Are organic agriculture and biotechnology compatible?

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Two agricultural issues that have gained considerable public attention are organic agriculture and the use of products from biotechnology. Oftentimes, these are viewed in opposition to each other. In this paper, I hope to bring out some of the major issues about organic agriculture and biotechnology so a more informed discussion can occur.

Question: What is organic agriculture?

Answer: The practice of organic agriculture has developed over decades. Rudolf Steiner's work in Germany on biodynamic agriculture is often considered the basis for modern organic agriculture, but J.I. Rodale popularized the term "organic agriculture" beginning in the mid-1940s. Today organic plant production has come to mean using farming practices without inputs of synthetic fertilizers or synthetic pesticides (herbicides, fungicides, and insecticides). There are similar restrictions for animal agriculture (e.g., no artificial hormones), but this article will limit its scope to plant agriculture because that is the larger segment of agriculture. For a discussion on animal biotechnology, see the related articles on this site.

Initially, organic agriculture was largely unregulated and what was an acceptable practice for one farmer or consumer was not necessarily acceptable for others. In the U.S., groups of organic practitioners developed local and regional sets of practices. Beginning in 1990, the U.S. Department of Agriculture (USDA) became more involved in regulating organic agriculture to help stem the confusion about what it meant and to harmonize labeling practices.

In 2000, the USDA, together with many organic agriculturalists, formed the National Organic Program (NOP) (www.ams.usda.gov/nop/). The NOP defines organic agriculture as "a production system that is managed and responds to site specific conditions by integrating cultural, biological and mechanical practices that foster cycling of resources, promote ecological balance and conserve biodiversity."

For a product to be labeled as organic under NOP, there are several requirements. The main differences between USDA's organic regulations and USDA's conventional farming regulations include: mandatory certification for organic farmers; land must be free of synthetic fertilizers and synthetic pesticides for at least three years; farms must have buffers with nonorganic land; and organic farmers may only use nonsynthetic biological, botanical, or mineral inputs or substances that are included in a national list for insect, weed, or disease control (www.omri.org).

In other words, all natural fertilizers and pesticides are allowed, unless explicitly forbidden (e.g., strychnine) and all synthetic compounds are banned unless explicitly permitted on the national list. Synthetic compounds are approved for use in organic agriculture when there are no organic alternatives. Worldwide, there are still different standards for organic agriculture. Sales of organic foods have grown by an estimated 20 percent per year in the U.S. (see table below).

Insects, weeds, and pathogens can cause crop losses in organic agricultural systems, just as they can in other types of farming systems. Organic agriculture relies on cropping practices and on pesticides to prevent crop losses and information on acceptable pesticides can be obtained at http://www.nysaes.cornell.edu/pp/resourceguide/. Additional information on organic pest management practices is available in a recent book by Gillman (Gillman 2008).

Organic food sales in the United States from 1997 to 2005 (Source: Organic Trade Assn., 2006)

Question: What are biotechnology and genetic engineering and how are they used in agriculture?

Answer: Biotechnology is not a farming system but a set of tools that can be used in multiple farming systems. Biotechnology, or biotech, involves methods of using plants, animals, or microbes, either wholly or in part, to make or modify a product or change an existing organism (http://www.nysaes.cornell.edu/comm/gmo/). Some biotech involves the use of genetic engineering, as well as many other technologies commonly used for decades. For example, some types of biotechnology have been used to develop plants that are routinely used in both

conventional and organic farming. This includes techniques such as marker-assisted breeding and mutation breeding (see article on genetic modification of crop plants) that have produced many plant varieties in use today.

Genetic engineering is one form of biotechnology that is not allowed in organic agriculture. It involves copying a gene from one living organism (bacteria, years, fungi, plant, or animal) and adding it to another living organism. Today's breeders define a genetically engineered organism as an organism that has been modified using genetic engineering techniques in which only a small piece of one organism's genetic material (DNA) is inserted into another organism.

