Crop breakthrough! No GMOs! Let's celebrate!–Why advanced farm technology scares us

Over the past month I've read four very interesting articles highlighting advances in crop breeding with similar headlines that underscore how uncomfortable many people view food and agricultural technology. The coverage of two of the breakthroughs, however, had a similar theme, along the lines of: "The amazing crop innovation that didn't need GMOs!" There seemed be what amounted to a sigh of relief that something revolutionary in breeding might be achieved without 'subverting nature' without 'resorting' to GMOs.

Clearly, the articles played to the large audience of readers skeptical or fearful of genetic engineering. But what the headlines and often the stories themselves didn't address was the potential costs or benefits of these "amazing crop innovations" as compared to other means to achieve similar or even more ambitious goals. Are the risks, for example more or less than what we confront with new GM crops? Why the need to hype solutions that don't involve transgenics as if they would lead to ethically superior outcomes?

We'll get to the cultural angle later. But first let's look at the science.

Making photosynthesis more efficient

Most plants face a major evolutionary challenge. Plants, as you may know, make their way in this world by turning carbon dioxide and water into sugar and oxygen, and as a result they suffer a bit from their own success. When they got started with that strategy for metabolizing what was on hand into energy, the Earth's atmosphere had more carbon dioxide and less oxygen than it does now. This has changed largely owing to the plant's own hard work. That has played a bit of havoc with the workings of an enzyme called Rubisco which works to grab carbon dioxide from the air for fuel. Unfortunately, it didn't evolve to be that careful about what it absorbs, so it takes in both useful CO_2 and useless oxygen. When it first got started, it didn't matter so much because there was so much more CO_2 than oxygen. Not so much anymore.

Most plants, but not all (think fast growing weeds), have evolved in response to the change in atmosphere in a straightforward way. They produce more Rubisco. This works, but it's very inefficient. It has however, made Rubisco one of the most abundant proteins on Earth (so it's got that going for it). Some plants have evolved a version of the Rubisco enzyme that can distinguish CO_2 from oxygen. So have some bacteria, and bacteria tend to be amenable to moving genes around.

So a team of researchers headed by Maureen Hanson from Cornell University and Martin Parry of Rothamsted Research in England, have taken two genes that produce an efficient version of Rubisco from cyanobacterium, along with a helper gene, and successfully introduced them into tobacco plants, while silencing the tobacco's Rubisco genes. Biotech breeders often start with tobacco plants, like bacteria, as they tend to be very accepting of new genes, This makes them an easy plant to test out new ideas. The new Ebola drugs are being developed in this very way.

In a paper in Nature, they report testing two variations of helper genes against a control tobacco plant.

The group was successful in moving the new Rubisco into tobacco and activating it, while silencing the native version. Both versions performed CO_2 fixation considerably better than the control.

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About this breakthrough, biologists Dean Price and Susan Howitt wrote in Nature: “The work is a milestone on the road to boosting plant efficiency. The advance can be likened to having a new engine block in place in a high-performance car engine — now we just need the turbocharger fitted and tuned.”

Unlocking the wheat’s full potential

Wheat has always been a tough nut (grain seed?) for breeder to crack for two reasons. When wheat was domesticated, it went from a diploid, meaning something with two sets of chromosomes, to an allohexaploid with six sets. As the ancient grain spelt crossed with two other species, wheat ended up with six sets of chromosomes, two sets from each of three different species. This means that wheat ended up with an incredibly complex and gigantic genome. This has made the process for pairing chromosomes in reproduction more complex than in other plants. In a piece entitled, “Wheat gene discovery clears way for non-GMO breeding”, Eric Sorensen, Washington State University science writer explains:

