Turbo Charging Nature?

The fast promises and slow delivery of gene edited crops

A BIGGER CONVERSATION

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The Promise of Speed

"We can turbo charge the natural breeding process our farmers have used for generations."

— Rt Hon Daniel Zeichner MP, Farming Minister, 2024-25

Over the past decade, the narrative surrounding gene editing in agriculture has been dominated by promises of speed, precision and efficiency.

Advocates, including policymakers, scientists and industry stakeholders, have repeatedly asserted that this technology can dramatically shorten crop development timelines, transforming processes that normally take more than a decade into faster, more targeted interventions.

This message, relentlessly driven by the biotech industry, became central to UK government — and therefore public and media — narratives during the passage of the Genetic Technology (Precision Breeding) Bill.

'Speed' has always been more than a scientific claim; it has been a political story. The new gene editing enterprise presented itself as the opposite of bureaucracy and delay — as a way to free innovation from regulation and to deliver miracles to market faster. In this telling, the real obstacle was not biology but the rules that governed it.

What began as a technical ambition has become a political doctrine: faster science means lighter regulation, less scrutiny, and the quiet rewriting of what counts as progress.

Prior to the draft Bill being introduced, in a 2021 press release announcing plans to "*unlock the power of gene editing*", the Department for Environment, Food & Rural Affairs (Defra) claimed that gene editing "*makes plant breeding more precise and efficient*" and enables outcomes "*similar to those that could be produced more slowly by natural breeding processes*"[1].

In early 2022, Chief Scientific Adviser Professor Gideon Henderson echoed this sentiment, stating that gene editing "*will help us make plant breeding more efficient and precise by mimicking natural processes that currently take many years to complete*"[2].

When the draft bill was introduced in May 2022, the government had renamed gene editing as "*precision breeding*" — a term intended to distance the process from genetic modification (GM) and reassure both parliamentarians and the public.

Today, various terms are used interchangeably — including "*precision bred*", "*gene-edited*", "*modern biotechnology*" and "*new genomic techniques*" — further muddying public understanding and obscuring the fact that these techniques remain laboratory-based genetic engineering.

As the draft Bill passed through parliament, MPs and peers consistently emphasised speed as a defining advantage of precision breeding over traditional breeding. In the first House of Commons debate on 28th June 2022, the then-Environment Secretary George Eustice claimed that gene editing enabled

the development of new plant varieties "*far more efficiently than was ever possible with conventional breeding*"[3].

In the same debate, Conservative MP Julian Sturdy asserted that "*Gene editing speeds up natural changes that can otherwise take up to 15 years*". In the Lords, the Earl of Caithness stated that "*Its great advantage is that it speeds up the process considerably by many years in the same way that keyhole or minimally invasive surgery has transformed the ordeal of a full-blown surgery*"[4].

This relentless messaging continued as the skeletal Bill became the Genetic Technology (Precision Breeding) Act 2023. In May 2025, when regulations to implement parts of the Act were signed into law, Minister for Food Security and Rural Affairs, Daniel Zeichner said "*We can turbo charge the natural breeding process our farmers have used for generations*"[5].

The only significant differences between gene editing and older-style GM arise from an intensive PR campaign that has convinced politicians, media and the public they are distinct, which in turn has created a regulatory fiction

This framing of gene editing as a high-speed version of traditional breeding has helped secure political support for deregulation of precision bred and other GMOs and has continued to shape public policy and define research funding priorities.

It has quietly and without any critical questioning seeped into environmental and food policy where the continued investment in agricultural genetic technologies is justified as a way of swiftly and efficiently meeting urgent global challenges in food provision and climate change mitigation.

This ignores the fact that many of the most desirable traits — such as enhanced nutrition or increased tolerance to climate stressors — are complex traits, conferred by many genes working together. These can take years or decades to achieve through genetic engineering techniques, if indeed they can be achieved at all.

Gene editing vs. genetic modification?

Gene editing has been repeatedly framed by government and industry as fundamentally different from genetic modification — faster, cleaner, and more precise; a way to speed up changes that could occur naturally or through traditional breeding.

This narrative has underpinned the passage of the Genetic Technology (Precision Breeding) Act 2023 and its 2025 Regulations and supported the false claim that gene editing is not genetic modification. Together, these narratives justified rebranding gene-edited organisms as "precision bred organisms" (PBOs) and exempting them from the regulatory and environmental safeguards that apply to GMOs.

In reality, gene editing is not a new process but a newer tool within the genetic modification toolkit. Early literature described it as a means to accelerate and refine genetic engineering, delivering the same endpoints — including transgenesis — through greater targeting precision[6, 7].

The European Court of Justice confirmed in 2018 that these "new genomic techniques" fall under existing GMO law[8].

Even the Act itself defines PBOs as resulting from "modern biotechnology" — a term drawn directly from UK GMO legislation[9]. The law thus first classifies them as GMOs and then exempts them from the existing GMO regulations.
Like older GM techniques, gene editing is a lab-based intervention in DNA using CRISPR, TALENs or zinc-finger nucleases (ZFNs).

Despite claims that it is just a 'small snip' in the genome, in reality edits range from single cuts triggering an organisms innate repair mechanism to the insertion of repair templates, which direct the organism in how to repair itself and the use of 'foreign DNA' to achieve specific traits — which, where possible, may later be 'bred out'. Under the Act, all of these can be exempt from regulation.

