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The future of sustainable food production

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By the year 2050, the number of people on Earth is expected to increase from the current 6.7 to 9.2 billion. What is the best way to produce enough food to feed all these people? If we continue with current farming practices, vast amounts of wilderness will be lost, millions of birds and billions of insects will die, farm workers will be at increased risk for disease, and the public will lose billions of dollars as a consequence of environmental degradation. Clearly, there must be a better way to resolve the need for increased food production with the desire to minimize its impact.

Keywords: food; organic farming; genetics; genetic engineering; sustainable agriculture

Some scientists and policy decision makers have proposed that genetic engineering (GE), a modern form of crop modification (Table 1), will help create a new generation of plants that will dramatically reduce our dependence on pesticides, enhance the health of our agricultural systems, and increase the nutritional content of food. They believe GE will be a dramatic step forward that will allow agriculture to topple decades of criticism about the dangerous overuse of pesticides and toxic herbicides, leading us to a more ecological way of farming.

Or will it? While the public has generally accepted the application of GE for the production of new medicines, some consumers indicate grave unease over the consumption and production of GE food, viewing it as unnatural, potentially unsafe to eat, and environmentally disruptive. Of these skeptics, the organic farming community has been particularly vocal in its criticism (Table 2). Some consumers believe that because organic farmers have learned how to produce healthy nutritious food, GE plants are not needed.

Over the last 10 years of marriage, we, Raoul Adamchak (an organic farmer) and Pamela Ronald (a geneticist), have discussed these issues with each other and with others. We both work at the University of California at Davis, a world-class research institution that is located amid some of the world's richest soils in the fertile Central Valley. An unusually high percentage of the people who live in the small town of Davis studies or cultivates plants. Here, organic growers and geneticists routinely mingle together in the same social circles. Many of our friends, family, and colleagues see GE and organic farming as representing polar opposites of the agricultural industry, and they often ask us how GE will affect the environment and our food. On the other hand, some of our scientific colleagues have asked us to explain why many people in the organic farming community oppose the genetic engineering of crops. This short article and our book, *Tomorrow's Table: Organic Farming, Genetics, and the Future of Food,* is the result of our investigations and our response to these questions.

We believe that the judicious incorporation of two important strands of agriculture—genetic engineering and organic farming—is key to helping feed the growing population in an ecologically balanced manner. We are not suggesting that organic farming and GE alone will provide all the changes needed in agriculture. Other farming systems and technological changes, as well as modified government policies, undoubtedly are also needed. Yet it is hard to avoid the sense that organic farming and genetic engineering each will play an increasingly important role, and that they somehow have

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Table 1. Genetic engineering

GE is not a farming method. It is a modern form of crop modification that differs from plant breeding in two basic ways:

1. Plant breeding allows gene transfer only between closely related species. With genetic engineering, genes from the same species or from any other species, even those from animals, can be introduced into a plant. Therefore genetic engineering creates a vast potential for crop alteration.
2. Plant breeding mixes large sets of genes of unknown function, whereas genetic engineering generally introduces only one to a few well-characterized genes at a time.

Table 3. Criteria for the use of organic farming and genetic engineering in agriculture

We advocate the use of a technology or farming practice if it serves to:

- Produce abundant, safe, and nutritious food
- Reduce harmful environmental inputs
- Provide healthful conditions for farm workers
- Protect the genetic make-up of native species
- Enhance crop genetic diversity
- Foster soil fertility
- Improve the lives of the poor and malnourished
- Maintain the economic viability of farmers and rural communities

been pitted unnecessarily against each other. An important goal for policy makers is to determine if GE and/or organic farming can contribute to a future sustainable food production.

Table 2. Conventional and organic farming

Conventional agriculture is a catch-all term used to describe diverse farming methods. At one end of the continuum are farmers who use synthetic pesticides and fertilizers to maximize short-term yields. At the other end are growers who use chemicals sparingly and embrace the goals of ecological farming. Increasingly, many conventional farmers, particularly in the United States, are growing GE crops.

Organic farming is an ecologically based farming method that avoids or largely excludes the use of synthetic fertilizers and pesticides. As much as possible, organic farmers rely on crop rotation, cover crops, compost, and mechanical cultivation to maintain soil productivity and fertility, to supply plant nutrients, and to control weeds, insects, and other pests. The United States Department of Agriculture (USDA) National Organic Program standards established in 2000 prohibit the use of GE seed or other GE inputs. Currently, organic farming is practiced by less than 2% of U.S. farmers.

We believe that the broader goals of ecologically responsible farming, and the adherence to those ideals, are more important than the methods used to develop new plant varieties. To this end, we have generated a list of key criteria to help guide policy decisions about the use of GE in food and farming (Table 3). Farmers, consumers, and policy makers can better evaluate the usefulness of a particular crop variety or farming technique by using these criteria. By looking beyond the ideologies and ahead to a shared vision, we hope to better achieve these goals.

We hope that consumers, farmers, and policy decision makers will begin to make food choices and policy that will support ecologically responsible farming practices. Consumers need accurate information about genetically engineered crops and their potential impacts on human health and the environment. They wish to know more about the food they eat, besides just how to prepare it. Science-based decision making is needed to ensure the health of our families and for the future of our planet.

Conflicts of interest

The authors declare no conflicts of interest.