Green Revolution 2.0 is unfolding, driven by biotechnology innovation. Here is what you can expect

We are in the early stages of a revolution in food and agriculture that will exceed the tremendous accomplishments of the “Green Revolution” of the 1950s and 1960s. That ‘positively disruptive’ upheaval spurred agricultural development in many developing countries, helping to alleviate poverty and boost life expectancy. Green Revolution 2.0 will be even more consequential.

The first Green Revolution involved the introduction of high-yielding crop varieties of cereals, particularly wheat and rice, and the expanded use of fertilizers, agrochemicals, irrigation methods, pesticides and mechanization. It is closely associated with the pioneering work of the agricultural scientist Norman Borlaug, who received the Nobel Peace Prize in 1970.

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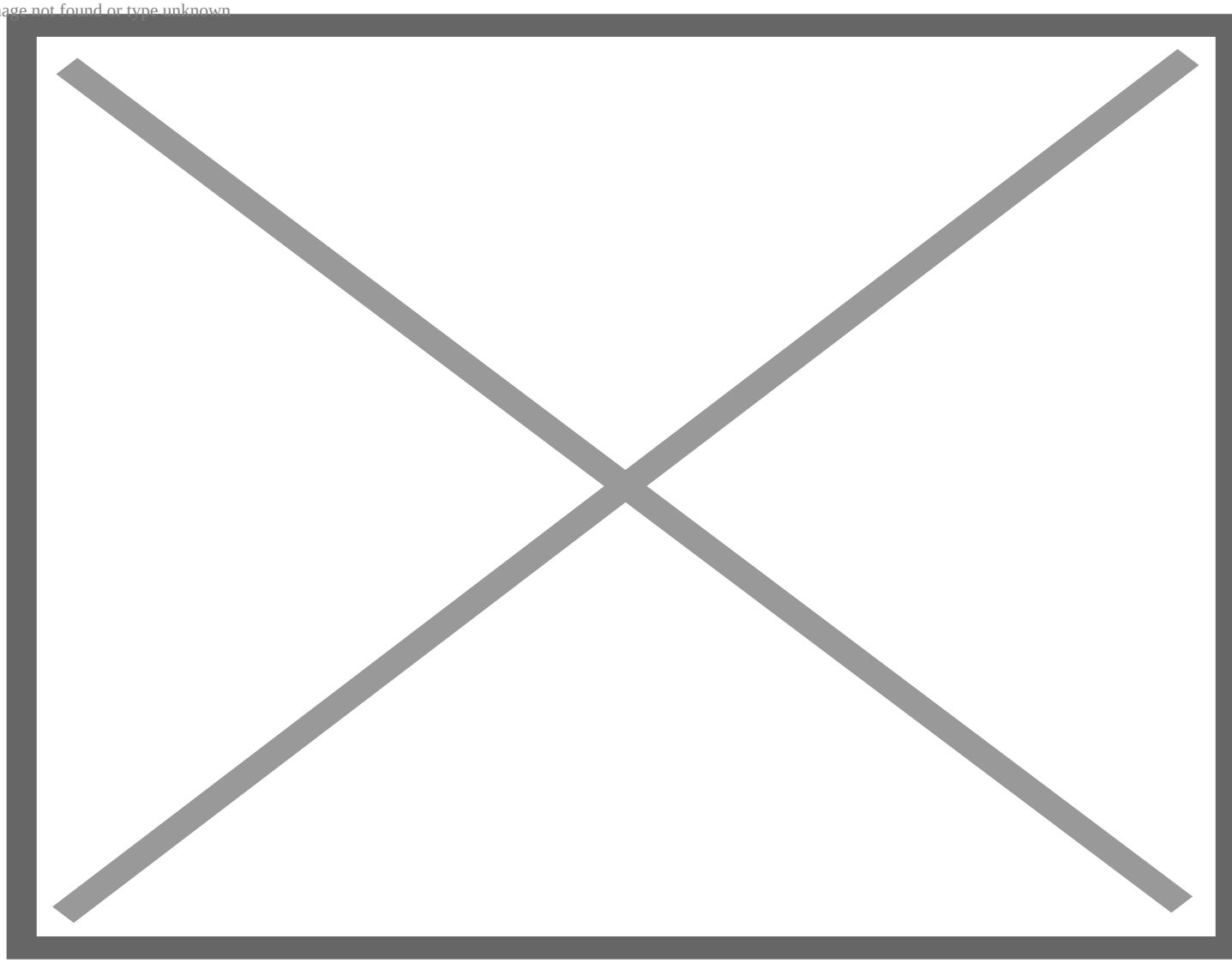

