

SELF-FERTILISING CROPS

Synthetic nitrogen fertiliser is one of modern farming's most significant inventions and one of its biggest problems.

Manufacturing and applying it accounts for a significant share of agriculture's energy use and emissions, and much of the nitrogen crops fail to take up leaches into rivers, lakes and coastal waters, driving algal blooms and oxygen-depleted "dead zones".

The proposed fix is familiar: engineer major cereal crops to have the ability that beans, peas and clover already have. Legumes host nitrogen-fixing bacteria in their roots, converting nitrogen from the air into a form they can use, negating the need for synthetic nitrogen fertiliser. If wheat, maize, barley or rice could do this, the argument goes, there would be less need for synthetic fertiliser.

In the second half of 2025, two research teams published peer-reviewed papers a few months apart, and both were swept up in a late-November wave of [headlines](#) about crops "fertilising themselves". Both merit closer scrutiny.

What are they trying to do?

The [first result](#) came from a team at the University of California, Davis. Rather than trying to get a cereal to host bacteria in nodules the way a legume does, the team used CRISPR to boost wheat's natural production of apigenin, which the plant releases into the soil through its roots.

Apigenin encourages existing soil bacteria to cluster around the root and form protective biofilms — sticky coatings that create the low-oxygen conditions a bacterial enzyme called nitrogenase

needs to fix nitrogen. The idea is to recruit bacteria that are already there, rather than engineering new ones or building a structure to house them.

The second result came from Aarhus University in Denmark, and took a different route. Plant roots carry receptors that sense chemical signals from soil bacteria and decide, based on what they detect, whether to mount an immune attack or open the door to a partnership.

In legumes, a receptor called NFR1 is what lets nitrogen-fixing bacteria through: it recognises a bacterial signal known as a Nod factor. This, in turn, switches on the symbiotic programme that eventually builds a nodule.

The Aarhus team, writing in [Nature](#), pinpointed the exact stretch of that receptor that decides whether "welcome" or "attack" gets triggered, and showed that changing two amino acids there was enough to convert a normally defensive receptor into a symbiotic one.

Co-lead researcher Simona Radutoiu [described](#) the finding as bringing agriculture "one step closer to a greener and climate-friendlier food production."

Despite [claims](#) that this discovery "may unlock nitrogen-fixing super-crops that slash global fertilizer demand," researchers are clear that it's one piece of a larger puzzle. Radutoiu has said only a handful of the "essential keys" needed for full nitrogen-fixing symbiosis have been found so far, and this is one of them.

But are these real advances, or the latest in a long line of 'breakthroughs' that never reached a field?

How far have they got?

Until recently, the closest scientists have come to engineering crops to fix their own nitrogen was a 2022 [University of Oxford-led study](#) of barley.

Researchers from Oxford, the Sainsbury Laboratory in Cambridge and MIT engineered barley to secrete a signalling molecule that switched on nitrogen-fixing genes in bacteria on its root surface. They had some success: engineered bacteria on engineered barley activated nitrogen-fixing genes that stayed off on ordinary barley.

But the study's reported results show its limits. The engineered bacteria struggled to colonise the roots, responded only weakly to the plant's signal and, even where fixation was detected, it reached only around 5-15% of what wild-type bacteria manage naturally. The reaction only worked reliably once researchers reduced the surrounding oxygen to a concentration too low to sustain normal plant growth.

Against that backdrop, the 2025 papers look like significant results, but they also come with caveats. In the Aarhus study, changing the two amino acids reliably switched a Lotus receptor from triggering an immune response to triggering nodule formation. Lotus is a legume commonly used as a model plant in lab research. A barley version of the receptor worked too, but the test didn't use barley itself. Instead, the barley receptor was placed into Lotus and run on the Lotus plant's own nodule-building machinery.

This shows only that a piece of barley's signalling apparatus is compatible with legume symbiosis, not that barley has gained any ability to recognise bacteria or build a nodule on its own. And even in Lotus, this is only the signalling step of a four-step process (more on this below).

The UC Davis team reported a significant benefit: spike number, seed count and grain yield rose by 72-100% in the edited wheat compared to unedited plants under nitrogen-limiting conditions. But no field trials have been conducted — the plants were grown in pots of an agronomic soil mixture and depended on nitrogen-fixing bacteria already present in that soil's own microbial community.

The CRISPR wheat worked by enriching nitrogen-fixing (diazotrophic) bacteria that were already there, not by introducing new ones, so how well it performs is likely to vary with what a given field's soil already contains.

