COMMERCIALIZATION OF BIOTECHNOLOGY IN AGRICULTURE

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Introduction

From 1960 to 1990, the agricultural industry successfully met a tremendous demand surge. During this thirty-year period there was an 80% increase in global population and a dramatic increase in quality of diet among the world's developing nations. Economic development and rising disposable incomes resulted in improved diets (more calories and more protein per capita per day). The success of the Green Revolution can be seen in the increase in total global kilocalorie consumption from 9 to 14 trillion kilocalories/day between 1960 and 1990.

Population growth will result in a doubling of present world population by the year 2050. This will lead to a dramatic increase in demand for food while land under cultivation is expected to remain virtually constant. Changes in dietary regimes are also expected as increases in per capita income lead to increases in consumption of animal protein. This will further increase demand on the global agribusiness industry. For example, in the recent past, the Chinese have consumed an average of 12 g/person/day of protein while USA citizens have averaged 74 g/person/day. The per capita income of China is increasing rapidly, and the impact of these 1.2 billion people alone will have important influences on world's protein supply. The demand in other major regions of the world is also increasing in a similar manner.

Clearly, there will be tremendous pressure on the world's agriculture to meet these increases in demand for food. Even now, approximately one billion people are malnourished. Production increases needed to feed the growing population can be accomplished by increasing surface (acreage cultvated), increasing productivity, increasing quality or decreasing losses. One of the major opportunities for increasing food production by the world's agriculture is through the application of biotechnology.

Commercial Biotechnology Products

At least 25 varieties of transgenic plants have been approved by at least one or more countries for commercial use. Approximately 70 million acres were planted with genetically modified crops world-wide in 1998. The benefits provided by biotechnology at various parts of the food chain, including transgenic traits in plants, can significantly improve the world's ability to feed itself by increasing per unit productivity, improving nutritional quality and reducing pre- and post-harvest losses. Among the several benefits from these crops are improvements in agronomic traits such as adding pesticide and/or herbicide resistance. It is expected that the global farm gate market for agricultural biotechnology products will be $20 billion by year 2010. There were

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sales of only $0.5 billion in 1996.

Two major animal-related biotechnology products are approved in the US. The first was an E. coli-produced chymosin for use in the production of cheese, and the second was bovine somatotropin for enhancing milk production in dairy cows. These products are also sold in many other countries. In Australia, porcine and equine somatotropin products are sold as well. In 1998, approximately $200 million of these products will be sold. Sales of bovine somatotropin have been increasing at a rate of about 20% per year since it was introduced in 1994.

Biotechnology Products in Development

Many grain, fiber and vegetable crops with genetically modified traits are currently in development. Many benefits are expected from these biotechnology enhanced products, e.g., quality and quantity produced, stability of production, food safety, nutrition of grain and oil, sustainability by protecting the environment, new industrial uses, and health benefits (nutraceuticals). Inevitably, the biomass will gradually displace petroleum and natural gas as energy resources due to depletion of fossil fuel reserves, future rise in energy prices, environmental sustainability practices (greenhouse gas emissions) and the need for renewable energy resources. This complex series of events will require many innovative uses of biotechnology to make the cost of raw materials competitive, to provide the enzyme systems required and to produce the volumes of required feed stocks. Plants will play a major role because of their potential for built-in storage of solar energy and cellulose production which can be converted into gaseous, liquid or solid forms to supply the feed stocks for industry. These feed stocks will be used for the production of dyes, detergents, inks, paints, medicines, cosmetics, clothing, synthetic fibers, biodegradable plastics, adhesives, lubricating oils, industrial chemicals, construction materials and paper. Even genetically modified plants will be used much more for environmental remediation, i.e., to remove, destroy or sequester hazardous substances.

Transgenic animals are in development for both enhanced food production and high value protein (antithrombin-III) biosynthesis. The development of GH transgenic salmon, by A/F Proteins, Inc., may be the first transgenic food animal approved for the human food chain. The greatest input for research and development for transgenic animal production is for high-value medicinal protein and xenotransplant products. The multi-hundreds of millions of dollars influx in this development will in time make possible the high volume but lower per unit value applications of the animal transgenic technology. The additional use of cloning for the production of transgenic sheep, goats, cattle and pigs will make transgenic animal applications for medicinal use more competitive with alternative technologies. Again, the important input of resources of developing and optimizing technologies which utilize these animals, bioreactors, will make applications for food-producing animals more probable in the near future. Cloning of food-producing animals with gene modifications, either enhanced gene function or dysfunction, as required, will make possible step changes in productivity

and quality traits. These new strains of animals will greatly enhance the possible sustainable roles that food-producing animals will play in the human food chain.

Commercialization Timelines

Plant applications of biotechnology are making remarkable progress. There have been unprecedented adoption rates of gene-modified corn, soybeans, cotton and canola, for example, in North America. It is probable that there will be numerous introductions of plants with gene-modified agronomic traits over the next ten years. The marketing of biosynthetic enzymes produced by transformed organisms will continue to grow for many applications, from converting the biomass to feed stocks for industry to using agricultural products more efficiently for food for animals, including humans. The first medicinals from the use of transgenic animals for the required bioreactors may be introduced by year 2000. Additional medicinals and probably nutraceuticals from gene modified plants will be introduced in the market place by year 2005. This will enhance potential net returns down the whole value chain for these agricultural products. Transgenic and cloned food-producing animals may start to have an impact on production costs and quality traits by year 2005. By year 2010, plants will also play major roles in industrial feed stocks for manufacturing and energy supplies. Clearly, agricultural applications and the development of novel products from gene-modified plants and animals will have a major impact on the value of agricultural products and the feeding of the next five billion people.