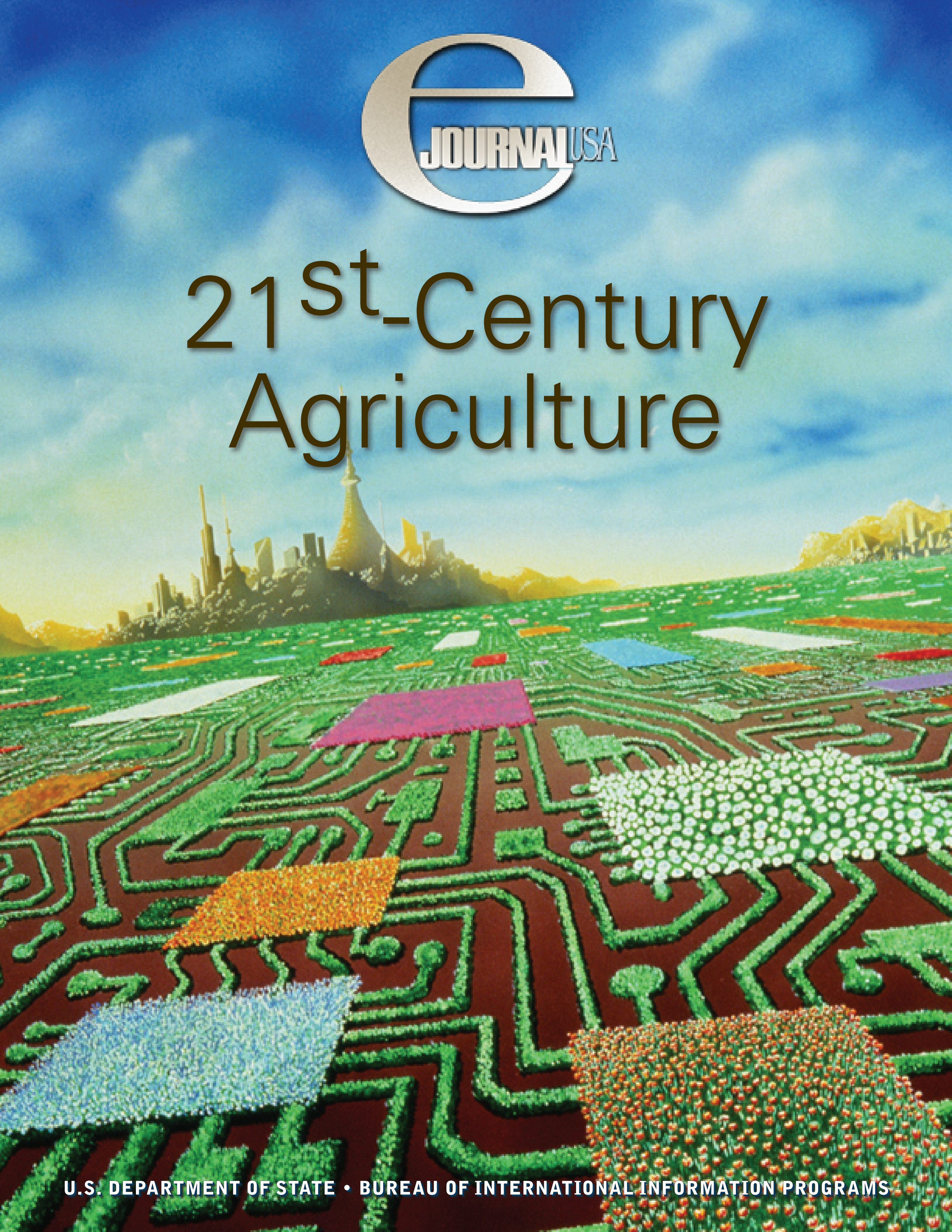
eJOURNAL USA

21st-Century Agriculture



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Cover: Vast gardens surround a futuristic city in a 21st-century landscape imagined by artist Kauko Helavuo. © Getty Images

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About This Issue


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Humanity's longest struggle has been the ongoing battle, waged with different weapons on different fronts, adequately to feed itself. The British scholar Thomas Malthus (1766–1834) doubted humanity's chances. Writing in 1798, he concluded that "the period when the number of men surpass their means of subsistence has long since arrived." The result, Malthus predicted, would be "misery and vice." On the whole, Malthus has been proven wrong, at least until now. As the India-born Nobel economics laureate Amartya Sen pointed out in 1994, world population had by then grown nearly six times since Malthus first published his "Essay on Population." And yet per person food consumption had increased, life expectancies lengthened, and standards of living generally improved. A significant factor was the "Green Revolution," pioneered by the agronomist and Nobel peace laureate Norman Borlaug (1914–2009), a name that appears throughout these pages.

But the contest between population and food supply has not yet been definitively won. "It took the world population millions of years to reach the first billion, then 123 years to get to the second, 33 years to the third, 14 years to the fourth, 13 years to the fifth billion…" writes Sen. The human population today stands at an estimated 6.8 billion, of whom an estimated 1.02 billion are undernourished. How we fashion a 21st-century agriculture capable of feeding them is the subject of this *eJournal USA*.

The marriage of technical prowess and agricultural skill promises advances on many fronts: a greater abundance of food, much of it more healthful, and available in a global marketplace that affords more of us access to this bounty. Agriculture even holds a key to delivering new forms of clean energy.

The voices collected here include scientists, administration officials, and Indian and American winners of the World Food Prize. All are united in what Dr. Borlaug in his Nobel acceptance speech called a "vast army" in the battle against hunger. More broadly, 21st-century agriculture represents a noble application of our collective human ingenuity. May victory in this struggle come soon.

— *The Editors*

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21st-Century Agriculture

Every Link in the Food Chain

An Interview With M. Vijaya Gupta and Philip E. Nelson

© AP Images/Imaginechina

Juice packaged in boxes stays fresh because of the work of World Food Prize winner Dr. Philip Nelson.

Producing enough food to nourish populations of the future is among the most urgent and compelling problems facing humankind today. The World Food Prize is presented each year to an individual who has "advanced human development by improving the quality, quantity, or availability of food in the world." Launched in 1986, the prize has honored the work of diverse individuals whose achievements have focused on different aspects of agriculture, such as the development of stronger plants or techniques to make fallow land productive. World Food Prize laureates are among the most qualified people to find ways to meet food demands of the future. Two of these scientists offer their views on these pages.

Dr. M. Vijaya Gupta of India won the 2005 World Food Prize as a leader of the "blue revolution," a campaign to promote aquaculture. His methods of fish farming have increased the protein and mineral content in the diets of more than 1 million families. Dr. Philip E. Nelson, an American citizen, holds the 2007 World Food Prize for his technological breakthroughs revolutionizing the food industry in the area of sanitary, large-scale storage and transportation of fresh fruits and vegetables.

Question: What do you consider to be the single most effective action that could be taken in the near term with available technologies to increase world food production?

Gupta: I think the most effective action that is needed is technology and financial transfer from the developed countries to the developing countries. I consider this to be the most important action if you are looking at short-term gains in production. We need a technology transfer along with the financial assistance to implement these technologies in developing countries.

Presently agriculture productions are low in most of the developing countries as compared to the developed countries due to lack of appropriate technologies — from production to marketing — and the financial resources necessary for the governments to implement development projects. The developing countries need the improved production technologies — especially in the area of biotechnology and genetics and improved seeds without excessive royalties — for increasing food production in the near term.

Nelson: I'd certainly agree with technology transfer. I think the main thing we really need to focus on is the total food chain. Production is critical, but also preserving that product after it has been harvested and before it is delivered to the consumer. I would say we could have a big immediate impact by looking at that total food chain delivery system.

Q: An estimated 1 billion people globally don't have enough to eat. I have heard it said that adequate food is produced in the world, but it just isn't available to all the people who need it. Is that what you gentlemen are saying — if distribution or storage were better, the hunger problem would be solved?

Gupta: Yes, probably storage is one thing because there are quite a bit of losses in transportation and storage. But besides that, you need to have adequate food production, and access to the food is another concern because of the poverty. In India, some years we have surplus food production, but the government doesn't have adequate silos to store the surplus food during the monsoon rains. On one side we have the excessive production; on the other side, people are starving and dying because they do not have the purchasing power.

Nelson: I agree with all that. The biggest thing that we misunderstand is that malnutrition is probably because of poverty. So if we can get some funding in the hands of the poor, and get the distribution accomplished, we could go a long way in reducing starvation and hunger.

Gupta: Presently, what is happening is starvation and hunger in the developing countries. Food aid is coming into the countries where there is need. But we have to develop the production within the countries or within the region as that will create livelihoods and employment opportunities and produce the food at an affordable price. We have to look at that, rather than growing the food in the developed countries and then transporting over long distances to the developing countries at a very high cost.

Nelson: I agree with that 100 percent. There's no question that we're always going to need agencies like the World Food Programme, and other aid agencies, because of natural disasters — as we saw earlier this year in Haiti — political unrest, or other unforeseen, disruptive events. We are going to need that kind of emergency input, but we've got to establish agriculture in the local communities and develop markets for their goods at the local sites.

Q: Turning now to the ongoing progress in the areas where you gentlemen specialize, Dr. Gupta, are you seeing further expansion of small-scale aquaculture ventures?

Gupta: Very much so. Though my work was originally concentrated in Asia, now the same technologies and methodologies are being transferred to African nations. If you look at their core concern, 90 percent of the world's aquaculture production comes from Asia. So lots of

Courtesy of World Fish Center/Fern Corn

Bodies of water in low-lying Bangladesh give local people an opportunity to increase food sources through aquaculture. Dr. M. Vijaya Gupta's promotion of aquaculture helped to increase fish production in Bangladesh by tenfold.

Development of markets at the local level, such as this one in Nepal, is another step toward improving access to food and building food security, experts say.

efforts have been made in the past in Africa to take these technologies from Asia in toto and transfer them to Africa without taking into consideration the social, economic, and cultural aspects of the people in those countries. And this effort has failed. Millions of dollars have been put into these countries by the donor nations. So that was a mistake that had been made in the past.

My research is concentrated in starting the development of technologies by working closely with the communities, first understanding their social background, economic situations, and cultural aspects, and then developing technologies that are suitable to those communities.

