



FAILURE TO YIELD

Biotechnology's Broken Promises

Genetic engineering has been touted as a major solution to the global hunger problems that are expected to worsen as the world's population grows. But a new analysis of this industry's nearly 20-year record in the United States shows that, despite proponents' claims, genetic engineering has actually done very little to increase the yields of food and feed crops. Given such a track record, it appears unlikely that this technology will play a leading role in helping the world feed itself in the foreseeable future.

There is a new urgency, prompted by recent spikes in food prices around the world, to boost global food production in order to feed a rapidly growing population. In response, the biotechnology industry has made optimistic claims about the ability of genetically engineered (GE) crops—in which the plant DNA is changed using spliced genes that are often from unrelated organisms—to substantially increase farmers' yields.

But are those claims valid? For the answer, the Union of Concerned Scientists carefully examined the industry's record in the United States, where GE crops have been commercially grown since the mid-1990s and where the best and most extensive data are available.

Because our focus was food production, we reviewed the data on soybeans and corn, the main GE food/feed crops. Soybeans engineered for herbicide tolerance currently account for more than 90 percent of all U.S. soybean acres planted, and GE corn makes up about 63 percent of the national corn crop. Within the GE corn varieties, some are engineered for herbicide tolerance; others contain genes from the *Bacillus*

thuringiensis (*Bt*) bacterium, which render the plants resistant to several kinds of insect pests; and some have both types of genes. Now that these crops have been grown commercially for 13 years, there is a wealth of data on yield under well-controlled conditions. But our investigation of yield data for these GE crops shows that genetic engineering is not living up to its promise.

As described in our report, *Failure to Yield: Evaluating the Performance of Genetically Engineered Crops*, we found that since the commercial introduction of GE food crops in the United States:

- Herbicide-tolerant (HT) GE soybeans and corn have not increased yields any more than conventional methods that rely on commonly available herbicides.
- Insect-resistant *Bt* corn varieties have provided an average yield advantage of just 3–4 percent compared to typical conventional practices, including synthetic insecticide use.
- Meanwhile, non-GE plant breeding and farming methods have increased yields of major grain crops by values ranging from 13–25 percent.



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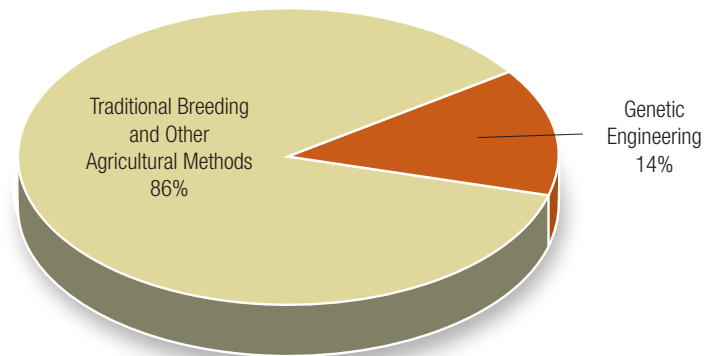
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Genetically engineered herbicide-tolerant soybeans, like the ones planted in this field, use large amounts of herbicides but produce no operational yield gains.

Contribution of Genetic Engineering to U.S. Corn Yield Increase, Early 1990s to Present



Per-acre corn production in the United States has increased 28 percent since the early 1990s. Genetic engineering is responsible for only 14 percent of that increase (or 4 percent of total U.S. yield increase); the majority of the increase is attributable to traditional breeding and other agricultural methods.

The Real Dirt on Genetic Engineering and Crop Yield

There are two kinds of crop output measures: intrinsic yield and operational yield. Intrinsic yield reflects what could be achieved if crops were grown under ideal conditions; it also may be thought of as potential yield. By contrast, operational yield is what is obtained under actual conditions, where plants are subject to pests, drought stress, and other environmental factors. Genes that improve operational yield do so by reducing losses from such factors, but because they do not also increase potential yield they will probably not be sufficient to meet future food demand.

In examining the record of GE crops in raising both types of yield, we found:

1. Genetic engineering has not increased intrinsic yield.

No currently available GE varieties enhance the intrinsic yield of any

crops. The intrinsic yields of corn and soybeans did rise during the twentieth century, but not as a result of GE traits. Rather, they were due to successes in traditional breeding.

