The Impact of Biotechnology on Agricultural Worker Safety and Health

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Abstract

Biotechnology applications such as the use and production of genetically modified organisms (GMOs) have been widely promoted, adopted, and employed by agricultural producers throughout the world. Yet, little research exists that examines the implications of agricultural biotechnology on the health and safety of workers involved in agricultural production and processing. Regulatory frameworks do exist to examine key issues related to food safety and environmental protection in GMO applications. However, based on the lack of research and regulatory oversight, it would appear that the potential impact on the safety and health of workers is of limited interest. This article examines some of the known worker health and safety implications related to the use and production of GMOs using the host, agent, and environment framework. The characteristics of employers, workers, inputs, production practices, and socio–economic environments in which future agricultural workers perform various tasks is likely to change based on the research summarized here.

Keywords. *Worker safety and health, GMO, Agricultural safety, Biotechnology.*

In recent years, public attention and controversy have blossomed regarding the use and production of genetically modified organisms (GMOs) and other biotechnologies as agricultural inputs or produced as outputs. Two examples of genetically modified organisms used as agricultural inputs are Roundup–tolerant crops (e.g., corn, soybeans, canola, and cotton) and plants that carry a gene from the bacteria *Bacillus thuringiensis* (Bt). These two products of biotechnology research have been adopted more rapidly by farmers than any other comparable technologies in agricultural history (Fernandez–Cornejo et al., 2000; Riley et al., 1998). The purpose of this article is to explore the implications of GMOs and other biotechnology and genetic engineering applications in production agriculture on the safety and health of workers.

Little has been published documenting the human health and safety effects on workers who produce, handle, store, process, or otherwise have contact with genetically engineered inputs or products. This article examines the worker safety and health implications that result from exposure to genetically engineered inputs and outputs. In addition, the differential exposures that result from production practices,

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worker skills, and the knowledge needed to produce genetically modified products or use them as inputs during the production process will be discussed.

Background

The USDA broadly defines biotechnology as “the use of biological processes of microbes, and of plants or animal cells for the benefit of humans” (USDA, 2001). Grace (1999) defines biotechnology as “the umbrella term that covers various techniques for using the properties of living things to make products or provide services.” Such definitions would therefore include the use of yeast to make bread, or bacteria in yogurt production. Biotechnology, in the purest sense, has been around for hundreds of years, based on the above definitions. In recent times, many people have interchanged the terms “biotechnology” and “genetic engineering.” Genetic engineering is one specific technique within the science of biotechnology. According to Grace (1999), genetic engineering “allows us…to transfer the properties of a single gene from one organism to another.” Transferring a gene is done so that the target plant or animal into which the gene is placed expresses a desirable trait.

Genetically engineered crops can directly benefit the farmer by altering the inputs needed to produce a crop, such as herbicides or fertilizer. Other plants are designed to benefit the consumer when the end product expresses a desirable outcome, such as improved quality, nutritional content, or storability (Riley and Hoffman, 1999). The best way to understand this concept is to provide a few examples of genetically modified organisms that have been created by transferring (or manipulating) genes within a plant or animal used in agriculture.

Examples of genetic engineering to benefit the grower include:

- Glyphosate– or Roundup–tolerant soybeans — A gene from another plant is introduced into the soybean plant, allowing farmers to spray the crop with glyphosate herbicide. Most weeds die, decreasing competition for water, nutrients, and sunlight, but the desirable crop is left unaffected.
- Bt corn — A gene from a bacteria (*Bacillus thuringiensis*) is introduced into corn, cotton, and other plant types. The plants then produce the same protein crystal that the bacteria produce. This substance, now produced by the plant, is toxic to many types of damage–causing insects, including the European corn borer.

Examples of genetic engineering and biotechnology to benefit the consumer include:

- High–oleic soybeans — These plants produce soybeans that contain less saturated fat than conventional soybeans, leading to consumer health benefits, lower processing costs, and longer shelf life for the oil.
- High–lauric canola — An inserted gene allows the plant to produce an oil composed of 40% lauric acid, a key ingredient in many soaps, detergents, lubricants, and cosmetics.