> For some 35 million years, the wild ancestors of wheat routinely traded genes as they accidentally cross-bred with each other. But with the rise of agriculture and cultivated wheat 10,000 years ago, the plant’s genetic structure changed. Instead of being diploid, with two sets of chromosomes like humans and most other living things, it became polyploid, with, in the case of bread wheat, seven sets of six related chromosomes.
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> Starting in 1958, just five years after the discovery of DNA’s double-helix structure, researchers suspected that a specific gene controls the orderly pairing of wheat chromosomes during reproduction.
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> “If this gene was not present, there would be chaos in the nucleus,” said Gill. “Six chromosomes would pair with each other and sometimes five chromosomes would go to one cell and one to the other, resulting in a sterile plant. Because of this gene, wheat can be fertile. Without this gene, it would be more like sugar cane, where it is a mess in the nucleus and it can only be vegetatively propagated.”
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> But the gene also prevents wheat from breeding with related ancestors that can contain a vast array of traits preferred by growers.
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> “This gene would not allow rye chromosomes to pair with wheat,” said Gill. “We cannot get a single gene transfer into wheat as long as this gene is present.”

The other problem facing breeders is wheat’s massive genome – 17 gigabases (each gigabase is a billion pairs of DNA and RNA). This also stems from the fact that wheat is essentially three genomes rolled into one. For researchers trying to work with the wheat genome, this presents a serious data management and processor power challenge. However, a new method for dealing with wheat's massive genome has been developed by Laura Gardiner, a PhD student at the University of Liverpool, who has devised a program that cuts down massively on the amount of computing power necessary to look for useful mutations in different varieties of wheat:

> To find the right mutations, she takes advantage of the fact that 90% of the wheat genome is repetitive sequence and therefore not useful for the study, and picks out the remaining 10% that is gene sequence. By comparing the existing information on wheat with a simpler, but related plant, Brachypodium distachyon, Laura is able to 'stitch' together the active parts of the wheat gene and identify with confidence the areas which she is investigating.
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> "We have the complete sequence for brachypodium already," Laura explains. "This means that we know which areas of this plant's genome control flowering. We can then match them up to sections of the wheat genome and compare them with plants that we think are showing a mutation."
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> This means that a huge amount of computer power is saved. The whole genome of wheat is 17 gigabases – each gigabase is a billion pairs of the basic building blocks of DNA and RNA. Looking only at the 10 percent of wheat containing genes this is reduced to 110 megabases – a megabase is a more manageable million pairs.

This will be of great help to breeders down the road, let's get back to the bigger problems of breeding wheat with related grains and the gene that controls chromosome pairing in wheat propagation. In 2006, British researchers believed that they had identified this gene, known as P1. But a new paper, published in the journal Proceedings of the National Academy of Sciences by WSU professor Kulvinder Gill, shows that the Brits had the wrong gene and he identified the correct one. He confirmed this by temporarily silencing the gene and cross breeding wheat with a wild relative:

> "Now that we have the gene, we can actually use that gene sequence to temporarily silence the gene and make rye and other chromosomes pair with wheat and transfer genes by a natural method into wheat without calling it GMO," Gill said.
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> Their first effort involves transferring a gene from jointed goatgrass, a wild relative of wheat, to confer resistance to stripe rust. The fungus is considered the world's most economically damaging wheat pathogen, costing U.S. farmers alone some $500 million in lost productivity in 2012.

> While facilitated by technology, the actual exchange of genetic material is similar to what has long taken place in nature, only faster. Incorporating the gene transfer into the overall breeding process, researchers can develop a new variety in five years, said Gill.
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> "If we let wheat evolve for another few millions years in the wild, maybe it will develop enough variation, but we don't have that kind of time," said Gill. "We need to solve this problem today."

This opens the door for potentially breeding a wide range of useful traits into wheat that have been tantalizingly out of reach, without transgenic breeding. It could allow breeders to breed for disease and pest resistance, drought and heat tolerance. Possibly even herbicide resistance. There is another, broader, economic reason why this is exciting. When wheat growers rejected the idea of transgenic wheat, investment in wheat breeding plunged, which has meant that wheat has fallen behind corn and soy in terms of yield, making it less attractive as part of a crop rotation. Getting wheat breeding back in the game could have benefits beyond those conferred by any single trait.