2. Genetic engineering has delivered only minimal gains in operational yield.

The best available data suggest that HT soybeans and corn have not increased operational yields in the United States, whether on a per-acre or national basis, compared to conventional methods that rely on available herbicides.

Bt corn varieties, engineered to protect plants from either the European corn borer or corn rootworm, have fared better, but only slightly so. They provide an operational yield advantage of about 7–12 percent compared to typical conventional practices, including insecticide use—but *only when insect infestations are high*. Otherwise, *Bt* corn offers little or no advantage, even when compared to

non-GE corn not treated with insecticides. Both varieties of *Bt* corn together provide an estimated operational yield increase of about 3–4 percent averaged across all corn acres, given that most corn acreage does not have high infestations of target insects. Averaged over the 13 years since 1996 (when *Bt* corn was first commercialized), this result amounts to about a 0.2–0.3 percent operational yield increase per year.

3. Most yield gains are attributable to non-genetic engineering approaches.

The biotechnology industry promotes the idea that GE technology has steadily increased U.S. farm productivity over the past 13 years. But while U.S. Department of Agriculture (USDA) data do show rising crop yields nationwide over that period, most of those gains cannot be attributed to the adoption of GE crops.

Take the case of corn, the most widely grown crop in the United States. Corn yields increased an average of about 1 percent per year over the last several decades of the twentieth century—considerably more in total than the yield increase provided by *Bt* corn varieties. More recently, USDA data have indicated that the average corn production per acre nationwide over the past five years (2004–2008) was about 28 percent higher than for the five-year period 1991–1995, an interval that preceded the introduction of *Bt* varieties. But on the basis of our analysis of specific yield studies, we concluded that only 3–4 percent of that increase was attributable to *Bt*, meaning an increase of about 24–25 percent must have resulted from other factors, such

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Although genetic engineering receives disproportionate attention, traditional crop breeders have been more successful at raising yields.



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as traditional breeding (see the chart on p. 2). No increase at all was attributable to GE HT corn.

Yields have also risen in other grain crops, but not because of GE. For example, total U.S. soybean yield has increased about 16 percent since the early to mid-1990s, yet our analysis of the data suggests that GE technology has produced neither intrinsic nor operational yield gains in commercialized varieties. Perhaps most striking is the case of wheat, where yields have risen 13 percent during this period of time, *in the absence of any commercially grown GE varieties*.

4. Experimental high-yield genetically engineered crops have not succeeded, despite considerable effort by the industry.

USDA records show that GE crop developers have applied to conduct thousands of experimental field trials since 1987. More than 650 of the applications specifically named yield as the target trait, while some 2,400 others listed target traits—including disease resistance and tolerance to environmental stresses such as drought, frost, flood, or saline soil—often associated with yield. But only the *Bt* and HT varieties discussed above, along with five disease-resistant varieties (grown on limited acreage), advanced from the experimental stage and are now being grown commercially. If the numerous other yield-enhancing test varieties were going to achieve results worthy of commercialization, at least some of them would have done so by now.

Increasing Crop Yields— At What Cost?

Engineering crops for increased yield is a difficult proposition. Unlike *Bt* and HT genes, most genes that control yield also influence many other genes. These complex genetic interactions typically have multiple effects on the plant, and early research is confirming that such effects can be detrimental. Even when the added yield-enhancing genes work as expected, they may diminish the crop's agricultural value in other ways.

In some cases, these genes may also have a variety of indirect but no less important impacts. Since their beginning, GE crops have sparked considerable public controversy, with critics warning of possible adverse health effects (including new allergies or toxicity when these foods are eaten), environmental impacts (such as the creation of new or more aggressive weeds), and economic outcomes (as in the contamination of other food crops with new genes). With their greater genetic complexity, crops specifically engineered for increased yield will likely present even more side effects, which will not always be identified under existing regulatory requirements. Thus, improved regulations will be needed to ensure that harmful side effects are discovered and prevented.

