Biotech's impact on agriculture's future

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> PROFESSOR PAUL NICHOLSON

Technology is advancing at an exponential rate and agriculture is coming along for the ride. *CPM* explores what agricultural biotech is and how it could shape the future of the industry.

By Melanie Jenkins

Biotechnology, or biotech for short, is a field that combines biological processes and engineering science. It's an area of research and development that offers the potential for significant scientific advancement with scope to reshape agriculture.

Some areas of plant breeding where this is already being realised at 'muddy boots' level is through improved disease and pest resistance, increased drought or flood tolerance and better nutrient use efficiency. There are already companies producing biofertilisers, crops able to be grown in high salt conditions, and others which provide added nutritional benefits when consumed.

"What biotech is doing in every area, whether in therapeutics, agriculture or clean power generation, is creating extraordinary technologies developing at an exponential pace. Science fact increasingly looks like science fiction," says Andrew Craig, author of *Our Future is Biotech*. "It might seem like hype, but we're very likely to be on the cusp of a number of huge breakthroughs technologically."

So what's making advances in biotech possible? Moore's Law is an observation that the number of transistors in an integrated circuit doubles

The realms of fact

Andrew Craig of Plain English Finance notes that advancements made in biotech, which at times might seem the realms of fantasy, are happening as much within agriculture as anywhere.

around every two years. However, the term has become synonymous with a wider industry trend whereby the processing power and capability of technology increases on an exponential scale at a rapidly increasing pace.

Andrew sees this as a recognisable phenomenon in the advancements made in biotech, which at times might seem the realms of fantasy, but is in fact happening as much within agriculture as anywhere. "It's an area that can be seen as brushing up against the limitations of known physics, but computer chips have become as much as 1Bn times more powerful in my lifetime," he says.

Other factors such as Metcalfe's Law, or the exponential effect of a growing network, is helping scientists advance research at an extraordinary rate, adds Andrew.

Related to all of this is the hot topic of AI, which has been a key focal point in mainstream press of late. As such, it may come of little surprise that its reach has extended as far as agriculture. "The application of AI and machine learning could advance the next generation of genome sequencing analysis, making it far more accessible and affordable," he says. "We've already seen technology make this far more affordable for example, it cost $3Bn to sequence a single genome 20 years ago, when we did it for the first time – today it can be done in hours for as little as $100."

EXPONENTIAL UNDERSTANDING

"Putting all of this together means we have a level of understanding of biology that's unprecedented and developing exponentially. Through scientific collaboration, datasets can be interrogated while machine learning AI can be used to extrude substantive conclusions because without it the data is too sizeable and complicated to analyse," he says.

But bring up technology-based genetic modification in conversation and the likelihood is there'll still be those who blanch at the concept, whether they understand it or not, says Andrew. This is something he believes is entirely unjustified and has been propagated through bad press coverage and sensationalist approaches.

And with the more recent advances in gene editing technologies such as CRISPR, there remain communication issues whereby this technology hasn't been well differentiated from genetic modification. The former involves the precise alteration of a living organism's genome, and the latter usually consists of introducing foreign DNA into an organism.

In essence, gene editing simply speeds up a process that would have happened naturally or through traditional breeding techniques, but over a far longer period of time. "It's one thing to understand the genome and another thing to be able to do things with it, but with CRISPR we can," says Andrew.

While the UK government is still preparing to introduce legislation on the growing of gene-edited crops in England and Wales, the European Union

Resisting disease

How biotech could unlock the genetic potential of wheat

Prof Paul Nicholson heads up a team of researchers looking into the genetic basis of disease resistance in wheat at the John Innes Centre. Primarily working on fusarium head blight, he's also conducting research into a newer disease – wheat blast.

Fusarium is the more complicated of the two diseases and although there are 'known' resistance genes, there's some controversy around whether these are the correct ones, highlights Paul. "Two genes have been identified by other groups but our research doesn't support them. We believe we've identified a resistance gene but we can't publicise it without proof, demonstrating just how difficult it is to work with this disease."

The interactions within the plant when it comes to fusarium aren't simply to do with genetic resistance, but down to removing susceptibly factors to prevent the disease essentially hijacking and colonising the plant, he says.