The second aspect that we looked at was the fish production by the small farmers to improve their nutritional status by consuming the fish they have grown in their backyard ponds. Our assumption at that time was that they'll be able to eat more of the fish they have produced and have better health. But this was a mistake that has been made in the earlier stages of our research because the small farmers are looking for cash economy. They want the cash income because their needs are much more than eating the fish. So what we found in our work is that actually 80 to 90 percent of the fish produced by the small farmers, even from homestead ponds, are sold in the market as they fetch high prices. Then they'll buy cheaper dried fish for their own consumption and other daily necessities. This has resulted in improved nutrition, not because they are eating the fish they have produced in the homestead pond, but because of the cash income they were able to generate through farming fish in their ponds.

So this is what we have taken into consideration in my work, closely understanding their needs, and the market demands, and developing technologies that will bring cash income to these poor households.

Q: Dr. Nelson, how do you see that the storage and preservation technologies in which you specialize may be applied to the output of aquaculture producers to greater effect?

Nelson: I'm very excited about Dr. Gupta's work because I think it really contributes significantly to our world food security. I have a slide I use in presentations that uses the Chinese proverb: Give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime. I add another line to that: If you teach a man to preserve his fish, he will live forever, feed a community, and have some money.

So that is the focus of my activity, on that piece of the total food chain, trying to give developing world farmers the means to preserve fish, grains, fruits, and vegetables, and then also to develop local markets. In many developing countries, now in their large cities, there is a greater demand for more product. If small, developing world farmers can learn how to produce and transport product to fulfill that demand, I think we have some opportunities now to have a major impact on poverty and hunger.

Q: Small farmers in developing countries are frequently lacking adequate vehicles to get their products to market, or passable roads that lead to the market. How do donor nations help address those problems?

Nelson: It will take a team effort. Addressing just one aspect won't do. There's got to be market development, improved infrastructure. Certainly it is more complicated than simple technology transfer. We have some good examples where pockets of these activities are working.

In Malawi, a project called Millennium Villages has brought significant improvement to villages that include agriculture, water conservation, health improvement, improved education, etc. Still, Africa lags behind the rest of the world in all aspects of infrastructure development.

We want to take those examples and multiply them. I

A fisherwoman in Cameroon displays the catch. Fish is a major source of dietary protein for Africans.

hope to do that by having an international center, which will be focused on food technology development and the expansion of markets. I'm hoping for a major thrust with lots of support from an array of organizations to focus on this activity.

Q: Give us one of these good examples you refer to.

Nelson: Working with plant breeders, food technologists have found a mutant variety of sorghum grain. A protein within that grain acts a lot like wheat protein. To a country like Senegal where they like baguettes, they import all the wheat to make the bread that the local people desire and want. The concept we're testing now is that this mutant sorghum strain would produce a grain that could be used to replace, maybe, 50 percent of the imported wheat with the locally grown sorghum grain. We're hoping that would produce a baguette that is acceptable to the population. You can imagine how that would improve the market opportunities for the local farmers and reduce the need for imported wheat in Senegal.

Food prices are another factor in world hunger. When you are importing great quantities of commodities, that can be a problem and it's a drain on their resources.

In Malawi, we're working with women, and developing small, entrepreneurial groups that will be able to better market their products. But we're talking about 10 small groups and we need to spread this model 10 thousandfold.

Q: Dr. Gupta, will you share an example where a village adopted some of your aquaculture techniques and improved overall quality of life for its people?

Gupta: Take, for example, my work in Bangladesh, where I went way back in 1986. As you know, two-thirds of the country goes underwater for about four to six months of the year. There's so much water, but very little fish, even though fish is the most important commodity in the lives of the Bangladeshis. The country is flooded almost every year, so the rural households construct their small huts and houses on elevated land. To have an elevation for the house, they dig some soil from land adjacent to the house, and in the process they create small ditches or ponds. There were hundreds of thousands of such ponds and ditches in the rural scenery. When I went there, they were lying fallow, covered with water hyacinth, an obnoxious aquatic weed, and were breeding grounds for the mosquitoes. So I was looking at how we could use these little ponds that could provide nutrition for the families.

I'm a biologist, so I didn't know at that time about the rural way of life — the culture of the people, or the economy of the people. I joined hands with some of the nongovernmental organizations (NGOs) of the country who were working at a grassroots level so we could move faster toward aquaculture that could increase the family income and improve the nutrition of the family members. Once these nongovernmental organizations were convinced of the economic viability of these technologies, we went to the villages; first we made an effort to understand the people, their culture, their economic situation. Then we started with small, low-cost technologies without risk of investment, trying the technology in their ponds, demonstrating these technologies to them.

We went to a number of villages, and actually we had more than 10,000 farmers as collaborators in our technology demonstrations and "on-farm" research. So once we were able to show that the unutilized ponds and small roadside ditches can give anywhere from two to three tons of fish per hectare within four to six months of time, there was tremendous response and adoption of technologies.

I should say that this has revolutionized rural aquaculture that has led to improved livelihoods and nutrition of the rural populace. That was the first step we did.

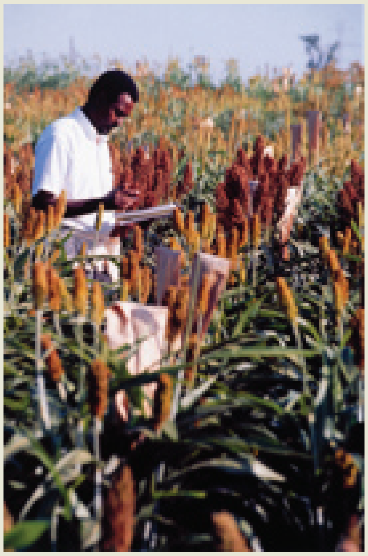
Second, we realized that most of the rural women were working in the house, but not employed otherwise. We thought that if we could involve the women in this low-cost, low-input simple technologies, the women would add income to the family in addition to that of the husband, who works as an agricultural laborer or some other position as that. So we motivated them, trained them, and the NGOs came forward with small loans without any collateral. This has worked very well. Now about 60 percent of rural fish farmers in Bangladesh are women.

So that has resulted in increasing the household income, and improved the status of the woman in the house and also in the society. Before that, she was just a worker.

I have seen a picture, promoted by one of the NGOs there, of a woman with 12 hands. One hand is holding the baby, the other is sweeping the house, the other is cooking, another cutting the firewood, and on and on. The title of the painting was "My Wife Does Not Work." She does everything! But unless she is bringing in a cash income, she is not regarded as working. So that's why we brought women into the picture with a low-input technology. Then once they got trained, and got the confidence, they wanted intensive production technologies for higher benefits. Now some of them are involved in fish-seed production [controlled breeding of fish as in a hatchery], which is more lucrative than fish aquaculture.

When I went to Bangladesh the aquaculture production was less than 100,000 tons. Now it is nearing 1 million tons. So it is not only increasing the production, but creating livelihoods for rural communities where there are very few opportunities for income.

Food for the World



Courtesy of Purdue University

Dr. Gebisa Ejeta, winner of the 2009 World Food Prize, works in a field of sorghum, a primary food grain in many countries. He developed sorghum hybrids that can survive harsh conditions.

For more than 20 years, the World Food Prize has rewarded individuals from any country who have made great strides in improving the quantity, quality, or availability of food for the world.

The prize represents a dream of Dr. Norman Borlaug. Known as the father of the Green Revolution, Borlaug devoted his life to increasing agriculture productivity. The methods he pioneered provided greater crop yields to feed expanding populations in the developing world. After winning the 1970 Nobel Peace Prize, Borlaug envisioned a similarly prestigious award to focus attention on agriculture and to inspire others to achievement in the field.

Since its 1986 inception, the World Food Prize, a $250,000 award, has recognized scientists and politicians from all world regions for diverse accomplishments. It is sponsored by businessman and philanthropist John Ruan and is headquartered in Des Moines, Iowa, a city in one of the great U.S. farming regions.

Dr. Gebisa Ejeta, an Ethiopian expert in plant breeding and genetics, won the Food Prize in 2009 for his development of sorghum hybrids that can survive harsh conditions. Sorghum is one of the world's principal cereal grains, a dietary mainstay in some regions. Ejeta's achievement will increase crop productivity and enhance food supplies for hundreds of millions of people in sub-Saharan Africa.

Other winners have been recognized for making unproductive land suitable for farming, developing new plant hybrids, and designing social programs to feed the poor.

Q: Political factors can also be influential in food security. Policies can encourage or discourage production, and certainly there are regimes in the world that don't place great importance on the nutrition and well-being of their people. How do you weigh the political issues contributing to hunger?

Nelson: I'm a scientist, a technologist, so that question is best posed to others. But certainly that is a major barrier in a number of areas of the world, particularly Africa. We have seen what can be done in countries where that has changed. Malawi is a good example. India is going through a renaissance as the government is beginning to focus on developing more processing techniques as a way to preserve their products and get them distributed. Governments can make a big difference.

Gupta: We are not just to look at technology, but must also look at procurement prices for farmers. When there is a bumper crop, the market price comes down and the farmers are not able to make any profit. On one side, the input costs — the fertilizer, the pesticide — are going up while on the other side, there is no guaranteed or minimum price for their commodity. It has happened in my country — when there is a bumper crop, the market price comes down and the farmers are not able to recover the expenses incurred for producing that crop.

Because of this, at times the farmers involved in food production are moving away from food crops toward the farming of commercial crops — cotton, tobacco, sugarcane, and things like that. So the government needs to ensure a minimum price for the farmers, which will take care of their well-being.

Q: The great unknown challenging global agriculture today is the effect that climate change may have as time unfolds. Let's talk about your expectations a moment. Dr. Gupta, take us back to Bangladesh, a low-lying country that will be especially vulnerable to the sea level rise that is predicted to result from climate change.

Gupta: Much work has been done with regard to the impact of climate change on crops, but not much information available as it relates to fish. Nevertheless, looking at what might happen in the oceans, there is going to be a big impact on capture fisheries. Global warming will change the fish diversity, the fish distribution, and abundance. Climate change and global warming will result in the acidification of the seawater that will have an impact on shell-bearing organisms, like the shrimp, oysters, clams, etc. To an extent, this will have an impact on aquaculture. So we are looking at developing strains of fish that are tolerant to salinity. So more needs to be done to mitigate the impact of climate change.

Q: Dr. Nelson, what's going on in the processing and preservation links of the food chain to cope with climate change?

Nelson: Climate change is putting pressure on the geneticists and plant breeders to develop varieties that can withstand droughts and reduced temperatures. That part of the production chain is critical, and without that kind of activity, I think we're looking at some major effects. On the other hand, as climate changes that means there will be differences in the production areas. That means more distribution is going to be required as we move products from one area to another, as temperatures and climates lend themselves to production.

