Genetically engineered crops: Experiences and prospects: new report

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An extensive study by the National Academies of Sciences, Engineering, and Medicine has found that new technologies in genetic engineering and conventional breeding are blurring the once clear distinctions between these two crop-improvement approaches. In addition, while recognizing the inherent difficulty of detecting subtle or long-term effects on health or the environment, the study committee found no substantiated evidence of a difference in risks to human health between current commercially available genetically engineered (GE) crops and conventionally bred crops, nor did it find conclusive cause-and-effect evidence of environmental problems from the GE crops. However, evolved resistance to current GE characteristics in crops is a major agricultural problem.

A tiered process for regulating new crop varieties should focus on a plant's characteristics rather than the process by which it was developed, the committee recommends in its report. New plant varieties that have intended or unintended novel characteristics that may present potential hazards should undergo safety testing—regardless of whether they were developed using genetic engineering or conventional breeding techniques. New "-omics" technologies, which dramatically increase the ability to detect even small changes in plant characteristics, will be critical to detecting unintended changes in new crop varieties.

The committee used evidence accumulated over the past two decades to assess purported negative effects and purported benefits of current commercial GE crops. Since the 1980s, biologists have used genetic engineering to produce particular characteristics in plants such as longer shelf life for fruit, higher vitamin content, and resistance to diseases. However, the only genetically engineered characteristics that have been put into widespread commercial use are those that allow a crop to withstand the application of a herbicide or to be toxic to insect pests.

The fact that only two characteristics have been widely used is one of the reasons the committee avoided sweeping, generalized statements about the benefits and risks of GE crops. Claims about the effects of existing GE crops often assume that those effects would apply to the genetic engineering process generally, but different characteristics are likely to have different effects. A genetically engineered characteristic that alters the nutritional content of a crop, for example, is unlikely to have the same environmental or economic effects as a characteristic for herbicide resistance.

The committee examined almost 900 research and other publications on the development, use, and effects of genetically engineered characteristics in maize (corn), soybean, and cotton, which account for almost all commercial GE crops to date. "We dug deeply into the literature to take a fresh look at the data on GE and conventionally bred crops," said committee chair Fred Gould, University Distinguished Professor of Entomology and co-director of the Genetic Engineering and Society Center at North Carolina State University. In addition, the committee heard from 80 diverse speakers at three public meetings and 15 public webinars, and read more than 700 comments from members of the public to broaden its understanding of issues surrounding GE crops.

In releasing its report, the committee established a website that enables users to look up the places in the report that address comments received by the committee from the public, and also find the reasoning behind the report's main findings and recommendations. "The committee focused on listening carefully and responding thoughtfully to members of the public who have concerns about GE crops and foods, as well as those who feel that there are great benefits to be had from GE crops," said Gould.

Effects on human health. The committee carefully searched all available research studies for persuasive evidence of adverse health effects directly attributable to consumption of foods derived from GE crops but found none. Studies with animals and research on the chemical composition of GE foods currently on the market reveal no differences that would implicate a higher risk to human health and safety than from eating their non-GE counterparts. Though long-term epidemiological studies have not directly addressed GE food consumption, available epidemiological data do not show associations between any disease or chronic conditions and the consumption of GE foods.

There is some evidence that GE insect-resistant crops have had benefits to human health by reducing insecticide poisonings. In addition, several GE crops are in development that are designed to benefit human health, such as rice with increased beta-carotene content to help prevent blindness and death caused by vitamin A deficiencies in some developing nations.

Effects on the environment. The use of insect-resistant or herbicide-resistant crops did not reduce the overall diversity of plant and insect life on farms, and sometimes insect-resistant crops resulted in increased insect diversity, the report says. While gene flow—the transfer of genes from a GE crop to a wild relative species—has occurred, no examples have demonstrated an adverse environmental effect from this transfer. Overall, the committee found no conclusive evidence of cause-and-effect relationships between GE crops and environmental problems. However, the complex nature of assessing long-term environmental changes often made it difficult to reach definitive conclusions.