"With resistant genes, these see the fungus, respond and resist to it, but the fungus must produce a protein for the genes to recognise. In some cases, the fungus doesn't actually require the protein and so evolves without it, leaving the plant blind to it.

"But the fungus also requires the plant to cooperate, and when we remove susceptible pathways the fungus will struggle to colonise it. We've discovered that deleting a piece of chromosome in wheat has resulted in increased resistance to fusarium. But it's critical to determine that in losing this, there are no trade-offs such as loss of yield or other agronomic features."

Because pathogens are so complex, increasing the resistance to one can lead to susceptibility to another, adds Paul. "So we have to conduct downstream analysis to determine if a single change will be beneficial overall."

Using techniques such as CRISPR, it's possible to knock-out multiple susceptibility factors at once, so alongside the use of GM, this is an area of research with the potential to revolutionise genetic resistance to disease, he adds. "The industry requires more resistance technology. It amuses me that researchers work to increase yield by 1-2% when a disease can easily take out 40% of it. And if we can't apply fungicides or manage disease with agronomy, this 1-2% is pointless."

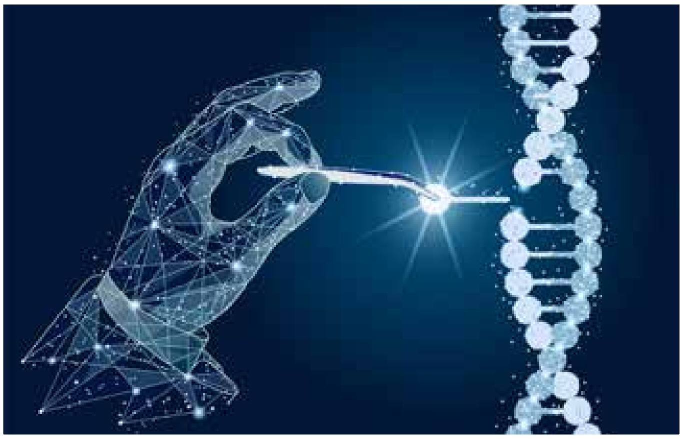
Wheat blast first appeared in Brazil in 1985, a likely result of the introduction of grass species from Africa which carried fungal isolates that generated a new disease, explains Paul.

This disease is now of concern in South America but was recorded in Bangladesh and Zambia in 2016 after wheat consignments due for bread consumption ended up being sown.

"Wheat blast is an easier disease for us to work on because resistance to it

Genetic resistance

Deleting a piece of chromosome in wheat has resulted in increased resistance to fusarium.



Gene editing potential

The UK government is still preparing to introduce legislation on the growing of gene edited crops in England and Wales.

has taken an about turn on its more cautious approach, voting on 7 February to lessen the regulatory oversight of gene-edited crops.

Other parts of the world, including the US, Brazil, Argentina, Australia, Canada and India, among many others, have been growing GM crops for years and all have either no restrictions or an approval on a case-by-case system in place for gene edited crops, according to the Global Gene Editing Regulation Tracker. ▶

involves major genes, so we can see and follow the isolates involved. The hard is part is finding those genes in plant material because it's rare. Additionally, we know we don't want these genes used singularly against wheat blast because it's more likely the resistance will be overcome, so we only want to deploy resistant genes in combination."

Using conventional markers for each resistance gene, biotech comes into play in the form of advanced sequences and genomic testing and improved affordability of these techniques. "We can now afford to do this by ourselves, whereas at one point the cost would have required the input of an entire international consortia.

"We're able to identify the resistant gene, isolate and test it, validate it and then produce a marker for conventional breeders to use in their own programmes to create varieties with resistance for growers," explains Paul.

The alternative to this approach is through GM, whereby genetic material from other plants is used to insert resistance. This would allow breeders to follow a single marker to follow resistance in a wheat's genome. "And we aren't talking about using genes from ridiculous sources, but from wheat relatives, such as grasses that already have resistance.

"GM crops have been in the environment for a while now and despite early scaremongering, the planet is still functioning," he says. "And as our understanding of plant material has progressed, there's been a realisation that what we think of as wheat isn't that simplistic.

"As more of the wheat genome has been sequenced, there's been an appreciation that it's naturally made up of crosses with wild grasses. So GM is something nature does all of the time, but we can now do it with a fine pair of tweezers or forceps rather than relying on pure luck."