I mentioned earlier that we are beginning to develop an international center here at Purdue. We've received some funding to do that, and the focus will be on technology and market development and reducing product losses in that part of the world where hunger threatens populations. We think there is a need to bring international focus to this area of the food chain, reduce hunger, and increase food security.

Gupta: I think that improving the livelihood of the farmer has to be part of the solution too. Food production by itself will not solve the problem unless we can reduce poverty and hunger. So we are working from the perspective of creating livelihoods and improving the lives of the people in rural communities. ■

The opinions expressed in this interview do not necessarily reflect the views or policies of the U.S. government.

Bring Fish From the Waters

Farmers everywhere have faced the same problem for millennia: They need land and rain to coax a crop from the ground.

M. Vijaya Gupta won the World Food Prize in 2005 because he found a new answer to that age-old problem. He showed poor people in South and Southeast Asia how to yield a crop from abandoned ponds, roadside ditches, and other unused bodies of water. He showed them how to recycle what was thought to be farm waste — weeds, manure, and rice bran — and use it as feed to raise a crop of fish.


Courtesy of the World Food Prize Foundation

Dr. M. Vijaya Gupta (center) taught aquaculture techniques to rural people in their South Asian villages.

With these lessons from this Indian scientist, more than 1 million poor families have increased the protein and minerals in their diets, contributing to better health and greater longevity.

Called a leader in the "blue revolution," Gupta taught poor families to convert small bodies of water into "mini-factories," producing fish for food. He, and organizations he recruited to assist, taught aquaculture techniques to poor people, training them to breed fish and increase yields for greater income. Gupta's work began with the Indian Council of Agricultural Research in the 1960s and spread over the decades to Bangladesh, Vietnam, Indonesia, and other countries.

In Bangladesh alone, fish yields increased from 304 kilograms per hectare involved in aquaculture to more than 5,000 kg per hectare. In his native India, his aquaculture techniques increased yields as much as twentyfold.

Gupta's work has focused not on yields alone, but also on sustainability. He coordinated the International Network on Genetics in Aquaculture to encourage support for maintaining biodiversity, and has trained some 300 Asian scientists in developing sustainable production techniques.

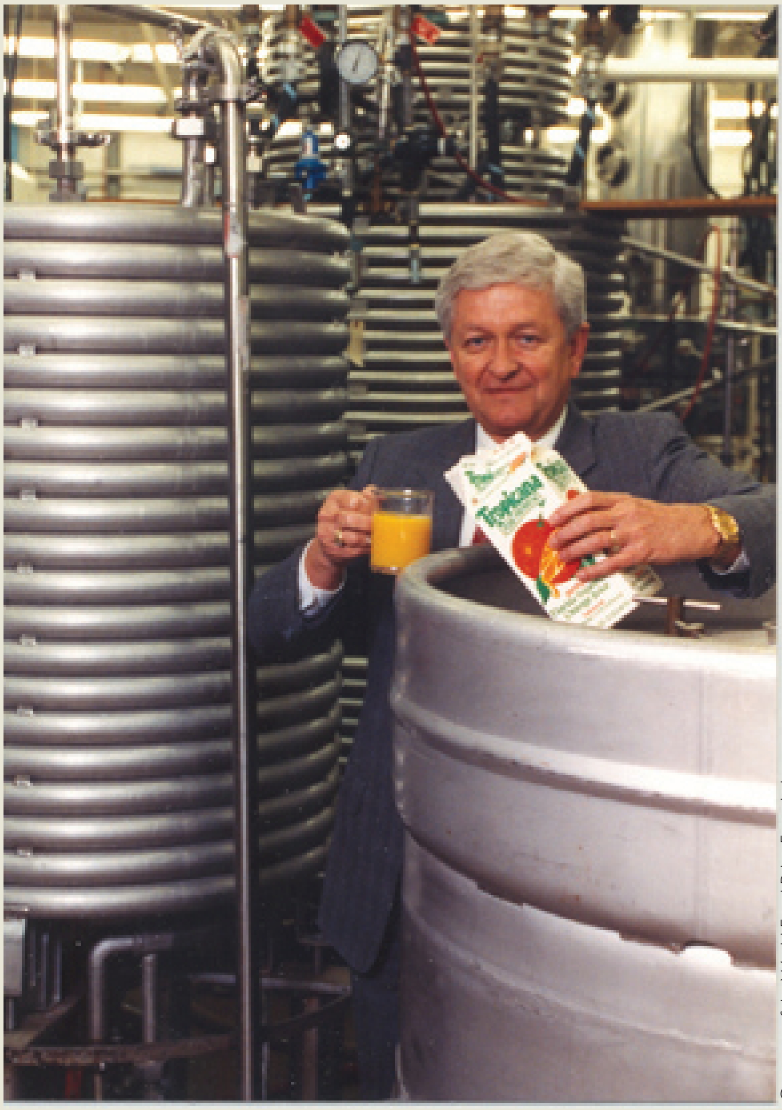
According to the World Food Prize citation, "Dr. Gupta has been a lifelong catalyst in expanding the global reach and effectiveness of aquaculture."

Gupta has been a consultant to many organizations such as the World Bank, the Asian Development Bank, the U.S. Agency for International Development, the U.N. Development Programme, the U.N. Food and Agriculture Organization, and others. Gupta is a retired assistant director general of the World Fish Center and remains a senior research fellow at that organization, devoted to reducing poverty and hunger through the improvement of fisheries and aquaculture. ■

Fresh From Farm to Plate

If you've ever had soup or milk or juice from a box, then you know the work that won the World Food Prize in 2007. Aseptic (sanitary) food processing technologies allow consumers in developed nations to toss a box of juice in a picnic basket. But these methods also preserve crops, prevent spoilage, and increase the availability of safe and nutritious foods.

Dr. Philip E. Nelson developed "innovative breakthrough technologies, which have revolutionized the food industry … in the area of large-scale storage and transportation of fresh fruit and vegetables," according to the World Food Prize citation. Aseptic food processing allows juices and other liquid foodstuffs to be packaged and shipped around the world in mass quantities.



Courtesy of the World Food Prize Foundation

Dr. Philip Nelson won the World Food Prize for his development of packaging methods that allow safe and sanitary transport and storage of liquid foods and juices.

Here's how it works. Once plant or animal products are made into food — fruits into juice, for instance — Nelson's process allows sterilization of the food and the package, and the transfer of the food into the package. The output is a safe, stable product that can be easily transported without refrigeration, and can remain in storage for considerable periods of time before being shipped to market or being used by the consumer.

In the process, food is passed through a thin pipe in which it is rapidly heated to kill any pathogens, then quickly cooled to maintain the freshness of the food. Nelson began his innovative work while on the faculty at Purdue University in Indiana. The process already had been developed, but Nelson found ways to apply it on a large scale, as large as the 500,000-gallon containers used in intercontinental shipping.

Nelson's techniques have benefitted developing world countries where crop spoilage can consume as much as 50 percent of yields in some places. Aseptic processing has also been a key technology in the expansion of feeding and nutrition programs in the developing world and in providing stores of products available for transport to regions stricken with disaster, such as the 2004 tsunami in the Indian Ocean.

Nelson is the Scholle Chair Professor of Food Processing in the Department of Food Sciences at Purdue University in West Lafayette, Indiana. ■

U.S. Food Policy Aims for "Transformational Change"

The Obama administration initiative to improve food security worldwide

© AP Images/Saurabh Das

The U.N. Food and Agriculture Organization reports that one in nearly every six people lacks adequate food to live an active and healthy life.

"The true sign of success is not whether we're the source of perpetual aid that helps people scrape by, it's whether we are partners in building the capacity for transformational change."

President Obama in Ghana, 2009

Secretary of State Hillary Clinton and Secretary of Agriculture Tom Vilsack announced details of the U.S. Food Security Initiative on World Food Day in October 2009.

The goals are:

- Reduce hunger sustainably,
- Raise the incomes of the rural poor,
- Reduce the number of children suffering from under-nutrition.

Five key principles guide the initiative:

- The United States will work with partner countries to create and implement plans.
- The initiative will invest in the tools necessary to support farmers, their skills, and perseverance.
- The initiative will coordinate closely with local and regional efforts.
- The initiative will support the multilateral institutions combating world hunger.
- The initiative will be a long-term and accountable U.S. commitment.

In fulfilling the initiative, scientists and experts at the U.S. Department of Agriculture will:

- Apply themselves to improving the nutritional and productive value of crops around the globe;
- Help partners resolve technical challenges related to irrigation, crop improvement, pest eradication, and other problems;
- Help other nations train their future agricultural leaders.

U.S. officials emphasize that food security is important in achieving economic, environmental, and national security. ■

Life on the Land

© AP Images/Anupam Nath

An Indian farmer goes to work in a paddy field near Gauhati, India.

Anthropologists have long believed that agriculture provided the seeds from which civilization grew. When early humans realized how they might nurture the growth of food plants, rather than simply forage for their fruit, many gave up a nomadic life to tend the same land each year. Scholars of early human civilization believe that this settled lifestyle, and the cultivation of crops, led to a need to barter or sell the harvest, and so came markets, settlements, and towns.

Agriculture has served as a force to build communities throughout human history — the shared work of the fields, the shared bounty and hardship, the community celebration of the harvest.

In many countries, rural populations have dwindled as farming has become more mechanized and young people seek opportunities in the cities. The dominance of farming as a way of life has diminished in industrialized countries. World demographers calculate that recent years marked a turning point where more people live in cities than in the country. Still, a shared life on the land remains a bond for families and communities in many places. What they produce is the food, fiber, and fuel of the entire population, nurturing and sustaining us all each day. ■

Life … Land

© AP Images/Geoff Caddick PA Wire

This roof garden atop London's Trafalgar Hotel is part of an effort to create new gardens across the city where citizens may grow food for themselves or their communities. The Capital Growth scheme has provided both financial support and coaching to create 100 gardens around the city.

Farm workers carry cucumbers to market in Allahabad, India. Agriculture employs more than half of India's population, although it comprises less than 20 percent of the economy.

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First lady Michelle Obama invited elementary school children to the White House in 2009 to help plant a vegetable garden. She also is leading a campaign to combat childhood obesity and to promote the health benefits of eating fresh foods.

© AP Images/Pavel Rahman

Village women separate dust from rice grain, the most important crop of Bangladesh. About 45 percent of the population works in agriculture. Seasonal monsoons flood nearly a third of the country each year, frequently destroying crops and causing extensive damage to agricultural infrastructure.

