Agricultural Biotechnology: Dividends and Drawbacks

By Julie A. Stanley

Biotechnology is changing the face of agricultural production. Several biotech products are already used in the United States and many others are in late stages of development. With more widespread adoption these products offer substantial dividends, but they also have potential drawbacks.

All groups associated with production agriculture, therefore, will need to prepare themselves for both the positive and negative effects of biotechnology. Toward that end, this article first reviews the biotech products currently or prospectively in use. The article then examines the possible dividends and drawbacks of the use of biotech on such groups as farmers and ranchers, policymakers, agribusiness, agricultural bankers, and consumers.

Animal and Plant Biotechnologies

Biotechnology offers tremendous potential for improving animal agriculture and crop production. This section defines biotechnology and discusses animal and plant technologies that may help production agriculture in the near future.

What is biotechnology?

Biotechnology is the use of scientific techniques to improve animals or plants. Biotechnology focuses on genetic engineering—that is, on recombinant DNA and cell fusion procedures.[1] Under these procedures, scientists can transfer genetic material into animals and plants to control their characteristics. Biotechnology also includes the modern extensions of age-old tools of animal and

Julie A. Stanley is an assistant economist at the Federal Reserve Bank of Kansas City. Mark Drabenstott, a vice president and economist at the Bank, advised in the preparation of the article.

plant breeding.[2] In the past, animal and plant breeding efforts were aimed at entire organisms. Today, biotechnology concentrates on individual genes—and their associated traits—within an organism.

Biotechnology is superior to traditional methods of animal and plant breeding in speed, precision, and scope. Scientists can produce generations of animals and plants in the time of one traditional breeding season. They can also manipulate just one characteristic of an organism by locating and transplanting a gene that controls an economically important trait. Scientists also are able to transfer desirable characteristics between organisms that cannot be crossed sexually—for example, from an animal to a plant. In 1989, scientists exchanged genes between bacteria (an animal) and yeast (a plant), opening up wide possibilities for transferring traits between the animal and plant kingdoms (Booth and others).

How can biotech improve animal production?

Some biotechnologies have been used in animal production for more than a decade, while others are in the first stages of discovery and testing. This section examines how various technologies may affect livestock production and how quickly they may be available for use on U.S. farms and ranches.

Embryo transfer. Embryo transfer was one of the first tools of biotechnology used in livestock production, and its use is now widespread. Embryo transfer involves transferring multiple fertilized eggs, or embryos, from one mother to host mothers. As a result, a genetically superior animal can produce tens of offspring in a single breeding season. In use for more than a decade, the technology is still being refined and improved.

Livestock vaccines. Genetically engineered vaccines are a useful tool for livestock producers because normal antibiotics are generally ineffective in treating viral diseases in livestock. Normal antibiotics are unable to attach to an animal virus to kill or sterilize it. The protein in a genetically engineered vaccine, however, can attach to a virus and kill or deactivate it so it cannot reproduce.[3]

Vaccines are both therapeutic and preventive; that is, they help heal existing illnesses and ward off other illnesses. Genetically engineered vaccines were first introduced in 1985 when the government approved a vaccine against pseudorabies, a disease that costs U.S. swine producers up to $60 million annually (National Research Council). A vaccine for foot-and-mouth disease is also on the market. In the future scientists hope to develop a vaccine to control inflamation of the udder (mastitis), which affected 100,000 beef cows and 1.3 million dairy cows in 1990 (Doane Marketing Research Inc.).

Diagnostic tools. Monoclonal antibodies have proved to be multipurpose tools for livestock producers. Monoclonal antibodies are disease-fighting proteins produced by fusing a rapidly growing cell with one that produces an antibody to a particular substance, such as a hormone, virus, or bacteria.

These antibodies can be used to diagnose disease, monitor the efficacy of drugs, and develop therapeutic treatments and vaccines to immunize against certain diseases. Monoclonal antibodies have been used for treatments against both calf and pig scours, illnesses that affected nearly three million cattle and more than eight million swine in 1990 (Doane Marketing Research Inc.). Antibodies that detect time of ovulation in cows help to ensure the highest efficiency in breeding. A more recently marketed product is a detector for blue-tongue virus, which reduces growth and reproduction efficiency in cattle, sheep, and goats.