Similar applications are occurring in animal agriculture. On the input side, a synthetic version of a naturally occurring hormone has been created using recombinant DNA methods (another practice within the science of biotechnology) to increase milk production in dairy cattle. Research is underway to develop low–phytate corn and other types of animal feeds that increase the availability of phosphorus in an animal’s digestive tract, meaning less phosphorus in the animal’s waste, thus reducing pollution and feed costs (Riley and Hoffman, 1999).

On the output side, experiments are occurring in laboratories throughout the world where transgenic animals are being created to produce beneficial products as a result of gene transfer. Examples include alpha–1–antitrypsin (AAT), a drug used in the treatment of cystic fibrosis, which can be produced in a transgenic sheep's milk (Harris et al., 1997). Another animal–related example is the production of recombinant antibodies that can be derived from goat's milk (Pollock et al., 1999).

Insects can be manipulated to benefit agriculture, too. According to an article in *The Wall Street Journal* (26 January 2001), some scientists hope to give beneficial insects, such as honeybees, immunity to diseases and pesticides, or develop a way to attack harmful insects without chemicals.

Public Health Framework

The public health framework is a method of looking at an issue and evaluating it from the perspectives of the host, agent, and environment.

Host

Host refers to workers. For this discussion, "worker" is defined as any person who provides labor in the agricultural production process. Migrant and seasonal farmworkers, farm owners and operators, family members, children, and contract laborers are included in this discussion.

Agent

The agent is generally referred to as the element performing or carrying out an action or event. The term "agent" in this article includes the physical components of GMO products or inputs. Examples include dust from Bt corn, and milk produced by transgenic pigs that contains a clotting agent to help people with hemophilia (Shreeve, 1999). Another example is the use of Roundup herbicide substituted for a mix of other herbicides that have traditionally been used.

Environment

Environment refers to the social and structural environment in which workers perform their jobs. In this article, water, soil, and air quality will not be covered. Instead, "environment" includes the abundance and potential overload of information from numerous public and private sources. As the structure of agriculture evolves, and as more products of biotechnology are adopted by producers, increasingly complex production and business relationships among input suppliers, producers, transporters, processors, and end users will be created. The concept of information technology as a part of this mix will be covered within the environmental discussion.

Analysis and Implications

Host

When examining host characteristics and how biotechnology might affect the health and safety of people working in agriculture, keep in mind that cause and effect relationships are not implied in this discussion. Numerous personal and socioeconomic factors are associated with the adoption of genetically engineered inputs and products. More research is needed to determine the true impact on the structure of production agriculture, as well as the socioeconomic characteristics of the people who will be the active users of these technologies. Many of the trends and directions that will be discussed are driven partly by technology but are also affected by other economic and social forces, such as global competition and changes in farm policy.

Dr. Mike Boehlje, agricultural economist, said in his 1999 speech *Megatrends in Agriculture*, "We will be moving from a system where we grow corn and raise pigs to an industry where we manufacture biological products with specific consumer–driven attributes" (Boehlje, 1999). Boehlje points out that this change is being driven by changes in biotechnology and information technology. This trend will influence the characteristics of the people who will be manufacturing these agricultural products.

Two studies suggest a strong positive association between technology adoption and level of education. In the case of recombinant bovine growth hormone (rBGH), a technology introduced in the dairy industry in the 1990s, studies in Wisconsin (Douglas, 1995) and New York (Stefanides and Tauer, 1998) show that rBGH adopters have higher levels of education. These rBGH adopters also operate larger farms and are more productive than rBGH non–adopters. As we look at other types of technologies, including computer and Internet use, this trend is confirmed, as adoption of technology is associated with farm size, total sales, level of education, and operator age, although adoption of technology goes down after age 44 (Wojan, 2000). It is difficult to predict what this might mean for agricultural worker's risk related to injury and occupational illness. More research is needed to examine relationships between level of education and farm size for people working in agriculture and their risk of work–related injury and illness. Only one case–control study was found in a review of the literature that suggested that increased education was a protective factor for machinery–related injury (Gerberich et al., 1998).