Products of genetic engineering are often commonly referred to as "genetically engineered organisms" or "GE products" or "genetically modified organisms" or "GMOs." Since plants and animals have been selectively bred for more than 10,000 years, they have all been "modified," so scientists tend not to use the term "genetically modified." Products developed through genetic engineering are more properly referred to as "GE products" (http://www.nysaes.cornell.edu/comm/gmo/).

Question: Does organic agriculture allow the use of GE products?

Answer: The intentional use of GE products is not allowed in organic agriculture at this time. This distinction can be made most apparent by using the example of a commonly used insecticide, a naturally occurring bacterium called *Bacillus thuringiensis* (Bt). Bt contains proteins that are toxic to some insects when they consume foliage sprayed with Bt (see article on Bt). Bt is an insecticide commonly used by organic growers and many conventional growers.

Genes from Bt have been engineered into some crop plants (presently corn and cotton) so that the plants express essentially the same proteins as if Bt were sprayed onto the plant. Much better insect control is achieved with Bt plants than when Bt is sprayed onto plants because the coverage is superior and multiple applications are not required. However, Bt plants are not permitted under NOP standards. The NOP also does not allow use of virus-resistant plants produced through genetic engineering (see article on virus-resistant plants).

Question: Does biotechnology allow the use of organic practices?

Answer: Biotechnology is not a farming system but rather a set of tools that can be used in any farming system that allows such tools. Thus, farmers who use GE crops can also use any suitable practice that is also used in organic agriculture. For example, a fundamental tenet of good organic agriculture is to have healthy soil. This is achieved through maintaining soil structure, ensuring proper nutrient recycling, and ensuring sufficient organic matter in the soil. This is the same goal for conventional growers. Thus, conventional growers may use organic practices, as well as other practices not allowed in organic agriculture, to achieve this end. One example of

this is that conventional growers can use GE crops for weed management, rather than plowing, and this will help retain soil structure and reduce erosion.

Question: What is the rationale in the NOP for organic agriculture not permitting the use of some forms of biotechnology such as GE crops, while allowing biotechnology to be used to help develop non-genetically engineered crops?

Answer: In my opinion, this decision was made by organic growers who varied in their reasons for excluding GE crops and other forms of genetic engineering. Some may have been concerned about biological issues while others may have based their decisions on philosophical arguments. The organic community, like most groups of people, is not monolithic and some organic growers have expressed interest in using GE crops to control hard-to-manage soil diseases and other pests.

For an interesting discussion on this issue, I suggest the 2008 book, *Tomorrow's Table* (Ronald and Adamchak 2008) that was written by a husband-and-wife team in which the husband is a long-term organic farmer and the wife a professor of plant pathology at the University of California, Davis, who helps develop GE crops.

Question: Are the goals of farmers who practice organic agriculture different than farmers who use tools of biotechnology such as GE crops?

Answer: I don't think they are different. I work with organic farmers and conventional farmers who use the tools of biotechnology and both must use economically viable practices to ensure a decent and sustainable livelihood. Fundamentally, they are both producers of food and fiber who wish to use practices that have the least amount of negative impact on human health and the environment. As in any comparison, there are more or less capable organic and conventional farmers.

In meetings with organic and conventional farmers, I have repeatedly heard both sets agree that they have far more in common than most nonagriculturalists think. In fact, many conventional farmers who use GE crops also set aside part of their farms to grow crops organically according to NOP standards. This takes good farm and business planning but allows conventional farmers to diversify their markets.

Question: Why are products of organic agriculture generally more expensive at the market?

Answer: The premium paid for organic produce varies by crop, but is generally at least 20 percent higher (see figure below from Stevens-Garmon et al. 2007). This is largely the result of increased production costs by organic farmers and the generally lower yields of many organic

crops. In a 21-year study of agronomic and ecological performances of organic and conventional farming systems in Central Europe, investigators found crop yields to be 20 percent lower in an organic system than in a conventional system (Mäder et al. 2002).

