Blueprint for a Better Soybean

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Soybeans Through the Ages

The soybean is one of the world's most important crops. It's also one of the oldest. First domesticated in China more than 3,000 years ago, the soybean was so essential to the nation's culture that the Chinese people revered it as one of their "five sacred grains."

The first soybeans were brought to the United States in 1765 and were planted primarily as a forage crop. Today, the soybean has become an important source of high quality oil and protein. Soybean oil is used for both human consumption and industrial applications. Soybean protein has applications for animal and human diets.

With an ever-increasing focus on human health around the world, the consumption of soy as part of a healthy diet is getting more attention. Pioneer Hi-Bred International, Inc., research efforts to improve health through soybean genetics are focused on developing oils with improved health profiles and enhancing the flavor of soybean protein.

New technologies – modern planting and harvesting equipment; herbicides and fertilizers; and the introduction of biotechnology – have helped spur the soybean industry's rise. As new management techniques have been developed, farmers have quickly adapted them to their own operations.

The Contributions of Plant Breeders

There is another important element in the soybean story – the contributions of plant breeders. These scientists have focused their attention on changing the soybean plant to make it more productive and its end-use products more valuable. They have developed high-yielding varieties adapted to specific geographic areas, climates and growing conditions, and they have improved the quality of the protein and oil.

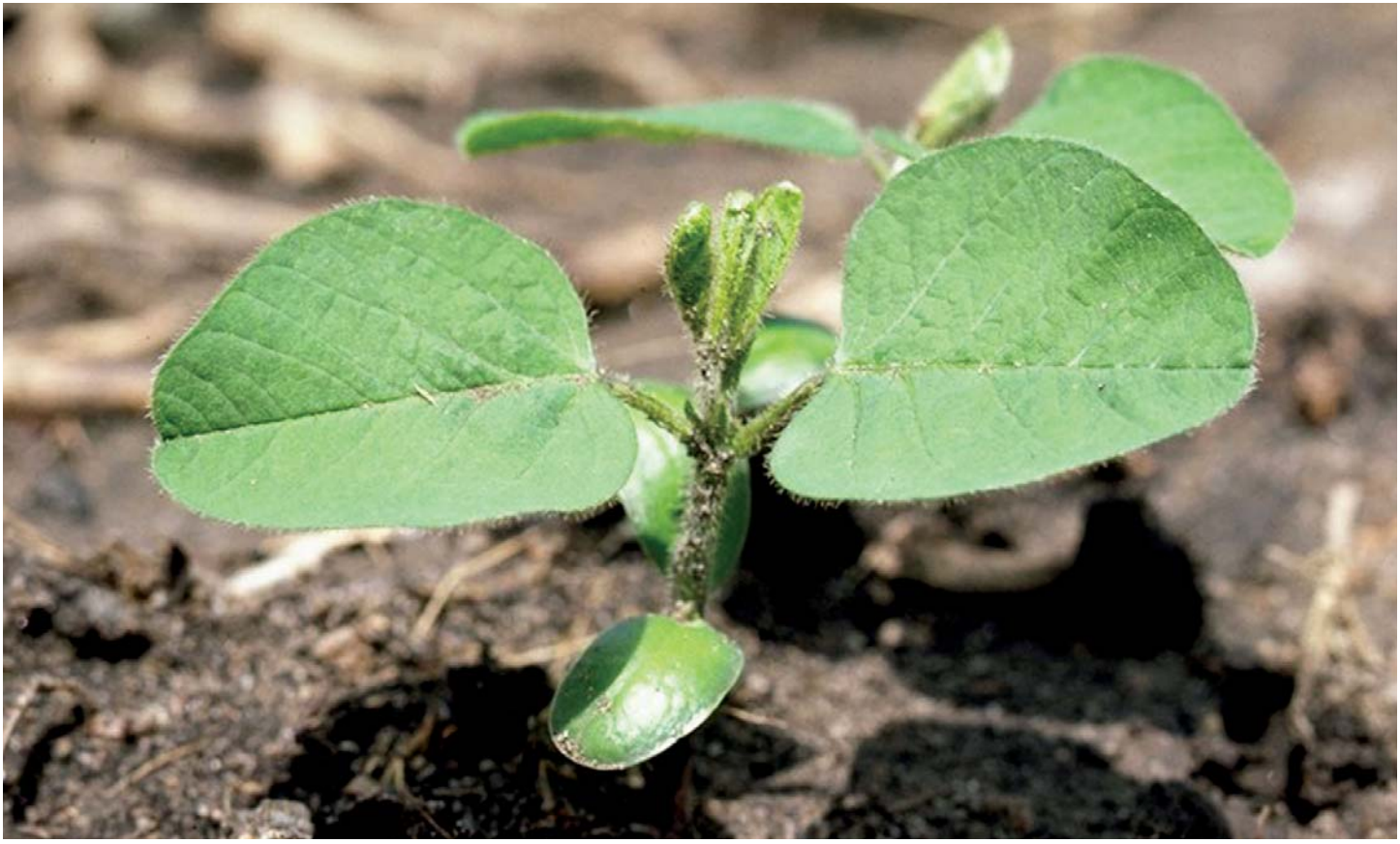
Varieties that farmers plant today have improved resistance to important diseases, insects and other pests. The plants stand better, allowing easier harvest and reduced losses in the field. These genetic improvements, and many others, have helped soybean growers around the world produce higher yields more efficiently.