These trials did not establish a reduction in pollution. The UC Davis trial measured yield, plant nitrogen content and nitrogenase activity, not nitrate leaching. Reducing pollution requires cutting the total reactive nitrogen entering a field, in sync with what the crop can use, not just adding another nitrogen source alongside existing fertiliser.

Whether biologically fixed nitrogen behaves any differently from synthetic nitrogen once it's in the soil, or whether farmers using it would actually apply less fertiliser rather than more, are separate questions from anything these trials measured.

The question of reduced inputs is sharpened by the example of Pivot Bio's nitrogen-fixing system, which doesn't engineer the plant at all. Instead it [engineers the bacteria](#), leaving the crop, and the system built around it, untouched. The catch is that farmers still buy and apply the bacteria fresh each season, much as they would fertiliser.

The fifty-year promise

Scientists have chased the idea for [more than a century](#), and for nearly fifty years it has, on and off, been described as on the verge of a breakthrough.

In 1980, [researchers called it](#) “a realistic long-term goal to genetically engineer new nitrogen-fixing plants”. In 2012, when the Bill & Melinda Gates Foundation gave £6.4m to the John Innes Centre for a five-year nitrogen-fixation project, [its representative said](#) the research had “the long-term potential...to transform the lives of small farmers” as it “could dramatically boost the crop yields of farmers in Africa.”

In 2014, the UK government's Council for Science and Technology still described the target of nitrogen-fixing cereals as a “long-term and high-reward programme.”

A [2020 review](#) acknowledged the biological “challenges” to achieving nitrogen-fixing cereal

crops, but stated, “Recent advances are creating paths to transgenic nitrogen-fixing cereal crops” as a “feasible and sustainable alternative” to synthetic nitrogen fertilisers. The authors added that “Gene editing of associative nitrogen-fixing bacteria may be a near-term solution.”

Then, in 2022, University of Oxford researchers [claimed](#) a “major breakthrough in establishing the ability of cereals... to make their own nitrogen fertiliser.”

The 2025 papers are both peer-reviewed, and the UC Davis result includes actual yield data rather than a signalling mechanism alone. However, the narrative is the same: lead researcher Eduardo Blumwald, discussing why the wheat matters for smallholders in Africa, [said](#) that “people don’t use fertilizers because they don’t have money” — almost identical to the 2012 Gates Foundation framing, thirteen years later.

Crucially, while the headlines claimed success, Blumwald himself talked about the possibility of [saving around 10% of the fertiliser used](#) — a long way from a crop that fertilises itself.

Not a single problem

Coverage of this research tends to describe ‘nitrogen fixation’ as one trait waiting to be switched on. In practice, the two recent studies represent different strategies for getting there.

The first strategy tries to recreate something like legume-style nodule symbiosis in cereals — a nodule housing bacteria that fix nitrogen inside a protected, low-oxygen environment the plant builds for them.

Natural nodulation involves at least four steps: recognising bacterial signals, building a nodule to house the bacteria, allowing the right bacteria to colonise it, and maintaining a tightly controlled low-oxygen environment in the nodule.

Of these, the signalling step addressed by the Aarhus work is the best understood — and, as described above, even that has so far only been shown working inside a legume. No complete, functional system has yet been established in a cereal.

Key questions

Journalists, policymakers and consumers evaluating claims about self-fertilising crops should be asking the following questions to assess how much weight the media narrative can actually bear.

Evidence and real-world applicability

- What does the research address — signalling, nodule formation, bacterial colonisation, or the low-oxygen step — and was it tested in the crop or a substitute system?
- Were results achieved in the field, or in pots, growth chambers, or hydroponics under controlled conditions?
- How much does a result depend on conditions that vary, e.g. a particular soil’s existing bacteria?
- What is the timeline from lab result to commercially available, field-tested crop, compared with the urgency implied by the coverage?
- Does increased nitrogen fixation reduce nitrate leaching or nitrous oxide emissions, or just add more nitrogen to the system?

Ownership and access

- Who benefits from attention staying on a future genetic fix, rather than fertiliser affordability or nitrogen-pollution regulation?
- If a product reaches the market, would it, like Pivot Bio’s bacteria, need buying fresh each season — extending dependence on purchased inputs rather than ending it?
- If a product reaches the market, who would own it, and on what terms?

Risks and unintended consequences

- Could energy-intensive nitrogen fixation divert a plant’s energy and reduce yield or other traits?
- Could engineered traits spread beyond a trial site into wild relatives or the wider bacterial population, and with what effect?

