UK & USA scientists collaborate to design crops of the future

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Three teams of UK and USA researchers will begin a programme of novel research to revolutionise current farming methods by giving crops the ability to thrive without using costly, polluting manufactured fertilisers.

The three highly innovative projects include: searching the planet for a lost bacterium with special, sought-after properties; using synthetic biology to create a new intracellular machine allowing plants to produce fertiliser themselves; and engineering beneficial relationships between plants and microbes.

$8.86M of Biotechnology and Biological Sciences Research Council (BBSRC) and US National Science Foundation (NSF) funding has been awarded following an 'Ideas Lab' to generate new approaches that address growing global food demand, which will need 190.4M tonnes of nitrogen-fertiliser by 2015.

Plants need nitrogen to grow. There is a lot of it in the atmosphere but it is mostly unusable. Atmospheric nitrogen needs to be 'fixed' - combined with other elements into a biologically usable form. Most arable farming therefore relies on industrially produced fertiliser to ensure crop yields that meet demand.

Producing artificial fertilisers is costly and uses vast amounts of fossil fuel. Fertiliser use also generates environmental problems such as the runoff of fertiliser into rivers and emissions of nitrous oxide, a greenhouse gas with a much greater global warming effect than carbon dioxide. This funding is aimed at generating innovative technological stepping stones that will reduce the need for fertiliser by enabling crops to fix their own nitrogen.

The three projects are:

$1.87M quest to solve the mystery of the lost bacteria

Unique bacteria, discovered in a German charcoal pit in the 90s, could hold the key to enabling plants to fix their own nitrogen. However, studies on this bacterium, which grows in hot toxic environments, stopped over a decade ago and the bug appears to be lost. Now, scientists will scour the fiery corners of the globe, searching Hawaiian volcanoes, American coal seam fires and German fire pits for the elusive bacterium, in a bid to recover its lost potential.

Maren Friesen, Michigan State University, said: "Rediscovering this bacterium, or ones with similar properties, would be a game-changer. It contains an unusual system for fixing nitrogen in the presence of oxygen, which could be a missing piece in the puzzle for creating nitrogen-fixing plants."

In nature, the reaction that fixes atmospheric nitrogen into a biologically usable form requires an enzyme called nitrogenase. The enzyme is inhibited by oxygen, rendering it useless in the normal oxygenated cells of plants. While some organisms can fix nitrogen, they have to have special adaptations to limit oxygen. However, the lost bacterium was reported to have a unique nitrogenase that could fix nitrogen in oxygen-rich environments, eliminating the requirement for oxygen limitation. This could be extremely useful in the development of nitrogen-fixing plants.

Maren Friesen will collaborate with Bill Rutherford and Martin Buck, from Imperial College London, in the hope of finding the original bacterial strain, as well as new oxygen-tolerant, nitrogen-fixing strains, in these seemingly inhospitable environments. The team will then study the genetics and biochemistry of these strains with an eye towards transferring oxygen-tolerant nitrogenase into plants.

$1.89M for a synthetic intracellular fertiliser factory for plants

This project aims to design and build a synthetic biological module that could work inside a cell to perform the function of fixing nitrogen.

Some photosynthetic bacteria (cyanobacteria) are able to fix nitrogen using solar energy via specialised cellular machinery. The scientists hope to re-engineer this machinery so that it can be transferred into a new host bacterial chassis as a first step towards transferring the machinery, and thus the ability to fix nitrogen, into plants themselves. This will require identifying and transferring the genes responsible for nitrogen fixation as well as alterations to cellular processes.

Devaki Bhaya, Carnegie Institution for Science, said: "Nature has given us a toolbox of functional units that we can use to build complex biological modules. The goal is to use these to build a novel synthetic nitrogen fixing unit that can be transferred to other hosts and ultimately give plants new functionality. It could mean the crops of the future will be able to make use of the nitrogen around us without needing fertilisers."

The project will combine efforts from Carnegie Institution of Science with the skills of John Golbeck (Pennsylvania State University), Christopher Voigt (Massachusetts Institute of Technology), Susan Rosser (University of Edinburgh) and Bill Rutherford (Imperial College London).

$5.09M to engineer synthetic relationships between plants and bacteria

Some plants have developed close symbiotic relationships with bacteria. These bacteria are held in root nodules and convert the nitrogen gas found abundantly in the air into nitrogen fertiliser that plants need for growth. Researchers hope to transfer this nitrogen-fixing process into important crops to deliver nitrogen without using artificial fertilisers.

The researchers will genetically alter a nitrogen-fixing bacterium and a simple grass species, which is similar to more complex cereals such as maize, to ensure a lock-and-key interaction between plant and microbe, while maximizing nitrogen fixation by the bacterium and the amount of usable nitrogen delivered to the plant.

The bacterium will be genetically tuned to respond to plant signals and nutritional needs to control the production of nitrogen fertiliser for the plant.

Once the researchers have perfected the technique, they hope to develop effective interactions between maize and nitrogen-fixing bacteria.

Professor Philip Poole from the University of Oxford said: "This research could pave the way for a 'Green Revolution' that will increase crop yields for resource-poor farmers and decrease the use and environmental impact of industrial fertilisers by wealthier farmers."

The John Innes Centre's Professor Giles Oldroyd will join Professor Poole on the project and John Peters (Montana State University), Jean-Michel Ane (University of Wisconsin Madison), Michael Udvardi (Samuel Roberts Nobel Foundation) and Christopher Voigt (Massachusetts Institute of Technology) will provide the US expertise.

Prof Douglas Kell, BBSRC Chief Executive said: "The outputs of the Ideas Lab have offered fresh ideas and fresh approaches to the challenge of feeding a growing population in a sustainable way. By bringing together world-leading researchers from the US and UK, we are rethinking current farming practices. Thanks to this exciting research, farms of the future could one day produce crops that do not rely on costly and polluting man-made fertilisers."

Dr John Wingfield, NSF's Assistant Director for Biological Sciences said: "The reliance of artificial nitrogen fertilizers for food crop production and their damaging environmental effects are in many ways underestimated. Fortunately, there are scientists paying attention to how these artificial fertilizers can be replaced by abundant atmospheric nitrogen. NSF's investment in Ideas Lab nitrogen projects provides a unique opportunity to engage cross-disciplinary scientists and engineers to generate novel and innovative approaches to creatively address a worldwide problem."

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