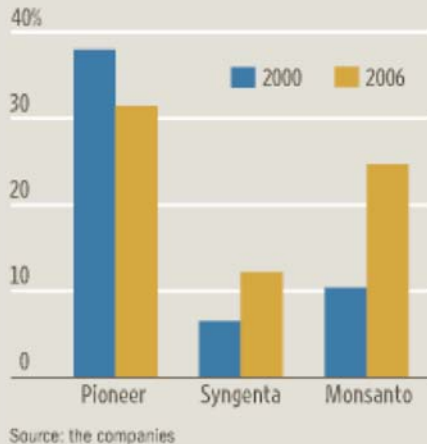


Seed Money

Growth in genetically modified seeds has shifted the balance of power for seed companies. U.S. corn-seed market share:



New Leaf

Seed Firms Bolster Crops Using Traits Of Distant Relatives

By SCOTT KILMAN

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SLATER, Iowa -- In a low-slung building amid farm fields, agriculture's second biotechnology revolution is dawning.

Rows of robotic devices are deciphering the DNA in slices of thousands of corn plants sent daily from as far away as Chile and Hawaii. Scientists here search the results for subtle genetic differences that explain why a particular plant is better than others at tolerating cold, repelling insects, surviving drought or making more seed.

Armed with this knowledge, crop breeders can create better corn. But not by gene-splicing, the method that has stirred resistance, especially in Europe, to crops spiked with DNA from other organisms. The new technology uses old-fashioned selective breeding -- finding plants with desirable traits and mating them. Except that in this case, selective breeding is turbocharged.

Thanks to the decoded genetic blueprints, seed producers can know with precision which plants carry a desired trait and which genes cause it. Just as important, once they've planted seeds from such a plant, they can learn quickly through gene tests whether its offspring sprouting in a test field have inherited the trait.

The result is that breeders who used to need a decade to develop marketable new seeds by traditional selective breeding can do it in half the time. And they can bring about some crop improvements that were once thought attainable only by splicing in foreign genes to create genetically modified organisms.

It is too early to know when these changes will hit grocery shelves in force, or how much farmers will be charged for these new seeds. But critics of "GMO" crops generally accept this new gene technology since it brings in no foreign DNA. "The public is lukewarm on GMO products," says George Kotch, research director of **Syngenta** AG's North American vegetable seeds business. "Now we have a technology that doesn't have an image problem."

Using it, Syngenta, the big Swiss biotech company that operates the Iowa laboratory, is developing drought-resistant corn, which someday could open up more of the Great Plains to the crop. **DuPont** Co.'s Pioneer Hi-Bred unit is developing corn that resists a Midwestern bane called Anthracnose stalk rot. **Monsanto** Co. has developed soybeans whose oil stands up to repeated reheating, as in fast-food restaurants, without having to be hydrogenated, which creates artery-clogging trans fats.

To prepare for such feats, seed companies tap a trove of native traits that already exist somewhere within a plant's species, but often not in the uniform crops that now populate farm fields. These traits were built up over the ages by plants evolving in a range of circumstances, but began to be filtered out thousands of years ago as farmers domesticated the varieties that best suited their immediate needs.

Companies are looking at a weedy ancestor of corn in Mexico, for instance. They are testing wild relatives of cucumbers and watermelons in Thailand. A side benefit of breeding such plants with today's varieties would be to add back a bit of genetic diversity. That could give today's homogeneous crops some protection from the risk of being decimated by a single killer disease.

The technology shift spells change in the way crop-biotech companies wage their battles. Monsanto has grabbed customers from Pioneer by getting to market first with more genetically modified seeds. That and acquisitions have driven Monsanto's share of U.S. seed-corn sales to roughly 25% from 10% six years ago, while Pioneer's has slipped to about 31% from 38% in 2000. Syngenta lifted its share to about 12% from about 7% through acquisitions. Now, GMO seeds have largely saturated U.S. markets for corn, soybean and cotton seeds.

At the same time, gene-marker technology is speeding the rate at which these major crops become more productive. Yields per acre have been growing steadily for decades -- the gain being due mostly to careful breeding by seed companies, not to genetic engineering. Since gene markers accelerate plant breeding, companies think their use will double the rate at which yields increase, currently a bit under 2% a year. Such a change could return seed companies to competing more heavily on the vitality and productiveness of their seeds, not just the latest trick of bioengineering.

"Breeding is getting better and faster," says Monsanto Chief Executive Hugh Grant. "The competitive dynamic is moving back to what it had always been."

The seed companies are beginning to boast of their prowess with marker technology by touting such things as their computer power. Plenty of that is needed for the extensive calculations involved in linking a plant trait to a subtle DNA variation. Monsanto says that by next year its data-storage needs will be up 12-fold from 2003. Seed companies are starting to hire Ph.D. mathematicians.

At the heart of the new enhanced crop breeding are what are called gene markers. Once scientists identify a gene that imparts a desired trait, they build a probe that will find and attach itself only to a DNA fragment, or marker, unique to that gene. The marker becomes a handy way to monitor crop breeding efforts, letting breeders tell quickly whether a given plant has inherited the trait they want to encourage. There's no need to wait around until the plant matures.

"For plant breeders, markers are the biggest thing to happen since Mendel," says Dan Dyer, head of Syngenta's soybean development, referring to the Austrian monk who plumbed the laws of heredity in the 1800s by mating pea plants. Seed companies sometimes call the use of markers molecular breeding.

