FORUM

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PAMELA RONALD

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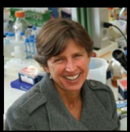

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Opening: PAMELA RONALD

Genetically modified foods are safe for humans and pose no special environmental risk. Yet there are serious policy questions to consider.

Topics: FOOD AND AGRICULTURE, SCIENCE AND TECHNOLOGY, ENVIRONMENT AND CLIMATE, HEALTH, GLOBAL

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Mama Moses has been growing bananas on her farm in southwestern Uganda for twenty years. She farms only bananas, which is typical of subsistence farmers in Sanga, the impoverished village where she lives. Last year, when she saw the flowers on her banana plants begin to shrivel and yellow bacteria ooze from the cut stems, she knew her crop was doomed. Within months the bacterial infection turned her healthy crop into a black, wilted mess.

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Banana *Xanthomonas* wilt disease (BXW) is one of the greatest threats to banana production in Eastern Africa. Cultural practices provide some control, but they are ineffective during epidemics. More than a thousand kinds of banana can be found worldwide, but none has robust resistance to BXW. Even if resistance were identified, most scientists believe that breeding a new variety using conventional methods would take decades, assuming it is even possible.

BXW creates precisely the sort of food insecurity that affects the world’s poorest people. Bananas and plantains are the fourth most valuable food crop after rice, wheat, and maize. Approximately one-third of the bananas produced globally are grown in sub-Saharan Africa, where bananas provide more than 25 percent of the food energy requirements for more than 100 million people.

For anyone worried about the future of global agriculture, Mama Moses’s story is instructive. The world faces an enormous challenge: with changing diets and population growth of 2–3 billion over the next 40 years, UNESCO predicts that food production will need to rise by 70 percent by 2050. Many pests and diseases cannot, however, be controlled using conventional breeding methods. Moreover, subsistence farmers cannot afford most pesticides, which are often ineffective or harmful to the environment.

Yet many emerging agricultural catastrophes can almost certainly be avoided thanks to a modern form of plant breeding that uses genetic engineering (GE), a process that has led to reduced insecticide use and enhanced productivity of farms large and small.

In spite of these benefits, genetic engineering is anathema to many people. In the United States, we’ve seen attempts to force labeling of genetically modified organisms (GMOs). In much of Europe, farmers are prohibited from growing genetically engineered crops and so must import grain from the United States. And “GMO-free” zones are expanding in Japan.

The strong distrust of GE foods is curious. Opponents typically profess a high degree of concern for human welfare and the environment. They want the same things that scientists, farmers, food security experts, and environmentalists want: ecologically sound food production accessible to a growing global population. But their opposition threatens the great strides that have been made toward these goals through deployment of new technologies.

For 10,000 years, we have altered the genetic makeup of our crops. Conventional approaches are often crude, resulting in new varieties through a combination of trial and error, without knowledge of the precise function of the genes being moved around. Such methods include grafting or mixing genes of distantly related species through forced pollinations, as well as radiation treatments to induce random mutations in seeds. Today virtually everything we eat is produced from seeds that we have genetically altered in one way or another.

Over the last twenty years, scientists and breeders have used GE to create crop varieties that thrive in extreme environments or can withstand attacks by pests and disease. Like the older conventional varieties, GE crops are genetically altered, but in a manner that introduces fewer genetic changes. Genetic engineering can also be used to insert genes from distantly related species, such as bacteria, directly into a plant.

Given that modern genetic engineering is similar to techniques that have served humanity well for thousands of years and that the risks of unintended consequences are similar whether the variety is derived from the processes of GE or conventional gene alteration, it should come as no surprise that the GE crops currently on the market are as safe to eat and safe for the environment as organic or conventional foods. That is the conclusion reached by diverse agricultural and food experts. There is broad consensus on this point among highly regarded science-based organizations in the United States and abroad, **including** the American Medical Association, the National Academy of Sciences, the World Health Organization, and European Commission Joint Research Centre. In the seventeen years since GE crops were first grown commercially, not a single instance of adverse health or environmental effects has been documented.

Genetically engineered crops currently on the market are as safe to eat and safe for the environment as organic or conventional foods.

To understand why farmers have embraced GE crops and how they **benefit the environment**, consider genetically engineered cotton. These varieties contain a bacterial protein called Bt that kills pests such as the cotton bollworm without harming beneficial insects and spiders. Bt is benign to humans, which is why organic farmers have used Bt as their primary method of pest control for 50 years. Today 70–90 percent of American, Indian, and Chinese farmers grow Bt cotton.