Norman Borlaud. Credit: Arthur Rickerby/National Portrait Gallery

India was a particular beneficiary. During the mid-1960s, the country was devastated by two severe droughts that resulted in food shortages and famine in parts of the country. In the late 1960's, the government introduced the "Green Revolution" with the assistance of international donor agencies in the Punjab province, the "bread basket" of India. Food production in the Punjab responded strongly to these measures with galloping output.

India is now self-sufficient in grain and, according a recent report by the U.N. Food and Agriculture Organization, is the world's largest producer of milk, pulses and jute, and ranks as the second-largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruit and cotton. This would not be possible without the "Green Revolution" and the continued application of science and new technologies to the cultivation of crops which have proved essential to feeding a growing population that will soon overtake China as the most populous nation.

Today's revolution in agriculture

Looking beyond the Green Revolution's advances, agriculture will become much more productive and efficient as it incorporates nano-technology, robots, drones and artificial intelligence in the food production process. Crops will be more nutritious and tastier and will be disease-, insect-, browning-, bruising-, drought- and disease-resistant as a result of advances in genetic engineering. Plant-based meat, eggs and dairy will be created by the manipulation of cells and using genetic engineering and synthetic biology. Some foods may be made in the laboratory and not on the farm. Agriculture's greenhouse gas emissions will be slashed, the number of animals slaughtered for meat will be reduced and there will be a wider array of food options for consumers.

The genomics revolution has ushered in another revolution in food production. The first GMO crops began to be cultivated in the mid-1990s. They involved the transfer of genes between species–transgenesis-to create plants that were insect resistant (*Bt* crops) and herbicide resistant. A 2020 report by Graham Brookes and Peter Barfood noted that

> GM crop technology has been used by many farmers around the world for more than twenty years and currently nearly 17 million farmers a year plant seeds containing this technology. This seed technology has helped farmers be more efficient with their application of crop protection products, which not only reduces their environmental impact, but saves time and money. The technology is also changing agriculture's carbon footprint, helping farmers adopt more sustainable practices such as reduced tillage, which has decreased the burning of fossil fuels and allowed more carbon to be retained in the soil. This has led to a decrease in carbon emissions.

A meta-analysis of 147 studies concluded that the adoption of GM technology led to a reduction of 37% in chemical pesticide use, increased crop yields by 22% and boosted farmer profits by 68%.

GM continues to be popular—among farmers

Despite protestations by anti-biotechnology advocates who have been experts at spreading misinformation and raising unwarranted fears, GMO crops now dominate many of the most important staple crops grown in the US. They have been genetically modified to be herbicide and insect resistant (Bt crops). According to the FDA,

> In 2018, GMO soybeans made up 94% of all soybeans planted, GMO cotton made up 94% of all cotton planted, and 92% of corn planted was GMO corn…In 2013, GMO canola made up 95% of canola planted while GMO sugar beets made up 99.9% of all sugar beets harvested…More than 95% of animals used for meat and dairy in the United States eat GMO crops.

Besides, soybeans, cotton, corn and sugar beets, there are also GMO potatoes (bruising- and browning-resistant), papaya (disease-resistant), apples (browning-resistant), summer squash, canola and alfalfa grown in the US.

