

Huge Potential Importance-influence on my futures.

T

he 4,400 acres Dustin Spears farms with his father-in-law stretch for 50 miles across northern Illinois in an archipelago of disconnected, mostly rented plots. Even in the best of circumstances, it's a race to get the corn in the ground in time to take advantage of the full growing season. When spring is unusually cold and rainy, as it was this year, the window narrows even more.

Which is why Spears is in his tractor at two in the morning the first Monday in May, moving at 8 miles per hour through a halogen-lit haze of stirred-up topsoil. On the 60-foot planter behind him, a \$47,000 sensor array helps deposit each corn kernel at a depth of 2 inches, no matter how hard or soft the soil. A computer in the cab calculates the fertility of different parts of the field and adjusts the planter accordingly. The seeds themselves are a new hybrid with a candy-green coating containing insecticides and fungicides. DNA inserted into the seeds produces a protein that kills pests such as corn borers, earworms, and rootworms. Other spliced-in genes confer immunity to the weed killers Spears uses, greatly simplifying his spraying schedule.

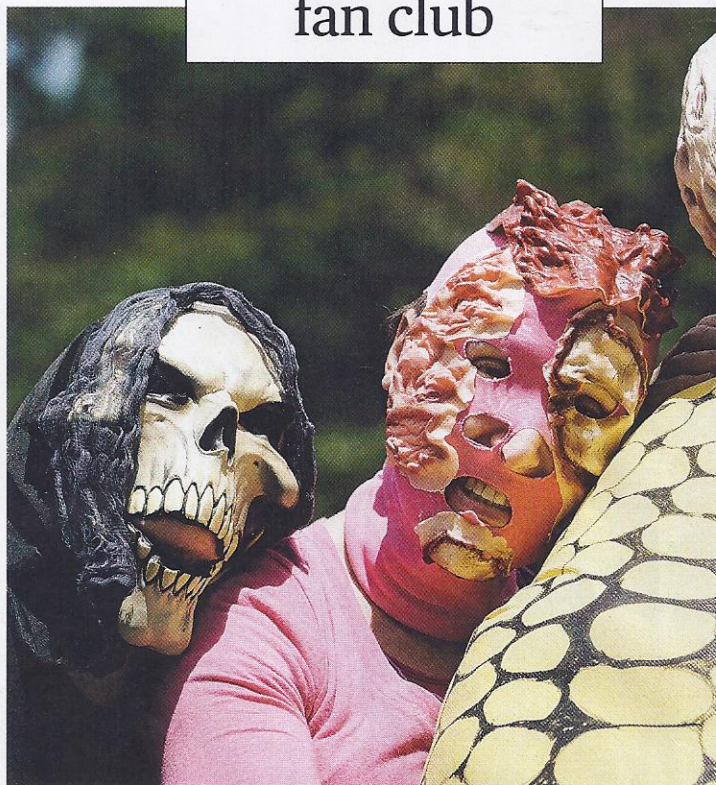
The 32-year-old farmer sits in the bouncing tractor cab, wearing a hooded sweatshirt, a baseball cap, jeans, a Bluetooth headset, and a look of fatigue. The steering wheel is folded up out of the way. When the tractor nears the end of a row, its autopilot beeps cheerfully, and he taps a square on one of the touchscreens to his right. The tractor executes a turn, and he goes back to surfing the Web, watching streaming videos, or checking the latest corn prices. "You see how boring this gets?" Spears asks. "I'll be listening to music for 12 hours. I'll refresh my Twitter timeline, like, a hundred thousand times during the day."

Spears is an early adopter who upgrades his equipment every 12 months (next year's tractor will have a fridge in the cab, he says) and who just bought a drone to monitor his fields. He can afford to: Corn prices are high, and farmers like him can take home hundreds of thousands of dollars a year. Still, he thinks such technologies—the smart planter software and sensor array, the iPad app offering planting and growing advice—are only going to get more common. So does the company that makes many of those tools, as well as the high-tech seeds Spears is planting: Monsanto, one of the most hated corporations in America.