© AP Images/Mohammad Abu Ghosh

Women farmers share their lunch in a field in southern Jordan. Almost 50 percent of farm workers in many countries are women, and they play a vital role across the range of agricultural systems including production, processing, and marketing of farm products.

Life … Land

Ted Spiegel/National Geographic Stock

Young men harvest squash on a farm in New Brunswick, Canada. Agriculture comprises only 2 percent of the Canadian economy, but its vast land expanses allow this North American country to be the world's second largest producer of rapeseed, grown for animal feed; the vegetable oil, Canola; and biofuel.

Chinese farmers operate a reaping machine, harvesting wheat in Jiangsu province. China is the world's biggest grain producer, and aims further to boost production to feed its population, approaching 1.4 billion, the largest in the world.

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John Eastcott & Yva Momatiuk/National Geographic Stock

A family in Poland farms at the foothills of the Tatra Mountains. About 60 percent of the nation's land is devoted to agriculture and the country is a significant exporter of bacon, ham, and frozen fruits and vegetables.

Life … Land

© Russ Munn/AgStock Images/CORBIS

A farmer and his wife survey their soybean crop in the U.S. state of Iowa. This couple owns one of more than 88,000 farms in the Midwestern state.

© AP Images/Paulo Santos

A farmer works in his cocoa plantation in Brazil's Para state. Brazil is a major food supplier to international markets, with the agricultural and food sectors comprising 28 percent of the country's gross domestic product. Economic and trade stability and regulatory reforms have encouraged agriculture and boosted the nation's output in recent years. Brazil is an important producer of sugar, ethanol, beef, poultry meat, and coffee.

© AP Images/Ramakanta Dey

Farmers carry bundles of straw to market in Agartala, India. The straw is used as cattle feed in India. Indian farmers lead the world in production of lemons, limes, and other tropical fruits.

© AP Images/Mohammad Abu Ghosh

A shepherd milks sheep, a product that ranks fourth in Jordan's overall agricultural output. Although agriculture remains economically important, its share of Jordanian gross national product has been in decline as the industrial and service sectors of the economy have expanded.

© AP Images/The Roanoke Times/ Kyle Green

Diverse people meet in community gardens, such as this one in Roanoke, Virginia. Forty gardeners share a space in a working class neighborhood. Burundian refugee Shemezimana Ezekiel meets garden founder Mark Powell (center) and Judy Powell.

Life … Land

© AP Images/Greg Baker

A Chinese woman in Guangxi province waters her vegetables, using water carried by buckets from the lake in the background. China is a major producer of a variety of vegetables such as carrots, turnips, eggplant, squash, and onions.

A farmer from the U.S. state of Illinois handles soybean seeds in a bin attached to planting machinery that will sow multiple seed rows. This farmer grows corn and soybeans on his 525 hectares. Nearly 80 percent of the state's area is agricultural land, divided into more than 75,000 farms. Marketing of soybeans accounts for about one third of the state's $9 billion annual agricultural production.

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The Borlaug Legacy: A New Paradigm for Agricultural Research

Roger Beachy

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Dr. Norman Borlaug (standing, left) introduced planting techniques to increase yields and feed greater numbers of people. He talks with other agricultural researchers in Mexico in 1983.

Norman Borlaug applied the latest technological and scientific advances to the age-old goal of feeding the world's people and revolutionized food production. The U.S. Department of Agriculture (USDA) aims to continue his work and achieve equally transformative change for the health of global society.

Roger Beachy is chief scientist and director of the National Institute of Food and Agriculture in the U.S. Department of Agriculture. Prior to his 2009 appointment, Beachy was founding president of the Donald Danforth Science Plant Center, which is dedicated to improving the human condition through plant science.

The opportunity to truly transform a scientific field occurs at best once a generation. The recently deceased Norman Borlaug seized one such opportunity. In a career spanning four decades, but especially during the 1960s, Borlaug revolutionized production of wheat, rice, and maize — the staple crops that feed most of the world.

The Nobel Peace Prize was only one among the many honors bestowed on Borlaug for his contributions to the "Green Revolution." At his death in 2009, he was hailed by developing countries as one of America's great heroes for his many contributions to global food security. The president and prime minister of India, to offer but one example, called Borlaug's life and achievement "testimony to the far-reaching contribution that one man's towering intellect, persistence, and scientific vision can make to human peace and progress." Today, Borlaug's insights inform an intense effort to harness the latest scientific advances to the oldest of goals: assuring adequate, nutritious food for all the world's citizens.

Borlaug's Work

Borlaug's early work in Mexico aimed to develop and introduce disease-resistant wheat strains. It was so hampered by inadequate resources, poor equipment, and the lack of trained scientists that Borlaug thought seriously about leaving the project. His new idea — to shuttle wheat seeds to new locations where altitude and temperature differences would allow a second growing season — ran afoul of conventional botanical wisdom. But he persevered. Risking his career and reputation, he pursued the new double season regimen. He held fast to a tightly focused agenda, developing new strains with high potential for quick and tangible outcomes, scaled up his work to include many geographic areas and environments, and kept the end goal — reducing hunger by improving wheat yield — fixed firmly in mind.

By 1963, 95 percent of Mexico's wheat harvest derived from Borlaug's improved varieties — and the harvest was six times higher than in 1944, when he first began his work there. Mexico had not only become self-sufficient in wheat production, it was a net wheat exporter.

Borlaug's success in boosting Mexican yields repeated itself over six decades of incredible scientific advances. These saved hundreds of millions throughout the developing world from starvation and malnutrition. His work touched small- and large-scale farmers alike. It is hard to imagine a staple crop anywhere in the world where Borlaug's tools, techniques, or actual hands-on research have not led to substantial improvements in production, nutritional quality, or resilience of crops to pests, disease, or adverse climatic conditions.

Borlaug's sweeping transformation of global plant cultivation is truly a legacy to admire. But for those of us who manage scientific endeavors, he left another enduring legacy: He was not afraid to take risks. He focused on solving large-scale problems with similarly large-scale research, and he worked on projects where the payoff in food security was tangible and immediate.

Borlaug proved that science and technology could improve the well-being of people across the globe. In his last years, he realized that future challenges demanded new tools, new strategies, and new intellect if science is to improve the human condition further. In the agriculture community, we can put this legacy, and this insight, into action.

Adapting Borlaug's Legacy for a New Era

New challenges make it necessary that we again transform agriculture through science and new technologies. Our food production systems face many challenges that threaten our ability to provide a safe, adequate, and nutritious food supply. The U.N.'s Food and Agriculture Organization predicts that food production must double by 2050 to meet global demand, even as it faces new threats. Our food supply must adequately address nutritional issues that range from

Courtesy of Scott Bauer/USDA

The Agriculture Research Service of USDA is enhancing the phytonutrient content and longevity of tomatoes with genetic engineering techniques. This scientist is working at an agency laboratory in Beltsville, Maryland.

© AP Images/Mary Altaffer

The National Institute for Food and Agriculture conducts research to achieve national objectives, such as improving childhood nutrition. These New York City students are eating in a school cafeteria where they are served nutritious, low fat, and locally grown food.

obesity to malnutrition. Additionally, we need to develop processes and technologies that protect our food from microbial contamination.

Even as demand for food grows, competition for the energy needed to produce it increases. The *International Energy Outlook 2009,* published by the U.S. Department of Energy, projects that total world consumption of marketed energy will increase by 44 percent from 2006 to 2030, most notably in China and India. New renewable energy sources must enter the production chain if we are to assure adequate food supply. Agriculture can play a key role in developing those energy sources.

Agricultural science must respond to these pressures, both to ensure the sustainability of the U.S. food, fuel, and fiber system and to address some of the world's most intractable problems. In this spirit, Borlaug would have welcomed the National Academy of Sciences' new report, *A New Biology for the 21st Century*, as the next great step in harnessing science to solve societal challenges. Its recommendations speak to values he held dear:

- Taking bold, risk-taking approaches to understanding fundamental questions in biology;
- Tackling complex scientific challenges with a laser-tight focus on areas where the "new biology" can offer the most promise of transformative breakthroughs;
- Scaling up research efforts across disciplinary boundaries to match the complexity and magnitude of 21st-century problems;
- Ensuring that our progress in science is measured by tangible impacts on human health, food security, and environmental stewardship.

The *New Biology* report recognizes the magnitude of these challenges and of the research effort required to meet them. The report explains how future advances will rely upon a more fundamental understanding of plant life itself:

> The long-term future of agriculture depends on a deeper understanding of plant growth. Growth — or development — is the path from the genetic instructions stored in the genome

to a fully formed organism. Surprisingly little is now known about this path in plants. A genome sequence provides both a list of parts and a resource for plant breeding methods, but does not give the information needed to understand how each gene contributes to the formation and behavior of individual plant cells, how the cells collaborate and communicate to form tissues (such as the vascular system, or the epidermis), and how the tissues function together to form the entire plant.

The report recommends deploying new technologies to help understand how plants grow and thrive, including modeling and simulation tools to visualize growth and development at the cellular and molecular levels. The goal, the report says, is a more efficient approach to developing plant varieties that can be grown sustainably under diverse local conditions. Developing these new tools will make possible new methods and techniques to address problems in health, energy, and environment as well as traditional agriculture.

We take precisely this approach at the U.S. Department of Agriculture. We are committed to combating world hunger by developing new crop varieties that can grow and thrive under environmental stress. We will employ every means in the science toolkit to this end; we cannot afford to ignore any scientific field that promises breakthroughs toward global food security. We know that this research will yield collateral health, energy, and environmental benefits. The advances will help American farmers remain competitive in the global agricultural marketplace, even as we reduce the toll from starvation and malnutrition in other countries.

Today's challenges require more than new ideas and new tools. A new approach to how research is funded and managed, and its successes measured, is required. For USDA, that new approach is represented by the National Institute of Food and Agriculture (NIFA), launched by Secretary of Agriculture Tom Vilsack in late 2009.

In setting up NIFA, USDA turned to colleagues in other U.S. government scientific agencies to identify "best practices" for managing federal grants. Among the lessons we learned and will implement:

- Greater transparency and accountability will inform our grantmaking.
- We shall resolve many problems into a limited and discrete set of issues and tackle their root causes.
- Instead of trying to grow as many narrow, single-issue or single-focus research programs as we can, we shall identify and recruit the best minds — wherever they are — and make sure we retain their services and reward their work.

Now is the time carefully to assess and agree on broad but discrete challenges. By identifying these skillfully and deploying resources effectively, we can help solve large and previously intractable societal problems — climate change, food safety, child nutrition and obesity, food security at home and abroad, abundant and renewable energy — and hold the promise of doing so while preserving and improving our environment and generating wealth in rural America and the world.