Growth promotants. Genetically engineered growth hormones could be the next widely used biotech product for improving livestock production. Such hormones, including bovine somatotropin (BST) and porcine somatotropin (PST), are naturally occurring proteins in cattle and hogs. The proteins can now be replicated in the laboratory and then administered to livestock to enhance productivity traits.[4] BST-treated cows may produce 10 to 40 percent more milk (Jacobs; National Research Council). PST-treated hogs have shown up to 30 percent greater feed efficiency and have also produced leaner pork (Boyd and others).

Growth hormones may be used widely in cattle and hog operations in a few years. BST was approved by the Food and Drug Administration in 1985 for use in trial dairy herds to evaluate its effects on milk production and on the animal itself. BST developers expect the hormone to be available to all dairy farmers within a year, although consumer resistance could slow or even derail full commercialization.[5] PST has been successfully administered to hogs in research trials and could be used commercially within a few years.

Transgenic animals. Designing transgenic, or genetically altered, animals is the major goal of animal biotechnology, but scientists are a long way from achieving it. This process involves injecting genes from another organism directly into the nucleus of a newly fertilized egg and thereby changing the growth and quality of the mature animal and its offspring.

Gene transfer is very complex in animals. Scientists have transferred genes into pigs, but the procedure is not consistently successful. In the future scientists hope to transfer the booroola gene, a gene from Australian merino sheep that controls the incidence of twins and triplets, into sheep and cattle to help improve production efficiency. Overall, scientists are studying many techniques that might produce transgenic animals, but the technologies may not be available until the next century.

How can biotech improve plant production?

Most genetic engineering discoveries in plant production have surfaced only in the past few years. Some products have been improving crop characteristics, altering microorganisms associated with plants, and controlling crop pests for many years. More advanced products with greater potential to affect U.S. crop production are still on the horizon.

Crop characteristics. Perhaps the most direct way biotechnology can improve crop agriculture is by genetically engineering plants—that is, by altering their genetic structure. The process of genetically engineering plants requires a scientist to locate and extract the desired gene and then insert it into a cell from the targeted plant. The scientist then induces the transformed cell to grow into an entire plant having the desired trait. For example, assume a scientist identifies a gene that would increase the protein content of corn. The gene must be inserted into the right place in the genetic code so that protein is added in the seed, not in the stalk or another part of the plant.

In one important breakthrough, scientists have recently produced plants resistant to herbicides. For example, glyphosate-resistant soybeans are now being field-tested in the United States. Glyphosate is a common herbicide that is both effective and environmentally safe. But because it indiscriminately kills crops as well as weeds, it can only be used before a crop germinates. Scientists have transferred a glyphosate-resistant gene from petunias into soybeans, a discovery that in a few years may allow growers to use glyphosate herbicide instead of herbicides that are more costly, less effective, and more damaging to the environment.

Scientists also hope to alter plants genetically to improve the nutritional qualities of grain. For example, scientists are developing high-oil corn hybrids to supply a more valuable feed grain. Livestock and poultry may gain weight more efficiently on corn that contains significantly more oil and protein than present commercial hybrids, resulting in feed cost savings for the producer. A company recently applied to the U.S. Department of Agriculture to begin field testing transformed corn plants.

Microorganisms. Microorganisms in the environment affect the growth of plants in both beneficial and harmful ways. Some microorganisms protect plants from bacterial or fungal infections, while others help protect plants from the stress of acidity, salinity, or high concentrations of toxic metals. Some microorganisms also attack weeds that compete with crops. Other microorganisms, such as certain bacteria and fungi, attack crops and cause disease. The Dutch Elm disease is a dramatic example of the damage a fungus can cause. This disease has killed millions of North American trees in the 20th century.

Through genetic engineering, scientists have improved crop productivity by enhancing the abilities of beneficial microorganisms and inhibiting the effects of harmful microorganisms. Microbial soil inoculants to increase nitrogen uptake by plants have been available for years. Genetically engineered bacteria, dubbed "ice-minus" bacteria, have the potential to protect plants from frost damage. The bacteria interfere with a natural population of organisms that promotes frost formation on fruit trees, thereby insulating fruit from damage. Ice-minus bacteria have been field-tested since early 1987. In the next several years, scientists hope to insert a bacterium into crop plants to alleviate the stress of subfreezing temperatures, allowing them to grow in cooler climates.