The fungus that confers drought tolerance

OK, this one isn't exactly a breakthrough in breeding, but it does deal with a trait breeders have long sought. More like a potential solution to one of the crop breeding's major puzzles, one that seed companies have been seeking a biotech solution to for a long time, with mixed results.

In a piece entitled "A Fungus Could Create Corn Crops Strong Enough That We Won't Need GMOs" Co.Exist writer Ben Schiller reports on the discovery and commercialization of a fungus that confers heat resistance to plants that it is in symbiosis with. Researchers first noticed it in the 90s. They were exploring geothermal areas of Yellowstone and noticed that Panic grass was able to grow in extremely hot areas that other plants could not. The difference was a fungus that the grass carried allowing it to survive in temperatures of up to 65 degrees Celsius (149 degrees Fahrenheit), when the grass would normally die at around 38 degrees Celsius.

The scientist who discovered this, Russell Rodriguez and Regina Redman, tested to see if this would work with crops like corn and rice. It did and today their company is in the final regulatory stages for marketing a product called Bioensure.

> Rodriguez and Redman developed a fermentation process to replicate the endophyte and produce formula in both liquid and powder form. The liquid is sprayed onto seeds before planting. The powder is aimed at the developing world, where refrigeration is an issue (the liquid needs to be kept at a constant temperature). Eighteen U.S. states now allows sales of BioEnsure, and Zachery Gray, Adaptive's VP of business development, says he expects the full 50 to come onboard in the next four months.
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> Under lab conditions, the corn seeds used 32% less water and produced 50% more mass compared to conventional corn, Gray says. The company charges based on the yield

> increases it promises. So, if a farmer can expect a minimum 3 percent increase—4.5 extra bushels on an acre that would normally produce 150 bushels—that's the premium they would pay. Adaptive actually promises to double farmers' investments.
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> Companies like Monsanto have developed drought-tolerant varieties of crops using genetic modification methods. But Gray claims they are not as effective as Adaptive's fungus-laced seeds. "There's nothing on the market that's had the success we've had," he says. "It's ironic that major companies that have spent a lot of money on producing drought-resistant genetically modified crops have all contacted us. If they were successful, they wouldn't be coming to talk to us."

This is all really cool stuff. I think the science is fascinating and exciting in every case. These are amazing times for those of us interested in food and agriculture. (The good and the bad. All amazing.)

What is also interesting is the positioning of the wheat and the fungus innovations specifically as non-GMO solutions. I saw them touted as such in the twittersphere, repeatedly. But why would people who have qualms about transgenic breeding feel more comfortable with these innovations? We can go through the checklist of objections to GMOs and they are nearly all there.

- "Wouldn't occur in nature" Check
- "Created in a lab." Check
- "Foreign genes" Check
- "No long term human testing" Check
- "Unknown impact on the environment" Check

While there are analogues to gene silencing in nature and some of the tools used to silence genes come from nature, all of those tools result in a biotech driven genetic modification that is highly, highly unlikely in nature. Use gene silencing to allowing breeding with non-compatible species and it's no longer clear why this isn't consider genetic engineering, it certainly is, except for a legal definition. It seems odd that people misgivings hinge so carefully on a fairly arbitrary legal definition rather than on a coherent philosophical and science-based one.