It is not only in the US where GMO crops have proliferated. As of 2020, there were 22 different crops in 41 countries that are growing GMO crops or crops developed via new breeding techniques that involve genetic engineering of some form or another (such as CRISPR). The US is the largest grower of genetically engineered crops, accounting for 37.6 percent of all the GMO cultivated land area in the world in 2019. Brazil and Argentina were in second and third place followed by Canada, India and Paraguay.

As of 2018, 78 percent of all the global area used to produce soybeans were utilizing biotechnology. The comparable figure for corn was 30 percent, for cotton, it was 76 percent and for canola, it was 29 percent.

Many developing nations are embracing GMO crops as a means of increasing food production and boosting economic activity and farm income. In 2014 for example, Bangladesh began growing insect-resistant *Bt* brinjal (a variety of eggplant); in 2015, Vietnam began the cultivation of GMO corn; in 2018 eswatini (formerly Swaziland), began growing GMO cotton; in 2019, Ethiopia commercialized GMO cotton, in 2020 Nigeria, Malawi and Kenya started growing GMO cotton and in December 2020, Cuba began planting GMO corn.

In 2021, Nigeria commercialized GMO insect-resistant cowpeas and is currently conducting confined field trials for GM insect-resistant and drought-tolerant corn. Kenya has authorized the approval of field performance trials for a disease-resistant cassava and will begin growing GMO corn this year. Ghana is likely to follow Nigeria and approve the growing of GMO cowpeas in 2022. Burkina Faso is field testing GMO cowpeas.

In 2021, the Philippines approved the cultivation of golden rice, which enhances the vitamin A content of the crop, thus helping to reduce health problems associated with an insufficient amount of Vitamin A in the diet. Bangladesh is expected to follow the Philippines.

Indonesia is on track to begin commercializing a genetically engineered potato that is blight resistant by 2025. The Indonesian Institute of Science, meanwhile, has completed confined field trials of stem borer-resistant rice and is also researching drought-tolerant, salinity-tolerant, and blast-resistant rice, and shelf-life extended cassava. The University of Jember is conducting research on golden rice.

GMO crops will be perceived as fairly “primitive” in comparison to crops grown with the assistance of the New Breeding Technologies (NBTs), such as CRISPR. Instead of transferring genes, the DNA of a plant can be rearranged or edited thus creating desirable traits more easily.

Genetic engineering might be able to create new hybrid crops in a shorter period of time then it took to create such hybrids as tayberries, tangelos, blood limes, peacotums, netacots and pineberries. Crops may have the ability to ripen faster or slower depending on their life cycle and they may have a longer storage life.