As we look at the mix of people and farming operations in the U.S., technology is supporting the trend toward larger–scale farming operations. According to the 1997 U.S. Census of Agriculture, 72.1% of total agricultural product value in the U.S. is generated by just 8.2% of the nation's farms (USDA, 1997). Boehlje (1999) suggests that the U.S. is moving toward an agricultural economy in which 90% of the product is produced by 10% of the agricultural population.

This trend toward increased technology does not necessarily signal the demise of small family–operated farms, at least not in the foreseeable future. The 1997 Census of Agriculture indicates that 50.3% of the nation's farms are quite small, with total product sales of less than $10,000, and nearly 75% have total sales below $50,000 (USDA, 1997). So there remain many small family farms, and a considerable amount of exposure to occupationally related hazards will continue in these operations.

Some of the same producer trends related to education and skill level are consistent between large–scale farms and successful small farming operations. Successful small farms are similar to larger operations (Perry and Johnson, 1999) in that they tend to:

- Use production strategies to control costs (e.g., forward pricing of inputs, diversification of production, land rental).
- Actively market their products (e.g., hedging, futures and options contracts, forward contracting).
- Adopt effective financial strategies (e.g., crop insurance, maintaining cash and credit reserves to take advantage of time sensitive business opportunities).

Small–scale farmers are more dependent on outside income to support their families (Hoppe et al., 2000). Working one or more off–farm jobs has important agricultural safety implications in terms of family members' exposure to hazards, level of adult supervision available for children, child labor, children's exposure to farm hazards, and stress and fatigue related health and safety issues.

The implications of host–level trends within the farming population and structurally related trends that are at least mediated by the adoption of biotechnology are summarized as follows:

- As farms continue to grow larger and as production becomes increasingly concentrated among a smaller group of producers, the need for additional non–family labor will likely increase. From 1992 to 1997, expenses allocated to hired labor in production agriculture did not change dramatically as a percentage of total product expenses, but expenses for contract labor did increase (USDA, 1997). Some labor–related economies of scale exist as farms grow larger, as is noted in the pork industry (Ben–Bellhassen and Womack, 2000), but labor demands are likely to remain high. The work of agricultural safety and health professionals with larger farms is considerably different than the traditional Midwestern model of working with small, single–family operations. Once a certain labor threshold is met, agricultural safety and health professionals and their clientele face many new challenges, such as regulatory compliance, occupational health screening, workers compensation, and other complex inter–related personnel issues (Boehlje et al., 1997).
- If the vision of many agricultural economists and futurists comes to fruition, then many of the farm operators who employ biotechnology to produce products will become part of a vertically integrated food system. For example, a Midwestern farmer might produce a genetically modified high–oil or high–protein corn for a specific food processor or livestock producer. Most often, this will involve farming under a contract that specifies the types of inputs to be used, such as seed, fertilizer, pesticides, and labor practices (Perry and Banker, 2000). This increased vertical integration could mean that occupational safety and health professionals will have a secondary market in which to influence safety– and health–related decisions among producers, who are working at the front end of a production process that extends from the field or feedlot to the consumer.
- As education increases among all producers, so will the producers' demand for information on a variety of production–related topics as well as their ability to process and use this information to make key decisions (Boehlje et al., 1997; Wojan, 2000). In terms of farm safety and health information, it will be important to provide information that is timely, is seen to have economic value to the producer, and can compete with a growing quantity of other production information.

Agent

The fastest growth in the on–farm input use of genetically modified organisms has been Bt and herbicide–tolerant crops. Little published literature exists documenting the specific worker–related exposure and risk implications of these two technologies. Heimlich et al. (2000) documented reductions in acre–treatments of pesticides between adopters and non–adopters of genetically engineered crops for 1997 and 1998. The GMO technologies examined by Heimlich et al. included Bt corn and cotton as well as herbicide–tolerant soybeans, corn, and cotton. However, the difference in the total quantity of pesticide active ingredient applied between adopters and nonadopters was small in 1997, with only a 331,000–pound difference (0.1%). This difference dropped to 153,000 pounds in 1998 (Heimlich et al., 2000).