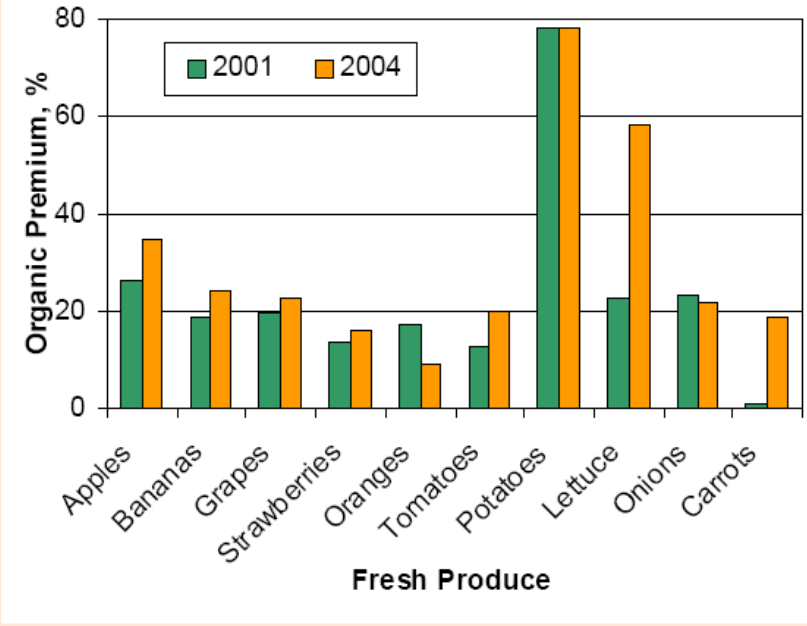


Figure 3. Average price premiums as % of conventional price for the top 10 most valuable organic produce.

Question: Why is organic agriculture often associated with small-scale, local production?

Answer: Local production simply means the crop was grown and processed locally, and has nothing to do with whether it was produced using organic practices or GE plants. Likewise, seeds and other inputs (e.g., machinery, energy, and pesticides) used in organic agriculture have similar off-farm sources as conventional farming. Small-scale farming also is not unique to organic growers. In fact, many organic farms follow the large-scale, industrialized model, as described in Michael Pollan's *The Omnivore's Dilemma*. What ultimately defines organic farming is not its scale or location, but adherence to the NOP standards.

It is also important to emphasize that organic is not synonymous with sustainable. As stated by Jeff Gillman in his 2008 book, *The Truth About Organic Gardening: Benefits, Drawbacks, and the Bottom Line*, those who are simply replacing synthetic inputs with organic ones are missing the point. To be sustainable, farmers must reduce inputs. Thus, conventional farming that uses GE crops or organic agriculture can be sustainable or unsustainable, depending on how it is carried out.

Question: Is organic agriculture safer than conventional agriculture, including when GE crops are used?

Answer: Simply put, no. From the standpoint of the final product delivered to the consumer, some studies have shown that organic produce has fewer synthetic pesticide residues, and this might sound reassuring. However, the situation is more complicated since such studies have not measured residues of organic pesticides, some of which are much more harmful to humans and the environment than their conventional counterparts. Furthermore, for all pesticides, whether conventional or organic, the amount that remains on the harvested crop must be under a mandated tolerance for safety or is subject to legal action. Finally, one should consider the fact that if pesticides were not used (and therefore no residues occurred) this would result in lower crop yields, more damaged produce, and more produce with harmful microorganisms. For example, studies have indicated that use of GE corn for insect control has dramatically reduced the amount of hazardous mycotoxins, a known health hazard to animals and humans (Shelton et al. 2002). Mycotoxins remain a serious concern in organic corn.

The goal in agriculture should be to produce food with the least harmful effects on people and the environment, and this will require the use of the safest pesticides, whether they be ones approved for organic or conventional agriculture, including the use of GE crops. Organic agriculture tends to rely more on what I would call "preventative pest management" since it has a limited number of pesticides that can be used. Such practices should be encouraged for all growers.