Recently, a team of **Chinese and French scientists reported** in the journal *Nature* that widespread planting of Bt cotton in China drastically reduced the spraying of synthetic chemicals, increased the abundance of beneficial organisms on farms, and decreased populations of crop-damaging insects. Planting of Bt cotton also **reduced pesticide poisonings** of farmers and their families. In Arizona farmers who plant Bt cotton spray half as much insecticide as do neighbors growing conventional cotton. The Bt farms also have **greater biodiversity**. In India, farmers growing Bt cotton **increased their yields** by 24 percent, their profits by 50 percent, and raised their living standards by 18 percent, according to one common standard that measures household expenditures.

GE papaya, engineered to withstand a devastating viral infection, has been similarly successful. First developed in 1998, it is now grown by **99 percent of Chinese** and about **70 percent of Hawaiian** papaya farmers. The GE papaya carries a snippet of the viral genome that immunizes it against infection. Conventional and organic papayas, which lack resistance, are infected with thousands-fold higher levels of the virus. There is currently no other method—organic or conventional—that can adequately control the disease.

Genetic engineering can be used not only to combat pests and diseases, but also to enable farmers to use less harmful chemicals to control crop-choking weeds. That is why 80–90 percent of the cotton, corn, soybeans, and sugar beets grown by U.S. farmers is genetically engineered for resistance to an herbicide called glyphosate. Farmers and home gardeners prefer glyphosate because it is much less toxic than earlier herbicides; indeed, the Environmental Protection Agency’s “worst case risk assessment of glyphosate’s many registered food uses concludes that human dietary exposure and risk are minimal.” Glyphosate kills the weeds but not the herbicide-tolerant crop. This approach greatly reduces the need for ploughing or digging, the conventional and organic method for controlling weeds. In Argentina and the United States, the use of herbicide-tolerant soybeans is associated with a 25–58 percent decrease in the number of tillage operations. Such **reduced tillage** practices correlate with **reduced soil erosion** and a significant **drop in greenhouse gas emissions**. In 2005 the decreased tillage that accompanied planting of herbicide-tolerant soybeans was equivalent to **removing 4 million cars** from the roads.

There are dozens of other useful traits in the GE pipeline: nitrogen-efficient crops that reduce fertilizer run off; golden rice, a provitamin A–enriched rice; cassava that is resistant to viral infection; and drought-tolerant corn. My laboratory at the University of California, Davis has genetically engineered rice for tolerance to flooding and resistance to disease.

Some of these crops, such as cassava and golden rice, are important to poor farmers and their families in developing countries who lack nutrients and cannot pay the price of improved seed. Consumption of golden rice, within the normal diet of rice-dependent poor populations, could provide sufficient vitamin A to reduce substantially the estimated 2,2000–6,850 deaths caused every day by vitamin A deficiency and save the sight of several hundred thousand people per year. This “biofortification” approach complements conventional supplementation, such as the World Health Organization’s distribution of Vitamin A pills, which **costs many times more** and often does not reach the rural poor who have little access to roads.

These well-documented benefits of GE crops, which have been repeated around the world, appear to be precisely the kind of triumph of biology over chemicals envisioned by Rachel Carson, food security experts, and organic farmers who have long dreamed of reducing the use of synthetic chemicals and enhancing biological diversity on farms.

Considering our long history of plant genetic manipulation and the success of modern GE seeds in enhancing the sustainability of our farms and food supplies, why do some consumers still express grave unease over the planting of GE crops?

Much of the concern relates to a general distrust of large corporations, in particular, Monsanto, which produces a large proportion of the world’s seeds. GE opponents fear that such corporations are taking advantage of farmers. Yet one need only observe the overwhelming farmer adoption of GE crops in the United States and elsewhere to conclude that the GE crop varieties on the market are useful to farmers. It is unlikely that experienced and skilled farmers would buy GE seeds if their farm operations did not benefit economically. Many U.S. farmers prefer Bt seed because it reduces reliance on sprayed insecticides that can harm farm workers and the environment. A recent Supreme Court case, *Bowman v. Monsanto*, highlighted the lengths farmers will go to obtain the seed, even when non-GE conventional alternatives are available.

> **Unless you forage for wild berries, hunt game, or catch wild salmon, you are consuming a food that has been genetically altered.**

The practice of buying seeds from seed companies has been criticized by opponents of GE seed. But seed purchasing is the norm in any non-subsistence farming system, whether or not the seed is genetically engineered, a fact that points to the abundant misinformation that plagues the debate over genetic engineering of crops.