To truly measure the potential worker health and safety impacts, it is important to consider the qualities of the pesticides whose quantities are reduced. This includes the pesticide's toxicity and level of environmental persistence. In the case of Roundup

Ready or glyphosate–resistant crops, the analysis by Heimlich et al. (2000) showed that for soybeans during the study period 1997 and 1998, 5.4 million pounds of glyphosate herbicide were substituted for 7.2 million pounds of imazethapyr, pendimethalin, and trifluralin. These herbicides are 3.4 to 16.8 times more toxic than Roundup and other types of commonly used soybean herbicides, according to EPA published risk indicators. Roundup has an environmental half–life of 47 days, compared to 60 to 90 days for the herbicides it typically replaces.

Similar benefits are potentially gained from the use of Bt products. In the case of Bt corn and cotton, the Bt proteins expressed in plant tissues are intended to take the place of externally applied insecticides. Betz et al. (2000) contend that Bt crops have been extensively tested and established as safe to humans, animals, and the environment. They specifically address worker health–related benefits by stating:

"Bt provides growers with built–in pest protection and also greatly reduces the need to transport, mix, apply, and dispose of externally applied chemical pesticides. The risk of misuse, ineffective timing of applications, and worker exposure to pesticide is virtually eliminated. Of course, the Cry protein does not protect against all pests; supplemental applications of external pesticides may be required even on Bt crops to control those pests not controlled by the specific Cry protein produced" (Betz et al., 2000).

The U.S. Environmental Protection Agency's human health assessment of Bt plant pesticides states:

"Despite decades of widespread use of *Bacillus thuringiensis* as a pesticide (it has been registered since 1961), there have been no confirmed reports of immediate or delayed allergic reactions to the delta–endotoxin itself despite significant oral, dermal, and inhalation exposure to the microbial product. Several reports under the Federal Insecticide Fungicide and Rodenticide Act (FIFRA) § 6(a)2 have been made for various *Bacillus thuringiensis* microbial products claiming dermal allergic reactions. However, the Agency determined these reactions were not due to *Bacillus thuringiensis* itself or any of the Cry toxins" (EPA, 2000).

Presumably, this mention of the possibility of dermal–related health effects is the EPA's response to the work of Bernstein et al. (1999), which stated: "Exposure to Bt sprays may lead to allergic skin sensitization and induction of IgE and IgG antibodies, or both." A careful analysis or replication of this work by Bernstein et al. (1999) is needed, since the reactions they observed and documented resulted from contact with externally applied Bt proteins, a common type of pesticide used in organic agriculture.

No published research was found examining the potential human health impacts of dusts associated with GMO crop or livestock products, including Bt plants or other types of approved GMO products. The issue was raised by Hansen (2000) of the Consumer Policy Institute at an EPA Science Advisory Panel, where he stated: "Corn dust can clearly convey allergens, and the pro–delta–endotoxin [found in Bt corn] is potentially allergenic, so there is ample evidence to be concerned about occupational exposure to grain dusts, especially corn." Additional research is warranted in this area.

Research conducted by USDA scientists and others indicates that Bt technology in plants can potentially reduce the incidence of fusarium and aspergillus ear rots and stalk rots in corn, potentially reducing the level of fumonisin and aflatoxin mycotoxins, which are known to have negative human health effects (Munkvold and Hellmich, 1999).

In southern Minnesota and northern Iowa in the late 1980s and early 1990s, there was tremendous interest related to the safety and health implications of youth riding as workers on bean bars. Bean bars are tractor–mounted devices, generally with two to four seats, mounted on a toolbar attached to the front of a tractor. Operators riding on these seats carried a spray gun, brush, or other type of application device used to spray or dab liquid herbicide onto volunteer corn plants or other weeds that rose above the soybean canopy. The use of genetically engineered herbicide–tolerant crops has dramatically reduced the amount of hand labor involved in removing weeds from certain crops, although this phenomenon has not been documented in the literature.

Hiring youth or migrant workers to walk through soybean fields with machetes and other sharp tools to cut down weeds was another common practice. With more than 60% of the soybean crop in the Midwest now herbicide tolerant, we see far fewer of these devices and practices in use. Similar reductions in hand labor have been documented among sugar beet producers in northwestern Minnesota and in eastern North Dakota (Dexter and Luecke, 2000). At this time, the labor reductions in sugar beets are due to changes in general herbicide technologies and not GMO technology, although adoption of herbicide–resistant sugar beet plants has the potential to eliminate hand labor for weeding this crop.

