The Impact of Biotechnology and Information Technology on Agricultural Worker Safety and Health

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Introduction

In recent years, public attention and controversy have blossomed regarding the use and production of genetically modified organisms (GMO's) and other biotechnologies used as agricultural inputs or produced as outputs. Two widely used examples of genetically modified organisms used as agricultural inputs are RoundupTM tolerant corn, soybeans, canola, and cotton and other plants that carry a gene from the bacteria Bacillus thuringiensis (Bt). The Bt gene allows plants including corn and cotton to produce its own insecticide. These two products of biotechnology research have been adopted more rapidly by farmers than any other comparable technologies in agricultural history (Fernandez-Cornejo & McBride, 2000; Riley, Hoffman, & Ash, 1998). The purpose of this paper is to explore the implications of GMO and other biotechnology and genetic engineering applications in production agriculture on the health and safety of workers.

This is not an article about food safety, though there are valid points and considerations that justify the regulatory oversight related to food safety by the United States Department of Agriculture (USDA), Food and Drug Administration (FDA), and Environmental Protection Agency (EPA). These include potential health effects related to product toxicity, changes in nutritional qualities, allergenic properties, antibiotic resistance concerns, and other human health implications that are theoretically possible when humans ingest genetically engineered products (Donaldson & May, 1999; Frick, 1995). Nor is it the intent of this paper to explore environmental health implications in great detail, although there are implications related to changing products and practices such as pesticide use and toxicity, tillage practices (and water quality implications), pest resistance, and transfer of genes to other species (Cook, 1999; Wolfenbarger, 2000). In writing this paper I have tried to be objective and unbiased. I am neither endorsing nor casting doubt on the safety or viability of genetic modification of food products and inputs used in production agriculture. However, the fact that little published research exists related to the impact of GMO technology on worker safety and health suggests a need to make sure that potential risks and benefits to workers get appropriately weighed as regulatory officials and policy makers make decisions related to these products.

Embedded within the discussion of biotechnology and genetic engineering is information regarding the adoption of information technology, including the Internet and applications of e-commerce. Information technology will continue to play a role in the future work of professionals engaged in agricultural safety and health intervention activities. Biotechnology and information technology are symbiotic in terms of their potential economic impact for agricultural producers (Ackridge et al., 1997; Boehlje, 1999). The use of biotechnology and especially genetic engineering in production agriculture stems from science's knowledge of the information encoded in the genes of the plants and animals that farmers produce.

Farmers who are early adopters of many new technologies tend to operate larger farms. They are better educated. Their farms are more productive. In general, the productive use of technology requires that producers be more adept at locating, processing, recalling, and synthesizing information (Wojan, 2000). Likewise, the profitable use of biotechnology depends largely on farmers and agricultural workers possessing and using many of these same skills plus they must have timely and accurate information related to the food production and processing supply chain.

Agricultural safety and health professionals who work with the farming and food production industry to prevent injuries and occupational illness, will require basic knowledge of these trends in information technology as well as biotechnology to have maximum impact, success, and viability in the future.

What is Biotechnology?

The United States Department of Agriculture (USDA, 2001) broadly defines biotechnology as "the use of biological processes of microbes, and of plants or animal cells for the benefit of humans." 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. Obviously then, biotechnology in the purest sense has been around for hundreds of years. In recent times, many have interchanged the terms biotechnology and genetic engineering. Genetic engineering is one specific technique within the science of biotechnology. According to Grace, 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.

Desirable plant traits can directly benefit the farmer by altering the inputs needed to produce a crop (such as herbicides or fertilizer). Other traits are designed to benefit the consumer when the end product expresses a desirable characteristic such as improved quality, nutritional content, or store-ability (Riley and Hoffman, 1999). The best way to understand this concept is to provide a few examples where genetically modified organisms have been created by transferring (or manipulating) a gene(s) within a plant or animal used in agriculture. Below are a few examples from each of these categories representing genetic engineering applications (National Agricultural Library, 2000) within crop production.

Examples of genetic engineering and biotechnology to benefit the grower:

-- Glyphosate or RoundupTM 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 consumers:

-- Flavr SavrTM Tomato -- Tomato genes are manipulated allowing the fruit can stay on the vine for a longer period of time and ripen to full flavor. But, the tomato stays firm between the field and supermarket.
-- High-oleic soybeans -- Soybean plants produce beans that contain less saturated fat than conventional soybean oil, leading to consumer health benefits, lower processing costs, and longer shelf life.
-- High-lauric canola - A gene inserted into canola allows plants 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 & Hoffman, 1999).