Crop pests. Several biotechnologies are aimed at overcoming such crop pests as insects and viruses. In the past two years, for example, scientists have found a way to protect tobacco from the tobacco hornworm by inserting into the plant a protein found in potatoes and tomatoes that naturally repels hornworms. Scientists hope to use the technology in food and fiber crops and begin field testing within a few years.

Scientists have also developed biologically engineered insecticides to control insects that eat vegetable plants. Researchers have been able to produce endotoxin, a potent, naturally occurring insecticide, by inserting a gene into bacteria. The altered bacteria could be applied to cabbage, broccoli, lettuce, and other crops to control caterpillar attacks. Large-scale field trials were recently approved for the insecticide.[6]

A few plant biotechnologies have benefited crop production for some years, but the major impacts of the biotechnologies may not be felt until the next century. The immediate impacts have been greater for animal agriculture because some of the technologies have been in place for more than a decade. The future impact of biotechnology, however, may be substantially greater for plant agriculture as the number of developments begins to multiply more rapidly in coming years.

The Implications of Biotechnology for Agriculture

Biotechnology has far-reaching implications for farmers and ranchers, policymakers, agribusiness, agricultural bankers, and consumers. These groups will be especially affected as the number of biotech developments multiply in the next decade.

Implications for farmers and ranchers

Adoption of biotechnologies will have two major effects on production agriculture. The supply of farm production will increase which will tend to drive down farm prices. And, the nature of the new technologies will combine with lower prices to encourage larger farms.

The supply effect. Biotechnologies will lead to greater agricultural production. Using the technologies, farmers will be able to produce more output with the same complement of fixed resources, driving down unit costs. As profit margins in the commodity increase briefly, producers will expand production (Kalter and Tauer). Ultimately, the increased supply will drive down the commodity's price and discourage any further expansion (box).

The structure effect. Like other technologies before it, biotechnology seems likely to favor large farms. Lower farm prices appear likely to squeeze out smaller producers because they will not be able to cut costs as much as large producers.

Small farms will have relatively high costs of production because they will likely be reluctant to adopt the new technologies. The Office of Technology Assessment, for example, estimates that 70 percent or more of large farms may adopt biotech products by the year 2000, compared with only 10 percent of small farms (Office of Technology Assessment 1986).[7] Small farms may shy away from many biotech products because they are complex and require careful supervision. Many small farms may lack the management skills necessary to implement or fully utilize biotechnologies. By contrast, large farms usually have skilled management that allows specialized attention to complicated production tasks.[8]

Even if small farms do adopt biotech products they may pay more for them than large farms, blunting the cost savings of the technology. Quantity discounts appear likely to prevail for biotech products, such as BST, just as they do for most other farm inputs.[9]

In short, the adoption of biotechnology means that the most efficient scale of farming increases. With biotechnology, well-managed farms can effectively produce more output with the same complement of fixed resources, lowering the overall cost structure of the industry. The real test is whether a farm has the necessary management skills to incorporate biotech products fully and effectively and thereby cut costs. Large farms appear much more likely to meet that management test than small farms. Thus, large farms will produce more at lower cost and remain in business even though farm prices fall. Small farms, on the other hand, will be unable to lower their costs and thus their profits will diminish.

Implications for policymakers

The adoption of biotechnologies may require policymakers to adjust farm policy and regulation. Policymakers will need to determine whether current farm programs should continue in the face of changes in the industry. And they will have to sort out which government agencies will oversee the commercialization of biotechnology.

Federal farm policy. Policymakers may

need to adjust federal farm policy in light of increased supplies and lower prices caused by the adoption of biotechnologies. Policymakers are left with a dilemma. They can cut support prices, causing farm income to fall. Or they can keep prices high, increasing the costs to taxpayers.

The situation in the dairy industry illustrates the dilemma. Over many years dairymen have produced milk more and more efficiently, while government price supports have encouraged them to produce more milk than the market demands. As a result, milk surpluses have mounted, causing taxpayers to pay for the excess milk. If policymakers maintain price support programs while farmers adopt newer technology to produce milk more efficiently, taxpayers will end up paying for an even greater burden of milk surpluses.

How policymakers react to this policy dilemma will have major implications for the structure of agriculture. As already shown, biotechnology favors larger farms. Maintaining current price support programs, which peg payments to the quantity produced, may further encourage large farms. As an alternative, price supports could be cut while payments were targeted more specifically at smaller farms.

