UNDERSTANDING GENETICALLY ENGINEERED ORGANISMS
IN AGRICULTURE: *A SERIES OF WHITE PAPERS*

In spring of 2014 the Dean of OSU's College of Agricultural Sciences charged a faculty committee to review and summarize key considerations related to genetically engineered (GE) organisms. The committee chose five topics that engaged faculty expertise and that reflected public interest regarding GE organisms in agriculture.

Committee members drafted these white papers as a service to the public for the purpose of providing information from several scientific perspectives. These papers have been reviewed by all committee members and are intended to help inform public conversations about genetically engineered organisms in agriculture.

ECONOMICS OF GENETICALLY ENGINEERED CROPS IN AGRICULTURE: ISSUES FOR CONSIDERATION

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INTRODUCTION

The adoption of genetically engineered (GE) crops (also known as GMOs) in the U.S. began in 1996. It has been limited to a small number of crops, but now accounts for about half of U.S. cropland. By 2013, at least 90 percent of corn, cotton and soybeans planted in the U.S. were genetically engineered (Ervin 2014). Other GE crops include sugar beets and papaya. Internationally, GE crops have grown in economic importance, including soybeans in Argentina and Brazil, canola and corn in Canada, and cotton in China, India, Mexico, and Australia.

The information presented in this paper addresses questions about the economic and market effects of genetically engineered crops. Unless indicated otherwise the information is based primarily on the U.S. experience with soybeans, corn and cotton during the last 15 to18 years since these crops have been introduced and expanded. Given this relatively short period of time, some aspects of the long-term economic effects of these crops cannot be assessed based on available evidence. This caveat is relevant in particular to the effects of herbicide resistant weeds on farm-level costs and net benefits.

HOW HAS THE INTRODUCTION OF GENETICALLY ENGINEERED CROPS AFFECTED FOOD PRODUCTION AND FOOD PRICES?

Following the adoption and expansion of GE crops, many farmers have experienced lower costs of production. Many have obtained higher yields, mainly because of reduced pest damage by using GE insect-resistant crops.By contrast, yield increases for GE herbicide-tolerant crops have not been definitively documented. Many farmers have benefited economically from the adoption of genetically engineered Bt (*Bacillus thuringiensis*) crops by using lower amounts of or less expensive insecticide applications, particularly where insect pest populations were high and difficult to treat before the advent of Bt crops (Ervin et al. 2010).

Although it is difficult to isolate the yield changes due directly to the introduction of GE crops, studies have found U.S. yield gains to be only about 10 percent for cotton and 5 percent for Bt corn. These estimates are for the "gene effects" only, as distinct from the effects of also using other inputs (fertilizer, labor) to boost yield.

The effects of GE crops on total production (yields and acres) are more difficult to assess. Careful estimates have found that the overall effect on supply (due to both yield and acreage changes) varies from a low range of 2 to14 percent to a high range of 9 to19 percent of total corn supply (Qaim 2009; Barrows, et al., 2013; Sexton, and Zilberman 2013). The smallest estimates are for the U.S., Spain and South Africa.

It is difficult to evaluate how these production increases have affected market prices. One study has calculated that the adoption of genetically engineered corn lowered prices by 13 percent, and for cotton by 18 percent. For GE soybeans, the estimated price reduction ranged from 2 to 65 percent (Barrows et al. 2013). In general, however, the effect GE crops have had on prices received by farmers in not well understood (Ervin et al. 2010).

HOW LARGE HAVE THE ECONOMIC BENEFITS BEEN FROM GENETICALLY ENGINEERED CROPS, AND HOW HAVE THEY BEEN DISTRIBUTED AMONG PRODUCERS, CONSUMERS, AND SEED DEVELOPERS?

Increased production will generally lead to lower prices, which will benefit consumers but comes at the expense of farmers. A small number of studies estimate the share of the benefits accruing to farmers. One study concluded that the share of gains accruing to farmers was between 5 to 40 percent; seed developers were estimated to have captured 10 to 70 percent of the benefits; and the share going to U.S. consumers was estimated to be between 6 and 60 percent. Consumers in the rest of the world capture between 6 to 30 percent of the total benefits in other countries.

Some studies have found mixed evidence on the net return from adoption of GE crops. For example, a survey of evidence for net returns from adoption of GE herbicide-tolerant soybeans found that the evidence is inconclusive since some studies found no significant difference between net returns of adopters and nonadopters (Fernandez-Cornejo et al., 2014).

The global net benefit to producers from 1996 to 2009 has been estimated to be $65 billion, of which $30 billion accrued to U.S. producers (Brooks and Barfoot, 2012). Estimating the overall benefits of GE crops and the distribution of those benefits is an ongoing area of research.

The gains or losses to specific consumer and producer groups (e.g., GE crop producers versus non-GE crop producers) are difficult to predict. Some market analysis has concluded that all farmers who adopt GE crops do not necessarily gain from their introduction to the market; all consumers who object to GE crops do not necessarily lose from their introduction to the market; all farmers who refuse to grow GE crops do not necessarily lose because of their introduction; and all consumers who accept GE crops do not necessarily gain from their introduction (Desquilbet and Bullock 2009).

Another category of potential beneficiaries are farm workers. The data suggests that adopters of GE crops experience increased worker safety and greater simplicity and flexibility in farm management, benefitting farmers even though the cost of GE seed is higher than non-GE seed. Newer varieties of GE crops with multiple GE traits appear to reduce production risk for adopters (Ervin 2010).