The question of safety gets even more complicated because of the pesticides that are allowed in organic agriculture. The rules of organic production primarily allow nonsynthetic pesticides (www.omri.org). However, just because something is natural (i.e., nonsynthetic) does not mean it is safer. For example, organic growers are allowed to use sulfur for disease control, but sulfur is a broad-spectrum pesticide and is far more hazardous than most, if not all, synthetic fungicides.

In a comparison study of the production of apples in the northeast, organic practices resulted in a 10-fold higher environmental impact quotient (a measure of potential environmental damage caused by pesticides) than growers who used synthetic pesticides in an overall integrated pest management program (IPM) (http://nysipm.cornell.edu/publications/eiq/default.asp). This clearly indicates that natural is not always better. IPM, like organic, is a set of defined farming practices but can be considered a safer method of pest management since it encourages the farmer to select the safest and most effective management tool, including GE plants and some practices of organic agriculture. Most farmers in the U.S. and many other countries follow the principles and practices of IPM.

Question: Is the nutritional composition of foods produced with organic agriculture different?

Answer: Organic produce is not nutritionally superior to conventionally produced food. In a review of the available literature, Winter and Davis (2006) found that organic and conventional produced foods may differ on some levels, but they concluded that there is no evidence that "either food system is superior to the other with respect to safety or nutritional composition." In the end, food freshness is much more important to nutrient value than whether it was grown organically or conventionally.

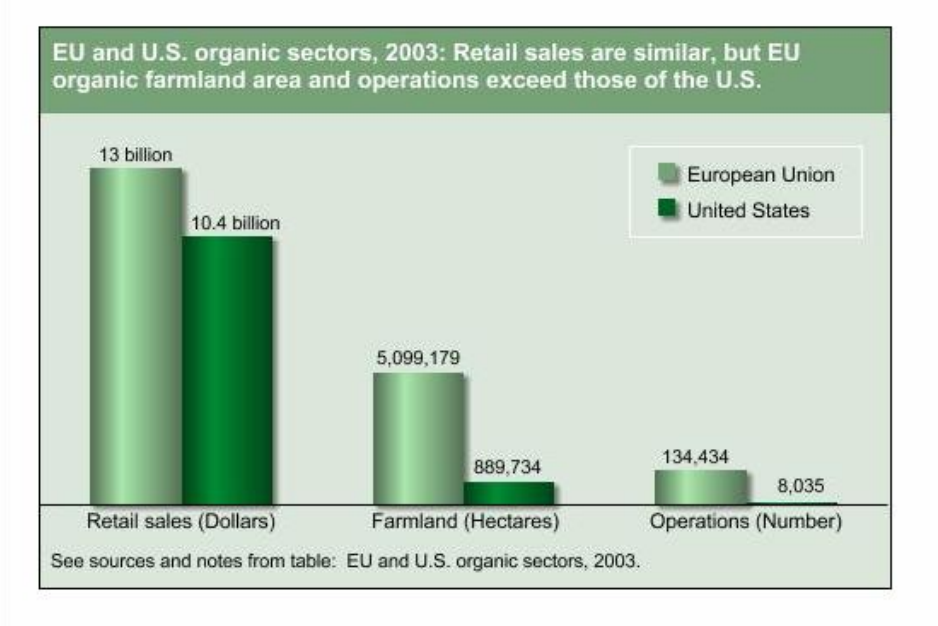
Question: Have GE crops for pest management provided any environmental and health benefits?

Answer: For insect and disease management, the only GE crops presently available are corn and cotton produced to resist insect attack (see article on Bt crops) and squash and papaya for virus resistance (see article on virus resistant crops). Studies have shown that Bt cotton resulted in a 22.9 percent reduction in the use of insecticides and reduced the environmental impact quotient (EIQ) by 24.6 percent, while Bt maize reduced insecticide use by 5.0 percent and the EIQ by 5.3 percent (Brookes and Barfoot 2008). GE virus-resistant squash and papaya have largely eliminated the need to spray for aphids since they are the vectors of the viruses that attack these crops.

