaborating Future Harvest℠ Research Centers:

International Center for Tropical Agriculture (CIAT), International Maize and Wheat Improvement Center (CIMMYT), International Potato Center (CIP), International Center for Agricultural Research in the Dry Areas (ICARDA), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI®), International Institute of Tropical Agriculture (IITA), International Rice Research Institute (IRRI).

Partner Collaborating Institutions:

National agricultural research systems (NARS) in developing countries; departments of human nutrition in developing- and developed-country universities; NGOs; University of Adelaide; University of Freiburg; Michigan State University; Plant, Soil, and Nutrition Laboratory, U.S. Department of Agriculture, Agricultural Research Service (USDA-ARS); Childrens' Nutrition Research Center, USDA-ARS.

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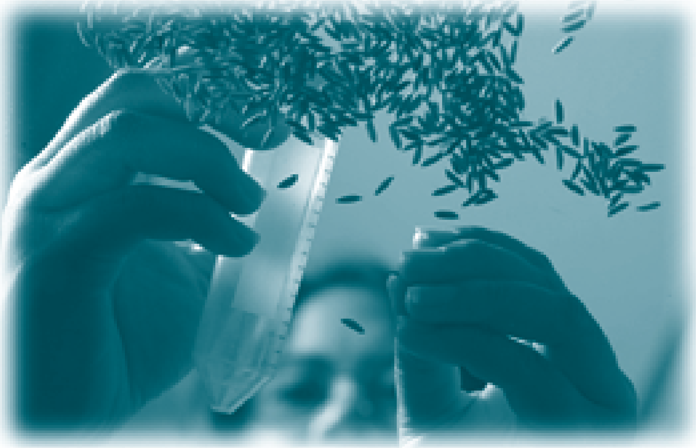
CGIAR



Once the genes controlling nutrient levels have been identified, marker-assisted selection can be used to transfer genes for high content of desired micronutrients into new varieties. Meanwhile, researchers will begin to measure the impacts of micronutrient-rich varieties on human nutrition.

Winning Acceptance of Biofortified Crops

A major advantage of biofortification is that this strategy does not require a change in behavior by farmers or consumers. The crops are already widely produced and consumed by poor households in the developing world. Changes in mineral content will not necessarily alter their appearance, taste, texture, or cooking qualities.

In cases where scientists can combine high micronutrient content with high yield, farmer adoption and market success of nutritionally improved varieties is virtually guaranteed. In fact, research showing that high levels of trace minerals in seeds also aid plant nutrition has fueled expectations of increased productivity in biofortified strains.

One way to ensure that farmers will like the new varieties is to give them a say in what traits are bred into the plants. Experience suggests that "participatory plant breeding," in which scientists take farmers' perspectives and preferences into account during the breeding process, can sometimes be more cost-effective than confining breeding to research stations.

Distributing the New Varieties

A common problem faced by supplementation and fortification programs is the lack of delivery systems to get products to the poorest people. This constraint is being met through seed-based technologies inherent in the biofortification approach. When households grow micronutrient-rich crops, the delivery system is built into the existing food production and marketing process. Little intervention or investment is needed once farmers have adopted the new seed. And micronutrient-rich seed can easily be saved and shared by even the poorest households.

Through their ongoing work with seed systems and their contributions to disaster-response, Future Harvest centers have gained valuable experience in building and promoting local seed distribution systems. These established systems offer a natural route for disseminating biofortified seed. Local agricultural research committees and small farmer seed enterprises, in particular, will play a crucial role in getting micronutrient-rich varieties into the hands of growers.

It Makes Sense

The ultimate solution to eradicating malnutrition in developing countries, of course, is to substantially increase the consumption of meat, fish, fruits, legumes, and vegetables among the poor. Achieving this will take many decades and untold billions of dollars.

Meanwhile, biofortification makes sense as part of an integrated food systems approach to reducing malnutrition. It addresses the root causes of micronutrient malnutrition, targets the poorest people, uses built-in delivery mechanisms, is scientifically feasible and cost-effective, and complements other ongoing methods of dealing with micronutrient deficiencies. It is an obvious first step in enabling rural households to improve family health and nutrition in sustainable ways.

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