HOW COSTLY WOULD IT BE TO LABEL GENETICALLY ENGINEERED COMMODITIES?

In order to label non-GE crops, they would have to undergo segregation and identity preservation which would involve additional costs for seed producers, farmers, and grain handlers in the U.S. Farmers would have to clean planting and harvesting equipment; product handlers would have to dedicate equipment and handling channels, one for GE crops and one for non-GE crops). For corn, an additional significant cost comes from preventing pollination of non-GE varieties by GE pollen at the seed and farm production stages. Tolerance levels are a key element of the costs of segregation (Bullock and Desquilbet 2002).

Very few studies have estimated the costs of segregation and identity preservation for crops like corn and soybean. Bullock and Desquilbet (2002) estimated the costs of on-farm segregation and identity preservation to be small ($0.07/ton). They estimated the costs of testing from farm to destination to be $0.87/ton for soybeans and $3.31/ton for corn.

In current segregated markets, such as exports to Japan, there is a premium price for non-GE products in the marketplace, but this cannot be interpreted as the additional costs of segregation and identity preservation alone because these premiums would also reflect the higher costs of production on-farm (due to lower yields, for example), and the demand-side willingness to pay a premium for non-GE products by some consumers.

Data from these export markets can provide an indication of the upper limits on these costs, however. Relying on the assumption that producers and contractors would not be willing to take a loss on these products, Bullock and Desquilbet infer from price data in exports to Japan that farmers contracting for non-GE soybeans receive a premium of $7.50/ton, and so this can be seen as an upper limit on the costs associated with non-GE segregation and identity preservation. Similarly in the case of handlers and exporters, Bullock and Desquilbet conclude that the additional costs for segregation and identity preservation in the marketing chain must be less than $20/ton.

Segregation and labeling of genetically engineered products could affect different consumer groups. Among consumers with different attitudes toward GE crops, it is difficult to know which group will benefit by the introduction and segregation of non-GE crops. A study of this topic finds, for example, that consumers who are indifferent toward genetic engineering may stand to lose more from their introduction than do consumers who oppose genetic engineering (Desquilbet and Bullock 2009).

ARE THE BENEFITS FROM GENETICALLY ENGINEERED CROPS SUSTAINABLE?

A full assessment of the sustainability of GE crops is an ongoing task, limited currently by information gaps on certain environmental, economic and social impacts. Ervin et al. (2010) reviewed existing peer-reviewed information and, with a focus on farm sustainability, concluded that genetic-engineering technology:

> "… has produced substantial net environmental and economic benefits to U.S. farmers compared with non-GE crops in conventional agriculture. However, the benefits have not been universal; some may decline over time; and the potential benefits and risks associated with the future development of the technology are likely to become more numerous as it is applied to a greater variety of crops."

In particular, when adopting herbicide-resistant GE crops, farmers substitute the herbicide glyphosate for more toxic herbicides. However, they say "the predominant reliance on glyphosate is now reducing the effectiveness of this weed-management tool.". Ervin et al. (2010) go on to indicate that:

“weed problems in fields of herbicide resistant crops will become more common as weeds evolve resistance to glyphosate or weed communities less susceptible to glyphosate become established in areas treated exclusively with that herbicide. Though problems of evolved resistance and weed shifts are not unique to herbicide resistant crops, their occurrence, which is documented, diminishes the effectiveness of a weed-control practice that has minimal environmental impacts. Weed resistance to glyphosate may cause farmers to return to tillage as a weed-management tool and to the use of potentially more toxic herbicides.”

Data reported in *Weed Science* indicate that herbicide resistance was found in an estimated 61.2 million acres nationwide in 2012, or about double the acreage found in 2010, based on a survey conducted by Stratus Agri-Marketing. Iowa State University weed specialist Mike Owen reports that the Iowa Soybean Association showed about 65 to 70 percent of Iowa soybean fields have resistant weeds to more than one herbicide (Iowa Soybean Association 2014).

Because pollen and seeds from many weed species can disperse between farms on equipment, animals, and in the air, the incentives are reduced to adopt best management practices that will maintain the effectiveness of glyphosate. This represents a “tragedy of the commons” problem when a farmer’s pesticide-use decisions do not take account of the effects on nearby farmers (Fernandez-Cornejo et al., 2014). This phenomenon has contributed to overreliance on glyphosate, a reduction in the diversity of weed management practices, and the evolution of glyphosate resistance in some weed species. Without interventions to change these incentives, the further evolution of glyphosate-resistant weeds can be expected to lead to higher management costs, reduced yields and profits, and increased use of less environmentally benign herbicides (Fernandez-Cornejo et al., 2014).

Other findings from Ervin et al. (2010) include:

- Adoption of herbicide resistant crops complements conservation tillage practices, which reduce the adverse effects of tillage on soil and water quality.
- Insecticide use has decreased with the adoption of GE insect-resistant crops. The emergence of insect resistance in Bt corn has been low so far and of little economic and agronomic consequence; two pest species have evolved resistance to Bt corn in the United States.
- Gene flow to non-GE crops has been a concern for farmers whose markets depend on an absence of GE traits in their products. The potential risks presented by gene flow may increase as GE traits are introduced to more crops.
- Given that agriculture is the largest source of surface water pollution, improvements in water quality resulting from the complementary nature of herbicide-resistance technology and conservation tillage may represent the largest single environmental benefit of GE crops. However, the infrastructure to track and analyze these effects is not in place.

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