Nothing in the law prohibits the use of foreign DNA in so-called PBOs, nor requires proof that it is absent[10]. Developers have already created transgenic lines and reclassified them as "precision bred" once inserted genes were supposedly removed — as in Rothamsted's low-asparagine wheat[11]. Yet this backcrossing is slow and technically difficult, undermining the narrative of speed.

Like speed, the issue of foreign DNA is also political. Most developers have no objection to its use — it is intrinsic to the biotechnology process — but government policy depends on presenting gene editing as 'natural'. Efforts to remove or disguise the presence of foreign DNA are therefore less about scientific necessity than about marketing a high-tech innovation as something nature-like and familiar.

Gene editing also enables intervention across the entire genome[12, 13], including regions protected from natural mutation. By design, it targets functional and regulatory sequences to alter traits[14], sometimes through multiplexing that changes growth, reproduction, and stress response. This is not "accelerated breeding" but direct genomic manipulation.

The "precision" claim is equally hollow. Studies show CRISPR-Cas causes numerous unintended off-target and on-target effects[15].

In a joint statement, led by Michael Antoniou, Emeritus Professor of Molecular Genetics at King's College London, more than 100 international scientists and policy experts observed that calling gene editing (which bypasses normal sexual reproduction) "breeding" is scientifically inaccurate. They noted also that "*the only aspect of gene editing that is precise is the initial double-strand cut in the DNA, which can be targeted to a specific site*"[16].

Finally, the political language of "precision breeding" is unique to the UK. No other country uses or recognises it. The term functions as a reassurance strategy — implying safety and naturalness that have not been demonstrated. In practice, precision breeding is neither natural nor 'nature-like': it is an artificial, patentable, laboratory-based intervention capable of producing novel traits[17, 18] — and risks[19] — that would not arise through breeding.

Failure to Launch

From the outset, the idea of speed has done more political work than scientific. It has become the story through which deregulation is justified — a narrative that frames caution and accountability as obstacles to progress rather than the conditions that make progress meaningful. In this way the narrative could, arguably, be called a 'success'.

But even on its own terms, the biotech industry's promise of speedier breeding has patently failed.

After two decades of research and tens of millions of pounds of public money, the UK's showcase projects — from low-asparagine wheat to blight-resistant potatoes — have not reached farms or supermarkets. The technology has not delivered speed; instead, the idea of speed has been used to weaken transparency, distort public understanding and undermine the kind of robust oversight such powerful technologies require.

The only significant differences between gene editing and older-style GM arise from an intensive PR campaign that has convinced

politicians, media and the public they are distinct, which in turn has created the fragile fiction upon which current UK regulations are premised.

An important part of that campaign is the way this narrative has hooked in to societal concerns that climate change and a growing population are pressing and connected problems that demand fast answers and action.

Few would argue against the urgency of current challenges. But policymakers have embraced the exciting myth of speedier breeding with gene editing, without examining the mundane reality that many of these innovative new gene edited crops have been in development for decades, with little to show for the investment of time and taxpayer money.

This report examines that question through a detailed analysis of five high-profile case studies. The first three — blight-resistant potatoes, low-asparagine wheat and virus-resistant sugar beet — are all candidates for approval as PBOs under the UK's new framework. The fourth and fifth — omega-3-producing camelina and the purple tomato — have not (yet) been reclassified as PBOs.

It explores the disconnect between the rhetoric of rapid innovation and the slow, iterative realities of crop development — highlighting implications for policy, investment and public trust in agricultural biotechnology.

Low-Asparagine Wheat

"If it comes through the field trial well it could be made available to wheat breeders. Even so, it would be another 5-10 years before very low asparagine wheat could appear on the market, and that would only be if the regulatory framework were conducive."

— Nigel Halford, Principal Research Scientist at Rothamsted Research, 2021[20]

The Problem

Acrylamide is a chemical that forms in starchy foods when they are cooked at high temperatures. It arises primarily when the amino acid asparagine reacts with certain sugars naturally present in foods[21] — the same reaction that browns foods.

The presence of acrylamide in food was first flagged by the European Food Safety Authority (EFSA) in 2002 and since then it has been widely reported as a potential carcinogen. Food processing businesses are required by law to ensure that acrylamide levels are as low as is reasonably possible in their products[22].

The Promise

Gene editing claims to significantly reduce the asparagine content in wheat grains, thereby lowering acrylamide formation in heated flour and ultimately in finished food products. The approach was marketed as faster and more precise than conventional breeding and essential for public health.

Scientific and Technical Challenges

Early field trials of the gene edited wheat reported poor seed germination. Ironically, this was resolved by adding low levels of exogenous asparagine, the compound they were trying to reduce, to the water used to spray the compost around the plants[30].

Introduction of transgenes are part of the CRISPR process. Usually, these are then removed at a later stage of the process, once

Developmental Timeline

- **2004** Rothamsted Research begins work on reducing asparagine content in wheat[23].
- **2021** Field trials finally begin 17 years after research began[24]. The plan was for a project of up to five years, ending in 2026, with plants being sown in September/October each year and harvested the following September[25].
- **2023** Researchers report success in reducing acrylamide formation in heated flour[26].
- **2025** Field trials are approved, starting in March 2025 and ending in September 2027, aiming to "*bulk up winter wheat cultivars*"[27].
- **2025** Researchers are struggling to remove foreign DNA, saying the project was not originally designed with the removal of GM elements in mind[28] (despite having previously said that the genome editing technique they used doesn't involve foreign DNA[29]).
- **2025** Still no commercial availability, 21 years later.

the DNA repair is complete. In this case, removal of the transgene element has proved complex - a known challenge when it has been inserted near the gene or genes that are important to the trait the developers are trying to introduce, as is likely in this case[31].