Plant breeders are continually making improvements. Estimates of genetic gain in soybeans range from 0.5 to 0.9 bushels per acre per year.

The Perfect Plant

One of the best ways to learn about soybean variety development is to trace the research path. During thousands of years, soybeans have evolved as self-pollinating plants. Physically, they have what botanists call "perfect" flowers; the male and female parts of the plant are found in the same flower. Self-pollination occurs naturally in soybeans prior to the floral opening.

Evolution and natural selection have influenced the soybean plant's genetic system. Soybeans exhibit little hybrid vigor, or heterosis, when they are crossed. Similarly, there is little inbreeding depression when soybeans self-pollinate. Plant breeders have used breeding techniques specifically developed for self-pollinated crops to make significant improvements in the soybean varieties currently available to growers.



Building a Better Soybean

The success of a soybean breeding program depends largely on three factors:

- selecting and creating new breeding populations using superior parents;
- evaluating a large number of experimental progeny (or offspring) from those populations; and
- deploying cutting-edge technologies to maximize the efficiency of the breeding process and minimize product development time.

Soybean breeding has often been called a "numbers game" because the chance of finding a superior variety is improved by increasing the number of new experimental lines evaluated each season. But it is also a task that requires meticulous planning in parental selection to ensure that experimental progeny contain the traits that customers demand. This is complicated by the fact that the breeding process is a lengthy one, requiring scientists to anticipate the needs of growers and end-users seven to 10 years into the future.

Pioneer soybean breeders rely on essential input from customers (farmers, processors, end-users), the Pioneer sales team and the Pioneer marketing group to help determine what characteristics farmers will need and want in future soybean varieties.

Technology, especially in the areas of DNA-based marker selection (see page 9 for more information) and disease and pest bioassays, assists in characterizing the vast amount of experimental materials. These technologies are used early in the process to select the breeding material with the highest likelihood of success, and quickly eliminate experimental lines that do not contain the yield potential and traits required by farmers.

Soybean variety development is also a "time game." The amount of improvement that can be made in a given period is a function of the time required for a cycle of selection. This cycle includes the crossing of parents, development of their progeny for testing, evaluation of the progeny and selection among them for those few that have what it takes to become commercial varieties and parents for the next cycle of selection.

Trade-offs are involved at every step of the breeding process. Researchers must decide which characteristics need the most attention in the geographic area where the new variety will be grown. The more traits a breeder must consider, the more time it will take to achieve maximum improvement.

Variety Development – The Beginning

Raw material for a new soybean variety is found in pools of germplasm, or seed. These germplasm pools contain thousands of genetically different types, developed by cross-pollinating two distinct pure lines. This crossing essentially "mixes" their genes and creates variability that is expressed as differences among their progeny. The progeny with the best combination of genes become experimental lines for testing.

The lines used as breeding parents come from many sources: elite varieties, experimental varieties, native landraces and germplasm lines from public breeding programs and soybean collections around the world. Adapted (elite, experimental, public) varieties are commonly used as parents to provide a genetic base for stable high yield, while unadapted (native) germplasm is typically used as a source of new genes for improvements in other traits, such as seed quality and pest resistance.

Each Pioneer soybean research center has its own breeding nursery plots. The parental varieties grown in these nurseries have been evaluated and cataloged to provide breeders with an inventory of characteristics they can use to match the best parents to their geographies. This performance data is shared with all Pioneer research centers through a complex database for use in similar geographies globally.

Each year, Pioneer breeders initiate the development of thousands of different germplasm pools by performing cross-pollination between specifically matched parents. At flowering time, the breeders tediously transfer pollen from a plant of "Parent A" to the female part of a flower on a plant of "Parent B." When pollination is completed, the flower is tagged.