Effects on agriculture. The available evidence indicates that GE soybean, cotton, and maize have generally had favorable economic outcomes for producers who have adopted these crops, but outcomes have varied depending on pest abundance, farming practices, and agricultural infrastructure. Although GE crops have provided economic benefits to many small-scale farmers in the early years of adoption, enduring and widespread gains will depend on such farmers receiving institutional support, such as access to credit, affordable inputs such as fertilizer, extension services, and access to profitable local and global markets for the crops.

Evidence shows that in locations where insect-resistant crops were planted but resistance-management strategies were not followed, damaging levels of resistance evolved in some target insects. If GE crops are to be used sustainably, regulations and incentives are needed so that more integrated and sustainable pest-management approaches become economically feasible. The committee also found that in many locations some weeds had evolved resistance to glyphosate, the herbicide to which most GE crops were engineered to be resistant. Resistance evolution in weeds could be delayed by the use of integrated weed-management approaches, says the report, which also recommends further research to determine better approaches for weed resistance management.

Insect-resistant GE crops have decreased crop loss due to plant pests. However, the committee examined data on overall rates of increase in yields of soybean, cotton, and maize in the U.S. for the decades preceding introduction of GE crops and after their introduction, and there was no evidence that GE crops had changed the rate of increase in yields. It is feasible that emerging genetic-engineering technologies will speed the rate of increase in yield, but this is not certain, so the committee recommended funding of diverse approaches for increasing and stabilizing crop yield.

Regulation Should Focus on Novel Characteristics and Hazards

All technologies for improving plant genetics—whether GE or conventional—can change foods in ways that could raise safety issues, the committee's report notes. It is the product and not the process that should be regulated, the new report says, a point that has also been made in previous Academies reports.

In determining whether a new plant variety should be subject to safety testing, regulators should focus on the extent to which the novel characteristics of the plant variety (both intended and unintended) are likely to pose a risk to human health or the environment, the extent of uncertainty about the severity of potential harm, and the potential for human exposure - regardless of whether the plant was developed using genetic-engineering or conventional-breeding processes. " -omics" technologies will be critical in enabling these regulatory approaches.

The United States' current policy on new plant varieties is in theory a "product" based policy, but USDA and EPA determine which plants to regulate at least partially based on the process by which they are developed. But a process-based approach is becoming less and less technically defensible as the old approaches to genetic engineering become less novel and as emerging processes—such as genome editing and synthetic biology—fail to fit current regulatory categories of genetic engineering, the report says.

The distinction between conventional breeding and genetic engineering is becoming less obvious, says the report, which also reviews emerging technologies. For example, genome editing technologies such as CRISPR/Cas9 can now be used to make a genetic change by substituting a single nucleotide in a specific gene; the same change can be made by a method that uses radiation or chemicals to induce mutations and then uses genomic screening to identify plants with the desired mutation - an approach that is considered to be conventional breeding by most national regulatory systems. Some emerging genetic engineering technologies have the potential to create novel plant varieties that are hard to distinguish genetically from plants produced through conventional breeding or processes that occur in nature. A plant variety that is conventionally bred to be resistant to a herbicide and one that is genetically engineered to be resistant to the same herbicide can be expected to have similar associated benefits and risks.

Regulating authorities should be proactive in communicating information to the public about how emerging genetic-engineering technologies or their products might be regulated and how new regulatory methods may be used. They should also proactively seek input from the public on these issues. Not all issues can be answered by science alone, the report says. Policy regarding GE crops has scientific, legal, and social dimensions.

For example, on the basis of its review of the evidence on health effects, the committee does not believe that mandatory labeling of foods with GE content is justified to protect public health, but it noted that the issue involves social and economic choices that go beyond technical assessments of health or environmental safety; ultimately, it involves value choices that technical assessments alone cannot answer.

Provided by National Academy of Sciences

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