Courtesy of Bruce Fritz/USDA

Scientists with the USDA's Agriculture Research Service examine different samples of alfalfa, genetically engineered for improved characteristics such as leaf retention and disease resistance.

Norman Borlaug applied agricultural science and technology to the challenging issues of his day. NIFA aims to honor his legacy by securing equally transformative change. Working with partners in the United States and other nations, we can build on recent scientific discoveries — incredible advances in sequencing plant and animal genomes, for example. We have new and powerful tools — biotechnology, nanotechnology, and large-scale computer simulations — applicable to all types of agriculture. Agriculture is a science and must draw widely from many disciplines and many technologies, but our science portfolio needs to be tightly focused to leverage other resources and to prioritize its efforts. With this approach, we can match Norman Borlaug's remarkable record of improving the health and well-being of our global society. ■

Feeding the "Hidden Hunger"


Courtesy of Anna Marie Ball/HarvestPlus

In a HarvestPlus pilot project, Ugandan women grow a sweet potato variety that is higher in Vitamin A content than the strains widley grown at present. The increased vitamin content of this food staple can help protect the population from infection and blindness.

Meeting the world's future food needs will test the capacity and ingenuity of agriculture producers everywhere. The problem is one not merely of quantity, but of quality. More than 1 billion people lack adequate amounts of nutrient-rich foods such as meat, eggs, milk, and vegetables, according to a 2009 U.N. Food and Agriculture Organization estimate.

"Hidden hunger" is how the Micronutrient Initiative, one of the advocacy groups seeking solutions to the problem, describes malnutrition. "When hidden hunger is widespread, it can trap families, communities and whole nations in cycles of ill health and poverty," the organization explains on its Web site.

Childhood deficiencies of key vitamins and nutrients that support proper growth can saddle youngsters with lifetime disabilities.

Supplying all the world's people today and in the future with abundant nutrient-rich foods is the most desirable, but the most difficult, solution. Other answers are to distribute nutrient supplements — vitamin pills — to populations, or to provide fortified foodstuffs like iodized salt and milk with added Vitamin D and calcium. These solutions received support in a United Call for Action from a coalition of many of the world's major aid agencies in 2009, including the U.S. Agency for International Development and the U.N. Children's Fund.

Still another answer to malnutrition is biofortification — creating new versions of staple food crops that come out of the ground with higher nutrient content.

HarvestPlus, one international agricultural research project, is pursuing this solution with efforts to boost the nutrient content of seven key staple crops grown in Asia and Africa. These crops are beans, cassava, maize, pearl millet, rice, sweet potato, and wheat.

Sometime later this year, HarvestPlus aims to get the first biofortified crop into the ground. A strain of beans with a higher than average iron content has been bred for cultivation in Rwanda and the Democratic Republic of Congo where up to 50 percent of children can suffer from an iron-deficient diet.

By 2011-2012, HarvestPlus aims to develop a strain of cassava that will triple the Vitamin A content of the starchy staple crop and provide about half of the recommended amount of the vitamin necessary for proper vision. Though still in development, the biofortified cassava is set to be in the fields of Nigeria and the Democratic Republic of Congo by 2011-2012. ■

Crops Will Provide 21st-Century Energy

Elisa Wood


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In Brazil, sugarcane waste is used to produce ethanol, which is mixed with gasoline in a mandated formula for automobile fuel.

As nations hunt for ways to fulfill their population's food needs in the future, the need to identify cleaner energy sources is also urgent. In the future, agriculture will likely meet some portion of energy production, and various nations are pursuing this potential today.

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One partial solution to our energy problems lies not in the oilfield but in the cornfield, as nations increasingly replace some petroleum needs with bioenergy — fuel made from plants. "Energy farming" increases demand and opens vast new markets for crops: for sugarcane in Brazil, for corn and soybeans in the United States, and for other grasses, seeds, and trees in other nations.

Crop-Based Fuels in the United States

Many nations already use bioenergy to run cars and trucks, often in a mix with gasoline or diesel fuel. The two major forms of crop-based fuel used in the United States are ethanol from corn and biodiesel from soybeans.

The market for these fuels is expected to grow. As U.S. liquid fuel needs expand over the next 25 years, bioenergy will help fill the gap, according to the U.S. Energy Information Administration. Europe, Asia, and Central and South America also rely increasingly on this resource.

Bioenergy holds special appeal because it is renewable — simply by growing agricultural crops. We cannot replenish petroleum, today's leading source of most transportation fuel. Economists say that as petroleum supplies diminish, we can expect prices will rise. Experts predict that bioenergy will serve as a 21st-century answer.

"Biofuels play a very, very major role in displacing petroleum-based fuels," says John Urbanchuk, a bioenergy specialist with LEGC Consulting, an expert services consulting firm with offices worldwide. Indeed, if the United States replaced just 5 percent of today's diesel with renewable fuels, it could displace as much crude oil as it now imports from Iraq for diesel production, according to the National Biodiesel Board, which Urbanchuk advises.

"And there are other benefits as well," Urbanchuk adds. "Biofuels provide market-based revenue for farmers, which is very important. If you can provide a market-based return that reduces the amount of government support that is provided to agriculture, that money can be used elsewhere."

Corn farmers, in particular, are reaping benefits from the bioenergy boom, because of a U.S. policy to increase the amount of ethanol in the gasoline mix. The nation added more than 34 billion kiloliters of ethanol to gasoline in 2008, using 3.2 billion bushels of corn. A federal mandate will quadruple ethanol production by 2022. As manufacturers expand, they will need more corn. By 2018 ethanol production will likely account for 35 percent of U.S. corn use, according to the U.S. Department of Agriculture.

Corn makes sense as an energy crop in the United States because "we grow corn, process corn better than anything else we do," says Urbanchuk. Corn is the nation's most widely produced feed grain, and the United States keeps finding more efficient ways to grow it. Last year the United States produced 13.2 billion bushels, a record crop, on 5 million fewer acres (2.02 million hectares) than the previous year.

Soybeans, the main crop for biodiesel, also are grown aplenty in the United States. The nation is the world's largest producer and exporter of soybeans, with almost 400,000 farmers in 29 states growing them. U.S. sales of biodiesel fuels, blended or used in pure form, totaled 1.7 million kiloliters for 2009. As one bushel of soybeans can produce 1.4 gallons (5.3 liters) of soy-based biodiesel, farmers supplied nearly 328 million bushels of soybeans to renewable biodiesel in 2009 alone.

International bioenergy drive

Biofuels and wind are expected to be the fastest growing renewable energy resources in the 30 countries making up the Organization for Economic Cooperation and Development. Estimates are that India will expand biofuel use 15 percent over the next two decades, and China 10 percent. Biofuel industry growth also is under way in various South American countries.

But the United States and Brazil are the leaders, and are expected to remain so. The two countries produce 70 percent of the world's bioenergy. While the United States produces more ethanol, Brazil is often described as the first biofuel economy. Backed by substantial government investment, Brazil for three decades has been perfecting production of ethanol from sugarcane. No cars in Brazil run on pure gasoline anymore. The government requires that all vehicles run on blended fuel of about one-quarter ethanol. Brazil produced about 25,000 kiloliters of ethanol

Bioenergy: Available, Renewable, Sustainable

© AP Images/Victor R. Caivano

Tanks filled with ethanol made from the adjacent fields of sugarcane are seen in this view of Brazil's biofuel enterprise.

Bioenergy is energy derived from recently living organisms.

Bioenergy does not contribute to climate change because the carbon dioxide (CO_2) it produces is derived from carbon that existed in the atmosphere in the form of another recently living thing. Fossil fuels, on the other hand, release into the atmosphere greenhouse gases that were previously encased within the earth.

Biomass is the total mass of living matter within a given habitat, including commonly used fuels such as wood, but also a lot of items usually thought of as waste: agricultural waste, dung, municipal solid waste, industrial waste, and some crops that may be cultivated expressly for their use as fuels. Another attractive feature of biomass: It's just about everywhere, not concentrated in a few countries.

Biomass is easy to grow, collect, use, and replace without depleting natural resources, so bioenergy is not only renewable, but also sustainable.

Ethanol, or ethyl alcohol as used in drinks and medicine, is currently the most widely used biofuel in the United States. About one-third of the U.S. corn crop is directed into ethanol production. This has led to a threefold increase in the amount of ethanol produced annually in the United States since 2003. About 34 billion kiloliters of ethanol were produced in the United States in 2009.

The U.S. Department of Energy supports research into new and cost-effective methods of developing liquid transportation fuels from abundant biomass sources such as crop and forestry residues. ■

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A Japan Airlines 747-300 takes on biofuel and traditional jet fuel in a 50-50 blend at Haneda Airport in Tokyo in 2009. JAL is one of several airlines that have tested biofuels in flight, but these alternatives have not been introduced widely in the industry.

in 2008, and exported about 15 percent. Whether Brazil's success can be replicated remains a source of debate, given that few parts of the world have a climate and land mass so well suited for cultivating sugarcane.

In developing nations, biofuels already are commonly used, but as sources of domestic heating and cooking. Markets for biofuel crops have not developed, so they are not a source of revenue. That could change, however, given that several developing nations offer vast untapped bioenergy potential, according to a study, *Certification Strategies, Industrial Development and a Global Market for Biofuels,* by the Belfer Center for Science and International Affairs at Harvard University's Kennedy School.

While bioenergy could provide poor rural areas with a foundation for new agricultural industries, real challenges remain. Stable government is required to attract the investors and the capital to build the necessary infrastructure. Biofuel production requires refineries to make the fuel, cars that can use the fuel, and transportation facilities to bring the fuel to market.

Further, while ethanol is a cost competitive fuel, at about $60/barrel, the export market for biofuels "is being shaped haphazardly by a series of different and sometimes conflicting" government policy goals, the Belfer Center report says. For example, when developed countries restrict imports to protect their own farmers' profits, they make it more difficult for newcomers to enter the market. Still the study sees potential for production and export of sugarcane ethanol in Suriname, Guyana, Bolivia, Paraguay, the Democratic Republic of Congo, and Cameroon.