On the output side, experiments are occurring in laboratories throughout the world where transgenic animals are being developed to produce beneficial products as a result of gene transfer. Examples include AAT, a drug used in the treatment of human cystic fibrosis produced by a transgenic sheep's milk (Harris, Andrews, Wright, Pyle, & and Asenjo, 1997). Another animal-related example is the production of recombinant antibodies that can be derived from goat's milk (Pollock et al., 1999).

Implications for the Health and Safety of Agricultural Workers

Little has been published documenting the human health and safety implications for workers who produce, handle, store, process or otherwise have contact with genetically engineered inputs or products. There are worker health and safety implications that result from exposure to genetically engineered inputs and outputs themselves. In addition, there are differential exposures that result from production practices, worker skills and knowledge needed to produce genetically modified products or use them as inputs during the production process.

Public Health Framework

These implications will be discussed using the traditional public health framework of host, agent, and environment (Green 1990; Murphy, 1992).

***Host* —** Host refers to the workers themselves. For this discussion, the term workers is broadly defined as any person who provides labor in the food production process. Migrant and seasonal farm workers, farm owners and operators, family members, children, and contract laborers are included in this discussion.

***Agent* —** In examining the agent, there are two parameters of interest. First, the term agent in this paper includes the actually physical components of GMO products or inputs. Examples would include the dust from Bt corn or milk produced by transgenic pigs that contain a clotting agent to help people with hemophilia or other pharmaceutical product (Schreeve, 1999). The second important agent category is the different mix of potential hazards that might result (or are resulting) from differences in using, producing, processing, storing, transporting, or managing genetically engineered products. For example, production of Roundup Ready soybeans results in a different mix of inputs and production practices. Roundup herbicide is substituted for a mix of other herbicides that have traditionally been used. The use of Roundup spray over the top of a soybean crop could render past practices such as youth riding on a bean bar herbicide applicator unnecessary or obsolete.

***Environment* —** Environment refers to the social and structural environment in which future agricultural workers will be producing food. In this discussion, the physical environment (water, soil, and air quality) will not be covered. The 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, there will be increasingly complex production and business relationships between input suppliers, producers, transporters, processors, and end-users. The concept of information technology being part of this new complex mix will be covered within this environmental section.

Host Implications

When examining host characteristics and how biotechnology might impact people and their health and safety risks related to agricultural work, keep in mind that cause and effect relationships are not implied in this discussion. There are numerous personal and socioeconomic factors associated with adoption of inputs and products that are genetically engineered, but more time and research is needed to determine the true impact on the structure of production agriculture and the socioeconomic characteristics of people who will be the active users of these technologies. Many of the trends and directions that will be discussed are being 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 people who will be manufacturing these agricultural products.
Several studies suggest a strong positive associations 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 1990's, studies in Wisconsin (Douglas, 1995) and New York (Stefanides & Tauer, 1998) show that rBGH adopters have higher levels of education. These

adopters also operate larger farms and are more productive than non-adopters. Looking at other types of technologies including computer and Internet use, this trend is confirmed as adoption is associated with farm size, total sales, level of education, and operator age, though adoption 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 the education level and farm size of 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 United States, technology is helping drive, or at least 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 fewer than ten percent (8.2%) of the nation's farms (USDA - National Agricultural Statistics Service, 1997). Boehlje (1999) suggests that the United States is moving toward an agricultural economy where 90% of the product is produced by 10% of the producing population.

However, 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 Agriculture Census indicates that 50.3% of the nation's farms are quite small with total product sales of less than $10,000; nearly 75% have total sales below $50,000 (USDA - National Agricultural Statistics Service, 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:

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

Smaller scale farmers are more dependent on outside income to support their families (Hoppe, Perry, & Banker, 2000). Working one or more off-the-farm jobs has important agricultural safety implications in terms of family member's exposure to hazards, level of adult supervision available for children, child labor, children's exposure to farm hazards other than while working, and stress and fatigue related health and safety issues.