Little published literature exists that outlines the implications of GMOs and other biotechnologies on the practices used to produce, process, store, and transport agricultural materials. Based on events that led to unapproved genetically modified corn that entered the food stream in the fall of 2000 (Holzman, 2001), farm–level harvest, storage, processing, and transportation systems will need to become more sophisticated, and workers' exposure to hazards will change. The incident referred to above involved a specific type of Bt corn approved for animal feed but not for human consumption. Small quantities of this corn entered the human food stream in the U.S. Tests revealed that the unapproved genetic material was present in taco shells and other human food products.

Because of concerns related to cross–contamination of agricultural products, farmers producing several types of GMO products will have to carefully produce, harvest, handle, store, and process their products. Contamination between approved and unapproved corn varieties is not the only example. Riley and Hoffman (1999) explored several different crops currently being produced or in a development phase that will likely be higher valued than traditional commodity crops like No. 2 yellow corn. Examples cited include crops that are genetically engineered to produce unique proteins or to improve some critical nutritional component. Riley and Hoffman (1999) discuss the likely on–farm production of nutraceuticals. Nutraceuticals are described as:

"a category of biotech or conventionally bred crops designed to produce medicines or food supplements within the plant.... Researchers claim nutraceuticals, also called 'functional foods,' could conceivably provide immunity to a disease or improve the health characteristics of traditional food — e.g. canola oil with high beta–carotene content" (Riley and Hoffman, 1999; Shafer, 2000).

The production of higher–value products and products not designed for direct human consumption as food will increase the level of complexity and costs associated with harvesting, storage, drying, processing, and handling systems (Lin et al., 2000) including those found on farms. Many of these high–value products may be grown by companies or institutions that are not typically viewed as farmers or agricultural producers but that instead produce agricultural products in laboratories, greenhouses, or in other controlled settings. Workers producing these products will have many of the same exposures and risks of injuries that result from working with machinery, tractors, animals, and other hazards.

In the future, there will be need to design and develop new types of harvesters, including combines or other novel farming equipment. Operator safety must be part of this design process, as it now is with traditional farming equipment. Production of unique niche–market crops has the potential to increase the number and reduce the size of storage units. Most likely, new types of handling systems will need to be designed to avoid cross–contamination of GMO products and to ease cleaning of storage and handling systems (Lin et al., 2000). These new handling systems will have an impact on workers' exposure to confined spaces such as bins, silos, and other storage structures, presumably increasing exposure, as there would be an incentive to enter storage areas frequently to check on and monitor the condition of higher–value specialty crops.

Researchers are working on genetically modified fruits and vegetables. For example, a tomato has been developed with controlled ripening characteristics and extended shelf life. Another type of genetically engineered tomato contains genes to improve processing traits, including higher levels of pectin (McBride, 2000). Such developments could change the needs and characteristics of hand labor in production and harvest operations, thereby changing the mix of hand labor versus mechanization. Further increases in the level of mechanization could spur additional growth in farm size, as more acreage is needed to justify the cost of new or different production machinery.

Increased mechanization in fruit and vegetable production and in other production sectors that are heavily reliant on manual labor could escalate the use of custom machinery operations. With a custom operation, the cost of a harvester or other specialized machines needed to produce a GMO product can be spread across many farms. Again, this will change the mix of labor involved similar to the way that hired labor in a custom wheat combining crew differs from family labor on a small grain farm.

Production of genetically engineered animal products (or products of transgenic animals) presents additional challenges. In all probability, there will be farming operations in which transgenic animals (e.g., pigs, sheep, goats, cows) will be produced and their milk will be used for high–value medicinal products such as those described earlier. Transgenic animal operations will require specialized handling systems, milking equipment, processing facilities, and security systems to prevent animal escape, theft, vandalism, and other threats. These operations will require a specialized labor force that will need basic safety information related to livestock behavior, appropriate restraint equipment, personal protective equipment, and materials and feed handling practices. This new area of production, often referred to as "pharming," presents many opportunities and challenges.

