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The Future of Biotechnology in Soybeans

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This article looks at rising soybean demand, how technology is improving soybeans, and the challenges that soybeans derived from biotechnology face. To help meet the challenges of increased soybean demand, biotechnology tools are being used to develop soybeans with improved nutritional value and greater resistance to disease, herbicides, and drought. Producers are increasingly turning to biotech soybeans because of the cost and time savings and reasonable yield enhancement these soybeans offer. Future traits offer the promise of further crop protection benefits, higher yield, and grain value enhancement through oil and protein modification. Despite all the opportunities, biotech soybeans face numerous challenges. Because of the cost of technology and regulatory clearance, it is challenging for developers to capture an acceptable return on biotechnology investments. In order for the full benefits of biotechnology to be realized by the world's farmers and consumers, global acceptance of biotech crops and grain is critical.

Key words: biotechnology, molecular markers, soybeans, soybeans and meat consumption, soybean cyst nematode, soy protein.

Biotechnology can be defined broadly as a set of tools that allows scientists to genetically characterize or improve living organisms. Several emerging technologies, led by transformation and molecular characterization, are already being used extensively for the purpose of plant improvement. Other emerging sciences, including genomics and proteomics, also are starting to impact plant improvement.

In soybeans, the first biotechnology trait offered was the Roundup Ready® trait, which has been widely adopted by growers. Looking forward, biotechnology promises to deliver products with improved nutritional value and yield enhancement through greater resistance to disease, herbicides, and drought. Enhanced productivity is increasingly important, because per-capita soybean consumption is growing. Combine this growth with a rising world population, and you have reason to bet on a positive future for soybean demand.

During the 2002 growing season, there were approximately 62 million acres of soybeans improved or enhanced through biotechnology planted in the United States and Canada, representing approximately 80% of the total. This represented an 11% increase over 2001, when approximately 62 million acres of improved soybeans were planted.

During the 2000 growing season, there were 24.4 million acres of soybeans derived through biotechnology in Argentina. In 2001-02, this increased to 26.7 million acres. Despite a lack of government approval, it has been estimated that Brazil had more than 4 million acres in enhanced soybeans during the 2001-02 season, up from more than 3 million the previous year.

These plantings were dominated by the Roundup Ready® trait, which provides glyphosate herbicide tolerance. Producers have increasingly turned to these soybeans because of cost and time savings combined with reasonable yield enhancement.

These are the kinds of benefits that soybeans derived from biotechnology can have for producers. The needs for such benefits have been driven by economics and by the need for producers to reduce production costs and produce crops that have enhanced value and bring stronger prices. Future traits offer the promise of further crop protection benefits, higher yield, and grain value enhancement through oil and protein modification.

Despite all the opportunities, biotech soybeans face numerous challenges. Because of the cost of technology and regulatory clearance, it is difficult for developers to earn sufficient returns on research investment for many biotech traits. Gaining acceptance of crops and grain derived through biotechnology, particularly in Europe, is yet another challenge. Although biotechnology acceptance is increasing around the world, significant challenges will be faced by those wanting to bring new transgenic traits to market.

In this paper, we will look at the reasons why soybean demand is up, how technology is improving soybeans, and the challenges of soybeans derived from biotech.

A Meaty Subject

Soybean consumption and production are increasing. Total world consumption of soybeans in 2002 was 7.128 billion bushels. Consumption in the United States and China amount to 42% of this total—1.82 billion in the United States and 1.19 billion in China. Soybean consumption is driven primarily by meat consumption in human diets, as soybeans are used primarily for animal feed.

Global soybean consumption is projected to increase because meat consumption is on the rise. It is expected to increase in such countries as Russia, Thailand, Mexico, Hungary, and China because of improved incomes. Consumption in the United States, Australia, Japan, Canada, and most European countries will increase as more people eat at restaurants, which serve larger portions than are typically prepared at home. This will lead to higher calculated per-capita consumption.

Specifically, beef continues to trend upwards, with the exception of Europe and the former Soviet Union. The decline in Europe can be tied to mad cow disease. In China, beef consumption has nearly doubled over the last five years. Broiler and pork consumption is up throughout most of the world.

As consumption increases, so does production. Soybean production has reached record levels in the United States in recent years. In 2002, the US soybean production area was more than 73 million acres, compared with approximately 60 million in 1991. Since Pioneer Hi-Bred International, Inc. entered the soybean business in 1973, US soybean acres have increased by 304%.

Several factors are driving the increase in soybean production acres. Corn-soy rotations have increased in the Corn Belt. Soybeans have displaced wheat and sunflowers in western plains states and alfalfa in lake states. Conversely, production has decreased in the south and southern plains due to improved cotton opportunities.

Yield also is increasing—an indication of the impact of plant breeding and biotechnology investments. Yield in 1973 was approximately 28 bushels per acre. In 2001, yield was approximately 38 bushels per acre.

Yield is vitally important for soybean producers. Soybean prices have trended downward since 1980, but although prices have been declining, per-acre income from soybeans has increased. Farm programs have had some role in this, but part of the positive story is that yield improvements have helped increase net farm income. Similar data on other crops indicate that yield improvements have helped income per acre increase or at least keep pace.

Although yields and production acres in the United States have increased steadily, the US share of world soybean production has been in decline. In 1991, US soybean production was approximately 2 billion bushels, which was 50% of the world's production. In 2002, production climbed to nearly 3 billion bushels but only accounted for 43% of the world's production.