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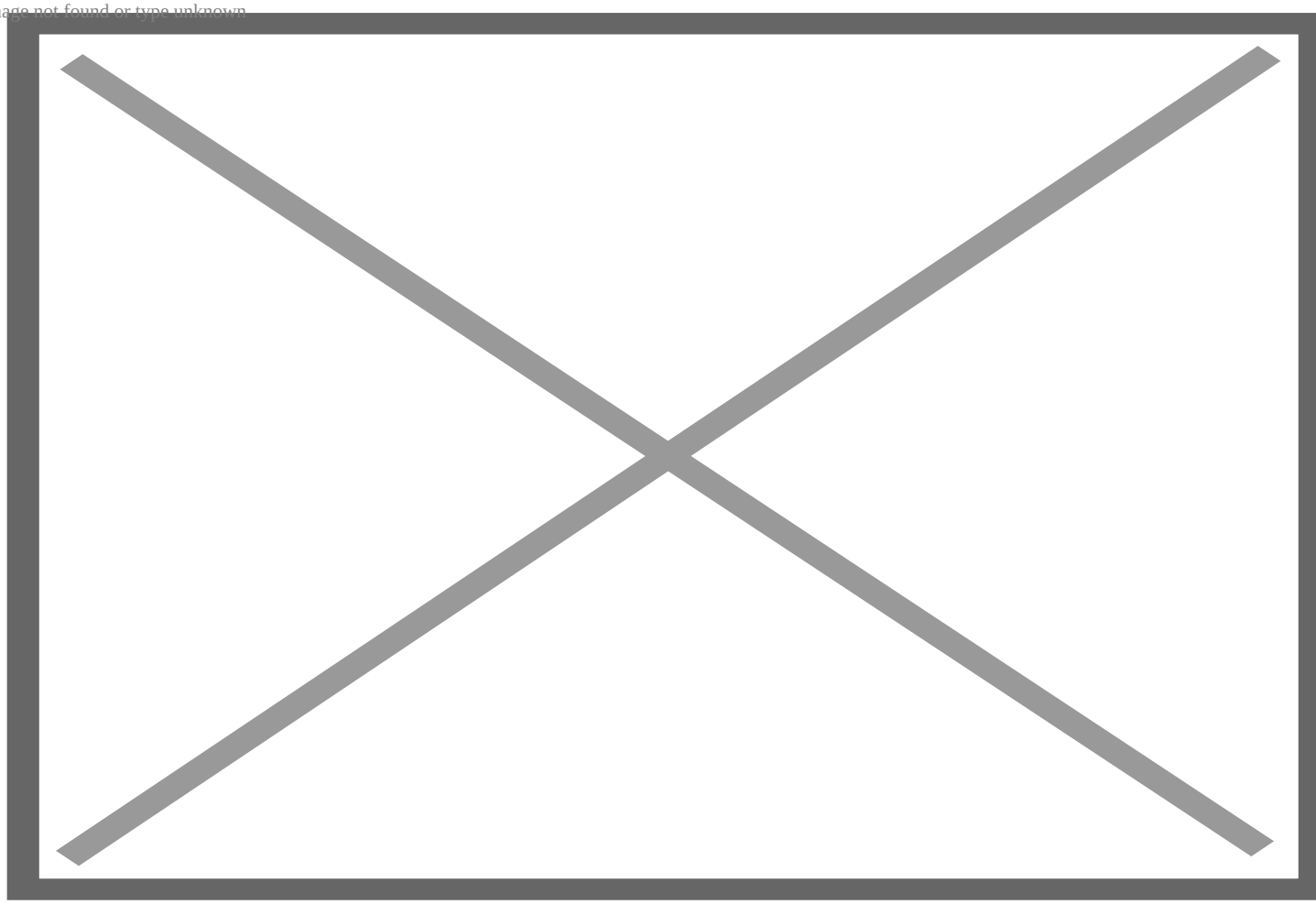

Tangelos. Credit: Julia Hartbeck/Spruce Eats

The very definition of what food is may be challenged in the coming years as a result of the advances of science and technology. Should beefless beef made from plant ingredients be labeled as beef? Similar is the case for plant-based chicken, fish and pork. Should cell based and plant-based milk be considered milk? Some foods will be made in the laboratory and not on the farms. They will be produced with ingredients that are genetic engineered and by utilizing synthetic biology. They may look, feel and taste like meat or milk but they will not be meat and milk.

Animals will be raised that are bioengineered to be heat resistant, produce more milk, grow faster such as the GMO Salmon, resist diseases and harvest organs for human transplants.

Political resistance from competition

As with all advances in technology, science and innovation, there will be winners and there will be losers, and the losers will fight and lobby strenuously against changes that are deleterious to their interests and profits.

Beef-producing organizations such as the National Pork Producers Council, the National Cattlemen's Beef Association and the Livestock Marketing Association are lobbying the federal government to force plant-based food companies to rename their products. Under present law, only the Food and Drug Administration (FDA) has the authority to order plant-based companies to refrain from using meat to define their products. The FDA is reviewing the issue.

"They're trying to get as close as possible to beef without actually being beef," said Danielle Beck, Executive Director of government affairs at the National Cattlemen's Beef Association. "But their entire marketing strategy is to disparage beef. They are trading on beef's good name, but disparaging beef in the process."

Pork producers are also objecting to plant-based companies calling their products meat. Dan Kovich, director of science and technology for the National Pork Producers Council, said,

> It's not pork…The ironic thing is that's impossible. You can't get pork from plants unless you feed them to a pig.