Most important, a nation must achieve food security before it channels agriculture resources into energy, says the report. Indeed, even in the United States, worries exist about the impact of biofuels on the food supply. During the food price hikes of 2007-2008, biofuels were named as a major culprit by groups such as the Earth Policy Institute. The use of corn for fuel increased demand for the crop, the Institute asserted, driving up prices for food uses as well. In retrospect, the U.S. Congressional Budget Office concluded that the diversion of corn to ethanol production effected food prices only minimally, accounting for between 0.5 and 0.8 percentage points of the 5.1 percent increase in the price of food. Other factors, such as skyrocketed energy costs, played a larger role in the food price spike, according to that office. But it is important for bioenergy advocates to address the perception that biofuels mean higher food costs. Many point out that not all of the grass or bean goes toward fuel. Meal and other byproducts are extracted for livestock feed and other purposes.

What's Next?

While corn and soybean demand is expected to remain solid, other crops now in various stages of development will compete for use in biofuel production. For example, researchers at the University of Idaho's College of Agriculture and Life Sciences see strong possibilities for mustard seed, canola, and rapeseed. Mustard seed can serve a dual purpose: the oils can be made into biodiesel, and the pungent meal into a pesticide spread on farmland, says Jack Brown, professor of Breeding and Genetics at the University of Idaho.

Biofuels are not expected to displace petroleum entirely. But even if they only reduce petroleum use by a small amount, analysts expect their presence to put downward pressure on prices. In the case of biodiesel, Brown urges the farm industry to replace all of its petroleum fuel needs with biodiesel products. Tractors and trucks should be run on farm-grown fuels, he says, not only to support the industry, but also to protect farmland from pollutants emitted by petroleum. This would have a small but significant impact on petroleum use — agriculture makes up just over 1 percent of U.S. gross national product. "Even if biodiesel became everything we want it to be, it would still produce only [a] small quantity of the fuel we need in this country. That is why biodiesel should not be used by Mrs. McGuinty to take her kids to school or by a ritzy California star. It should be used in environmentally sensitive areas," Brown says.

Work also is underway to make biofuels from more exotic raw materials: algae, castor oil, coffee grinds, microbes, feather meal, salmon oil, tobacco, and other various grasses, seeds and trees. Hollywood stars publicize their use of biofuels made from restaurant greases left over from fast food frying. Such substances, though, have

Raw Materials of Biofuels

First Generation (technologies fully commercialized)

Raw Material	Use
Corn, sugarcane, molasses, and sorghum	Ethanol
Soybeans and other vegetable oils, recycled grease, beef tallow	Biodiesel

Second Generation (emerging technologies)

Raw Material	Use
Agricultural residue, including corn stover, wheat and rice straw, manure, and bagasse (residue from sugarcane and sorghum stalks)	Methane, cellulosic ethanol, power plant
Forest biomass, including logging residues, wood	Cellulosic ethanol and power plant
Urban woody waste and landfills	Methane, cellulosic ethanol, power
Herbaceous plants, including switchgrass, miscanthus, reed canary grass, sweet sorghum, alfalfa	Cellulosic ethanol, power plant
Short rotation woody crops, including willow, hybrid poplar, cottonwood pines, sycamore pines, eucalyptus	Cellulosic ethanol, power plant

Information derived from The Economics of Biomass Feedstocks in the United States: A Review of the Literature, *by the Biomass Research and Development Board* limited range because of their tendency to freeze, and can only be made available in small quantities.

Meanwhile, the aviation industry is moving into biofuels. Boeing, the Mexican Airports and Auxiliary Services Agency, and Honeywell have teamed up to find ways of using Mexican crops for biofuel. In the United States, the shipping company Fedex has pledged that a third of its fuel will come from bioenergy by 2030. Bioenergy also is being used in power production, mostly at small generating plants. One area of promise is the co-firing of bioenergy and coal. The power plant uses coal part of the time, keeping costs low, and bioenergy the remainder to improve the power plant's environmental profile.

Worldwide demand for biofuel is projected to grow 8.6 percent annually through 2030. Achieving this depends on government support since biofuels, like most renewable energy sources, still rely on financial incentives. In the United States, for example, a federal standard mandates an increase in the biofuel mix in gasoline to almost 145 million kiloliters by 2022. In addition, the Obama administration has committed $80 million to advanced biofuels research.

Given this kind of support, coupled with the push for oil alternatives, bioenergy injects new vigor and livelihood to the very old business of farming. The agricultural industry, already responsible for products that create food, clothing, and material for shelter, is now firmly in the business of providing another necessity: the energy to make it all work. ■

The opinions expressed in this interview do not necessarily reflect the views or policies of the U.S. government.

INTERNATIONAL AGRICULTURAL TRADE

Some examples of the foodstuffs important to international trade

Leading countries in the export of the major commodities indicated

Argentina	Soybean Oil	Philippines	Bananas
Brazil	Chicken Meat	South Africa	Oranges
Canada	Wheat	Spain	Olive Oil
Costa Rica	Pineapples	Tunisia	Dates
France	Wine	Turkey	Dry Apricots
Malaysia	Palm Oil	United States	Maize

Data Source: U.N. Food and Agriculture Organization
Illustration by Nicolle Rager Fuller

Agriculture in the Global Marketplace

C. Peter Timmer

© AP Images/Feng lei sh/Imaginechina

A shopper chooses from a selection of imported foods at a Shanghai supermarket. Food imports to China are increasing, like many products from abroad.

Twenty-first-century agriculture is likely to build stronger links between farmers in rural areas and city dwellers in order to create market systems with greater efficiency and better technologies.

C. Peter Timmer is a leading economist in the fields of agricultural and development economics. He has held professorships at Stanford, Cornell, and the University of California, San Diego. He is currently the Thomas D. Cabot Professor of Development Studies, emeritus, Harvard University.

The increasing globalization of agriculture and the resulting dominant role of supermarkets benefit many but harm others. Those who influence the 21st-century global marketplace should seek to allocate its burdens equitably, while preserving the real gains that afford millions a greater variety of healthful, more affordable sustenance.

By its very nature, agriculture is mostly a local activity, its roots in the soil. Most of the world's billion or more farmers live within walking distance of the crops they grow and eat. The co-evolution of human societies and cultivated species has led to superb adaptation to specific environments, and has created highly diversified cropping systems that can meet the wide nutritional needs of household members. Localized agriculture is still the norm for the vast majority of the world's poor people.

Economists have long viewed this dependence as a cause of poverty, not a historical accident. Agriculture limited to indigenous crops, locally available soil nutrients, and household labor, they argue, is a recipe for poverty and malnutrition. Local food self-sufficiency, they conclude, impoverishes individual households and the overall economy. Two Nobel Prizes in Economics were awarded in 1979 for these insights: to T.W. Schultz for emphasizing the need for new technologies to overcome rural household poverty, and to W. Arthur Lewis, for his emphasis on the role of agricultural modernization as a crucial input to overall economic development.

Globalized Markets

Market interactions between farm and urban households are the key to solving both problems. However, markets bring not just access to better technology and greater efficiency, they also bring new risks — that price fluctuations may offset farmers' hard work and leave them in debt. At the same time, dynamic urban economies offer farmers, and especially their children, the chance for a new life in the city. Expand markets to a global scale, and the opportunities, choices, and risks at the farm and national levels all multiply.

The globalization of markets is not new. Those of us who live in the United States have relied on global markets for centuries — they supply our coffee, tea, and spices, for example, and buy our surplus grain, tobacco, and vegetable oils. Other parts of the world have been connected similarly since the beginning of modern economic growth. Wheat prices in 18th-century England were tied directly to prices in the Baltic ports; rice prices in Calcutta and Bombay, even Paris, were linked to prices in Rangoon and Saigon. Long-distance trade in agricultural commodities benefits people on both ends of the transaction.

Still, the modern round of globalization is broader and deeper than anything seen in the 18th or 19th centuries. Three revolutions have stimulated the rapid integration of commodity markets:

- The revolution in agricultural technologies that permits highly productive but specialized farming techniques;
- The revolution in communications and transportation that permits buyers and sellers to connect quickly and at low cost across vast distances;
- The revolution in global living standards that has brought billions of new consumers into a world of discretionary purchases.

Modern globalization is the result of progress in supply, marketing, and demand.

Driven by these forces, agricultural globalization shapes the diet of consumers and the practices of farm producers. The former benefit from the ready and affordable availability of more diversified foodstuffs, a cornucopia far beyond what domestic agricultural production can provide. European consumers have daily access to fresh green beans from Kenya; American consumers enjoy fresh Peruvian asparagus in February. Low-cost transportation systems and falling trade barriers offer many consumers a market basket that draws from the entire world's bounty and diversity.

At the same time, globalization can incentivize individual famers to specialize in a single crop even as national agricultural sectors on balance may grow more diversified. Unless agro-ecological conditions are nearly identical throughout a country, farmers will — for reasons of resources, soil quality, or a number of other factors — develop a competitive advantage in growing a particular kind of crop. They

© AP Images/Hasan Jamali

Saudi farmers sell dates at a market on the outskirts of Riyadh. Saudi Arabia is the world's third largest producer of dates, after Egypt and Iran, according to the U.N. Food and Agriculture Organization.

© AP Images/Eric Risberg

This farmer's market in San Francisco gives local growers an outlet to sell their produce directly to consumers in competition with supermarkets.

utilize their farm resources most efficiently by specializing in growing that crop. This narrow specialization is consistent with greater diversity at the national level because of the commercialization of agriculture and international trade in food commodities.

The Role of Supermarkets

Modern supermarkets afford consumers the bounty of an international marketplace. By focusing the purchasing power of billions of consumers, they can offer a wide variety of appealing foods at low prices. But supermarkets also amplify the globalization-driven pressure upon the farm sector to adopt efficient supply-chain management practices. The impact on the structure of farm production, on who participates in the marketing process, and on the nature and cost of products available to consumers is profound.

Supermarkets and the transnational corporations (TNCs) that commonly own them also face fierce competition. TNCs such as Wal-Mart in the United States, Tesco in the United Kingdom, Carrefour in France, and Ahold in the Netherlands try to escape the resulting squeeze on profits by applying new information technologies to lower supply-chain costs and by fleeing the home market and moving into countries where food retailing remains comparatively inefficient and profit margins high. Most transnational corporations engaged in food marketing have done both.

TNC-owned supermarkets increasingly dominate the global food supply chain. Backed by foreign direct investment, TNCs consolidate the food retailing industry in many countries and, some allege, extract high, even monopoly profits. But what does this mean for consumers? The answer is complicated.

Technology that lowers transaction costs throughout the food supply chain can enhance supermarket profits even as customers reap the benefit of lower prices. Increasingly, information technology affords supermarket managers exquisite control over procurement, inventory levels, and knowledge of consumer checkout profiles. This translates into powerful competitive advantages in cost control, quality maintenance, and product tracking in case of defects or safety problems.