As farms become more vertically integrated into a total production system, there is also the potential that additional on–farm processing may be needed to extract, preserve, or store the end products of genetic engineering practices. Presumably, this will be a highly specialized and technical area, and end–user companies will need to provide the production and processing expertise. Again, there may be additional safety and health implications related to chemical use and use of and exposure to microbes or enzymes used for processing, separation, extraction, or purification of products. As is the case with many of these new applications of biotechnology, simply working with the farmer will not be the most effective strategy. Because farmers will be part of an integrated production system, they will get much of their information from within that system, as opposed to relying on traditional external sources such as public–domain university research data, extension reports, and other sources. As agricultural safety and health professionals, we can meet these challenges by forming new relationships with private companies involved in the new systems that evolve.

Environment

Environmental changes will occur because of the changes in the people, inputs, products, and production systems that future agricultural producers will interact in and with. To summarize, these changes may include:

- Better–educated, larger–scale producers who are more apt to adopt new technologies and more open to new ideas.
- Producers who are less reliant on the production of raw commodity agricultural crops, livestock, and livestock products with specialized, niche uses. To make this type of production profitable, future farmers will enter into vertically integrated relationships with other businesses involved in production, processing, transportation, marketing, and end–product sales and distribution.
- The inputs, products produced, production practices, and their resulting exposures will continue to change. This will result in a more tightly vertically integrated food system.
- E–commerce will allow producers to purchase farm inputs and sell products electronically. Agricultural safety and health information could be added to these web pages to reach more producers.

There are a few other points related to this changing environment and the implications for farm safety and health that have not been discussed. As farmers and other related businesses become more intimately intertwined, it is likely that the public perception of farming will change, especially as it relates to the perceived agrarian lifestyle. A changing perspective could have a dramatic effect on the public's opinion toward currently acceptable practices, such as child labor within families or exemptions to labor regulations. This change in public perception is already apparent in the livestock industry, where public debate on zoning, odor, and environmental pollution is often intense and often juxtaposes non–agricultural and agricultural interests as well as large versus small farm interests. This debate is not likely to subside soon. Additional research is needed to study the net worker safety and health benefits and risks brought about by the structural and technological changes that will happen.

In terms of additional professional implications for the reader, many people are trained in basic agricultural human health and safety fundamentals. As the public debate intensifies around genetically modified food products, professionals may be called on to use their technical expertise and access to research–based information to help society evaluate the risks and benefits associated with this new technology. Agricultural safety and health professionals will at least need to make sure that work–related health and safety implications are considered by policy makers and by society as risks and benefits are assessed.

Many of our public and private partners with interests in funding programs related to protecting the health and safety of agricultural workers also have a stake in agriculture–related biotechnology applications. Many companies have invested heavily in genetic research and genetic engineering applications as they look toward to the needs of agriculture in this century. As we work with current and potential funders, we must understand and be aware of the forces shaping agriculture. We must be sensitive to and have knowledge of the real and perceived concerns raised by societies throughout the world.

Conclusion

This article has outlined just a few of the potential work–related health and safety implications, concerns, and opportunities related to the adoption of biotechnology inputs, products, and practices in production agriculture, as well as the implications associated with rapid adoption and use of information technology by farmers and ranchers. These concerns will affect the people involved; the types of products and inputs used in the production of food, fiber, and pharmaceuticals; and other future applications of biotechnology and genetic engineering. Most certainly, the environment in which our constituents and clientele produce and interact will also be directly impacted.

The risks brought about by the new practices and facilities needed to produce high–value GMO products are overlaid by the characteristics of the products themselves. Will we need new types of personal protective equipment? Will product dusts cause different types of health problems? Will silo gases, molds, and dusts generated by genetically modified products such as high–protein or Bt corn cause different reactions when inhaled as compared to traditional corn? There is clearly much work to be done in this area.

Worker safety related to GMOs and biotechnology in agriculture is an area where little work has been done. Yet millions of dollars have been spent on issues related to risk assessment of food safety and environmental protection. As agricultural safety and health professionals, we need to be proactive and provide a strong voice for the people whom we serve.

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