GE crops have also been developed for weed management and, according to the same report, have reduced the amount of herbicides (and corresponding EIQ values) in soybeans by 4.4 percent (20.4 percent), corn by 3.9 percent (4.6 percent), cotton by 14.3 percent (14.5 percent) and canola by 12.6 percent (24.2 percent). Studies have also indicated that use of Bt corn for insect control has dramatically reduced the amount of hazardous mycotoxins, a known health hazard to animals and humans (Shelton et al. 2002).

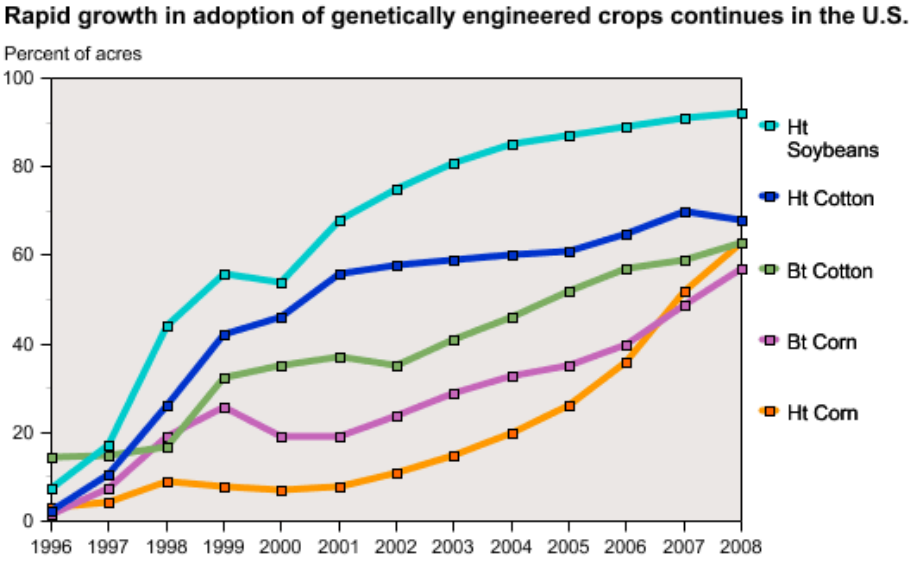
Question: How extensive is organic agriculture in the U.S. and the rest of the world?

Answer: The value of organic products in the U.S. has grown rapidly to an estimated $13.8 billion in 2005, yet this represents only about 2.5 percent of the total food sales. Fruits and vegetables constitute the largest sector of organic agriculture with over 40 percent of sales. In 2005 there were 8,493 certified organic farms in the U.S. and the leading production states, based on acres of organic production, were California, North Dakota, and Montana. The global organic market sales in 2006 were about $36.7 billion. The European Union (EU) and the U.S. market dominate the global sales of organic agriculture with relatively the same value.



Question: How extensively are GE crops planted in the U.S. and the rest of the world?

Answer: According to USDA's National Agricultural Statistics Service (http://www.ers.usda.gov/Data/BiotechCrops/), the adoption of GE crops has been rapid and steady since they were first commercialized in 1996 (see table below). By 2008, the majority of corn, cotton, and soybeans grown in the U.S. were GE crops, grown for either herbicide tolerance (HT) or insect resistance (Bt). In 2007, the total area planted to GE crops in the U.S. was 57.7 million hectares (142.6 million acres).



Data for each crop category include varieties with both HT and Bt (stacked) traits.
Source: 1996-1999 data are from Fernandez-Cornejo and McBride (2002). Data for 2000-08 are available in tables 1-3.

Although it is claimed that organic is the fastest-growing segment of the agricultural sector, the growth in GE crops has been far greater (see figure below, left). In 2008, GE plants were grown in 25 countries (15 developing countries and 10 industrial countries) on 308 million acres, by an estimated 13.3 million farmers (see figure below, right, http://www.isaaa.org).