This single pollination will produce one to three hybrid seeds to start the germplasm development process. The hybrid seeds are advanced during several generations using a breeding system called modified single seed descent. Breeders plant the seed from each cross, allow the plants to self-pollinate and harvest about an equal number of seed from each plant from the cross. This is repeated several times to get the breeding material to a level of true breeding, or purity, so selection can begin.

It's a race against time, so greenhouses, growth chambers and winter nurseries in tropical and Southern Hemisphere locations are used to advance up to four generations of the crop each year.

Line Extraction

The "Parent A" by "Parent B" population is advanced by self-pollination for several generations before they are ready for the next step, the line extraction phase. Hundreds of new experimental lines are extracted from each germplasm pool like the one created by crossing "Parent A" and "Parent B."

The extraction of new lines involves selecting individual plants that the breeder believes may possess all the desirable traits needed in a new variety. These traits include disease resistance, pest resistance, standability, shattering resistance, good seed quality, maturity and outstanding yield. Pioneer breeders use a combination of visual observation, analytical techniques and genetic screening to ensure that the selected progeny contain the key traits required for successful production and additional traits desired by end-users.

Today, new genetic technologies are speeding up product development timelines, bringing our customers better products, faster. Development and application of DNA-based high throughput marker diagnostics are now routinely used to select individual plants from breeding populations that are confirmed for key resistance traits such as *Phytophthora* root rot, brown stem rot and soybean cyst nematode prior to yield testing.

Unlocking the Soybean's Genetic Potential

Pioneer has been using its proprietary, marker-assisted selection technology since 1995 to identify the presence of a specific gene and/or gene combinations that confer desirable traits such as insect or disease resistance. Using this technology, Pioneer is able to more efficiently identify and develop traits that bring farmers the greatest value.

Here's how it works: Individual plants in the population are identified in the field with bar-coded tags, and leaf samples are collected from each plant. DNA is extracted from each leaf sample.

After processing the DNA in the laboratory, signal molecules (called probes) are used to identify the specific genes that each plant carries. The tracked genes include those controlling disease and pest resistance, quality traits and yield potential.

The results for each sample are collected in a database and reported back to the breeders. Breeders select and advance only those individual plant progeny that are confirmed for the traits required by our customers.

Yield Testing and Evaluation

Progeny of the "Parent A" by "Parent B" cross are selected, often aided by marker-assisted selection. The seed from each selected plant is harvested separately and prepared for planting during the next growing season. Breeders plant seed from each plant in individual rows, called progeny rows. These progeny rows are utilized for an initial assessment of yield potential and evaluation of agronomic characteristics. With the aid of Pioneer information management and analysis systems, breeders analyze the performance of the different soybean lines, selecting the best experimental lines for further evaluation.

Several hundred thousand new progeny rows, each a potential commercial variety, are evaluated by Pioneer each year. Only a small percentage of the best experimental lines are selected for further evaluation. Breeders focus on only the top performers for all important traits.

In the first year of yield testing, large numbers of progeny (or experimental lines) are typically tested at single locations. Only those lines that possess key traits, plus high yield for the correct maturity, are saved for additional testing the next year.

In the second and third years of yield testing, selected experimental lines are evaluated at three to eight locations. Again, only the best of the best are selected and advanced for more testing the following year.

In the fourth year of yield testing, the remaining experimental lines are challenged with evaluations across 10 to 30 locations spread throughout the lines' geographic area of adaptation. These tests provide the breeder with information about the line's ability to adapt to different soil types, moisture regimes, fertility levels, tillage practices, disease pressure and pest infestations. Once again, the breeder saves only the best of all the lines tested. But those saved lines are still not ready to enter the Pioneer soybean product lineup. They must still pass up to two more years of rigorous wide-area testing.

To best position the lines for maximum performance and customer success, researchers collaborate with the Pioneer sales team to jointly evaluate and position experimental varieties that have passed through several years of testing. The lines are tested not only in research trials, but also in on-farm trials. Those lines that exhibit superior performance in these evaluations are considered for commercialization and entry into the Pioneer product lineup.

Very few lines survive the rigorous, multi-year yield testing and evaluation. Of the several hundred thousand experimental progeny lines that enter the Pioneer yield testing program each year, only a select few become commercial varieties. Pioneer® brand soybean varieties are truly the best of the best.