In a Harris Poll this year measuring the "reputation quotient" of major companies, Monsanto ranked third-lowest, above BP and Bank of America and just behind Halliburton. For much of its history it was a chemical company, producing compounds used in electrical equipment, adhesives, plastics, and paint. Some of those chemicals—DDT, Agent Orange, polychlorinated biphenyls (PCBs)—have had long and controversial afterlives. The company is best known, however, as the face of genetically modified organisms, or GMOs.

On May 24, cities worldwide saw the second annual "March Against Monsanto." In New York City, a couple thousand protesters gathered in Union Square, next to a farmer's market, to hear speakers charge that the company was fighting efforts in states all over the country to mandate the labeling of GM foods; that organic crops were being polluted by GM pollen blown in on the wind, only for Monsanto to sue the organic farmers for intellectual-property theft; that Monsanto had developed a "Terminator" gene that made crops sterile. Some of the protesters were dressed as bees—studies have found a connection between the colony collapse die-off of honeybees and a common class of insecticides called neonicotinoids. (Monsanto does not make neonicotinoids, but it does incorporate them into some of its seed treatments.)

The Monsanto fan club

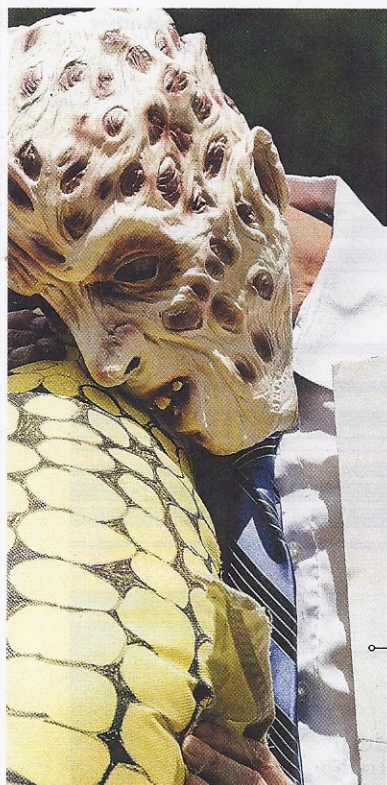


The company's name has become shorthand for corporate villainy, like Standard Oil a century ago or the private military contractor Blackwater. A rumor persists that Blackwater, whose own reputation problems have led it to change its name multiple times, has merged with Monsanto. At the New York march, one young man held a sign that read, "Why buy Blackwater if your goal is to feed the world?"

The company has not, in fact, merged with Blackwater. It has never brought a Terminator seed to market and has pledged not to try. It is, however, extremely profitable. Today's Monsanto was spun off in 2000 after a merger with the drugmaker Pharmacia & Upjohn. That year the new company's net income was \$149 million; last year it was \$2.5 billion. Since 2000, Monsanto's stock market value has grown from \$7 billion to more than \$66 billion.

Widespread public suspicion of GM crops has not stopped their spread: According to the Department of Agriculture, 90 percent of the corn and cotton and 93 percent of the soybeans planted in the U.S. last year were genetically modified. These are commodity crops used mostly for animal feed and fuel ethanol, but they also provide the corn syrup in bottled beverages and the soy lecithin in chocolate bars. And with the public still leery of the technology, it was perhaps inevitable that after a stretch of relative quiet the GMO wars would heat up again. The latest front is over food labeling: In the past two years, ballot initiatives that would have mandated labeling narrowly lost in Washington State and California; in May, Vermont's governor signed a bill into law.

While the debate about the impact of GM crops on the environment continues, the question of their effect on human health looks increasingly settled. The National Academy of Sciences, the American Medical Association, the World Health Organization, Britain's Royal Society, the



A May protest against Monsanto in Manhattan's Union Square

European Commission, and the American Association for the Advancement of Science, among others, have all surveyed the substantial research literature and found no evidence that the GM foods on the market today are unsafe to eat. One of the few dissenting research papers, a 2012 study in the journal *Food and Chemical Toxicology* that found tumors in rats fed modified maize, was retracted by the journal last fall after questions were raised about the researchers' methodology.