Globalized agriculture affords a number of other benefits. If Florida, for instance, experiences a killing frost, American consumers do not lack for orange juice; Brazilian and other substitutes are readily available in the United States, and vice versa. Global production boosts global food security, and affords a partial insurance policy against the impact of climate change on crop production.

But as the cost of information technology drops, determining the beneficiaries becomes less clear. As more competitors adopt the latest technology, competition among food retailers intensifies. The resulting low prices benefit consumers. The TNCs in turn require ever-greater efficiency from their suppliers. The constant pressure to lower costs in the food aisle ultimately is transferred all the way back to the individual farmer.

Concerns about Equity

The increasing dominance of supermarkets generates real concerns about fairness and equity in the agricultural marketing system. As many transactions shift from open and transparent public markets to supermarket procurement officers representing a few large buyers, food producers are more easily excluded from the negotiations. Prices are squeezed ever lower. Farmers adapt, or they are pushed out of farming.

But there is another side to this story. In a competitive environment, supermarkets must respond to customer preference. Some consumers care deeply about the environment. Others willingly pay somewhat higher prices to better sustain local farmers. TNCs manage some procurement contracts with these concerns in mind. Fears that a given TNC will establish monopoly control and market power in the developing world appear overstated: The success of one supermarket chain attracts others. The TNCs compete, fiercely, among themselves. The market for the food consumer's dollar seems to be highly contestable, even when only a small handful of retailers survive the cost competition.

Unquestionably, the growth of the TNC-owned supermarket poses risks to small farmers. Because of the high transactions costs, working with large numbers of small farmers is more expensive than doing business with a few large suppliers. Small famers easily can lose access to supermarket supply chains, and fall further into poverty. But with risk often comes opportunity. Some small farmers have gained profitable access to modern supply chains. Small farmers in Central Java, Indonesia, now sell their specialized "black watermelons" not just to local consumers, but to consumers in Jakarta, Singapore and Kuala Lumpur as well. Poor countries that successfully integrate some small farmers into the supermarket supply chain will benefit greatly.

Globalized food supply chains are a two-edged sword. They afford consumers lower prices and greater food security. But countries can lose control of their own food production and trade, as foreign consumers and producers drive local prices. A new international trade regime must balance equitably these positives and negatives, especially so that the poorest countries — the least food secure — do not suffer. ■

The opinions expressed in this article do not necessarily reflect the views or policies of the U.S. government.

Top Crop Producers

The nations that lead the world in producing various crops of interest are noted below, according to the latest data available from the U.N. Food and Agriculture Organization from the 2007 harvest.

Nation	Crop	Yield
China	Rice	187 million metric tons
China	Wheat	109 million metric tons
United States	Maize	330 million metric tons
France	Barley	9.5 million metric tons
Nigeria	Cassava	43 million metric tons
Brazil	Sugarcane	550 million metric tons

Nature + Science = New Crops

Courtesy of Stephen Ausmus/USDA

All of the food types included in this edible still life have been produced through genetic engineering, the process of inserting genes from one organism into another, giving the second plant a desirable quality of the first. The U.S. Department of Agriculture (USDA) reports the process is being used or tested on an increasing array of crops.

About 6,000 years ago, according to archaeological evidence, prehistoric farmers in the Americas cross-bred corn plants to create a crop with desirable traits that originally occurred in only a few plants. Centuries later, a 19th-century Austrian priest, Gregor Johann Mendel, experimented with tens of thousands of pea plants and identified the laws of cross breeding plants. The significance of his work was only properly recognized in the early 20th century when Mendel's Laws of Inheritance became a touchstone for the new science of genetics.

Today, most of the world's major food crops are grown from hybrid strains. Genetic science has advanced with the emergence of biotechnology and the creation of genetically modified organisms (GMOs). Though these technologies have been controversial, and adamantly opposed by some, many respected scientists assert that developing plants genetically capable of producing greater yields with less fertilizer and water is necessary to meet the food needs of the future.

Regardless of how the controversy over genetic engineering is resolved, there is no question that humans have a long history in the manipulation of plant species, resulting in greater abundance and variety in the modern diet. ■

Pearl millet is a staple crop for people in the semi-arid tropics. The plants in this field in southern India have been genetically engineered to resist diseases that can kill an entire crop.

© AP Images/Desikan Krishnan

Nature + Science

The Galaxy peach, also known as the Bagel peach for its flat shape, is a variety developed over 10 years of testing by the U.S. Agriculture Research Service. The sweet taste of the fruit and abundant yield of the tree have made it popular for backyard gardeners.

Courtesy of USDA

© AP Images/Andy Wong

This test field in China's Yunnan province is sown with different varieties of rice to determine which strain adapts most readily to environmental conditions particular to that region. Planting a strain that is well adapted, and thus more productive, can result in an improved yield, which makes a substantial difference in a farmer's livelihood.

© AP Images/Gary Kazanjian

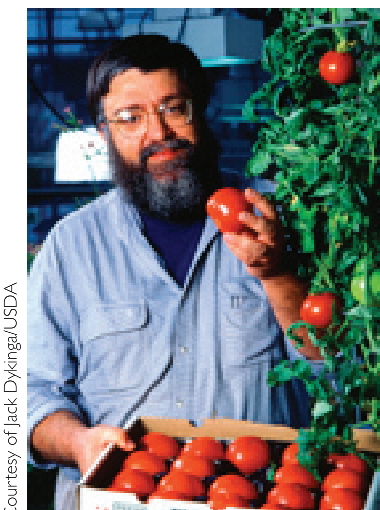
Nectarines roll down a packing line in a California plant. The nectarine is a natural mutant of the peach with the difference of only a single gene that results in a smooth skin. The peach is thought to have originated in China, but traders introduced it to the West perhaps as long as 2,000 years ago.

© AP Images/The Winchester Star/Scott Mason

A fruit grower in Virginia checks the blossoms of a pluot tree for frost damage after a late season freeze. The pluot is a fruit created through cross-breeding plums and apricots in a three-to-one ratio. The aprium is a genetically engineered fruit, also made through a mix of genetic material from plums and apricots, in a one-to-three ratio, creating a fruit that is subtly different in appearance and taste.

© AP Images/Kent Gilbert

The Bribi Indians of Costa Rica have adopted new agricultural methods and varieties of disease resistant crops developed by researchers at the University of Costa Rica.



Courtesy of Jack Dykinga/USDA

Plant physiologist Athanasios Theologis isolated and cloned the tomato's ripening gene. By manipulating this gene, Theologis and others created the Endless Summer tomato, a variety that can be left on the vine long enough to develop full taste and texture while still remaining ripe when it arrives at the supermarket.

© AP Images/Boris Heger

Rice sellers at a market in Kindia, Guinea, are selling Nerica, "new rice for Africa." Researchers created the variety by crossbreeding an African rice variety with another variety that resulted in a more productive strain. The plant provides growers with greater yields to sell and thus increases their incomes.

Water Sustains All

© Ed Darack/Science Faction/CORBIS

A sunset lights crop irrigation in the Santa Rita Hills of California, the nation's top agriculture producing state.

© Louie Psihoyos/Science Faction/CORBIS

In Bali, contoured terraces retain the water used in the cultivation of rice, the world's second most widely cultivated crop.

Centuries of experience and technological development separate today's farmer from the first people who scraped a crop from the ground thousands of years ago, but one thing these farmers still share — the need for water. Agriculture consumes about 70 percent of the planet's fresh water, up to 90 percent in some countries, surpassing industrial and domestic uses by far.

Reliable water supplies will be a critical factor in increasing agricultural production to meet the needs of the world's expanding population. The challenge will be to extract greater efficiency from every drop. Irrigated land in developing countries will increase by 34 percent by 2030, according to a U.N. Food and Agriculture Organization estimate, but the amount of water used to produce food crops will increase by only 14 percent because of improved irrigation practices.

So how much water does it take to grow food? Obviously different crops have widely diverse needs, but generally, between 2,000 to 5,000 liters of water are required to grow the food that an average person consumes per day.

The U.S. Environmental Protection Agency offers these estimates of the water needed to produce a variety of foods:

Water	Food
15 liters	Four liters of milk
1,514 liters	To raise one chicken
22.71 liters	One serving of fried potatoes
52.23 liters	One orange
378.54 liters	One watermelon
567.8 liters	One loaf of bread
11.35 liters	One tomato
132.48 liters	One serving of rice
454.24 liters	One egg

■

The Legacy of Plant Life

© AP Images/Eduardo Verdugo

Technicians at the International Maize and Wheat Improvement Center sort samples of wild maize seeds in Mexico. This center has shipped thousands of unique seed samples to the Svalbard Global Seed Vault for safe storage in the Arctic.

The international community is engaged in a concerted effort to safeguard the genetic wealth of the plant kingdom.

Seeds and plant samples — hundreds of thousands of different types — are being secured and stored so that they will not be lost to climate change, habitat depletion, or other natural or man-made disasters.

Preserving the discoveries of the future and the crops of today motivate the effort. Science has learned to modify the genetic code of plants, extracting a desired characteristic of one plant, and inserting it into another. This form of bioengineering is an accelerated version of the cross pollination that farmers have practiced for centuries. Today's capabilities raise awareness that any plant, anywhere, may hold a biological secret that will someday aid humankind — a cure for disease, an enriched food, or other useful compound.

"Plant genetic resources for food and agriculture provide the biological basis for world food security, and support the livelihoods of every person on Earth," according to a U.N. conservation plan for plant genetic resources. The 1996 document puts the international community's concern about and responsibility for plant diversification on record.

International Efforts

An international agricultural research consortium supports 11 gene banks, safeguarding more than 650,000 genetic samples of crop, forage, shrubs, and trees and keeping them in the public domain. The Center for Global International Agriculture Research (CGIAR) is dedicated to "conserving these collections for the long term and to making the germplasm [a collection of genetic resources for an organism] and associated information available as global public goods."

CGIAR maintains these vast storehouses of seeds and plants for the benefit of all humanity, according to its Web site: "Seed contributions have helped lay the foundations of recovery by jumpstarting agricultural growth in countries emerging from conflict such as Afghanistan, Angola, Mozambique, and Somalia." Areas stricken by natural disaster can retrieve precious seeds from the gene banks to revive plant life uniquely adapted to their specific climate and conditions.

U.S. Efforts

The U.S. National Plant Germplasm System (NPGS) maintains a network of gene banks to preserve genetic traits that can be used to combat emerging pests, pathogens, diseases, and other threats to the world's supply of food and fiber.