Alternatives Provide Greater Promise

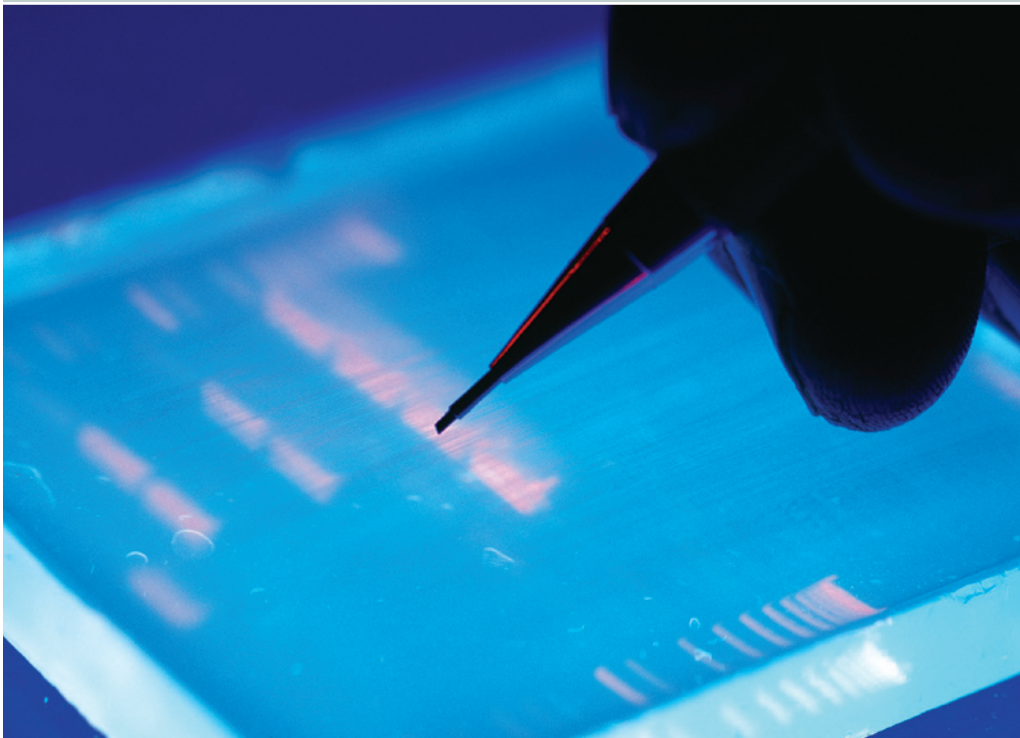
GE crops have received huge investments of public and private research dollars since their introduction. Yet

their minimal gains in yield stand in sharp contrast with the past gains and future potential of a suite of alternatives that require more modest initial investment and risk fewer potentially adverse impacts.

Traditional breeding has already proven itself capable of steadily increasing crop yields, and newer and more modern breeding methods are emerging. For example, high-tech genomic approaches (often called marker-assisted selection) use biotechnology—but not GE—to speed up the selection process for desired traits without actually inserting new genes from other species that could not mate with the crop. These approaches also have the potential to increase both intrinsic and operational yield.

Studies increasingly show the promise of agro-ecological farming methods. For example, farmers have long known that more extensive crop rotations, using a larger number of crops and longer rotations, can cut losses from insect pests and disease; such approaches also entail less reliance on pesticides than the corn/soybean rotations that currently dominate U.S. crop production. And research on low-external-input methods (which limit the use of synthetic fertilizers and pesticides) show that they can produce yields comparable to those of industrial-style conventional production methods (see the chart on p. 6). For example, non-GE soybeans in recent low-external-input U.S. experiments produced yields 13 percent higher than those of GE soybeans, although other low-external-input research and methods have shown lower yield.

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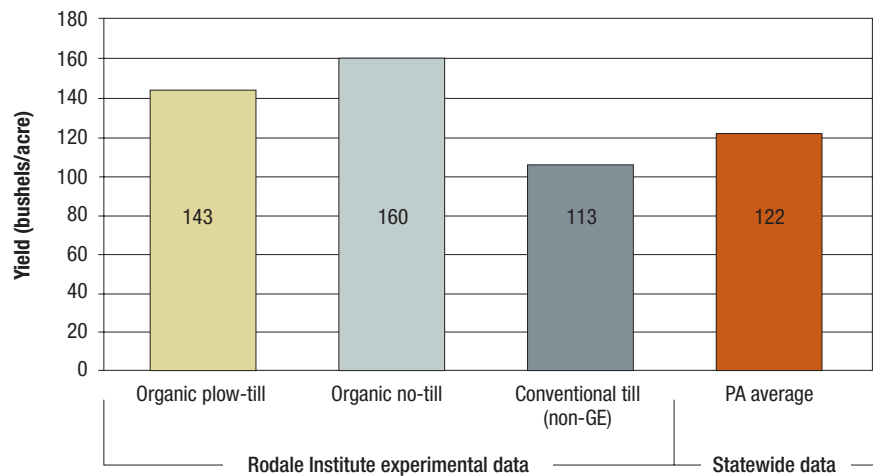