The implications of host-level trends within the farming population and structurally-related trends which 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 - National Agricultural Statistics Service, 1997). There are some labor-related economies of scale as farms grow larger as is noted especially in the pork industry (Ben-Bellhassen & 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, 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 the farmer producing the product under a carefully written contract that will specify the types of inputs to be used such as seed, fertilizer, pesticides, and labor practices (Perry and Banker, 1999). This phenomena of increased vertical integration could mean that occupational safety and health professionals may have a secondary market that could help influence safety and health related decisions among producers who are working at the front end of an entire production process that extends from the field or feedlot to the consumer.

-- As education level of sophistication increases among all producers (large and small farms alike), so too will the producer's 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 (Wojan, 2000; Boehlje, et al., 1997). In terms of farm safety and health information, it will be important to provide information that is timely and is seen to have economic value to the producer and it must compete with a growing quantity of other production information.

Agent

Agent Issues Related to Inputs

The most rapid growth in the on-farm input use of biotechnology and genetically modified organisms thus far have been Bt crops and herbicide tolerant crops. Relatively little published literature exists documenting the specific worker-related exposure and risk implications of these two technologies. Heimlich et al. (2000) documented significant reductions in acre-treatments of pesticides between adopters and non-adopters of genetically engineered crops for 1997 and 1998. The GMO technologies examined 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 positive 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. The primary herbicides that Roundup replaces are 3.4 to 16.8 times more toxic than 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, Hammond, and Fuchs (2000) state that "Extensive testing of Bt-protected crops has been conducted which establishes safety of these products to humans, the animals, and the environment." They specifically address worker health-related benefits by stating that,

"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, Hammond, & Fuchs, 2000).

The Environmental Protection Agency's human health assessment of Bt plant pesticides (EPA, 2000), states that,

"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 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."

Presumably, this mention of the possibility of dermally-related health effects is EPA's response the work of Bernstein et al. (1999) that included a statement, "Exposure to Bt sprays may lead to allergic skin sensitization and induction of IgE and IgG antibodies, or both." A careful analysis of this work by Bernstein et al. (2000) 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. It appears more research is needed in this area.

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." Clearly, additional research is warranted in this area.

Research conducted by USDA scientists and others indicate 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 & Hellmich, 1999).

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 does not appear to have been documented in the literature. In southern Minnesota and northern Iowa in the late 1980's and early 1990's, 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 on liquid herbicide onto volunteer corn plants or other weeds that rose above the soybean canopy.

Hiring youth or migrant workers to walk through soybean fields with machetes and other sharp tools to cut down weeds within soybean fields 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 & Luecke, 2000). At this time, the labor reductions in sugar beets, are due to changes in general herbicide technologies and not necessarily to GMO technology, though adoption of herbicide resistant sugar beet plants has the potential to virtually eliminate hand labor for weeding this crop.

Agent Implication Related to Practices

Little published literature outlining implications of GMO's and other biotechnologies on the practices used to produce, process, store, and transport these products is available. One trend is clear 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 referenced 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) explore several different crops currently being produced or in a development phase that will likely be higher valued than traditional commodity crops like #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) also discuss the potential and likely on-farm production of nutraceuticals. This term is 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-caortene content" (Riley & Hoffman, 1999 and Shafer, 2000).

The production of higher-valued products and products not designed for direct human consumption as food will necessarily increase the level of complexity and costs associated with harvesting, storage, drying, processing, and handling systems (Lin, Chambers, & Harwood, 2000) including those found on farms. Many of these high-valued products may be grown by companies or institutions that are not typically viewed as farmers or agricultural producers, but instead, produce agricultural products in laboratories, greenhouses, or in other carefully controlled settings. Yet, 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 needs to design and develop new types of harvesters including combines or other novel farming equipment. Operator safety will need to be part of this design process as it now is with traditional types of farming equipment. Production of unique, niche market crops also 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, Chambers, & Harwood, 2000). This will have an impact on worker's exposure to confined spaces such as bins, silos, and other storage structures, presumably increasing exposure, as there would be an incentive to more frequently enter storage areas to check and monitor the condition of higher-valued specialty crops.

The new risks brought about by these new practices and facilities needed to produce high valued GMO products is 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.

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 needed in production and harvest operations, thereby changing the mix of hand labor versus mechanization. Further increases in the level of mechanization could continue to spur an increase 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 other production sectors that are heavily reliant on manual labor could increase the use of custom machinery operations since 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 or transgenic animals) presents additional challenges. Presumably, there will be farming operations in which transgenic animals (pigs, sheep, goats, cows) will be produced and their milk used to produce high valued medicinal products such as those described earlier. Transgenic animal systems will require specialized handling systems, milking equipment, processing facilities, and security systems to prevent animal escape, theft, vandalism, or other threats. These types of 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 commonly 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, 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. Since farmers will be part of an integrated production system, they will increasingly 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.