The NPGS collections include approximately 511,000 samples of seeds, tissues, and whole plants at more than 20 gene banks in the United States under the authority of the Agriculture Research Service (ARS) of the U.S. Department of Agriculture. Many of the gene banks also receive support from universities and state agricultural experiment stations.

Useful traits identified in the samples have helped inoculate U.S. crops from dangerous pathogens. A wheat plant collected in Turkey in 1948, for example, effectively resisted a fungus that threatened U.S. crops 15 years later. Its genetics are now incorporated into virtually every wheat variety grown in the Pacific Northwest region of the United States, according to ARS documents.

A Russian wheat aphid spread to the United States in 1986, threatening the entire nation's commercial wheat crop. ARS scientists began an urgent examination of NPGS grain stores and found hundreds of potentially resistant genes. A crash project developed a resistant strain, thus averting a crop crisis.

Seeds in the Deep Freeze

Inside the Arctic Circle, 1,000 kilometers north of mainland Norway, average temperatures are so low that electricity isn't required to maintain freezing temperatures. There, dug into a mountainside, surrounded by permafrost and thick rock, the Svalbard Global Seed Vault holds hundreds of thousands of seed samples from all over the world in frozen isolation until mishap or disaster requires their use to replenish seeds native to warmer climates.

Built by the Kingdom of Norway with international cooperation and maintained by the Global Crop Diversity Trust, the Svalbard Vault is the world's final insurance policy for protecting plant diversity. Gene banks all over the world deposit duplicate samples of their stockpiles with Svalbard for safekeeping. The Svalbard vault insures that gene banks elsewhere have back-ups in case of unpredictable institutional failure — lost samples, neglectful management, or depleted funding.

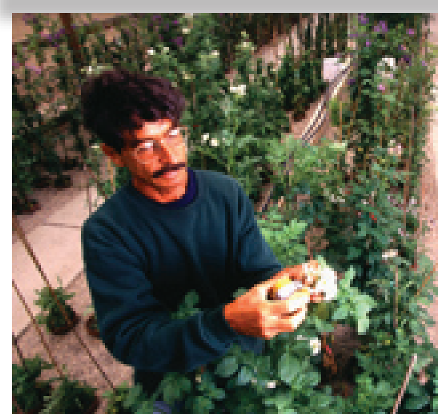
Since the Svalbard vault opened in 2008, the U.S. germplasm system has sent more than 20,000 plant samples to it for safekeeping; and the United States intends to send samples of its entire collection gradually over the next several years.

The Global Crop Diversity Trust is a public-private partnership raising funds to support key crop collections. In keeping with international plant diversity agreements, the trust works to advance an efficient and sustainable global system for long-term conservation of plant genetic resources.

The diversity of plant life on Earth is so great that it eludes humankind's attempts to quantify it all. Estimates of the number of known plant species range from approximately 300,000 to 400,000, but deep in remote forests, or high on mountain peaks, thousands more unknown species could be awaiting their first sighting by a scientist who recognizes their uniqueness. ■

© AP Images/John McConnico

Courtesy CGIAR/IITA



Courtesy of Scott Bauer/USDA

(Clockwise from left) Project gardener Charles Fernandez works with plants at the U.S. Potato Genebank in Wisconsin; Cary Fowler, director of the Global Crop Diversity Fund, is inside the Svalbard Global Seed Vault; a technician checks the inventory at the International Institute of Tropical Agriculture in Ibadan, Nigeria.

By the Numbers

1.02 billion: People worldwide who are hungry and undernourished. 642 million of them live in Asia and the Pacific, 265 million in Sub-Saharan Africa. (FAO)

148 million: Children being raised on inadequate diets. (unitedcalltoaction.org)

670,000: Child deaths annually traceable to Vitamin A deficiency. (unitedcalltoaction.org)

7 to 1: Ratio of dollars returned in increased wages and decreased disability to dollars spent on vitamin A fortification. (USAID)

28 to 1: Ratio for dollars spent on iodizing salt. (USAID)

84 to 1: Ratio for dollars spent on iron fortification. (USAID)

100 percent: Required food production increase to feed the Earth's anticipated 2050 population of 9 billion. (FAO)

$5.5 billion: Amount the U.S. Government will spend to fight world hunger over the next two years. (Agriculture Secretary Tom Vilsack)

55 percent: Proportion of global food aid paid for by the U.S. government over the last 50 years. (Vilsack)

70 percent: Amount of global fresh water supply used in agriculture. (FAO)

2,000–5,000: Liters of water required to produce the food in average daily diet. (U.N.- Water)

300 percent: Proportion by which Mexican wheat production increased while Norman Borlaug worked there. (Rand Study)

25 percent: Increase in calories consumed by average person in the developing world following the Green Revolution. (Gordon Conway)

250 percent: Increase in grain production between 1950 and 1984. (Kindall and Pimentel)

400 percent: Increase in yield over local varieties of weed-resistant and drought-tolerant sorghum hybrid plants developed by 2009 World Food Prize laureate Gebisa Ejeta. (World Food Prize)

300 percent: The increase in fish production in Bangladesh using aquaculture techniques developed by Blue Revolution founder, M. Vijaya Gupta. (World Food Prize)

Additional Resources

A selection of books, articles, and Web sites

Articles and Reports

Agricultural Biodiversity in FAO. Rome, Italy: Food and Agriculture Organization of the United Nations, 2008.
http://www.fao.org/docrep/010/i0112e/i0112e00.htm

Briscoe, John, et. al. *Water and Agriculture: Implications for Development and Growth*. Washington, DC: Center for Strategic and International Studies, 2009.
http://csis.org/publication/water-and-agriculture

Energy-Water Nexus: Many Uncertainties Remain about National and Regional Effects of Increased Biofuel Production on Water Resources. Washington, DC: Government Accountability Office, 2009.
http://www.gao.gov/new.items/d10116.pdf

Federoff, Nina, et. al. "Radically Rethinking Agriculture for the 21st Century." Science, vol. 327, no. 5967 (12 February 2010): pp. 833 — 834.
http://www.sciencemag.org/cgi/content/full/327/5967/833

Hausmann, Ricardo and Rodrigo Wagner. *Certification Strategies, Industrial Development and a Global Market for Biofuels.* Cambridge, MA: Belfer Center for Science and International Affairs at Harvard University's Kennedy School, January 13, 2010.
http://belfercenter.ksg.harvard.edu/publication/19856/certification_strategies_industrial_development_and_a_global_market_for_biofuels.html

International Energy Outlook 2009. Washington, DC: U.S. Department of Energy, 2009.
http://www.eia.doe.gov/oiaf/ieo/

McFadden, Steven. *Community Farms in the 21st Century: Poised for Another Wave of Growth?* Kutztown, PA: Rodale Press, 2007.
http://newfarm.rodaleinstitute.org/features/0104/csa-history/part1.shtml

A New Biology for the 21st Century: Ensuring the United States Leads the Biology Revolution. Washington, DC: National Academy of Sciences, 2009.
http://www.nap.edu/catalog.php?record_id=12764#toc

Pardey, Philip G. and Julian M. Alston. *U.S. Agricultural Research in a Global Food Security Setting*. Washington, DC: Center for Strategic and International Studies, 2010.
http://csis.org/publication/us-agricultural-research-global-food-security-setting

Quinn, Kenneth M. "Dr. Norman E. Borlaug: 20th-Century Lessons for the 21st-Century World"
http://www.worldfoodprize.org/borlaug/borlaug-history.htm

Timmer, C. Peter. "Do Supermarkets Change the Food Policy Agenda?" *World Development*, vol. 37, no. 11. (November 2009): pp. 1812-1819.

Von Braun, Joachim. *The Poorest and Hungry.* Washington, DC: International Food Policy Research Institute, 2009.
http://www.ifpri.org/sites/default/files/publications/oc63.pdf

Web Sites

AgNIC: The Agriculture Network Information Center
http://www.agnic.org

The Center for Global International Agriculture Research (CGIAR)
http://www.cgiar.org/

Food and Agriculture Organization of the United Nations
http://www.fao.org/

Global Information and Early Warning System (GIEWS): On Food and Agriculture
http://www.fao.org/giews/english/index.htm

International Food Policy Research Institute
http://www.ifpri.org/

Millennium Villages Project
http://www.millenniumvillages.org/

National Institute of Food and Agriculture
http://www.csrees.usda.gov/

Responding to World Hunger
http://www.america.gov/food_security.html

Svalbard Global Seed Vault
http://www.croptrust.org/main/arctic.php?itemid=211

U.S. Agency for International Development
Food Security
http://www.usaid.gov/our_work/agriculture/food_security.htm

U.S. Department of Agriculture
Global Food Security
http://www.ers.usda.gov/Briefing/GlobalFoodSecurity/

U.S. Department of Agriculture
Food Security
http://www.fns.usda.gov/fsec/

U.S. Department of State
Global Hunger and Food Security
http://www.state.gov/s/globalfoodsecurity/index.htm

U.S. National Plant Germplasm System (NPGS)
http://www.ars-grin.gov/npgs/

World Agricultural Forum
www.worldagforum.org

Filmography

Sustainable Table: What's on Your Plate? (2006)
Running time: 52 minutes
Director: Mischa Hedges
Summary: What's on your plate, and where does it come from? What are its effects on the environment and your body? This film presents questions about the sustainability of many agricultural practices, and attempts to pursue some answers.

Food Inc. (2008)
Running time: 94 minutes
Director: Robert Kenner
Summary: The film examines large-scale food processing in the developed world, arguing that its methods do not promote good health for consumers or the environment.

Diverseeds: Plant Genetic Resources for Food and Agriculture (2009)
Running time: 51 minutes
Director: Markus Schmidt, Austria
Summary: Large agricultural producers have adopted a few plant varieties with genetically engineered qualities desirable for crop production. This practice has narrowed genetic diversity, which, the filmmaker argues, is vital to meeting the world's future development needs.

King Korn (2009)
Running time: 88 minutes
Director: Aaron Woolf
Summary: Best friends from the eastern United States move to the agricultural producing regions of the Midwest to learn where their food comes from. They grow a corn crop and attempt to follow it through the food processing system.

Farm! (2008)
Running time: (not listed)
Director: Christine Masterson
Summary: This documentary is about a new generation of organic and sustainable farmers in the state of Georgia.

In Organic We Trust (2010)
Running time: (not listed)
Director: Kip Pastor
Summary: This film examines the organic food industry and the paths towards an organic, self-sustaining agriculture system.

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