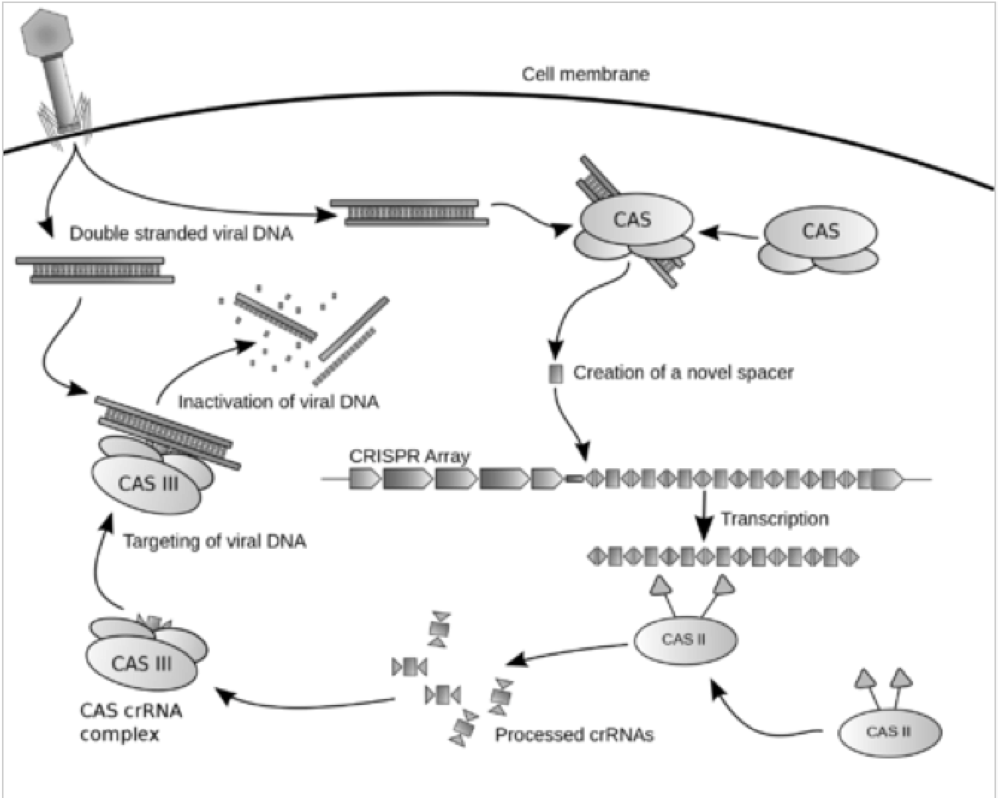

Diagram of the possible mechanism for CRISPR.[1]

Diagram of CRISPR a technique for gene silencing. (Image: Wikipedia)

Allowing wheat to cross with wild relatives means that it will have DNA from another species, species that we don't have experience with, either as food or as crops. We won't know the long term health or environmental effects of these cross breeds, and yet, because it doesn't use recombinant DNA, no one will bat an eye and there will be no mandatory testing or regulatory hurdles. This would be the case even if the trait bred for was herbicide resistance or caused the wheat to produce it's own pesticide.

Bioensure the product developed from a fungus found in geothermal areas and destined to sprayed on seeds to confer drought tolerance is apparently going through some testing, but it's as novel as any trait that has been bred into GE crops, yet, I haven't seen a peep from any environmental group. Those same groups would be going bananas if the genes that make the whole thing work were introduced to corn or rice transgenically.

None of this is to say that these innovations pose any special risks, it's just to point out that transgenic or not, the tools we are using these days are so powerful that the changes they can bring about are often as radical or more so than Bt corn or RoundUp Ready soy. Demarcations based on breeding techniques make little sense. Remember that quote how Gil characterized his breakthrough above?

> "Now that we have the gene, we can actually use that gene sequence to temporarily silence

> the gene and make rye and other chromosomes pair with wheat and transfer genes by a natural method into wheat **without calling it GMO**," Gill said.

Why are we hung up on semantics at this point? Instead of celebrating and scrutinizing each innovation based on the unique traits offered and the potential benefits weighed against legitimate risks, we get hung up over process and bicker over breeding techniques.

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Additional Resources:

- Marker-assisted plant breeding: agricultural genetics without GMOs, Genetic Literacy Project
- Global food shortage? How advanced breeding could domesticate 50,000 wild but edible plan, Genetic Literacy Project
- GMOs vs. mutagenesis vs. conventional breeding: Which wins?, FrankenFoodFacts