Environmental Implications

Environmental changes will occur because of the changes in the people, inputs, products, and production systems that future agricultural producers will interact in.

To summarize, these changes may include:

-- Better educated, larger scale producers, more apt to adopt new technologies, and be 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, and production practices and their resulting exposures will continue to change. This will result in a more tightly vertically integrated food system.

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 public perception will change regarding their image of farming, especially as it relates to the perceived agrarian lifestyle. A changing perspective could have a dramatic effect on the public's opinions toward now socially 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 related to zoning, odor, and environmental pollution is often intense and often juxtaposes non-agricultural and agricultural interests as well as big 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 structural and technological changes that will happen.

In terms of additional professional implications for the reader, many of us are trained in basic agricultural human health and safety fundamentals. Our training includes topics such as agricultural production practices, education, engineering, risk-benefit analysis, risk perception, hazard evaluation, hazard intervention, industrial hygiene, and personal wellness. Practitioners in this field often have a fundamental understanding of concepts such as human anatomy and physiology, toxicology, genetics, and injury and illness prevention. Agricultural safety and health professionals also have a broad knowledge of agriculture, including how food is produced, processed, and shipped. As the public debate intensifies around genetically modified food products, we may be called on to use our technical expertise and access to research-based information to help society evaluate the risks and benefits associated with this new technology. We 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 ag-related biotechnology applications. There are many examples of companies that 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 sensitive to the driving forces shaping agriculture. We must be sensitive and have knowledge of the real as well as the perceived issues raised by societies throughout the world.

Information Technology — A Key Environmental Factor

Recently published USDA - National Agricultural Statistics Service (1999) data indicate that nearly half of all U.S. farms now have a computer, and 29% of all farms have Internet access. More research is needed to determine the importance of the Internet in communicating agricultural safety and health to producers. Many land-grant universities and many other public and private institutions now have dedicated agricultural safety and health web sites. However, a survey by Tripp, Shutske, Olson, and Schermann (1998) of larger-scale pork producers in Minnesota and summarized by Shutske, Schermann, Tripp, and Olson (2000) indicates that the

Internet was among the least preferred information sources of worker safety and health information among the 19 listed on the producer survey. Additional research is needed to determine if agricultural producers' opinions related to the value of Internet-based safety and health content whether it is useful, or if their rankings have changed, since in most regions of the country, level of Internet access among farmers has more than doubled since this survey (USDA - National Agricultural Statistics Service, 1999). The quantity of on-line information available to producers has also increased dramatically.

This increase in Internet usage and exponential increase in available content is a double-edged sword. Just because farmers have access does not necessarily mean that they are seeking out information related to farm safety and health.

One trend is certain. The use of electronic commerce among agricultural producers is increasing. Morehart and Hopkins (2000) found that 15% of the farms with Internet access are using electronic-commerce to purchase farm inputs and sell products. A quick search of the Internet using "Google," a widely used search engine, shows 39 dedicated agricultural production e-commerce sites. These range from specialty sites that allow producers to match up unique products with buyers (such as a site that links licorice growers to candy manufacturers) to firms that allow growers to bid on traditional inputs like feed, fertilizer, crop chemicals, and veterinary supplies.

This trend toward increasing use of e-commerce is important because many of these commerce web sites are being set up also as information portals or one-stop information sources. For example, one website www.rooster.com allows customers to purchase farm input products and supplies, but it also contains information on commodity markets, weather forecasts, current farm news, and threaded e-mail lists allowing producers to exchange farming related knowledge and ideas. It appears that there are many opportunities to add farming health and safety related content on a variety of topics to these sites. Relationship building work is needed to sort out issues of intellectual property ownership, licensing, liability, and other farm safety and health content usage issues.

Conclusion

This paper has outlined just of 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 impact the people involved, the types of products and inputs produced and used in the production of food, fiber, 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. Worker safety related to GMO's and biotechnology in farming is an area where little work has been done. Yet millions of dollars have been spent on issues related on risk assessment related to food safety and environmental protection. As agricultural safety and health professionals, we need to be sensitive to the implications and provide a strong voice for the people whom we serve.

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