Nitrogen for nothing and your protein for free

By Anu Mathew, CSIRO

NITROGEN is key to producing the world's crops – but it comes at a cost. New research from CSIRO is developing future crops that produce their own fertiliser.

Over half of the protein within our body can be directly traced to a process invented more than 100 years ago by two German chemists, Fritz Haber and Carl Bosch. The Haber-Bosch process artificially fixes nitrogen by breaking the inert triple bond of nitrogen gas, into ammonia fertiliser.

Without this advance, our population would not have been able to feed itself. But the combined pressures of continued global population increases and a need for better quality protein have forced farmers to be evermore reliant on continued applications of nitrogen fertiliser. This has come at a price.

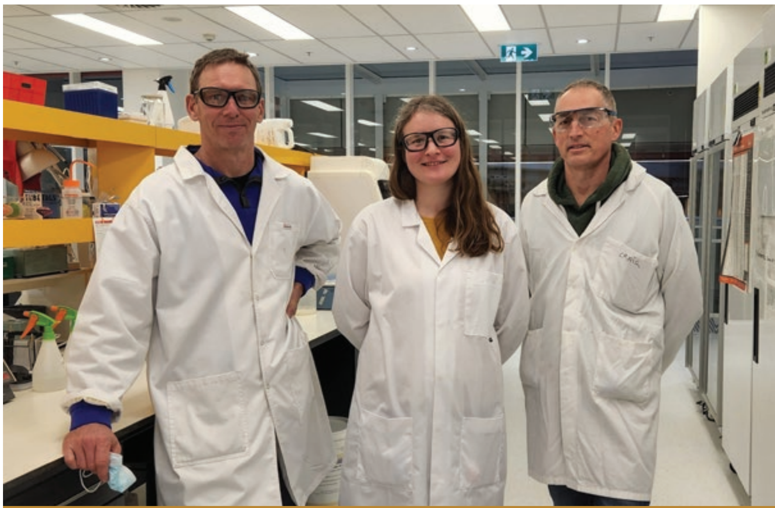
Aside from the direct costs of applying nitrogen fertiliser, there is also an increasing awareness of the environmental pollution produced by the overuse of fertiliser. Fertiliser use can particularly contaminate downstream waterways, such as the Great Barrier Reef. The global production of the fertilisers also causes ed by agriculture.

1.4 per cent of annual CO_2 emissions and its use is the major cause of non-CO_2 greenhouse gas emissions.

So, a conundrum exists for humanity: how can we provide enough food and protein for the growing population but also avoid the economic and environmental costs of applying nitrogen fertiliser?