Isolating that switch took extensive work: the team tested 15 versions of the receptor, solved its molecular structure, and mapped out which regions of the kinase mattered before narrowing in on the handful of amino acids responsible. And this is only the signalling step. Nitrogen-fixing symbiosis as a whole involves [hundreds of processes](#) and genes across both the plant and the bacteria.

The second strategy abandons the nodule altogether, keeping bacteria on the outside of the root and protecting their nitrogen-fixing enzyme from oxygen some other way. In the case of the UC Davis study, the gene edits amplified apigenin, a compound wheat already makes naturally, to recruit whatever nitrogen-fixing bacteria were already in the soil and prompt them to form protective biofilms.

Both strategies also assume a soil capable of supporting them in the first place. The UC Davis trial wasn't even run in field soil — the pots were filled with a formulated mix of sand, pumice, peat and composted bark. Whether either approach would work in real agricultural soil, let alone soil that's degraded or nutrient-poor, does not appear to have been tested.

There's a metabolic cost to all of these efforts: nitrogen fixation is energy-intensive. An important question is: Do the yield gains observed under controlled conditions persist across different field conditions, and could the energy demands of supporting nitrogen fixation create trade-offs in grain quality, stress tolerance or other crop traits?

A [2023 review](#) described energy supply as “*an important obstacle to be overcome*.”

Even if the nitrogen problem was aided by these interventions, the crops could not accurately be called ‘self-fertilising’. Nitrogen is the largest single component of global fertiliser use, at 58%, but phosphorus and potassium together [still account for over 40%](#), and biological nitrogen fixation does nothing for either.

Engineering a plant's own biochemistry to deliberately reshape the bacterial community living around its roots is closer to ecological engineering than many more contained examples of gene editing.

The UC Davis team found a broader bacterial community around the root, not just an increase in nitrogen-fixing bacteria within an otherwise unchanged microbiome. But the study only measured success in terms of yield and nitrogen fixation. It did not ask what else changes when a plant is engineered to reorganise its own rhizosphere, such as what gets displaced, or what other roles that original community was playing.

Alternatives already exist

Gene-edited nitrogen fixation isn't the only route to the outcome it promises, and the alternatives are neither speculative nor new.

A number of proven agronomic practices already exist. Rotating cereals with legumes is a well-established method to pass fixed nitrogen from one crop to the next, already practised in organic and agroecological systems, with the added benefit of breaking pest and disease cycles that continuous monoculture encourages.

Cover cropping and intercropping (growing legumes alongside or between main crops, rather than only in sequence) can also add nitrogen without taking land out of cereal production for a full season. Recycling livestock manure returns nitrogen already present in the farming system rather than requiring new synthetic input.

More targeted fertiliser application can cut the over-application responsible for much of the pollution problem, without requiring a new crop variety at all. Conventional breeding programmes drawing on [landraces like Sierra Mixe](#) (an indigenous Mexican maize variety which hosts nitrogen-fixing bacteria on its aerial roots) are another active avenue.

Many of the underlying problems of fertiliser dependence can be attributed to the industrial agricultural system. Continuous cereal monocropping, rather than the rotations that would cut fertiliser use, remains the default because commodity contracts, subsidies, equipment and supply chains are all built around it.

Switching to diversified rotations often means buying different planting and harvesting equipment, and finding buyers for crops that don't have the

same established markets as the dominant one.

The costs for this fall on individual farmers, not on the system that created the dependency in the first place. A gene-edited cereal, if one ever works, could slot into that system without requiring it to change. A return to rotation would require the system — including agronomic practice, markets and infrastructure — to change first.

Conclusion

Since 1980, the language has followed the same pattern: individual results get called a breakthrough, while the final product stays described as long-term. This is a clear and consistent example of how reporting blurs the lines between progress towards a goal and delivery of that goal. The two 2025 papers are real progress. They are peer-reviewed, published in respected journals, and in UC Davis's case backed by actual yield data rather than a mechanism alone.

However, there is still no self-fertilising wheat, maize or rice crop that a farmer can plant. Both results are early-stage, address only one piece of a multi-part biological problem, and are already being introduced with the same 'transform smallholder lives' framing used in 2012.

The closest thing to a commercial success this field has produced, Pivot Bio's engineered bacteria, hasn't ended reliance on purchased inputs. It has merely substituted one for another.

In this gene-edited 'solution', a single trait is being asked to do a lot: address both the pollution of over-fertilised systems and the affordability gap in under-fertilised ones, alongside the contracts, markets and infrastructure that keep farmers locked into their current practices. Those are political and economic problems which no trait, however successful, resolves on its own.