At the same time, after a decade concentrating on seeds and genetically engineered "traited" crops, Monsanto is broadening its focus. Much of its \$1.5 billion research budget goes into traditional plant breeding, the same craft the botanist Gregor Mendel pioneered on his pea plants a century and a half ago, though at a scale and speed that would boggle the friar's mind. Monsanto is also researching the targeted use of bacteria, fungi, and other living organisms to protect and nourish seeds: farming technologies that borrow, at least conceptually, from organic agriculture.

In perhaps the biggest shift, Monsanto is moving into computing. Through the purchase of two companies, Precision Planting and the Climate Corporation, Monsanto has begun offering software and hardware products that gather and process information relevant to a farmer—data about temperature, rain, soil, seeds, and pests. Big Data has already transformed everything from retail logistics to dating; Monsanto believes it can do the same for farming. "This isn't about a farm," says Hugh Grant, Monsanto's chief executive officer and chairman. "It's not about a field. It's literally about every square yard in that field and doing the best thing for the soil and the water in that yard-by-yard approach. I think it's a big piece of the future company."

Talk to Monsanto executives or the employees who develop and sell its seeds and sprays and software, and they'll tell you that everything the company does is aimed at making farming

more efficient and therefore more environmentally friendly. Monsanto's critics see this as the cynical rationalization of a profitable company with a problematic history. Whatever the company's motives, the overwhelming preponderance of scientists agree that in coming decades the world will grow warmer and more crowded. Feeding its swelling population will get more difficult, especially as billions rise into the middle class and develop a taste for resource-intensive foods like meat and fresh produce. Monsanto contends that its massive labs and global network of test plots, its DNA sequencers, plant breeders, software coders, and tireless intellectual-property lawyers are some of the best tools for dealing with those challenges. The argument over Monsanto is an argument, in part, over whether the same companies that gave us today's food system can also give us tomorrow's.

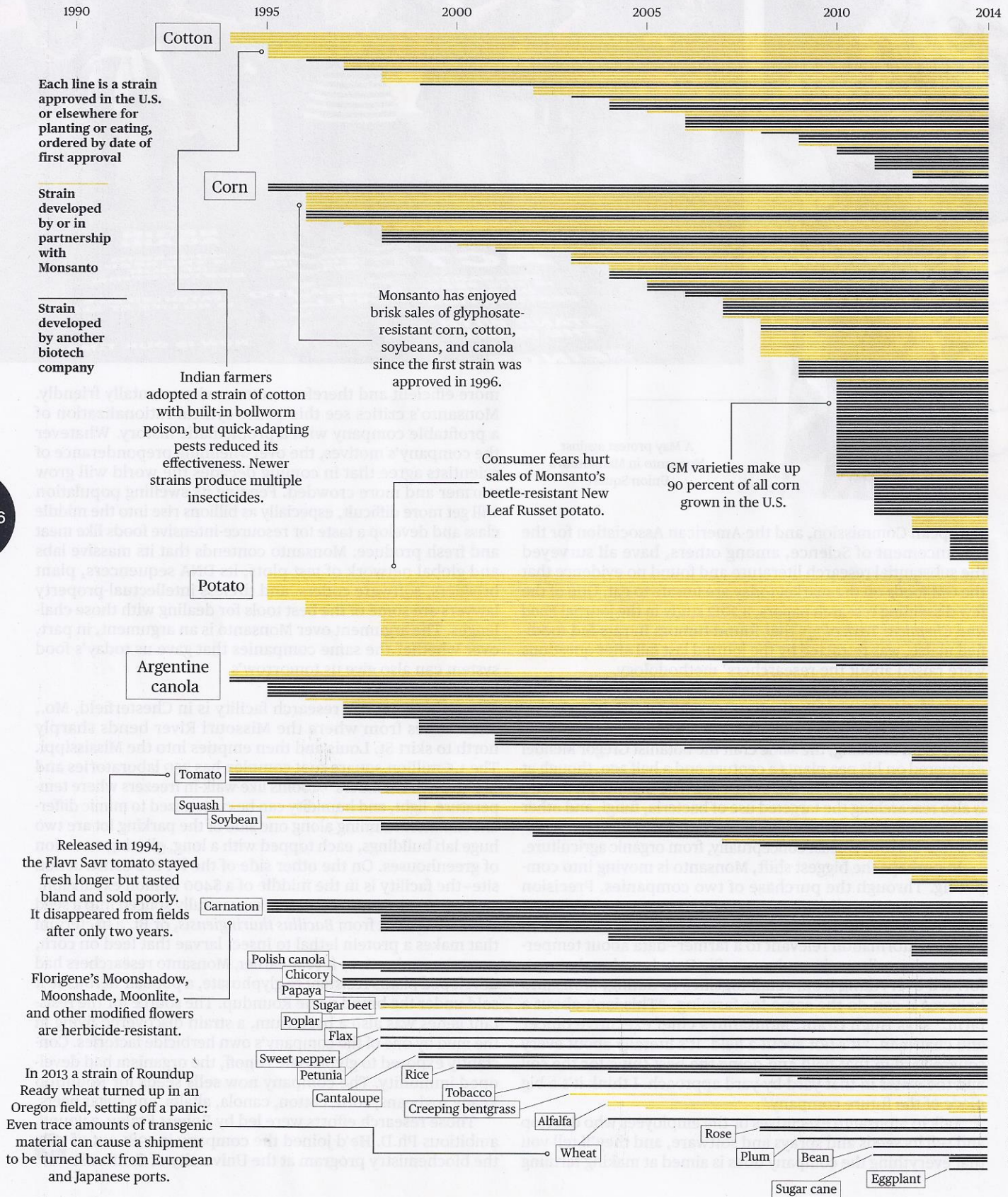
The main Monsanto research facility is in Chesterfield, Mo., a few miles from where the Missouri River bends sharply north to skirt St. Louis and then empties into the Mississippi. The 1.5-million-square-foot complex has 250 laboratories and 124 "growth chambers"—rooms like walk-in freezers where temperature, light, and humidity can be customized to mimic different climates. Running along one side of the parking lot are two huge lab buildings, each topped with a long, glinting serration of greenhouses. On the other side of the lot is a construction site—the facility is in the middle of a \$400 million expansion.