Wheat's genome is exceptionally complex – 35 times larger than the human genome. Bread wheat is what is known genetically as hexaploid (containing six complete sets of chromosomes rather than the typical two (diploid). The first mapping of a hexaploid wheat genome was not published until 2018, thirteen years later than the first complete mapping of the rice genome[32].

A 2021 press release by Rothamsted has the headline "*Genome Edited Wheat to Reduce Cancer Risk from Bread and Toast*"[33]. By 2023, Rothamsted announced that asparagine in the gene edited wheat was 50% lower than a comparable conventionally bred variety[34].

But there is no scientific consensus on whether acrylamide in food is a health risk.

Both the National Cancer Institute[35] and the American Cancer Society[36] have stated that there's no clear evidence of increased human cancer risk from dietary acrylamide

Cancer Research UK points out that dietary levels are much lower than those used in toxicology studies and suggests other dietary changes are more impactful for reducing cancer risk[37].

Conventional Breeding Alternatives

There are already commercially available varieties of wheat with low acrylamide-forming potential[38].

Agronomic solutions addressing soil health could tackle the root cause more effectively than genetic modification. Studies have found that the asparagine concentration in wheat is influenced more by soil sulphur levels than genetics[39]. The benefits of using a low acrylamide-forming-potential variety are lost if sulphur supply is inadequate[40].

Beyond the Hype

After 21 years, this gene edited wheat variety is not yet commercially available. In that time, the health rationale for developing the wheat has largely collapsed.

Political, regulatory and institutional incentives keep the line alive, not because acrylamide is a real risk, but because the crop has become symbolic as a test case for "precision breeding" regulation, a media-friendly narrative and a blueprint for how genetically modified crops can be re-classified at PBOs, opening the door for deregulation of other gene-edited cereals.

Nevertheless, the scientific challenges, combined with now contested health claims and effective non-gene edited alternatives, raise questions about the benefits of this ongoing biotech experiment.

Late Blight-Resistant Potatoes

"The British taxpayer has been funding me to do this work for 35 years."

— Professor Jonathan Jones, geneticist, Sainsbury Laboratory, Norwich, 2025[41]

The Problem

Late blight, caused by the water mould *Phytophtora infestans*, was a major contributor to the 1845-52 Irish potato famine.

It "*remains the single most important potato disease in the UK*"[42], requiring frequent fungicide application. In the UK, for example, potatoes like Maris Piper are sprayed with fungicides up to 10-15 times a season.

The Promise

Genetically engineered potatoes claim to provide durable resistance to late blight, protecting crops and reducing fungicide use.

Scientific and Technical Challenges

Natural resistance to potato blight exists in wild potatoes but transferring this resistance to commercial varieties by conventional crossing has proven difficult. Genetic engineering offered a blight-beating shortcut to farmer-friendly variety like Désirée or Maris Piper.

PiperPlus 1.0, the first genetically modified blight resistant potato, proved susceptible to Potato Virus Y, requiring development of PiperPlus 2.0 with additional genes[51].
The potato genome is complex — most commercial varieties are tetraploid, meaning they have four copies of each gene.

This makes it harder to edit all copies successfully and increases the risk of unintended side effects, including harmful ones. Also, many important potato traits — like

Development timeline

- **2000** The Sainsbury Laboratory begins isolating resistance genes from wild potato relatives[43].
- **2009** First resistance gene (Rpi-vnt1) is successfully isolated[44].
- **2010-2014** Initial field trials are heralded as a success[45].
- **2015** Announcement of £841,000 of public funding for a collaboration between the Sainsbury Laboratory, University of Leeds and Simplot to develop a resistant variety of Maris Piper[46].
- **2017** "*Early success*" reported in Maris Piper field trial[47].
- **2022** Late blight resistant potato – PiperPlus 1.0 — declared ready for commercialisation[48].
- **2025** The Sainsbury Laboratory is now developing a new variety — PiperPlus 3.0 — which would qualify as a PBO under new UK legislation[49]. Researchers are testing over 100 lines of Maris Piper and Charlotte, from which scientists are "*confident*" that they will identify the line that can be brought to market[50].

yield or disease resistance — are controlled by multiple genes, making it tough to identify which ones to target[52].

While the Sainsbury Laboratory says it is investigating the use of gene editing, much of its work on potatoes involves adding foreign or wild-derived R genes (immune receptor genes) from wild potatoes, rather than the simple 'snip' or deletions promoted in the gene editing narrative. Its not surprising, then, that its *Statement on Gene Editing*[53] argues that regulation (in reality de-regulation) should focus on the traits and risks, not the method,

But there are other challenges. Gene editing requires the regeneration of a whole plant in vitro culture conditions. After regeneration, plants can sometimes look and behave differently — e.g. they may have an altered shape or leaf colour, or deformed tubers.

Because potatoes are vegetatively propagated (by tubers), if a bad edit or off-target mutation is carried forward, it will persist in all clones[54]. This means precision and careful validation are a priority.