Farmers often prefer to buy hybrid seed, a type of seed that inherits its useful traits, such as high yield, from two genetically distinct parents. These beneficial traits are lost in the second generation, so it makes no sense to save the seed from a crop and replant. The production of hybrid seed benefits the farmers, who are able to reap the advantages of the high-yielding seed, and the seed companies, which are able to reap a tidy profit each year the farmer buys the seed. Seed companies do produce seeds that can be replanted, but they are often lower yielding or susceptible to disease, which is why many crops grown by conventional and organic farmers are hybrids. Hybrid seed is not generated through genetic engineering and has been available since the 1920s. Genetic engineering does not, in and of itself, affect the ability of farmers to save their seed.

The priority for Monsanto and other for-profit seed companies is to produce high-quality seed for farmers in the developed world who can pay for them. But most farmers live in less developed countries and grow crops such as cassava or rice, which are not a priority for crop improvement in the developed world. For this reason, we need strong investment in public-sector research to develop improved seed for farmers who otherwise cannot afford it. We also need regulation of the seed industry to ensure fair dealing and to avoid the rise of a single company monopolizing the world's seed supply.

Today, more and more countries are exploring the use of genetic engineering for a greater variety of crops. Currently there are 30 commercialized GE crops cultivated worldwide. By 2015 there will be more than 120. Half will come from national technology providers in Asia and Latin America and are designed for domestic markets. The reduced dominance of U.S. seed companies may alleviate concerns of consumers who oppose genetic engineering because they see it only as a tool of large U.S. corporations.

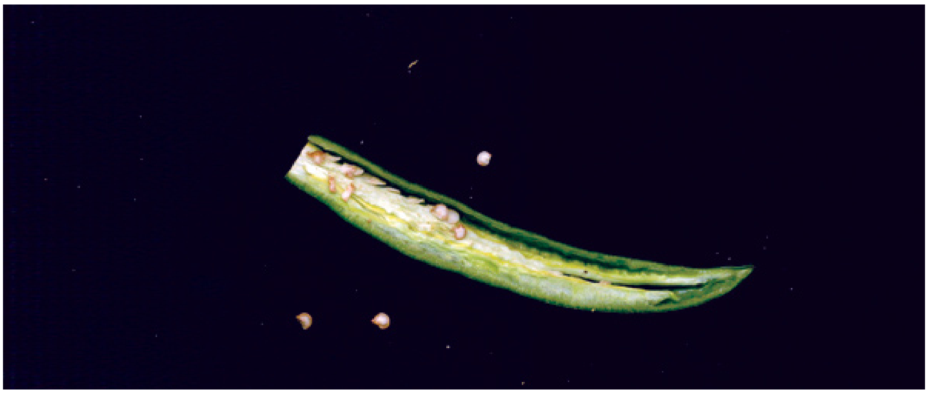
Another common fear of anti-GE activists is the emergence of "super weeds" in the fields of herbicide-tolerant crops. Indeed, one drawback to using a single herbicide is that overuse can lead to the evolution of weeds that are resistant to that herbicide. For example, the liberal use of glyphosate has spurred the evolution of **herbicide-resistant weeds**. Twenty-four glyphosate-resistant weed species have been identified since herbicide-tolerant crops were introduced in 1996. But herbicide resistance is a problem for farmers who rely on a single herbicide regardless of whether they plant GE crops. For example, 64 weed species are resistant to the much more toxic herbicide atrazine, and no crops have been genetically engineered to withstand it. So even if herbicide-tolerant plants were nowhere to be found, conventional farmers would still have to develop strategies to manage weeds that are resistant to herbicides.

Farmers face similarly complex issues when controlling pests. One limitation of using any insecticide, whether it is organic, synthetic, or genetically engineered, is that insects can evolve resistance to it. For example, one crop pest, the diamondback moth (*Plutella xylostella*), has evolved resistance to Bt toxins under open-field conditions. This resistance occurred in response to repeated sprays of Bt toxins to control this pest on conventional (non-GE) vegetable crops.

Partly on the basis of the experience with the diamondback moth, scientists predicted that pests would evolve resistance to Bt crops if they were deployed widely in monocultures. For this reason, U.S. farmers who plant Bt crops are required to deploy a "refuge strategy": creating refuges of crop plants that do not make Bt toxins. This promotes survival of susceptible insects and has helped to delay evolution of pest resistance to Bt crops.