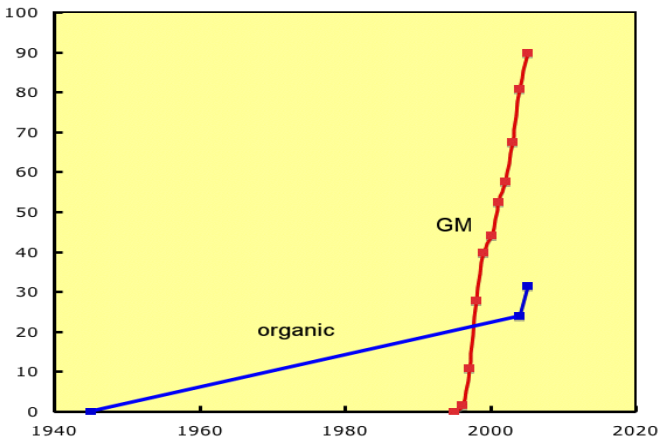


Figure courtesy of V. Moses

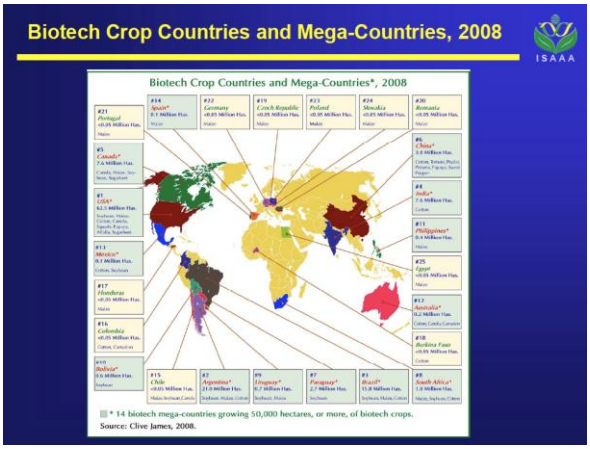


Figure from http://www.isaaa.org

Question: A frequently heard claim is that pollen from a GE field will 'contaminate' organic crops and lead to loss of their organic status. Is this true?

Answer: No. While the intentional use of most synthetic products and of GE crops is forbidden in organic agriculture, their unintentional presence is permitted. Synthetic pesticide residues are permitted at 5 percent of the EPA tolerances. In the U.S. there is no threshold for the presence of GE in an organic crop (the European Union Standard is 0.9 percent) but, as far as I know, no farmer in the U.S. has lost certification due to the unintentional presence of a GE crop (see the article on legal liability issues). The organic regulations read as follows:

> *As long as an organic operation has not used excluded methods and takes reasonable steps to avoid contact with the products of excluded methods as detailed in their approved organic system plan, the unintentional presence of the products of excluded methods should not affect the status of an organic product or operation.*

www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELDEV3004452

Question: What's the bottom line about organic agriculture, biotechnology, and the use of GE crops?

Answer: Organic agriculture has contributed many positive aspects to agricultural production such as an increased awareness of the value of soil health and preventative pest management. Likewise, biotechnology has contributed to organic agriculture through better means of developing crop varieties and increasing our ability to study processes such as nutrient management and other biological processes. However, plants developed through genetic engineering, a specific form of biotechnology, are not permitted in organic agriculture at this time but have been adopted by farmers worldwide and provided positive benefits to the general public by helping to reduce pesticide use and increase profits for growers. Some organic growers have expressed an interest in using GE crops.

From an environmental and human health safety standpoint, studies have indicated that the products produced with organic agricultural practices are no safer than those derived from biotechnology, such as GE plants. In fact, in some cases GE plants have proven to be safer, e.g., reduced mycotoxins.

It is unfortunate that discussions about biotechnology and organic agriculture often pit one against the other. From the perspective of this scientist who seeks effective solutions that are safer for the environment, and which produce safer products that people need and enjoy, there is no reason to dichotomize between organic agriculture and biotechnology. Biotechnology, including GE plants for pest management, is simply a set of tools that can be used in IPM to provide a safer food system.

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