Biotech for soil health
Advances in biotech will also come in the form of bioremediation which could help to improve soil health and remove contaminants from both soils and water.

"Improved crops and yields are hopefully what we'll see come out of gene editing and the hope is that in 3-5 years we could see significant advancements in what farmers could be able to grow," he continues.

Andrew observes that the increasing costs related with pesticides – both monetarily and environmentally – could drive innovation in this area with research scientists, innovative start-ups and larger chemical and breeding firms all looking to produce solutions to reduce reliance on these.

BIOREMEDIATION

"Advances in biotech will also come in the form of bioremediation. We know there are areas where soils are tired and depleted, but through the use of technologies alongside plants, fungi and bacteria, there can be a step-change in the health and productivity of soils. We'll be able to use microbes to clear up contaminants in both soils and water, for example."

He also believes there'll be further progression in the use of biofuels which will advance through breakthroughs in genetics and genomics to become more energy dense, efficient and productive.

And with these technologies becoming increasingly cheaper to explore, their integration within the existing status quo is likely to continue, he says. "For perspective, in the mid-1990s the components in a single iPhone would have cost something like $100M dollars. If you'd said to someone that there'd be a day where there would be 7Bn smartphones in the world, they'd have argued that the economics could never work, but that is precisely what happened. So I think many of the technologies we're seeing at the moment will follow a similarly exciting and surprising exponential trend." ●

Novel traits

Fast-tracking breeding to advance consumer benefits

Tomatoes aren't a regular feature in *CPM*. However, advances in biotech in these fruits are part of the larger picture, demonstrating how progress in this area could perhaps have an impact on cereals, pulses and root crops and their appeal to the wider industry in the longer-term.

Professor Cathie Martin's work at the John Innes Centre focuses on harnessing biosynthesis for sustainable food and health. Through her research, she's produced a purple tomato to provide a unique and niche product for consumers. This has been done through the introduction of high levels of anthocyanins – compounds found in fruits such as blueberries – using GM techniques.

"We've conducted experiments that suggest these purple tomatoes could have nutritional benefits similar to the berries as well, but this hasn't been definitively proven yet," she says.

The purple tomatoes have received FDA approval for human consumption in the US meaning she can now commercialise them and sell the seeds for home-use.

Because of advances in biotech and breeding technology, it's now possible to introduce new traits to tomatoes within a couple of years, rather than it taking the 10 years it used to, she notes. "It's also made it possible for small companies to enter this space whereas before it would've been the realms of larger companies with financial backing and scope at their disposal."

But while it took a long time to commercialise these tomatoes, she hopes the legislative approval process will become smoother with time. "It took us 16 years to get approval for the purple tomatoes, but this should be a lot shorter for genetically-edited material."

This leads to a second project that Cathie has been working on, namely to produce a tomato high in vitamin D. With few plants containing vitamin D and those residing in areas with low daylight hours in winter known to suffer from deficiencies, providing a source of the vitamin through tomatoes could have nutritional benefits to consumers, she explains.

Through gene editing, Cathie and her team have been able to knock-out a single enzyme in the tomatoes which has no negative effect on the plant but allows it to be enriched with vitamin D through exposure to sunlight.

"Through advances in technology we've achieved this trait in two years when it would've taken 10 using natural mutations. By accelerating our breeding procedures we can create novel products that provide nutritional benefits to consumers that might not have previously been possible."

But to get consumers on side, she has to provide evidence of the nutritional benefits which requires further trials and financial backing. "There's investment for sustainable and lower input crops because growers and producers can make money from this, but what do growers gain from added nutritional benefits?" she asks. "I'd really like to see a change in policy when it comes to nutritional research because improving diets has wide-reaching implications."

She also points out that any nutritional benefits have to be mirrored with yields and agronomic traits at least equivalent to what's already available. "We always have to focus on the traits producers want as well because they can't charge for nutrition."

And for consumers, products have to be visually appealing, something which can be achieved through gene editing, she says. "Then we have to get the rest of industry on board, and with supermarkets the bottom line always comes down to price," concludes Cathie.

Consumer appeal
Professor Cathie Martin's work at the John Innes Centre has produced a purple tomato to provide a unique and niche product for consumers.