Regulation. A network of policymaking groups governs the development and use of biotech products. The uniqueness of biotechnologies and the large number of recent developments have added to the confusion over policymakers' roles in the regulatory process. The U.S. Department of Agriculture and the U.S. Environmental Protection Agency (EPA) regulate field testing of biotech products. The EPA also has the power to approve the commercial sale and use of pesticides. Authority to approve animal health products is held by the Food and Drug Administration. The number of agencies involved may complicate the overall approval process.

The law requires regulators to evaluate each product on two important criteria before approving its use: effectiveness and safety. The product must perform as stated by those who developed it. Safety must be proven in three areas: safety of food for human consumption, safety to the target animal, and safety to the environment. Regulators do not consider economic effects of a product before approval.

Regulators thoroughly review human health aspects of each biotechnology. In 1985, the FDA reviewed the scientific evidence and affirmed that milk and meat from cows treated with BST is safe for human consumption (Ingersoll 1990a; Sugarman). The National Institutes of Health (NIH) completed a study that supported FDA's findings (Ingersoll 1990b). Notwithstanding FDA and NIH's rulings, consumers' perceptions of the safety of food produced with the new inputs will control whether BST and other biotechnologies move into the mainstream of U.S. agriculture.

The safety of biotech products to the animal is also important because the animal is expected to maintain a high level of production over time, reproduce efficiently, and be as healthy as possible. If increased costs from reproduction and health problems outweigh benefits of a technology, it is not useful in agricultural production.

Regulators also review the product's effects on the environment. Environmental risks have gained importance as public concern over the safety of the water supply and other environmental issues has grown. Chemicals now used in crop production have leaked into groundwater supplies, sending scientists in search of alternative production inputs for agriculture (Office of Technology Assessment 1990). Biotechnologies that take the place of chemical inputs may help alleviate the problem of contaminated water. But regulators may still want to determine the long-term effects on the environment of biotech products.

Product reviews must be thorough, but the length of the regulatory process will have a major influence on further developments of biotechnology. Many companies have shied away from biotech research because the review process is costly and protracted. Genetic engineering projects may be at a significant disadvantage in competing for research and development funds. Generating data for field testing approval can cost $250,000 or more, not counting the scientists' time (Hayenga). This may constrain product development and the survival of small biotech companies.

Implications for agribusiness

Biotechnology has significant implications for the competitiveness of individual firms and the structure of the agribusiness industry. Biotech products offer both new opportunities and new challenges for agribusiness.

Competitiveness. Innovations in biotechnology will provide new sales opportunities for agribusiness. Firms that engage in the development and distribution of products of biotechnology can benefit from more diversified product lines. In addition, firms tied to older technologies that will be replaced by biotech products will need to participate in production and sales of the biotech products to remain competitive in the industry. For example, the Monsanto Corporation has long manufactured chemical inputs for agricultural production. Now it is researching and developing genetically engineered alternatives to traditional chemicals. The company recognizes that chemicals will continue to be important inputs but is maintaining its competitive position by also developing more current technologies.

Structure. Small firms appear to be at a disadvantage in developing and marketing biotech products because the research and development process is long and costly. Because the biotechnology industry is young, few products have reached the market and generated returns on investments. Products have faced adverse public reactions and tough regulatory hurdles, causing developers to wonder when, and sometimes if, the products will ever reach the market. During this infant stage of the industry, larger companies with wider product lines are better equipped to support research and development and absorb unforeseen costs of developing biotech products. In the future, when more products are on the market, small companies may become more important to the overall industry.

The relatively large firms that now constitute the food processing industry may exert more control over agriculture as biotechnologies are adopted. The practice of contracting—arranging sales of commodities between producers and processors—will gain popularity as farmers use more biotech inputs. Contracting will ensure that complex biotechnologies are closely controlled to yield farm products of uniform quality. Food processors will probably prefer to contract with fewer large farms to keep fixed costs low, a practice that will further encourage development of larger farms (Barkema, Drabenstott, and Welch).

Implications for agricultural bankers

Agricultural bankers are in a unique position to encourage or discourage the use of biotechnologies on farms. Bankers may welcome loans to farmers that use cleaner biotechnologies instead of chemical products; lender liability may be less with biotechnology. But the use of biotechnology may require farm lenders to acquire additional skills.