For lines stably transformed with CRISPR/Cas, but removing the transgene used to make the trait is time-consuming as it requires several generations of crossing[55].

Conventional Breeding Alternatives

Maris Piper is the UK's most widely grown and commercially important potato variety, particularly for processing (chips, crisps, frozen products). Breeders, processors, and farmers all understand its agronomic behaviour, yield and storage properties intimately. A 'plug and play' gene edited version, therefore, promises no need to change machinery, contracts, supply chains or mindsets.

But other potato varieties are available. In 2018, a study found that a non-GM variety, Sarpo Mira, had the same blight resistance as a GM variety — resulting in an average 80-90% reduction of fungicide use compared to common practice[56].

In 2025, the Dutch company Solynta, which has bred potatoes with multi-gene-based blight resistance using innovative non-GMO hybrid breeding techniques, announced that it is ready to commercialise its lines at scale. The R&D process has been 18 years long — less than the Sainsbury Labs have taken so far[57].

Other conventionally-bred blight-resistant varieties (Setanta, Carolus, Sally and Orla) are widely available to growers[58].

Beyond the Hype

While the UK field trials for GM potatoes started in 2010, the broader Sainsbury Labs effort to building the science that underpins those trials tracks back to its founding in 1987 and its goal to showcase cutting-edge plant molecular biology.

Even as public opinion on genetically modified crops soured in the 1990s, the potato project survived because blight was an undeniable problem, solving it could be framed as an 'environmental good' and development of blight resistance was being spearheaded by an independent, university-based lab, not multinationals like Monsanto or Syngenta.

In 2023 the government advisory committee, ACRE, judged that potatoes developed with GM technology could possibly qualify for field trials as a precision bred plant under new rules[59]. But, still, no genetically modified or gene edited variety is commercially available.

In contrast, several conventionally bred (non-GM) resistant varieties have been bred, tested and commercialised in Europe and the UK over the same period delivering actual, not promised, environmental good.

Virus-Resistant Sugar Beet

"Gene editing could have the potential to accelerate the development of a truly resistant sugar beet variety much faster."

— Mark Stevens, Head of Science, British Beet Research Organisation, 2021[61]

The Problem

Virus Yellows is a disease complex caused by multiple aphid-transmitted viruses. It can reduce yields by up to 50% and is a major threat to UK sugar beet production.

The Promise

Gene edited sugar beet claims to provide virus resistance, reducing reliance on chemical pesticides – especially after neonicotinoids were banned due to their toxicity to pollinators.

Scientific and Technical Challenges

Sugar beet has notoriously low rates of successful introduction of new traits through transgenic techniques and is difficult to work with in the lab[68].

Both the viruses and their carriers — aphids — are complex. Virus Yellows isn't caused by just one virus, but by three or more, spread by different types of aphids. So if a 'resistant' variety only targets one virus, another could easily take over[69].

In addition, aphids reproduce quickly and different aphid 'families' vary in how well they spread the virus. Slowing the spread of the virus in one family might simply allow another to become dominant. This means there's no single silver bullet gene that can protect sugar beet forever.

Currently the UK is pinning its hopes on gene-editing to induce RNAi-based gene silencing, developed by Tropic Biosciences[70].

Development Timeline

- 1994: The introduction of neonicotinoid pesticides gave farmers a false sense of security, leading breeders to abandon previous attempts to breed resistant varieties[62].
- 2013: Beginning of phase-out of neonicotinoids[63] led to a renewed focus on breeding resistant varieties.
- 2015: A five year £1.13m pre-breeding project began, which aimed to quantify resistance/tolerance traits and to identify genes which protect against foliar damage. This initiative, part-funded by Innovate UK, involved the agricultural consultancy ADAS, the British Beet Research Organisation (BBRO) and seed companies SesVanderHave and MariboHilleshög[64].
- 2018: Neonicotinoid seed treatments were banned in the UK.
- 2020: Severe Virus Yellows outbreak caused a 25% reduction in overall UK yields[65].
- 2021: British Sugar announces gene-edited varieties could be grown "*by the mid-2020s*"[66].
- 2024: £1 million collaborative project launched between British Sugar, Tropic Biosciences, and John Innes Centre[67].
- 2025: Work remains pre-commercial, not yet in field trials.

Gene silencing, also known as RNA interference (RNAi), uses recombinant nucleic acid (RNA) molecules to 'silence' or shut down the expression of a particular gene.

Most development has focused on RNAI sprays that can be sprayed directly onto plants to target either or both the pest and the virus . With gene editing the plant's genome is altered so it produces those RNA controls.

This is a powerful intervention that requires careful target design, editing and greenhouse proof-of-concept before risking field plots. Its development adds steps and time — and, again, the durability question persists because aphids and viruses evolve fast.

Conventional Breeding Alternatives

Developers define the problem as virus transmission by aphids, which can be solved by making the plant resistant through RNA interference or gene editing. But that framing ignores the ecological cause: vast monocultures of sugar beet, often grown in short rotations, which create ideal conditions for aphid build-up.

Sugar beet used to rely heavily on neonicotinoid insecticides. As these have become restricted, instead of scaling up more 'nature friendly' measures — predator margins, flowering strips, intercropping, rotational diversity, soil health improvements — the industry has pivoted toward another input-based fix.