In 1986, Monsanto scientists successfully spliced into a seed a stretch of DNA from *Bacillus thuringiensis*, or Bt, a bacterium that makes a protein lethal to insect larvae that feed on corn, potatoes, and cotton. A year earlier, Monsanto researchers had developed plants resistant to glyphosate, a popular herbicide it sold under the brand name Roundup. The source for the resistant genes was also a bacterium, a strain discovered living in the mud by one of the company's own herbicide factories. Constantly exposed to glyphosate runoff, the organism had developed immunity. The company now sells seeds for Roundup Ready soybeans, corn, cotton, canola, alfalfa, and sugar beets.

Those research efforts were led by Robert Fraley, a young, ambitious Ph.D. He'd joined the company in 1981 out of the biochemistry program at the University of California

Frankencrops

It's been 20 years since the first genetically modified crops were approved for agriculture. Like them or not, GM cotton, corn, and other crops are a huge business. In 2013 plantings covered almost 700,000 square miles globally. —Evan Applegate and Keith Collins



at San Francisco, where genetic engineering had effectively been invented several years before. Today, Fraley is Monsanto's chief technology officer and, along with Grant, the company's public face. He tweets and blogs and maintains a steady schedule of speaking engagements. He's Monsanto's voice on state labeling laws: "It would just create unnecessary cost and confusion.... We are absolutely supportive of voluntary labeling." He's also the chief cheerleader for projects such as the company's research into how genetic technology might combat colony collapse: "A pretty cool example of using these very precise biological tools to target bee pests." The son and grandson of Illinois farmers—a fact he is careful to mention—Fraley speaks slowly, in a cadence as regular as a furrowed field. And while he tries for a tone of disappointment when talking about the company's opponents, his anger is not hard to discern.

"I'm always amazed that critics can figure out some simple sound bite to point out how all these things are bad and wrong, and that there's a better way," he says. "Show me that better plan for improving yields and doubling production to meet demand for food, and we'll probably be doing research on it." He rattles off studies demonstrating that Bt crops have reduced the use of pesticides and that Roundup Ready technology has allowed many farmers to stop tilling for weeds, increasing yield and reducing soil erosion and water loss. He doesn't dwell on the fact that those gains have been reversed somewhat in recent years, as insects begin to develop resistance to Bt proteins and as the widespread use of glyphosate has led some weeds to evolve resistance to it as well.