Global pest-monitoring data suggest that Bt crops have remained effective against most pests for more than a decade. Failure to provide adequate refuges appears to have hastened resistance of pink bollworm in India. In contrast, Arizona cotton growers who planted adequate refuges saw no increase in pink bollworm resistance. This example emphasizes the need to deploy a crop diversity strategy and crop rotation to reduce the evolution of insect resistance. This is the case for organic and conventional farmers too. Farmers cannot rely on seed alone to eliminate pests.

Perhaps the greatest concern surrounding GE foods is their effect on human health. Opponents regularly point out that GMOs have never been proven safe, which creates a great deal of anxiety. This is a difficult claim to rebut because GMOs don't define a testable class—in the same way that the Federal Aviation Administration can't test "planes" but can test individual aircraft—and because there is no evidence of harm for scientists to explore.



Yet individual GE crops have been studied extensively. A vast scientific literature considers the potential risk associated with GE crops. To help bridge the gap between consumers and scientists, one of my former students, Karl Haro von Mogel, and his colleague Anastasia Bodnar have created the **GENetic Engineering Risk Atlas**, a database that currently lists 600 studies examining safety, environmental impact, food composition, and other aspects of GE crops. One-third of these studies are not funded by companies that stand to profit from the results, and these studies support the scientific consensus that genetic engineering of crops is not inherently riskier than conventional methods of crop improvement.

There are a few intensely promoted and controversial studies that claim to refute the broad scientific consensus. For example, a study published last year purported to show that corn engineered for tolerance to glyphosate caused tumors and early death in rats. However, this finding was **widely dismissed** by scientists not involved with the study, including the **European Food Safety Authority** and six French science academies. They reported, "The authors' conclusions cannot be regarded as scientifically sound because of inadequacies in the design, reporting and analysis of the study as outlined in the paper."

Although the GE crops currently on the market are safe, every new variety must be assessed on a case-by-case basis. Each new plant variety, whether it is developed through genetic engineering or conventional approaches of genetic modification, carries a risk of unintended consequences. Whereas each new genetically engineered crop variety is assessed by three governmental agencies, conventional crops are not regulated. To date, compounds with harmful effects on humans or animals have been documented only in foods developed through conventional breeding approaches. For example, conventional breeders selected a celery variety with relatively high amounts of psoralens in order to deter insects that damage the plant. Some farm workers who harvested such celery developed a severe skin rash—an unintended consequence of this non-GE breeding strategy.

With all of the scientific evidence arrayed in support of the safety and environmental benefits of the GE crops currently on the market, we must look to other sources to understand opposition.

To some extent, it is a product of our political culture. There is often little critical scrutiny of the issues within a particular "tribe." For example, just as many on the political right discount the broad scientific consensus that human activities contribute to global warning, many on the left disregard the decades of scientific studies demonstrating the safety and wide-reaching benefits of GE crops.

Both the left and the right (and the center) discard reason when it doesn't suit their politics. Some activist groups **manufacture uncertainty** to stoke fear in consumers. They demand more testing despite the fact that GE crops are the most highly regulated crops on the market. As Daniel Engber aptly remarks in *Slate*, the success of the manufactured-uncertainty strategy "shows how the public's understanding of science has devolved into a perverse worship of uncertainty, a fanatical devotion to the god of the gaps."

Anti-science campaigns can have devastating consequences. Consider the anti-vaccination movement led by actress Jenny McCarthy and discredited physician Andrew Wakefield, which claims a link between the administration of the measles, mumps, and rubella vaccine and the appearance of autism and bowel disease. Many newspapers have promoted their views and many parents have chosen not to vaccinate their children, invoking a personal-belief exemption to skirt public school requirements.

The result has been a worldwide outbreak of measles and whooping cough. Marin County, California, home to a wealthy, educated populace, recently experienced the largest **outbreak of whooping cough** in the nation. Health care workers **descended** on Marin as if it were a third-world country to reeducate parents about the importance of vaccinating their children. Even today, despite the revocation of Wakefield's medical license because of his fraudulent claims and undisclosed conflicts of interest, the notion that vaccines can cause autism or other problems remains prevalent in some places, especially certain liberal, affluent ones.

Consumers tend to group all 'GMOs' together without regard to the the needs of the farmer or to the social, environmental, or nutritional benefits.

In the case of the vaccine fraud, skepticism isn't a product of political culture so much as scientific illiteracy. The respected science journalist Michael Specter **points out** that consumers have a tendency to trust anecdotes over peer-reviewed results, which may explain why today "the United States is one of the only countries in the world where the vaccine rate for measles is going down."