Lender liability. The high cost of cleaning up environmentally damaged property has made lenders cautious about loaning funds to farmers and ranchers that use chemicals. Under the federal Comprehensive Environmental Response, Compensation and Liability Act, a lender that forecloses on a property may be held liable for cleanup costs as an owner or operator (Turner and others). As a result, a property's value as collateral may be significantly reduced by the use of chemicals.

The use of biotechnologies may decrease the risks for the agricultural banker financing the farm. The use of a bioherbicide that displaces use of chemical herbicides may help avoid or reduce contamination by chemicals, for example.

But all of the future effects of the use of biotechnologies are not known. The lender may wish to reduce risk of supplying funds to farmers who use either chemicals or biotechnologies by taking additional precautions. To help protect their interests, lenders might conduct a thorough review of the history of the property and require the borrower to obtain environmental-impairment liability insurance. The lender could also consider alternatives to using real estate as collateral for a loan.

Educational needs. As biotechnologies are adopted, agricultural bankers will need to provide additional education for bank employees. Employees that determine credit needs for use of the technologies and perform reviews on farms that use biotechnologies will need additional training. Special training will help the employees learn production techniques that are more complex than traditional methods.

Lenders may also be in a position to encourage farmers and ranchers to improve their understanding of biotechnology. With the assistance of good consultants, extension agents, and university researchers, agricultural bankers may help extend the knowledge of growers and keep farmers up-to-date on new alternative products and practices. Farm and ranch operators will need to be encouraged to use the technologies to remain competitive and taught to use products correctly to improve profitability of operations.

Implications for consumers

Consumers will make perhaps the greatest adjustment to the use of biotechnology. They must sort out the related issues of food prices and food and environmental safety.

The greatest potential benefit of biotechnology to consumers may be lower food prices. As already shown, the use of biotechnologies allows producers to grow the same or greater quantity of food at a lower cost, resulting in lower retail food prices.

While lower food prices appeal to consumers, they are still troubled by food and environmental safety issues related to the use of both chemicals and biotech products. A 1990 study showed that about nine out of ten Americans are concerned about the use of pesticides on crops (Research & Forecasts, Inc.). While about 62 percent think biotechnologies should be explored as alternatives to chemical use, 52 percent feel biotechnologies might represent a serious threat to people or the environment.

Consumer fears or adverse perceptions of biotech products could stifle the adoption of some biotech products in agriculture. Although the FDA certified that milk produced by BST-treated cows is safe, five of the nation's largest supermarkets refused to buy dairy products from farmers who used the hormone (Sugarman). The supermarkets apparently feared that some consumers might boycott the products.

Consumers must weigh the scientific evidence supporting use of biotechnologies against any perceived risks. Consumers are concerned about levels of certain substances in food, such as hormones in milk. But milk from BST-treated cows, for example, has the same composition as milk from untreated cows. BST occurs naturally in cattle, so it is found in milk produced without supplemental BST. Furthermore, scientific evidence produced by the FDA, the American Medical Association, and health and safety regulators in many foreign countries has shown that milk from BST-treated cows is safe (Ingersoll 1990b). Also, some crop biotechnologies offer alternatives that may be safer for human consumption than chemical inputs. Such products may help alleviate problems with contaminated water and chemical residues on food, too. Further benefits of biotechnology, including lower prices and higher quality foods, may convince consumers that the benefits of biotechnology outweigh any perceived risks.

Summary

Biotechnology is opening an exciting frontier in agriculture. Although the technologies have been used in animal and plant production for more than a decade, scientists are now rapidly developing new products that will extend biotechnology's potential well beyond current uses.

Biotechnology offers both dividends and drawbacks for all groups associated with production agriculture. Farmers and ranchers will be able to produce more output at lower cost, but small farms may be reluctant to use the new technologies and could see their profits cut as a consequence. Policymakers must reevaluate the goals and costs of farm policy and also provide a system for thorough but speedy reviews of new products. Large agribusiness firms can remain competitive by developing biotech inputs, while small agribusiness firms may find it difficult to navigate a long and costly development process. Agricultural bankers could benefit from less lender liability with the use of biotechnology, but will need to provide additional education for bank employees to properly review use of the new technologies. Consumers will benefit from lower prices, but must weigh their perceptions of biotech products against an accumulating base of scientific evidence on food and environmental safety.