For Monsanto, the introduction of a new trait, including research, development, and regulatory approval, typically takes a decade and costs about \$100 million. The company is notoriously vigilant about that investment. It sends investigators to test farmers' crops to see if they're using its seeds without paying for them—either by getting them from a friend or replanting seeds saved from the previous year's crop. There is a toll-free number to report "seed piracy." Even before biotech seeds came on the market, corn farmers tended not to save seeds, since store-bought hybrids delivered higher yields, but the technology agreement farmers sign when buying Monsanto's biotech seeds forbids them from doing it.

The company has sued farmers, a practice that accounts for much of its reputation as a corporate bully. Monsanto says these suits are rare—250,000 American farmers buy its seeds every year, and since 1997 it has sued 145. Fraley argues that these are not farmers, organic or otherwise, whose crops are inadvertently pollinated by GMOs. They're growers who intentionally try to get the benefits of GM seeds without paying the \$40 or so extra per acre they cost. "We sue such a small fraction of our customers that, if you compared us to a software company or a pharmaceutical company, it would be trivial," he says. "These are usually large growers who are trying to make money reselling seed or growing it." In the cases that have gone through trial—most notably the 1998 case of a feisty Canadian canola farmer named Percy Schmeiser and a 2011 suit by the Organic Seed Growers and Trade Association—the courts have agreed with the company.

The size of Monsanto's R&D apparatus—it has 30 research facilities and more than 250 breeding sites around the world—only underlines how much the science behind its products depends on a brute-force approach. The term "genetic engineering" implies a level of control that plant science has not yet attained. Mostly, the process involves taking bits of genetic material, inserting them into the DNA of a seed, seeing what

sort of plant results, and repeating the process thousands of times until something useful happens.

Because genetic engineering is so expensive and time-consuming, the company uses it only for traits it has to bring in from other species. For everything else, an accelerated version of traditional breeding makes more sense. Monsanto researchers have sequenced the genomes of its major crop lines so that, rather than waiting for an entire generation of plants to grow to maturity, breeders can take samples from seedlings—using, in many cases, a hole punch to collect them—and test them for genetic markers associated with desired traits such as drought tolerance or stronger stalks. Monsanto breeders also use computer simulations to try out millions of virtual pairings.

The company has designed something it calls a seed chipper, a closet-size array of tubes and plungers that takes seeds—about one per second—and shaves off a tiny piece to test for genetic markers. It uses an optical scanning system to ensure that the embryo inside doesn't get nicked. Plants are tested for traits before they're even born. "You can run tens of millions of seeds through the lab that otherwise you'd have to go plant in the field," says Sam Eathington, the company's head of plant breeding. "You know, corn, you usually plant 30,000 an acre. So you can do the math, right? It's a lot of land."

Marker-assisted breeding has also helped Monsanto venture into the produce aisle. The company has begun selling seeds for its own brand-name fruits and vegetables, among them the Melorange, an extra-sweet cantaloupe, and the EverMild, a less lachrymose onion. The company's breeding armamentarium has allowed it to get these qualities into produce quickly, without having to run the regulatory gauntlet and deal with the cultural baggage of a GMO. According to industry analysts, sales

of the seeds have so far been disappointing. There are new products in the pipeline, though, among them a watermelon that, in the words of Kenneth Avery, head of Monsanto's vegetable business, "almost crunches like an apple."