Cutting environmental impacts, without impacting global food security

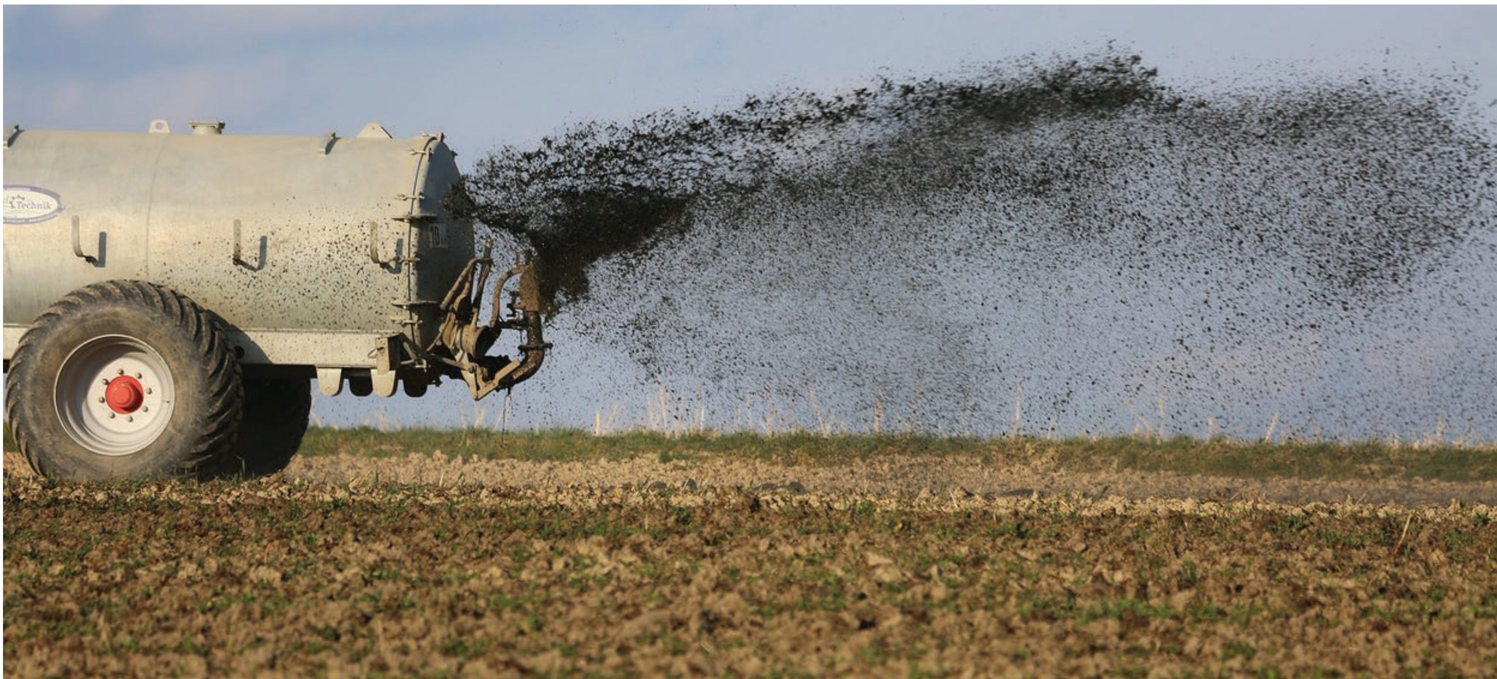
This challenge is being tackled by Dr Craig Wood and his team at CSIRO using advanced synthetic biology and crop biotechnology to create new crops that that can fix their own nitrogen for growth.



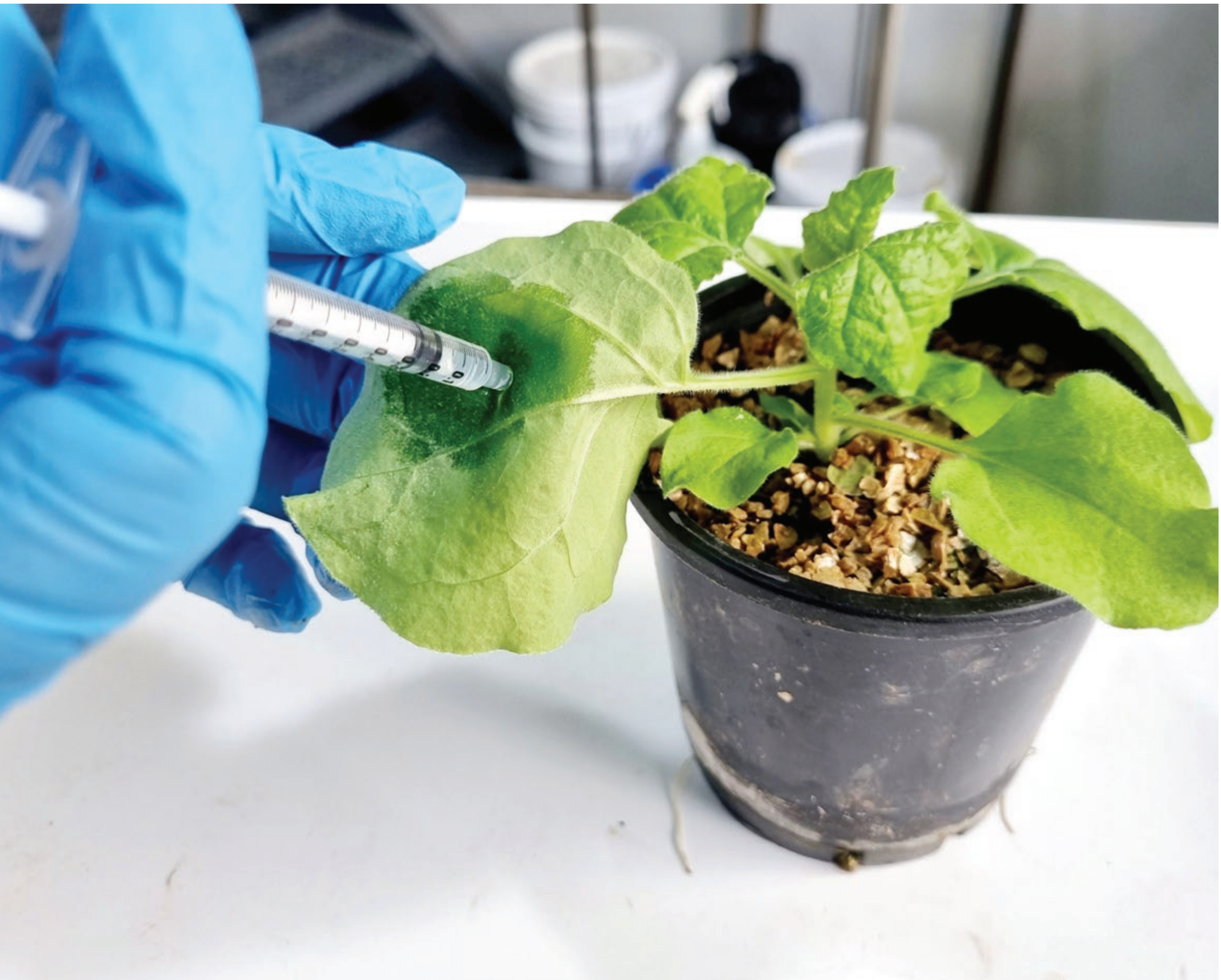
Left-to-right: Drs Rob Allen, Christina Gregg and Craig Wood are at the forefront of a global race to reduce the impacts of fertilisers.