Seed Production

Observation and testing of new varieties will continue. They will be the standard by which Pioneer breeders measure all new varieties in their maturity range. But the bulk of the research and development effort is completed prior to the time a commercial name or number is assigned.

Now, responsibility for producing and delivering genetically pure, high-quality seed to farmers passes to other parts of the Pioneer organization.

The Hand-Off

The seed production process actually begins years earlier. Anticipating future commercial release, breeders select plants from a variety for purification purposes. Selection continues until researchers produce a small quantity of "breeder seed," and then transfer it to Supply Management Parent Soybean Operations for further increase.

The next steps are crucial to the production process. Not only must the seed volume be increased as efficiently as possible, but the variety's genetic purity must be maintained. Pioneer has developed a unique, two-stage parent seed system to ensure that both of these goals are met.

Parent Seed – The First Stage

Production of this stage of parent seed involves many distinct steps, each designed to maintain the genetic purity and quality of the resulting crop. Supply Management employees select and work closely with the cooperating farmer-growers. Company employees personally assist and advise the growers during planting and harvest activities. Supply Management personnel visit all seed fields numerous times each season:

- Approximately 21 days after planting, parent seed fields are inspected for emergence, possible disease problems, plant population, weed control and varietal purity.
- Mid-season, parent seed fields are inspected again for off-type plants and insects and to make yield estimates.
- Just before harvest, a final inspection is made to check again for off-type plants, uniformity, plant color, pod color, plant height, weeds and maturity. If necessary, off-type plants are removed from the fields before harvest.
- If at any time a field fails to meet the high standards Pioneer has for quality, part or all of it may be abandoned as a seed field.

After harvest, the seed is again fully tested and evaluated, then conditioned for distribution to other Supply Management locations.

Parent Seed – The Second Stage

Producing a seed crop requires more of the same attention to detail. But Pioneer employees believe the benefits of genetic purity and high seed quality are worth the extra effort. And farmers know that effort is what sets Pioneer brand soybean seed apart from the rest.

Supply Management production locations increase the volume of seed so there will be an adequate amount of parent seed available for the final step in the development cycle – the production of commercial soybean seed.