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At the Rodale Institute, Farm Manager Jeff Moyer oversees fields of organic and conventional corn.

Corn Yield Comparisons by Production Type, 2006



On its research farm in Kutztown, PA, the Rodale Institute conducts the nation's longest-running side-by-side comparison of corn yields resulting from various agricultural methods. As this graph illustrates, organic farming methods outperformed conventional methods for corn yield in 2006. Rodale's organic corn also yielded substantially more than the statewide average for all corn (most of which is raised conventionally). Statewide average data are from the U.S. Department of Agriculture National Agricultural Statistics Service.

It is important to keep in mind where increased food production is most needed: in developing countries (especially in Africa) rather than in the developed world. Recent studies in these countries have shown that low-external-input methods can improve yield by more than 100 percent. And there are other benefits. Such methods are based largely on farmer knowledge rather than on costly inputs such as synthetic pesticides and GE seeds, and as a result they are often more accessible to poor farmers. Considering these advantages, a recent international assessment—supported by the World Bank, several United Nations agencies, numerous governments, several hundred scientists, and other experts—recommended that GE play

a secondary role to organic and other low-external-input farming methods. The assessment also recommended improvements in infrastructure such as better water harvesting and grain storage and the building of new roads for market access.

Agriculture's Role in a Sustainable Future

While the need to increase food production is expected to become more urgent, awareness of the complex interactions between agriculture and the environment is also on the rise. Many of the predicted negative effects of global warming—including greater incidence and severity of extreme heat, drought, flooding, and sea-level rise (which may swamp coastal

farmland)—are likely to make food production more challenging. At the same time, it is becoming clear that the past century’s industrial methods of agriculture have imposed tremendous costs on our environment. For example, conventional agriculture contributes more heat-trapping emissions to the atmosphere than transportation, and it is a major source of water pollution that has led to large and spreading “dead zones” devoid of fish and shellfish (themselves important food sources) in the Gulf of Mexico and other bodies of water.

As the world strives to produce more food, it need not be at the expense of clean air, water, and soil and a stable climate. Instead, we must seek to achieve this goal efficiently and in ways that do not undermine the foundation of natural resources on which future generations will depend.

Summary and Recommendations

The world is not yet experiencing a global food shortage—overall food production continues to exceed demand. Still, recent price spikes and localized scarcities, together with growing population and food consumption, highlight the need to boost food production in the coming decades. Agriculture will need to come up with new tools for enhancing crop productivity, and in order to invest wisely, policy makers must evaluate those tools to see which ones hold the most promise for increasing intrinsic and operational yields.

To ensure that adequate yields—both operational and intrinsic—are

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Organic and other low-input farming methods are based on knowledge rather than costly inputs, and can be highly productive for small-scale farmers around the world.



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realized from major crops in the coming years, the Union of Concerned Scientists recommends the following:

- The USDA, state and local agricultural agencies, and public and private universities should direct research, funding, and incentives toward proven approaches that show more promise for enhancing crop yields than GE. These approaches include modern methods of traditional plant breeding as well as organic and other sophisticated low-external-input farming practices.
- Food-aid organizations should work with farmers in developing countries, where increasing the local levels of food production is

an urgent priority, to make these more promising and affordable methods available.

- Regulatory agencies should develop and require the use of more powerful methods for identifying and evaluating potentially harmful side effects of the newer and more complex GE crops. These effects are likely to become more prevalent, but current regulations are too weak to reliably detect them or prevent them from occurring in the first place.

For more information and to read the full report, visit www.ucsusa.org/FailureToYield.

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