As with potatoes, thre re also conventionally bred alternatives with tolerance to Virus Yellows. The 2026 BBRO's recommended varieties list includes three varieties — Maruschua KWS[71], ST Tweed[72], Generosa KWS[73]. The latter two are new this year, indicating that conventional breeding is beginning to develop solutions to the problem, while genetic modification solutions are still trying to get a foothold.

Beyond the Hype

Despite years of investment and a string of high-profile public–private initiatives, genetically engineered sugar beet varieties with resistance to virus yellows are still stuck in a kind of pre-commercial limbo. Promises of durable, gene-edited or transgenic fixes have yet to translate into real fields and real harvests.

In the meantime, conventional breeding programmes — slower, less glamorous, but steadily advancing — are beginning to deliver varieties with partial tolerance. These may not be silver bullets, but they are already moving from trial plots into farmers' hands, offering practical, near-term tools to manage disease pressure in the here and now.

Ironically, the solutions that may reach growers first are not the headline-grabbing technologies of biotech labs, but more traditional breeding lines that continue to chip away at the problem.

Fish Oil-Producing Camelina

"The fact that I'm still talking about this 25 years later confirms it was more difficult than we initially thought"

— Professor Jonathan Napier, Rothamsted Research, 2024[74]

The Problem

Omega-3 long-chain polyunsaturated fatty acids, such as EPA and DHA, are essential for human and fish health. Global demand for these compounds is growing, yet current sources — primarily fish oil — are unsustainable and limited .

The Promise

Genetically engineering the oilseed crop *Camelina sativa* (False flax) to produce EPA and DHA claims to provide a sustainable alternative to fish oil, reducing pressure on marine ecosystems and helping secure supply that meets the demands of the human health supplement industry[75] and the aquaculture industry[76].

By inserting genes from marine microalgae into camelina, researchers aim to introduce a pathway for the plant to be able to convert its fatty acids into EPA and DHA fatty acids.

Scientific and Technical Challenges

The production of these novel fatty acids in camelina is not a straightforward 'one-gene-in-one-product-out' process. Instead, researchers had to build an entirely new biosynthetic pathway inside the seed.

This meant introducing a series of enzymes that could convert the plant's own C18 fatty acids into longer-chain omega-3s (C20+ LC-PUFAs)[83] — a stepwise process where each enzyme hands its product to the next in line.

Development timeline

- **2003** Rothamsted Research begins development by transferring genes from marine microbes[77].
- **2014** First UK field trials with GM camelina begin[78].
- **2015** Salmon feeding trials show equivalence to fish oil[79].
- **2018–2021** Rothamsted continues testing various lines under field conditions, refining gene stacking and improving oil content[80].
- **2024** Rothamsted announces that it has granted Yield10 Bioscience, Inc., based in Massachusetts USA, an exclusive global, commercial license to advanced technology for producing omega 3 Camelina[81].
- **2024** Yield10 Biosciences announces that the USDA has confirmed that its engineered omega-3 camelina will not be subject to GM regulations under the SECURE rule[82], paving the way for commercial release in the US.
- **2025** After more than 20 years of research, the crop has not yet been commercialised anywhere in the world.

Every stage of this chain had to be tested, adjusted and carefully integrated to make sure the whole system worked reliably and stayed stable in the seed environment[84].

Even once the pathway was in place, there were competing processes inside the plant that pulled resources in different directions.

To solve this, developers went a step further: they used CRISPR gene editing to shut down what's called the FAE1 pathway, which normally diverts carbon into unwanted fatty acids.

By combining transgenic 'additions' (to build the new pathway) with gene-editing 'subtractions' (to block competing pathways), they were able to increase the supply of precursors and channel them efficiently into omega-3 production[85].

Even so there are catches. Research indicates that the total seed oil yield decreases ad EPA and DHA increase and that these target seed oils develop at different rates in different amounts and differently in different geographies suggesting that a standardised end product may be difficult to achieve[86].

Conventional Breeding Alternatives

A plant that produces long-chain omega-3 fatty acids (EPA/DHA) is essentially an artificial construct. Conventional camelina doesn't do this, nor does any other oilseed crop. On a like-for-like basis, there are no conventional equivalents.

Algal oils are already on the market in non-GM form (derived from wild-type strains grown in fermentation tanks). But as demand grows, companies and research groups are actively using genetic technologies to push yields and cut costs[87].

When Rothamsted first began work on genetically modified camelina, farmed salmon and other fish were still widely promoted as a sustainable alternative to overfished wild stocks. Today, it is clear that the farmed salmon industry is not sustainable, has limited growth potential and raises significant animal welfare concerns. Simply providing a new source of feed will not change this. In other words, the solution is chasing a problem now recognised as structural, not merely nutritional.

The same logic applies to human health supplements. The issue of not getting "enough" omega-3 fatty acids stems less from crop supply than from decreased dietary diversity and increased consumption of highly processed foods[88]. Against this backdrop, the practical applications of genetically modified camelina remain narrow and niche.

Beyond the Hype

The project demonstrates that metabolic engineering of complex traits is slow and resource-intensive.

Fish oil from plants doesn't fix aquaculture's fundamental and systemic problems around animal welfare, environmental contamination or competition for scarce resources.

Instead it amounts to a type of resource shifting: fish oil camelina replaces one input but doesn't reduce the soya, wheat, maize and other ingredients already used in aquafeeds, which have their own land-use, biodiversity and pesticide footprints.