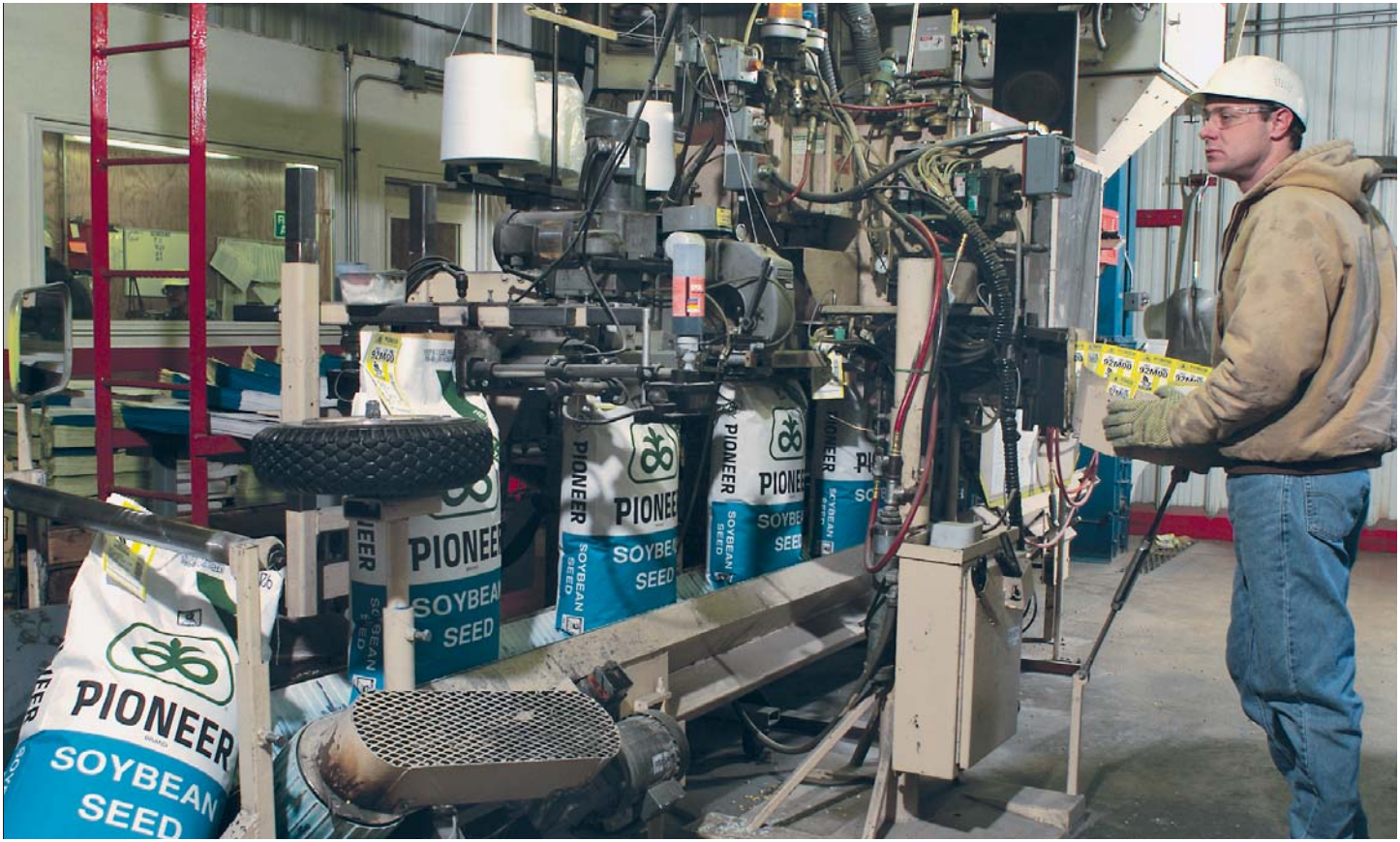
Full-Scale Production

The same cooperator selection and cultural practices are followed on a wider scale as the volume of seed increases to a level substantial enough to provide customers with adequate volumes of commercial seed.

Supply Management personnel supervise the planting, cultivation, harvest and storage of the seed crop to make certain it meets high-quality Pioneer standards. The seed is conditioned at modern facilities with the best equipment, operated by an experienced staff.

Before commercial seed is distributed to customers, each lot of seed is again tested for purity, germination and quality.

The variety development process may seem lengthy to farmers eager to plant new and better varieties. But decades of plant breeding experience have taught Pioneer there is no substitute for thorough and widespread testing of new varieties. Pioneer brand soybean seed is the result of years of research and development, all with the goal of helping farmers make the most value per unit of land.



Product Development for a Global Market

Increasing soybean yield and improving product performance for Pioneer customers are the top priorities of Pioneer soybean researchers. Other key attributes researchers focus on are:

- Maturity
- Standability
- Disease and Pest Resistance
- Herbicide Tolerance
- Oil and Meal Quality
- Emergence Speed

To achieve these attributes, researchers work across the globe to anticipate and find solutions to the challenges farmers face every day. Using both time-tested approaches and modern technologies, Pioneer researchers are focused on results that introduce new uses for crops, new markets for farm products and farm efficiency improvements that increase farmer profitability.

Fungal Disease and Pest Screening

Pioneer scientists focus on delivering varieties with consistent performance from year to year. To accomplish this, our varieties are extensively tested for resistance to various fungal diseases and pests. The severity of fungal diseases and pests varies from region to region each year.

For example, white mold caused by *Sclerotinia sclerotiorum* is a significant threat in many northern soybean regions. In the Midwest (United States), several fungal diseases, including sudden death syndrome, brown stem rot, *Phytophthora* root rot and soybean cyst nematode predominate. The southern United States also has a unique set of fungal disease issues, including stem canker, frogeye leaf spot, aerial web blight and root-knot nematodes.

Each of our regional research centers focuses on improving genetic resistance for the diseases that are present in that area. This is supported by a team of Pioneer plant pathologists who provide year-round screening in specially designed facilities. The Pioneer Agronomy Research Team provides additional support through evaluation of agronomic practices and fungicide and pesticide applications that can maximize grower profitability.

Asian Soybean Rust

As a global company, Pioneer is able to leverage its international locations to screen for diseases that rob farmers of profitability, or that appear to be an imminent threat to growers throughout the world. An excellent example of this global leveraging capability is the research Pioneer has done on Asian soybean rust (ASR).

ASR poses a severe threat to soybean production around the world and is a key target for genetic resistance solutions at Pioneer.

In fact, Pioneer has been working on developing soybean varieties resistant to ASR since 1995, when research work began in the Philippines. Today, Pioneer is leveraging its global research network to conduct resistance screening for ASR against various isolates of the disease. International testing, which has been expanded to include India, Brazil and U.S. locations, has uncovered sources of resistance that are being used by our breeding programs.