Last October, Monsanto announced the \$930 million Climate Corp. acquisition. In part an insurance company, Climate Corp. was started in 2006 in San Francisco by two Google engineers as a way to draw on historical weather data to create more accurate, localized forecasts. The founders, David Friedberg and Siraj Khaliq,

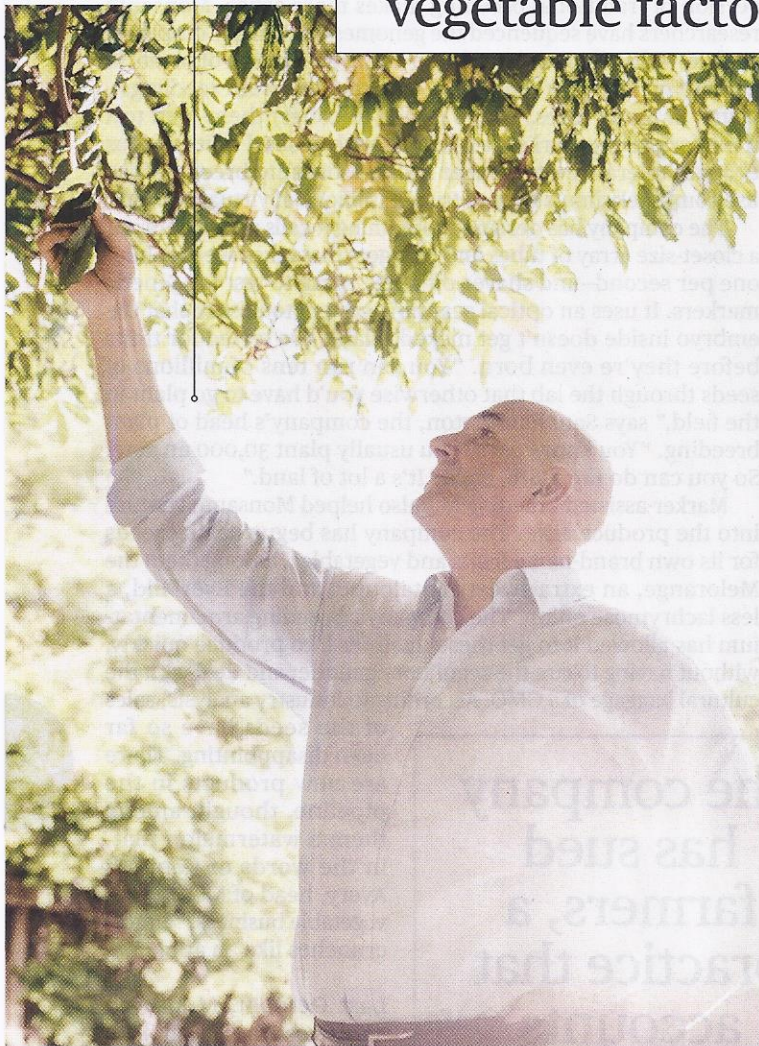
quickly realized that the business most dependent on the weather was farming and began using their software and the climatological data they'd gathered to offer a new kind of crop insurance. Climate Corp. policies have no claims process: If the company's models show that the weather over a farmer's field has been bad enough to hurt yields—too much rain or too little, daytime heat stress or an early freeze—and if that farmer has bought coverage to cover those events, he automatically gets a check.

"The first time I heard about Monsanto being interested, I had to ask, 'What's a seed company talking to a software company about?'" says Vinod Khosla, a venture capitalist and early investor in Climate Corp. Monsanto particularly liked the way the high-tech insurer used data to help protect

**The company
has sued
farmers, a
practice that
accounts
for much of its
reputation
as a corporate
bully**

Hugh Grant,
CEO

Inside the mutant vegetable factory



A scientist takes
soybean tissue
samples...



...and examines an
ear of corn

farmers not only from poor weather but also poor decisions. For \$15 an acre, Climate Corp. offers a set of software “advisors” that can tell a farmer what, when, and how deep to plant, whether to irrigate, which fertilizer to apply and where perhaps to reapply. “For a grower producing a corn crop in the U.S., he’s making somewhere between 40 and 50 decisions,” CEO Hugh Grant says. “And a lot of those are cascaded: If you made bad choices early, you live with them.”

Other agriculture giants have begun selling similar products—DuPont’s Pioneer seed division and Deere have formed a partnership to do so. In and of itself, helping farmers make better decisions is not a controversial idea. And yet Monsanto’s attachment to the concept has generated suspicion. “The more data they control, well, the more they’re going to control the farmers,” says Hans Herren, a Swiss agronomist who heads the sustainable development think tank the Millennium Institute and won the prestigious World Food Prize in 1995. (Last year, Fraley and two other pioneers of plant biotechnology won the award.) “So the farmers will go from being entrepreneurs to basically laborers for Monsanto.”