Despite over 20 years of effort, omega-3-producing camelina remains pre-commercial. In the United States, Rothamsted's commercial partner, Yield10 Bioscience, has obtained approval for field trials via USDA/APHIS, but food and feed approval has not yet been granted by the FDA. Nuseed's gene edited omega-3 canola brands — Aquaterra for aquafeed, Nutriterra for human nutrition and beauty products — are commercially available, though not in the UK and roll-out elsewhere appears slow.

Purple Tomatoes

"A lot of what we do is play."

— Professor Cathie Martin, group leader, John Innes Centre, 2021[89]

The Problem

How to deliver a gene edited product that will break through long-standing consumer resistance to genetically modified foods?

The Promise

Researchers aimed to create a tomato enriched in anthocyanins to boost dietary intake of these compounds, which are loosely associated with reduced risk of certain chronic diseases such as cancer[90] and heart disease[91].

Scientific and Technical Challenges

Anthocyanins are plant pigments with antioxidant properties found in purple berries. By inserting two regulatory genes from snapdragon, scientists have created tomatoes with a deep purple colour — throughout the flesh, not just the skin — that contains anthocyanins at levels comparable to other high anthocyanin foods like blueberries.

Commercially available tomato fruits don't naturally contain anthocyanins, though some can accumulate in the stems and leaves. Precise metabolic rewiring was required to redirect the plants' resources to make the anthocyanins. This is complex; the developers state in a paper that "*much of the metabolic engineering that has been reported for crop plants has not yet been applied successfully*"[102].

The developers acknowledged that "*the tomatoes had to look and taste great to stand a chance as a biotech food product*"[103]. They

Development timeline

- **2002** Prof. Cathie Martin at the John Innes Centre begins EU-funded research to increase antioxidants in tomatoes[92].
- **2004** First genetically modified purple-fleshed tomatoes are developed in the lab[93].
- **2007** Norfolk Plant Sciences (NPS) is founded to commercialise the trait[94].
- **2008** The GM tomato is promoted as having potential "*anti-cancer*" properties[95], though experts (e.g. Cancer Research UK) caution against exaggerated health claims[96].
- **2014** Due to EU restrictions, development shifts to Ontario, Canada; tomatoes are grown under glass and processed into juice[97].
- **2021** Norfolk Healthy Produce is established in the US with venture capital support[98].
- **2022** USDA grants regulatory approval for cultivation and consumption in the US[99].
- **2024** Purple tomato seeds become available to US home gardeners100. Approval in Australia and potentially Canada is pending[101].

therefore crossed the GM tomatoes with a range of heirlooms to get a variety which would be appealing to home gardeners — eventually settling on the yellow Goldkrone tomatoes. This, of course, took time.

The GM purple tomato has some unintended side-effects, including containing 336% more of the naturally occurring toxin α-tomatine compared to the wild variety from which it was derived[104]. While this level falls within the reported 'safe' range for conventional tomato varieties, it highlights a broader issue: genetic modification can lead to unanticipated changes in plant chemistry.

The snapdragon-derived transcription factors used to boost anthocyanin production showed no amino acid sequence similarity to known allergens or toxins, but toxicity and gene interactions are complex. As with any novel food, potential unknown effects cannot be ruled out. From proof-of-concept to first public availability took over 20 years, despite continuous funding and institutional support.

Conventional Breeding Alternatives

Anthocyanins are abundantly available in fruits and the quiestison of "*why tomatoes?*" has never been properly answered, However, if tomatoes are what you want, traditional breeding has achieved the same visual and nutritional goals more quickly and broadly.

In 2011 the Indigo Rose, developed by Jim Myers at Oregon State University through traditional breeding, became the first widely available purple-skinned tomato[105]. Myers began working on these tomatoes at about the same time that research began on the GM tomato, but the non-GM ones came onto the market thirteen years earlier[106].

Over 50 anthocyanin-rich cultivars derived from conventional breeding are now in circulation globally. These include varieties suited to commercial, home and organic growing systems. Heirloom alternatives (e.g., Black Beauty, Black Zebra, Black Krim offer visually appealing, nutrient-rich fruit without the need for genetic engineering.

In its 2024 catalogue, Baker Creek Heirloom Seed Company in the US offered a "*non-GMO purple tomato*", the Purple Galaxy. Baker Creek was then contacted by Norfolk Healthy Produce, the US subsidiary of Norfolk Plant Sciences and the Purple Galaxy seeds were withdrawn.

It remains unclear whether Baker Creek's collaborators did use the GM Purple Tomato in their breeding — as Norfolk Healthy Produce claim, but Baker Creek deny — or whether this was simply a case of the biotech industry intimidating smaller breeders[107].

Beyond the Hype

The GM purple tomato is underwhelming as a product and yet has become hugely symbolic in the narrative of modern biotechnology.

More than two decades of work led to the seeds being marketed US through Norfolk Healthy Produce, a spinout company of the UK's John Innes Centre, as a novelty for gardeners — and only in the USA — not a medical or nutritional breakthrough.

Indeed as far back as 2008 Cancer Research UK debunked the simplistic notion that more antioxidants = good[108]. There are no substantiated reports of how well it is actually selling or what gardeners think of them.

Where it has succeeded is in rebranding the application of genetic technologies away from industrial monocultures toward 'personal wellness' and 'choice'. It is emblematic not because of what it delivers, but because of what it represents: a PR victory, a regulatory milestone and a tool for shifting narratives around genetic engineering.