A similar lack of comprehension likely afflicts opponents of modern crop varieties. Consumers have a tendency to group all "GMOs" together without regard to the purpose of the engineering, the needs of the farmer, or the social, environmental, economic, or nutritional benefits. They may be unaware that research organizations and scientists they otherwise trust agree that all GE crops currently on the market are safe to eat and safe for the environment, that each new crop variety is evaluated on a case-by-case basis, and that because each GE crop is different, testing them as a group is simply not possible and contesting their safety, in general, makes no sense.

This misunderstanding of the nature of GE crops underlies the labeling campaigns we have seen in recent years. These are not only public campaigns. Grocery giant Whole Foods has **declared** that within five years it will require labeling of all GMO foods sold in its stores. The implication of this labeling is that there is something worrisome about GMOs that consumers need to be warned about.

But to those of us who farm, carry out scientific research, or regulate food safety, it is clear that a GMO label provides scant information to the consumer and hinders the advancement of sustainable agriculture. The Food and Drug Administration **does not support** a GMO label because there are no known health effects. Almost all food would require such a label because virtually every crop grown for human consumption has been genetically modified in some way: bananas are sterile plants with artificially induced triple chromosomes, some varieties of California-certified organic rice were developed through radiation mutagenesis, and most cheeses use genetically engineered rennet as a key ingredient.

In other words, unless you forage for wild berries, hunt game, or catch wild salmon, you are consuming a food that has been genetically altered. For this reason, the FDA has concluded there is no universal or logical definition of GMO food. The FDA already requires stringent testing of food products and labeling of those that carry an ingredient found to be potentially harmful (such as peanuts), so there is no nutritional need for more labeling. The claim that consumers have a right to know what is in their food, prevalent during a 2012 referendum campaign to require GMO labeling in California, is also specious. Consumers have a right to know about potentially harmful ingredients, but a right to know about the presence of harmless GE ingredients is tantamount to a right to know that fruits contain sugars.

Whole Foods either believes that it can safeguard the food supply better than the FDA can, or it simply wants to sell more of its high-priced products. A. C. Gallo, president of Whole Foods, recently told the *New York Times*, “Some of our manufacturers say they’ve seen a 15 percent increase in sales of products they have labeled.”

To reap greater profits is a perfectly legitimate goal for a corporation such as Whole Foods. But what about the health of families, farmers, and the environment? For those of us who want to advance sustainable agriculture, the fears promoted by Whole Foods and popular media figures such as Dr. Oz do a major disservice. These anti-GE forces have much to gain financially, but at great cost to farmers and their families in less developed countries, who benefit from what plant genetics can offer.

Once upon a time, if we needed more food, we could simply plough more land or cut down more rainforests for cultivation. No longer. This approach causes environmental damage and ignores the need of poor farmers in developing nations to enhance the productivity of their farms to ensure local food security.

It is time to change the debate about food production. Let’s frame discussions about agriculture in the context of environmental, economic, and social impacts—the three pillars of sustainability. Rather than focusing on how a seed variety was developed, we must ask what most enhances local food security and can provide safe, abundant, and nutritious food to consumers. We must ask if rural communities can thrive and if farmers can make a profit. We must be sure that consumers can afford food. And finally we must minimize environmental degradation. This includes conserving land and water, enhancing farm biodiversity and soil fertility, reducing erosion, and minimizing harmful inputs. We must work together to identify the most appropriate technology to address a particular agricultural problem.

In the last twenty years we have seen dramatic advancements in plant genetics. In 2000 the first

In the last twenty years we have seen dramatic advancements in plant genetics. In 2000 the first plant genome was sequenced after seven years at a cost of $70 million. This year the same project is expected to take two or three minutes and cost $99. Through genomic sequencing of diverse plant species and varieties, we have already learned an astonishing amount about the genetic diversity of our food crops. Seed is just one of many components needed for sustainable food production, but it is an important one. We would be foolish not to take advantage of the advances in plant genetics.

In the case of bananas and BXW, we may be able to control the disease by introducing genes from other plant species, such as rice, that confer resistance. Such resistance genes are widespread in plants and animals and are highly effective at controlling bacterial infection. These genes have already been incorporated in virtually all crops that we eat today, through conventional genetic approaches.

If millions of small-scale farmers see their banana crops wiped out for want of new disease-resistant varieties, it will be due both to the failure of world's agricultural scientists to make their voices heard and to the resistance of ideological opponents of modern genetic techniques. This is suffering that we can prevent.

Editor's note: The author is an employee of the University of California, Davis, a public institution. Her research is funded by the NSF, NIH, USDA, DOE, and the Bill and Melinda Gates Foundation. She is not funded by Monsanto.

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