Climate Corp.’s privacy policy emphasizes that the company does not own a farmer’s data. “Your Information remains yours

even after you provide it to us,” it reads. Information, however, is different from understanding, and the broader critique of both Climate Corp. and Monsanto is that they’re taking knowledge that once resided in farmers’ brains and centralizing it—some of it in seeds, some of it in software. Spears, the Illinois farmer, doesn’t pretend to understand the considerations that drive the recommendations he gets from his Climate Corp. software, any more than he pretends to understand the avionics inside his drone. “There are these yield curves that tell you you’ll get more bushels if you plant between this time and this time, but I don’t know how they come up with them,” he says. “I’m not a scientist.”

Technology has already dumbed down everything from flying an airliner to filing one’s taxes, and in so doing made those tasks safer and more efficient. But food feels different to many people. “You know, when this data-intensive system recommends you buy a certain seed, it’s going to be a Monsanto seed,” says the author Michael Pollan, a prominent critic of industrial agriculture. “So I have a strong objection to letting any one company exert that much control over the food supply. It depends on the wisdom of one company, and in general I’d rather distribute that wisdom over a great many farmers.”

Friedberg, Climate Corp.’s 34-year-old co-founder and CEO, is aware of this concern. He’s a lifelong vegetarian who will talk with little prompting about the environmental cost of meat and the great benefit of adding quinoa to North American crop rotations. He hadn’t heard many good things about Monsanto before he started negotiating with the company. What he realized, though, is that the best way to think about Monsanto is as a technology company. Its technology “just



happens to take the form of a seed,” Friedberg says. “As I got to learn about it I was like, ‘Wow, this company is as innovative and as impressive as Google.’”

“Farmers make economic decisions that they believe to be best for their families,” he goes on. “They choose to buy Monsanto seeds because it makes them the most money. They may not like the licensing terms or the licensing agreement, because that’s not how they used to do business, but it’s the way that Monsanto can afford to invest a billion dollars a year in R&D on finding new genetic traits that can help farmers get more yield per acre.”

Friedberg exudes an implacable rationality—one of his favorite words is “flawed.” He says the fear and skepticism about Monsanto is based in large part on misinformation and has taken it upon himself to help change that. In late January he hosted a small dinner at his apartment, a triplex in the Pacific Heights section of San Francisco. He invited Fraley, Pollan, Khosla, and a few other activists and Silicon Valley executives and investors. Friedberg and his six guests had drinks around a fire pit on the roof, taking in sweeping views of the city and the bay, then sat down for a vegetarian dinner prepared by a former cook at Chez Panisse, the Berkeley restaurant and temple of organic, locavore cuisine.

By all accounts, the conversation was friendly. Some of the guests disagreed about the scalability of organic farming

and the sustainability of current industrial farming practices, but there was also a consensus that there were instances—the creation of virus-resistant papayas, for example—where genetic engineering has brought clear benefits. “I mean, you know, there was a fair amount of back and forth between Robb [Fraley] and me, who disagree on many things,” says Pollan. “But it was cordial and interesting. And for me it’s a great privilege to get to talk to these people who make decisions that affect lots of people.”

Fraley’s recollection is similar. “Because I have spent so much time on the advocacy side and spent so much time wrestling with some of the critics, maybe one of the things I overlooked was how many people are in the middle,” he says. “And so that was exciting, and it was, for me, a small epiphany.”

The dinner went until 11:30, and afterward there was a round of e-mails, some with links to scientific papers people had mentioned. Pollan sent around a study showing that farms using organic methods, such as long crop rotations and limited chemical inputs, could outperform conventional industrialized ones. Friedberg read it; he thinks the research contains a number of “flawed assumptions.” Still, he’s planning to get Pollan over to the Climate Corp. offices and then out to Monsanto’s vegetable breeding site in nearby Woodland, Calif. As he puts it, “We’re going to try and keep the dialogue going.”

—With Jack Kaskey