The Myth of Speed

"Public engagement is, of course, an important part of science – but in the context of controversial technologies like GM, it can blur the line between informing and advocating."

The over-hyped myth of "*turbo charging*" nature is built on promissory narratives — big claims about future impacts that are likely to disappoint and indeed may never materialise.

In nearly every case considered in this report, conventional alternatives either beat biotech to market or arrived in a similar timeframe, despite having fewer resources. Yet, these narratives are dominating policy and media debates at a time when we urgently need to look to solutions that are replicable and scalable in the here and now.

Regulatory processes are frequently blamed for slow commercialisation of GMOs. But this knee-jerk finger pointing is a form of misdirection. The slowness of genome editing is not just a technical problem but a political revelation.

For years, 'speed' has been used as a slogan to justify deregulation, attract investment and present genetic engineering as an inevitable solution to complex food-system challenges. Yet the evidence from the case studies tells another story: even on its own scientific terms the enterprise is faltering, and the political narrative built around it is unravelling.

What follows looks at why — examining the biological limits, the shifting stories and the institutional incentives that keep the myth alive.

Technical and Biological Complexity

Many of the traits targeted — disease resistance, nutritional enhancement, stress tolerance — involve complex interactions across multiple genes and pathways, which makes editing slow, costly and uncertain.

In the case of omega-3-producing camelina, researchers had to build a completely new biochemical pathway into the plant, requiring extensive iteration.

Late blight resistance in potatoes required multiple resistance genes and has still not yet delivered stable performance. These projects aren't just about switching genes on or off — each new component can interact unpredictably with others, creating cascading effects. This makes trait development slow, costly and scientifically uncertain.

Difficulty Removing Foreign DNA

In genome editing, foreign DNA is often used to introduce or facilitate the desired genetic change. Developers often plan to remove it later through backcrossing or other techniques.

While the presence of foreign DNA, is a significant PR problem for government deregulatrors, it also has critical scientific implications: the presence of residual transgenes can compromise trait stability, interfere with other genes and/or introduce unintended effects[109, 110].

In the low-asparagine wheat project, researchers acknowledged a struggle to separate the transgene from the target trait, as the experiment hadn't been designed with transgene removal in mind.

More troublingly, developers are not always aware of what DNA persists because they do not carry out the correct analysis, using long-read whole genome sequencing.

The case of Recombinetics' gene-edited hornless cattle illustrates this. While the animals were declared free of 'off-target events', an FDA reanalysis found previously undetected bacterial sequences, including two antibiotic resistance genes, near the editing site[111].

These genes originated from the DNA repair template used to achieve the targeted gene insertion and went unnoticed by the developers. This scientific oversight has serious biosafety implications. It shows the importance of independent scrutiny and mandatory genomic analysis using in-depth search tools, not just developer-led risk assessment.

Trait vs Context

There can often be a mismatch between trait development and real-world agronomic context. For example, asparagine levels in wheat are strongly influenced by soil sulphur levels. In low-sulphur conditions, even gene-edited wheat may still produce high acrylamide levels. Environmental factors like soil health, water stress, or pest pressure can modify and influence how genes are expressed[112].

In these cases, conventional approaches like soil management or variety selection may be more effective than biotech interventions.

GM 'solutions' risk becoming expensive technical fixes for problems with broader ecological or agronomic roots. If more resources were invested in transforming food systems according to agroecological principles, many of the problems that GM seeks to address — disease vulnerability, poor nutrition, low yields — might not arise in the first place.

Shifting Narratives

As scientific hurdles persist, many GM projects have quietly shifted their stories over time. The purple tomato, once heralded as a cancer-fighting superfood due to its high anthocyanin content, is now marketed as a novelty item for home gardeners, with health claims notably downplayed.

Similarly, low-asparagine wheat was initially framed as a way to reduce cancer risk from acrylamide in toast and biscuits — but as scientific consensus questioned the significance of dietary acrylamide, the narrative pivoted toward food industry compliance and processing benefits.

These shifts don't reflect scientific breakthroughs as much as refocussing in response to practical limitations or diminished credibility.

These shifting narratives matter. They suggest that some high-profile gene editing projects are driven as much by the search for a compelling story as by a pressing agricultural or nutritional need. When the original rationale falters, developers often reframe their pitch rather than revise their priorities.

This raises questions about transparency, moving goalposts and whether the technology is genuinely targeting the most pressing food system challenges — or simply those that appear to be the most technically feasible. Many GM efforts focus on crops with well-characterised genomes, and which are the easiest to genetically engineer, rather than those with the greatest real-world urgency.

Scientists as Salespeople

Often, scientists are not only researchers but also active promoters of the technologies they develop. Public engagement is, of course, an important part of science — but in the context of controversial technologies like GM, it can blur the line between informing and advocating.

In relation to the wheat project, Prof Nigel Halford of Rothamsted stated, "*In addition*

to our research, an important aspect of our activities for many years has been public and stakeholder engagement"[113]. This includes speaking to the media, addressing public meetings and liaising with actors throughout the food supply chain — from breeders to retailers.

While engagement is often framed as education, it also serves to generate support, reduce resistance and present GM projects as necessary and urgent. This dual role — scientist and advocate — can raise questions about objectivity, especially when public funding is involved.

When researchers are simultaneously designing traits, trialling crops and shaping the public narrative around their benefits, it becomes harder to distinguish evidence from promotion. This may be especially problematic when the messaging continues even as core scientific or technical hurdles persist.