Current resistance screening efforts are aimed at identifying partial resistance and tolerance in the germplasm. Pioneer is using the latest breeding technologies such as genomics in its efforts to develop a genetic solution to counter ASR.

Healthier Soybeans

In addition to delivering customers the highest income-producing varieties available, Pioneer focuses on improving human health through soybean genetics. In the mid-1990s, Pioneer was the first seed company to introduce a low linolenic soybean variety. In 2004, Pioneer launched its first low linolenic soybean variety with the Roundup Ready® gene. These soybeans are currently used in the production of a branded low linolenic soybean oil, a product of the collaboration between DuPont, Pioneer and Bunge Limited.

That's important because the U.S. Food and Drug Administration mandates the labeling of all foods containing *trans* fatty acids. *Trans* fats are similar in structure to saturated fats and, at high levels of consumption, are known to raise levels of "bad" cholesterol and decrease "good" cholesterol levels. To minimize *trans* fats, the food industry wants alternatives to traditional oils that must be hydrogenated for shelf-life stability. Hydrogenation creates *trans* fats. Pioneer was the first seed company to offer stable, low linolenic oil that doesn't require hydrogenation.

The health benefits of soybean protein are becoming clearer, as food companies add product lines that offer consumers healthier choices. To this end, exciting new end-use traits that improve the health, flavor and functionality of soybean oil and protein are being developed and integrated into elite Pioneer varieties.

® Roundup Ready is a registered trademark used under license from Monsanto Company.

Our Commitment to Biotechnology

Pioneer has the most diverse, elite germplasm base in the world, and uses time-tested approaches, combined with cutting-edge technologies, for germplasm improvement. Pioneer is committed to safely and responsibly integrating the science of biotechnology into its products.

Traditional plant breeding approaches to introduce new traits into commercial varieties have typically involved the identification of such traits in exotic, unadapted germplasm and the subsequent transfer of these traits using many generations of breeding. Though this approach has proven successful for the transfer of traits such as *Phytophthora* root rot and soybean cyst nematode resistance, it is extremely tedious and time consuming.

Biotechnology allows scientists to be more precise and efficient in isolating genes and developing new varieties of plants, taking years away from the lengthy, trial-and-error traditional breeding process.

Biotechnology can be applied to produce two types of enhancements: intraspecies or transgenic. These words refer to whether scientists are incorporating a trait that is native to soybeans into another soybean variety (intraspecies), or a trait from a plant family other than soybeans (transgenic).

Beneficial genetic traits – those that enhance or protect an organism – can be transferred into the soybean to form a transgenic plant. Scientists follow these steps when using biotechnology tools to develop transgenic soybeans:

1. Identify and isolate a gene that improves the crop.
2. Link the useful gene to other DNA if the gene is to work properly. In nature, genes are surrounded on one side by DNA that precisely increases or decreases gene activity as conditions change (much like a dimmer switch), and on the other by DNA that marks the end of the gene (much like a stop sign). In crops developed with biotechnology tools, this genetic unit – the dimmer switch, gene and stop sign – is called a *transgene*.
3. Insert the new gene into a plant cell.
4. Grow a plant from the cell and confirm that the plant's DNA contains the new gene.
5. Conduct tests to ensure the plant exhibits the desirable trait.
6. Grow multiple generations to make sure future generations exhibit the new trait.
7. Begin field testing to determine whether the crop's agronomic properties are satisfactory and to measure trait performance.
8. Simultaneously conduct feeding trials, agronomic studies, etc. with regulatory agencies to ensure the safety of the new product.

Our Commitment to Stewardship

Pioneer is committed to the responsible development, marketing and distribution of products and services that improve our customers' ability to increase the quality and quantity of the world's food supply. In doing so, we are committed to preserving the environment, respecting people and cultures and reaching out to stakeholders.

Before Pioneer markets a new transgenic trait, we conduct thousands of tests to ensure that the product's nutritional value, safety and field performance are similar or superior to traditionally bred varieties. We conduct field tests at multiple locations during several years to evaluate agronomic performance and to thoroughly understand the transgene. We assess food safety and nutritional value of the transgenic crop by:

- measuring the amount and availability of nutrients;
- testing the safety of the new protein produced by the new gene; and
- voluntarily conducting animal growth and feeding studies.

Biotechnology is critical to sustainable agriculture throughout the world. And Pioneer will continue to utilize biotechnology tools to provide solutions that positively impact our customers' productivity and profitability.

Pioneer continues to use the finest germplasm, methods and technologies to deliver superior soybean varieties to our global customers.