The Center for Consumer Freedom, a nonprofit group that works on behalf of the fast food and meat industries, has launched a campaign to undermine consumer confidence in plant-based meat portraying it as unhealthy and "fake" made with chemicals.

Plant based food companies are pushing back on the objections from the meat industry.

Ocean Robbins, CEO of Food Revolution Network, a plant-based food group said, "In the long run, if these terms are banned, companies are going to figure out another way," Robbins said. "But it will have an impact. The meat industry is putting a lot of money into this because they're aware that the terms are impactful. And they're afraid of mainstream people giving this a try."

Doubts may subside with time

Spreading misinformation and falsehoods and disparaging and raising doubts about the health and safety of products produced by your competitors is not a new tactic. Instead, it has been part of the play book to boost market share at the expense of the competition.

Given the barrage of anti-genetic engineering propaganda and the unwarranted concerns that have be propagated it is not surprising that many people have a negative attitude towards the application of biotechnology to crop production. Many believe it can cause cancer and allergies and harm wildlife. This is not true. Many see it as a scientific experiment that has the potential to go terribly wrong. Many see it as a tool of big agribusiness designed to perpetuate their domination of the food industry. Many believe it is not natural as if there is anything natural about farming. Many are listening to and trusting celebrities who are experts at things they know nothing about. Many do not understand that humankind has been genetically

engineering crops by one means or another for tens of thousands of years. That is why we have hybrids crops such as tangelos, blood limes, pineberries and pluots, seedless fruit, different varieties of the same fruits and vegetables and broccoli, which was derived from a cabbage relative.

It is not unusual for new scientific discoveries and technological advances to be greeted by doubt and uncertainty. It often takes time for people to adjust to new thinking, new devices and new ways of looking at the world. Such will be the case with genetic engineering. There will always be doubters and luddites but with time the benefits of genetic engineering of food will be undeniable, irrefutable and widely recognized. Crops will be grown that require less water, that can make their own nitrogen, that can ripen faster or slower, bananas, potatoes and avocados will not brown, storage life will increase, crops may be sweeter or tarter depending on taste preference, less insecticide, fungicides and herbicides will be used, crops will be disease resistant, thus reducing spoilage and waste, new hybrid varieties will be created and there may be edible vaccines.

US farmers are not afraid of genetic engineering. They have embraced the technology because they understand it is powerful tool in helping them grow crops. It can reduce insecticide and fungicide use, increases output and produce disease resistant crops. European farmers also understand its importance which is why many of them are advocating the adoption of gene-editing technologies. Copa Cogeca , which represent European farmers and agri-cooperatives, has said,

> New Breeding Techniques are not a luxury but an urgent necessity for the vitality of the whole EU farming mode…it is now a matter of urgency that a real European strategy regarding these highly promising techniques is put in place, as they would ensure that our farming model is able to adapt to both the early effects of climate change and fierce international competition.

Aynard de Clermont-Tonnerre, Secretary General of the Assembly of European Wine Regions, has urged the EU to adopt gene-editing. He wrote in an article,

> the US and other countries have taken a much more laissez-faire approach to the use of gene-editing compared to the EU…The UK, post-Brexit, has taken a similar stance towards gene-editing, and…China amended its rules to allow for a fast-tracking of gene-edited crops. Long-term, the use of gene-editing holds great potential as a way to create plants that are more resistant to disease, pests and changes brought on by climate change.

We are at the beginning stages of the GR2 in food and agriculture that will alter and transform the way we grow and consume food. The changes in food and agriculture are likely to be startling over the next twenty years. It will allow us to alter foods in ways that once seemed to be in the realm of science fiction. These changes will increase crop productivity thus lowering prices, offer consumers more choices, reduce losses from insects, spoilage, browning, bruising and disease, help deal with the ravages of climate change and create new types of foods.

Steven E. Cerier is an international economist and a frequent contributor to the Genetic Literacy Project.