"Some bacteria are able to make their own fertiliser, and this unique and natural pathway is giving us the template for engineering crops with the same capacities," Craig says.

His team, including Drs Christina Gregg and Rob Allen, are using the genetic templates available in bacteria and re-engineering them to have stable expression in agricultural crops. The complete template of DNA found in bacteria produces



The production and application of fertiliser is one of the biggest environmental impacts caused by agriculture.



Benth (*Nicotiana benthamia*) plants are being grown and injected with nitrogenase genes to test the transient protein expression for nitrogen fixing.

the enzyme nitrogenase, the only biological process capable of converting inert nitrogen gas (accounting for almost 78 per cent of the gas in the Earth's atmosphere) into valuable ammonia.

The bacterial pathway has been investigated for the past 50 years, providing a wealth of biochemical and genetic insights. A fascinating aspect of nitrogenase is that it operates only in the absence of oxygen and requires lots of energy to break the inert triple bond of the nitrogen gas molecule. To allow nitrogenase to function within a crop, CSIRO researchers are locating the entire bacterial pathway into plant mitochondria, a subcellular compartment where the oxygen concentration is very low and there is an abundance of biological energy.

The genetic pathway for reconstructing nitrogenase within plants involves approximately 10 different components. CSIRO has shown that each of these parts can be relocated successfully to plant mitochondria. The next stage of the process is to assemble functional components within the plant, requiring advanced skills in molecular biology and biochemistry.

A global race to improve crop sustainability

"It's an exciting research project, both due to the complexity of the science and the potential impact to improve sustainability and reduce farmer costs," Craig says.

"CSIRO is in a race with similar approaches being conducted in Spain, China, USA and the UK. All these countries can see the need to reduce reliance on fertiliser and synthetic biology offers a unique chance to do just that," he says.

"There have been significant breakthroughs in the past two years, and in my opinion, we will have plants containing functional nitrogenase within five years."

The development of such technologies would open possibilities of engineering plants to produce high-quality proteins with less fertiliser and improved sustainability.

Previously CSIRO has developed genetically modified crops, with complex metabolic pathways resulting in the production of Omega-3 oils in canola seed. All these genetically modified approaches are subject to a full range of regulatory approvals to ensure the plants are safe to use in the food chain and in the environment.

Similar development and eventual adoption of crops with nitrogen-fixing abilities would play a significant role in transitioning agriculture towards a sustainable future. ■