In the coming years, Argentina and Brazil will surpass the United States in soybean production. In 2002, combined soybean acres in Argentina, Brazil, Bolivia, and Paraguay exceeded that of the United States. Ten years ago, the four countries produced 25 million acres less than the United States.

Per-acre productivity will continue to increase, supported by research investments that will lead to improved net income. Increased world production will come mainly from Brazil, because of its available land for cultivation. However, once Brazil's planting areas are completely opened up, there will remain little tillable land to develop for global soybean production. Therefore, higher yields will be needed to feed a growing world population. Defensive traits (insect, virus, fungus, herbicide resistance) brought about through biotechnology will help farmers maintain high yield and use less pesticides, soil, and water.

Ongoing research will also be aimed at improving quality traits to enhance end-use value. The bottom line is that new technology must show value for the consumer and must be shared all the way back to farmers and input suppliers.

The Impact of Technology

The soybean is particularly difficult to transform. The first products of transformation took a great deal of resources. At present, there is a near doubling in efficiency and quality of events derived through biotechnology every five years, bringing the number of new potential trait offerings from tens to thousands per year. The experimental plants can offer traits that provide healthier ingredients for our diets and the diets of farm animals, as well as increased disease and insect resistance.

Despite the wide-ranging impact and notoriety of biotechnology solutions, there are additional biotechnology tools that are quietly, yet effectively, improving the productivity of soybeans. One of these is the use of molecular markers, which help scientists track and select key genes during breeding. The story of how Pioneer is tackling a serious soybean pest is an example of the role this biotechnology tool can play in agriculture.

The soybean cyst nematode (SCN) is the most destructive soybean pest in the United States, causing yield losses estimated at more than $1 billion a year. Nematodes attach to roots, causing significant damage, plant stunting and yellowing, and yield loss. While attached, female nematodes are fertilized by male nematodes and produce a large number of eggs. At season's end, the female dies and the eggs remain in her body, which forms a protective shell or *cyst*. Nematode cysts may remain in infested fields for more than a decade.

Field screening has been the traditional approach to battling SCN. This method has several challenges: It is labor intensive, destructive, and costly. Infested fields are not typically uniform in SCN density and race makeup. Cysts are the size of pinheads and are difficult to see with the naked eye. The genetics of SCN resistance are complex, requiring that large numbers of plants be inspected to identify varieties with resistance.

Pioneer has patented a molecular marker approach that solves these challenges and results in enhanced products faster. It combines biotechnology, robotics, and information management technologies.

Gene mapping has been used to identify the location of SCN resistance genes on specific chromosomes. Marker-assisted selection is used to confirm the presence of these genes in experimental varieties. This assay requires only a leaf tissue sample to extract DNA. The DNA samples are placed on a nitrocellulose membrane and then DNA probes are added to the samples. If a DNA gene or genes of interest exist in the sample, the probes bind to it and allow for detection. This technology allows researchers to evaluate more experimental varieties, leading to higher yield income per acre on SCN-infested land and more SCN-resistant variety options.

Another emerging tool of biotechnology is genomics, which refers to the study of the function and structure of genes. The soybean genome, as with genomes of other species, holds a vast resource of blueprints that determine what this great plant can provide. Genomics is helping researchers understand soybean DNA structure and function to change traits that affect pest resistance, yield, and grain composition. This understanding is converted to knowledge-based tools to develop gene markers for trait selection or trait solutions by use of specifically enhanced genes and promoters. As an example, public researchers at Indiana University have been able to use genomics tools, in combination with traditional trait mapping, to identify disease resistance genes for response to soybean bacterial blight.

Genomics, in combination with other approaches, is helping researchers address the need for protein to meet the needs of our global community. The movement to an enriched diet globally, in the developing world in particular, is putting more pressure on the soybean meal market. Agricultural economists predict that protein needs met through pork and poultry in 2025 will exceed 1960 levels by 659% and 1,652%, respectively.

Challenges

Capturing value for quality-enhancing traits is one of the biggest challenges facing biotech soybeans. Put simply, to capture value, value must be created. To ensure adoption, this value must be sufficient to reward adequately all participants in the value chain (developer, grain producer, grain handler, and end user). Biotech solutions will likely be used to expand the use of soybean protein and oil in the food market. This might include improvement of soybean isolate flavor and functionality and improved oil/protein health characteristics for consumers. Biotechnology also will be used to create traits that lead to soybeans with increased industrial and energy uses (e.g., biodiesel, lubricants).

However, capturing value also hinges on acceptance of the technology used to create the value. To help ensure acceptance, soybeans derived through biotechnology must be developed while following stringent safety and regulatory guidelines established by industry and government agencies. These guidelines must be followed from product concept to postmarket.

Today, every product is subject to extensive regulatory scrutiny. Approval costs for a product can reach into the millions of dollars. The value of new soybean traits, however beneficial they may be for producers and consumers, could be derailed by increased regulatory cost. The biotech industry will likely face more and tighter regulations with increased scrutiny of field research and more data requirements. There will be increased pressure on technology globally. If biotech soybeans are going to provide the hoped-for benefits, the industry and others will need to work to help consumers and regulators understand the impact of additional regulatory proposals and the safety procedures that are already in place.

The industry has a responsibility to support efficient, effective efforts to ensure that the technology is being used safely. The industry also needs to promote consumer trust and encourage companies outside the United States to engage their own governments on global biotechnology issues.