Conventional Breeding is Often Faster and More Effective

Across these case studies, conventionally bred crops have reached the market faster than their gene-edited counterparts.

Purple tomatoes were beaten to market by over 50 conventionally bred anthocyanin-rich cultivars. Blight-resistant potatoes are now available, achieved through traditional breeding.

Even for the complex Virus Yellows resistance challenge, conventional breeding is progressing — despite being sidelined for years due to over-reliance on chemical controls. These examples raise questions: why pour public funds into speculative biotech solutions when conventional plant breeding, often underfunded, can deliver faster, more reliable results?

Implications for Policy and Investment

Policy support for GM has been driven by a narrative of urgency: that we need these tools to deal with immediate agricultural, climate and/or public health crises. But the case studies show that gene-edited and other types of GM crops take decades to develop, carry substantial uncertainty and often arrive after other solutions have already emerged.

Meanwhile, effective and more systemic approaches to sustainable food production are being sidelined and underfunded. If speed and impact are the goal, public investment should prioritise the most effective solutions, not the most technologically novel or exciting.

Speed Distracts from Need

The focus on speed and technological fixes has significantly narrowed the conversation about food-system change. Gene editing promises to tweak individual traits — disease resistance, nutrient content, drought tolerance — but it does not address the deeper causes of vulnerability: degraded soils, monoculture dependence, poor diets, and economic inequity.

Over the past three decades, plant breeding — reimagined through the lens of genetic engineering — has been promoted as a transformative solution to hunger, malnutrition and climate change. Yet a longstanding body of scholarship questions this.

Political economist Jack Kloppenburg argued, in his renowned 2004 work *First the Seed*[114], that breeding innovations often serve to consolidate control of seed systems rather than address structural causes of food insecurity.

Similarly, the Union of Concerned Scientists demonstrated how GM crops were oversold on yield and sustainability benefits, while their risks and alternatives were under-examined[115]. There is no evidence that gene edited crops will be any more successful.

Glenn Stone's anthropological studies of Bt cotton in India found that while initial pest

control benefits were real, they quickly gave way to new pest problems, debt cycles and farmer distress[116].

Decades of effort on Golden Rice — engineered to address vitamin A deficiency — have produced little impact compared to simpler interventions like diet diversification and supplementation[117].

In the 2010 book *Dynamic Sustainabilities* by Leach, Scoones and Stirling, of the UK's STEPS Centre[118] warned of 'innovation lock-in', where technological fixes like GM and gene editing crowd out systemic approaches such as agroecology. The International Panel of Experts on Sustainable Food Systems (IPES-Food) echoes this, arguing that food insecurity is driven less by absolute shortages than by poverty, inequality, and governance failures[119].

The lesson is not that genetics has no role, but that promises speed and novelty have become a proxy for progress. A genuinely transformative food policy would start with ecological and social priorities and ask how technology can serve them — not the other way around.

And finally...Time is (Also) Money

These decades of research have been funded by taxpayer money. But trying to find out how much public money has gone into the UK's long-running GM and gene-edited crop experiments is frustratingly difficult. There is no single place where government, research councils or institutes publish a full account of taxpayer investment, crop by crop, year by year.

Despite repeated calls for transparency, neither the Government nor UK Research and Innovation (UKRI) has ever published a consolidated account of public spending on agricultural biotechnology, or any clear measure of what the country has gained in return.

In May 2025, a report by the National Audit Office found that the Department for Science, Innovation and Technology (DSIT) and UK Research and Innovation (UKRI) "*lack the data and outcome definitions needed to track where grant money actually goes and what value is delivered*"[120].

The House of Commons Public Accounts Committee (July 2025) concluded that UKRI shows "*insufficient clarity in how it invests its money*" and that even Parliament "*cannot see a coherent picture of R&D spending across government*"[121].

None of this is new. A very comprehensive independent review in 2010 — *Bioscience for Life?* — by GeneWatch UK noted: "*Major investment decisions in R&D and in research infrastructure are being made by the EU and by the UK Government without due diligence — including scientific diligence — or cost-benefit analysis*"[122].

The fragmentary public records published by the Biotechnology and Biological Sciences Research Council (BBSRC) and UKRI suggest tens of millions of pounds of public funds have gone to the research institutions involved in our case studies; into projects that, decades later, still have not delivered viable products to the UK market.

This is likely a significant underestimate since it excludes institute core grants, EU or overseas public funding, and other UK allocations — for instance to other research groups doing similar work — that are not published in project-level form.

The true public cost has, therefore, been significantly higher.

Until government publishes crop-level, project-level spending and outcomes — including the large BBSRC Institute Strategic Programme grants that underwrite much of this work — return on investment andvalue for money cannot be assessed. Nor is it possible to

determine whether comparable investment in agroecological or conventional plant breeding might have delivered better results.

In the end. the story that gene editing would make plant breeding faster and more efficient was never only about technology. It was, and remains, about power — who gets to decide how science is governed, whose interests it serves, and which risks are ignored in the name of momentum.

The real myth is that the concept of speed is neutral. In practice, it has been used to portray caution, consultation, and democratic oversight as obstacles to innovation. But a food system built on haste cannot be a resilient one. The slow work of stewardship, testing and public accountability is not the enemy of progress; it is the ground on which genuine progress stands.

The question is not, and never has been, how fast we can go, but whether we are moving in the right direction.

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