The BST Example

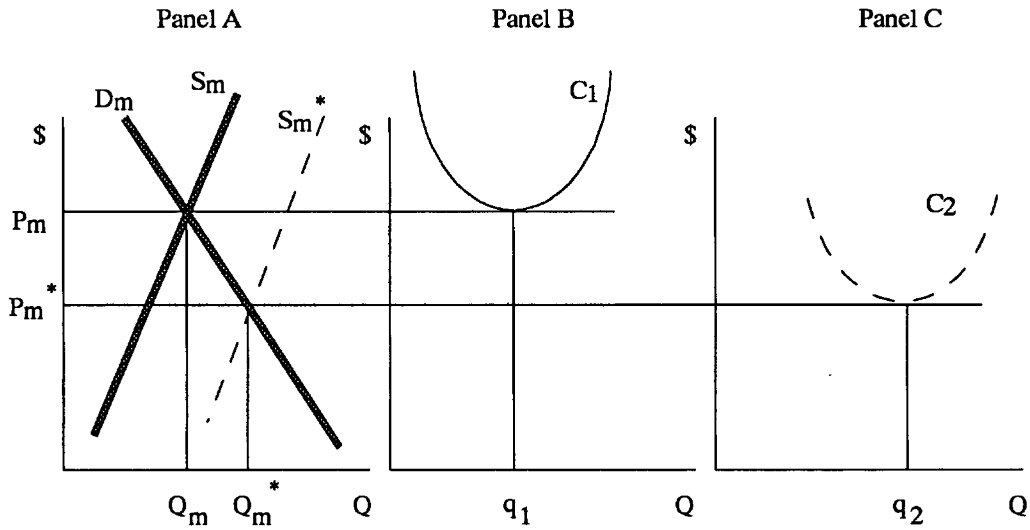
The use of BST in dairy herds provides a good example of how biotechnology can increase supply and lower prices. The increase in milk supply and the subsequent structural changes in the dairy industry are illustrated in the three panels of Figure 1. Panel A shows the effect of an increase in the milk supply on the price of milk and the consumption of milk. The milk demand curve (D_m) shows the quantities of milk consumers are willing to purchase at various prices, and the milk supply curve (S_m) shows the quantity of milk producers are willing to produce at various prices and with old technologies. At the initial equilibrium price (P_m), determined at the intersection of the demand and supply curves, consumers are willing to buy the same quantity (Q_m) that producers are willing to produce.

Adopting BST has the effect of shifting the supply curve to the right, resulting in bigger output and lower prices. The rightward shift of the milk supply curve to S_m* shows that producers are now able to supply more milk at any given price. As the supply curve shifts to the right, the milk market reaches a new equilibrium at a greater quantity of milk (Q_m*) and a lower price (P_m*).

The increase in milk production affects the structure of the dairy industry, as shown in Panels B and C. Curve C_1 in Panel B shows short-run, per-unit costs for various milk production levels for producers using old technologies. At the old equilibrium price of P_m, farms of this type produce milk at a rate of q_1 and cover all costs. At the new equilibrium price of milk (P_m*), however, the farms using older technologies can no longer cover their costs and are forced out of business.

At the new equilibrium, adoption of BST allows farms to produce more at lower cost (Panel C). Even at the lower price P_m*, the farms using BST can cover all costs. The net effect, therefore, is that the most efficient farms operate at a much larger production (q_2) than previously, and thus the industry becomes concentrated in fewer, larger farms.

Figure 1
The BST Example



Milk supply and demand

Average costs in farms using traditional technologies

Average costs in farms using BST technology

Endnotes

[1] The recombinant DNA procedure is the technique of isolating DNA molecules and inserting them into the DNA of a cell, "recombining DNA." It is also called genetic engineering.

[2] The most promising extensions of traditional tools of animal and plant breeding are cell culture, plant regeneration, monoclonal antibodies, embryo transfer, and bioprocess engineering. Cell culture is the technique of producing identical copies (clones) of genetically engineered cells. Plant regeneration is the technique of growing a whole plant from a single engineered cell or piece of plant tissue. Monoclonal antibodies are disease-fighting proteins produced by fusing a rapidly growing cell with one that produces an antibody to a particular substance, such as a hormone, chemical residue, virus, or bacteria. Embryo transfer is transferring multiple fertilized eggs, or embryos, from one mother to host mothers. Bioprocess engineering is genetically manipulating life processes.