Some food companies are turning to gene-marker technology on their own. **H.J. Heinz Co.** scientists use it to help them improve "processing qualities" of the tomatoes farmers grow for Heinz. Commodity processor **Archer-Daniels-Midland Co.** is using gene markers to assist it in trying to improve pinto and lima beans.

Tailored Crops

Crop breeders are increasingly using gene markers to grow plants with desired traits. Examples in the works:

BREEDING PROGRAM	PLANT
Arcadia Biosciences	Wheat safe for sufferers of celiac disease
Monsanto	Soybeans for making beeflike veggie burgers
DuPont's Pioneer	Stalk-rot-resistant corn
Syngenta	Aphid-resistant soybeans
Washington State University	Fungi-resistant organic wheat

Source: the companies and university

While marker technology has been around in some form for years, only now is it becoming practical on a large scale. The cost to scan a sample of plant tissue has dropped to pennies from dollars in five years, thanks to advances from instrument makers such as Applied Biosystems Group.

One result may emerge in the produce aisle. Major seed companies have historically saved their big money for crops with the most growers, such as corn, soybeans and cotton. Many fruits and vegetables haven't been the target of gene-splicing efforts. One reason is that consumers are considered more sensitive about GMO crops eaten whole, as fruits and vegetables are, than about crops used as ingredients or livestock feed. But now there are efforts to develop fruits and vegetables through selective breeding assisted by gene markers.

Last winter, a virus swept through the tomato fields of Mexican farmers. Scientists at Syngenta identified a tomato variety that was immune, and isolated a snippet of DNA responsible for the immunity.

With this as a guide, they think they'll be able to pass the resistance on to other tomatoes in three to four years, which they say is about half the time it would take without the aid of gene markers.

Arcadia Biosciences Inc. in Davis, Calif., is using markers to help it breed lettuce and tomatoes that stay fresh longer. Arcadia has a contract with the Defense Department, which spends about \$500 million a year on produce but sees much of it spoil. The contract goal is to double the shelf life of tomatoes to 54 days and extend lettuce's 50% to 32 days.

"We have no objection to genetically modified crops [but] if we can do it without transgenic technology, it doesn't hurt," says Gerald Darsch, director of the Pentagon's combat feeding program.

Organic crop breeders are embracing this benign version of biotechnology, which makes it easier to take advantage of natural plant traits. An example involves fungi that often infest fields of organic wheat in the Northwest. Stephen Jones, a wheat breeder at Washington State University, and his colleagues found genes in some wild wheat that resist the fungi. They're breeding a fungi-resistant wheat-crop variety with the help of gene markers. Mr. Jones says they hope to have it available in two or three years, or nearly five years sooner than it usually takes to develop a new wheat variety. "A lot of big problems can now be solved for organic growers," he says.

Using genes to speed selective breeding doesn't threaten the business of GMO seeds. For one thing, genetically modified seeds are very lucrative. Farmers around the world paid a premium of \$2.2 billion last year for GMO seeds such as corn that makes its own insect killer and thus doesn't need chemical insecticide.

Another reason is that not every trait that companies would like to impart to seeds can come from plant DNA. The corn that makes its own bug killer gets this skill from a bacterial gene inserted in the corn, not from anything that corn somewhere in the world already did.



Geoff Graham

But gene-marker breeding also can do things that genetic engineering can't. For instance, some desirable plant traits involve so much DNA it's impractical to try to transplant it. Yet plant breeders think they can lasso such traits through selective breeding, with markers making the job easier. As a result, the crop biotechnology industry -- led by DuPont, Monsanto and Syngenta -- is pouring hundreds of millions of dollars into programs to fingerprint the DNA of millions of individual plants across the globe.

Even with its new high-tech angle, crop breeding is still arduous, and still mostly done in the field rather than in a lab.

Geoff Graham, a 38-year-old Pioneer Hi-Bred breeder, walks many miles each summer among rows of Iowa corn. When his eye is drawn to a plant with a desirable trait, such as an extra-sturdy stalk, he sets out to mate it with similar plants he has identified elsewhere in the field.

He collects the plant's pollen by throwing a paper bag over its top -- called the tassel -- bending the plant over and shaking until pollen from the tassel falls into his bag. Then he goes to a row of corn plants that have had their ears -- the female parts -- covered with wax paper to shield them from wind-blown pollen. Removing the paper, he mates the plants by sprinkling pollen onto the threadlike "silks" that emerge from the ears.

It's a process he repeats hundreds of times a day in midsummer. The corn matures in the fall and is harvested, and the next spring in Iowa Mr. Graham plants kernels from the plants he mated. In the past, he then had to wait all through the next summer and fall for this newly planted corn to mature before he knew whether it carried the desired trait. Now, marker technology lets him test weeks-old seedlings in a greenhouse to see if they carry the gene. "With gene markers, one breeder can do the work of eight," he says.

The quest for corn resistant to stalk rot shows how much gene markers have helped. Researchers at the University of Delaware discovered that certain corn plants -- rare in the U.S. Midwest but more common in Brazil -- resist the rot. They mapped the gene's location in collaboration with DuPont's Pioneer Hi-Bred unit. Together the teams then developed a marker so breeders could screen their plots for plants that happened to carry the rare gene. This let them avoid the time and expense of observing how grown plants react to an outbreak of the stalk disease.

Crop scientists hope there are many other valuable genes out there like the one that fights stalk rot. As U.S. agriculture developed over many decades, the focus was always on developing crop varieties that do best in temperate areas like the Midwest. Scientists think that during this long process, many useful genes were unknowingly left behind in crops growing in other climates, such as at high altitudes or in the tropics. By some estimates, 80% of the genetic diversity of certain crops has yet to be mined.

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