[3] The production of genetically engineered livestock vaccines involves reproducing certain proteins that are taken from genes of a disease agent. The protein is then injected into an animal to stimulate its immune system to protect it from infection. Such vaccines offer an effective, safe, and easy-to-manufacture tool to fight disease.

[4] Growth hormones can now be produced in laboratories in large quantities. Scientists extract the gene that produces the hormone in animals and mix it with bacteria to produce the hormone in abundant quantities. Producers can then administer the hormone to animals by injection at any recommended level.

[5] Some farm groups fear that increased milk production among large producers will lower prices, put family farmers out of business, and only create a larger surplus of milk in the country. For these reasons, several states, including Wisconsin and Minnesota, have introduced legislation to ban BST-produced milk.

[6] The gene to produce the pest toxin was transferred from another bacterium, *Bacillus thuringiensis*, which itself has been marketed as a biological insecticide for more than 20 years.

[7] The rate of adoption may differ markedly by product. Genetically engineered seeds, for example, may become widely adopted by both small and large farms. Animal biotechnologies, on the other hand, are more complex and may be adopted less by small farms. In general, biotechnology requires more careful record-keeping and more precise production practices, demands that appear to favor greater adoption by large farms.

[8] Larger farm units will be able to extract more benefits from biotechnologies, because they have better resources to implement the technologies and manage expanded production (Molnar and others).

[9] Most biotech products are not yet commercially available and thus price discounts cannot be thoroughly documented. Discounts for other farm inputs are widespread and it would be unlikely that they would not be found in biotech products.

References

Barkema, Alan, Mark Drabenstott, and Kelly Welch. 1991. "The Quiet Revolution in the U.S. Food Market," Federal Reserve Bank of Kansas City, *Economic Review*, May/June.

Booth, William, Malcolm Gladwell, and Kathy Sawyer. 1989. "Crossing Distant Species," *The Washington Post*, July 24.

Boyd, R. D., M. Harkins, D. E. Bauman, and W. R. Butler. 1987. "Impact of Somatotropin on Growth Performance and Carcass Composition of Growing Swine." Bloomington, Minn.: Minnesota Nutrition Conference, September.

Doane Marketing Research Inc. 1990. "Animal Health Market Study 1990," St. Louis.

Hayenga, Marvin L. 1988. *Biotechnology in the Food and Agricultural Sector: Issues and Implications for the 1990s*. UC AIC Issues Paper No. 88-5.

Ingersoll, Bruce. 1990a. "Growth Drug for Milk Cows Draws More Fire," *The Wall Street Journal*, December 4.

____________. 1990b. "Treated Milk, Meat Are Safe, Panel Concludes," *The Wall Street Journal*, December 10.

Jacobs, Eleanor. 1989. "BST Believers," *Michigan Farmer*, August 5.

Kalter, Robert J. and Loren W. Tauer. 1987. "Potential Economic Impacts of Agricultural Biotechnology," *American Journal of Agricultural Economics*, May.

Molnar, Joseph J., Keith A. Cummins, and Peter F. Nowak. 1990. "Bovine Somatotropin: Biotechnology Product and Social Issue in the United States Dairy Industry," *Journal of Dairy Science*, November.

National Research Council, Board on Agriculture. 1987. *Agricultural Biotechnology-Strategies for National*

Competitiveness. Washington.

Office of Technology Assessment, Congress of the United States. 1990. *Beneath the Bottom Line: Agricultural Approaches to Reduce Agrichemical Contamination of Groundwater*. Washington.

____________. 1986. *Technology, Public Policy, and the Changing Structure of American Agriculture*. Washington.

Research & Forecasts, Inc. 1990. "The Novo Nordisk/Entotech Report: American Attitudes toward Pesticides." A nationwide survey of 1,200 randomly selected households.

Sugarman, Carole. 1989. "Grocery Chains Refuse 'Engineered' Milk Products," *The Washington Post*, August 24.

Turner, Steven C., John P. Heil, and Anne M. O'Brien. 1990. "Environmental Considerations in Agriculture & Agribusiness Lending," *Journal of Agricultural Lending*, Spring.