Renewable nitrogen fixation in crops – enhancing food security and sustainability

Dr Karsten Temme is CEO and co-founder of Pivot Bio, a company that uses groundbreaking, sustainable technology to revolutionise the agricultural industry. In particular, Pivot Bio is focused on creating a biofertiliser that provides a better alternative for the planet, while also reducing the amount of nitrogen fertiliser used by farmers. This can be achieved by enabling microbes to fix and supply nitrogen to crops, improving crop productivity, and thereby enhancing food security.

Pivot Bio, originally founded by Dr Temme and his colleague Alvin Tamsir, PhD, is focused on using cutting-edge science to solve agricultural problems. The team is particularly passionate about developing innovative ways of enhancing nitrogen fixation in microbes, which can be used to supply nitrogen to crops such as corn. Not only is this research invaluable to farmers all over the world who are economically reliant on crop production but it also offers an environmentally sustainable alternative to synthetic nitrogen fertilisers.

WHY IS NITROGEN FIXATION IMPORTANT?

The process of nitrogen fixation is essential for the majority of life forms, including both plants and animals. Nitrogen compounds are required for the biosynthesis of important biomolecules, including amino acids and nucleotides for DNA/RNA. Although 78 percent of our atmosphere consists of nitrogen, it is inert and biologically unusable in its gaseous form. However, certain microbes can convert nitrogen gas into ammonia via the enzyme nitrogenase, which can then be further processed to produce other nitrogenous biomolecules that are usable by the plant. Some microbes take it one step further – forming a symbiotic relationship with their plant neighbour, exchanging their nitrogenous products for photosynthetic outputs.

However, nitrogen is one of the most limiting elements for plant growth and production. This is a major obstacle for the agricultural industry, especially as the pressure to feed and support a growing global population builds. As a result, synthetic fertiliser is often used to supply crops with the nitrogen they need to grow, develop and reproduce. In fact, many farmers are completely reliant on fertilisers and inefficient application can lead to huge losses. Incredibly, it has been estimated that in 2008, nitrogen fertilisers were responsible for feeding 48 percent of the global population.

IMPACTS OF NITROGEN FERTILISERS

Despite the importance of fertiliser for crop production, its usage can result in many

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A scientist at Pivot Bio scraping corn roots to measure the colonisation of Pivot Bio's nitrogen producing microbe.

adverse effects. For example, it is very expensive, with growers spending more than $200 billion each year on fertiliser purchases worldwide. High costs and regulatory limitations make it difficult for farmers in poorer countries to access these products and, subsequently, they may often struggle to make a living. Furthermore, surface runoff and groundwater leaching can remove 50 percent of applied fertilisers, making the process extremely inefficient. Nitrate from wasted nitrogen fertiliser goes on to pollute our water systems, encouraging the formation of algae blooms which deplete oxygen in the water in a process called eutrophication, meaning that other aquatic inhabitants die.

As the climate changes and the population increases, farmers will be faced with a tough challenge: How can crop yields be maintained in a sustainable way without threatening the environment?

Testing nitrogen delivery from microbes developed through ON Technology™.

NOVEL MICROBIAL TECHNOLOGY DEVELOPED BY PIVOT BIO

How can this process be improved to help both farmers and the environment? This question inspired the team at Pivot Bio to develop a revolutionary approach, utilising the innate abilities of nitrogen-fixing microbes. In any soil habitat, there are wide ranges of both beneficial and harmful microbes that interact and communicate with plants via their roots. Generally, soil microbes that have the genetic ability to fix atmospheric nitrogen tend to form symbiotic relationships with legumes – plants producing seeds in pods (such as peas, beans and lentils). However, it is cereal crops – and not legumes – that feed the world. In fact, 50 percent of the worldwide dietary energy comes from corn, wheat, rice and sorghum. These commercially important cereals also have associations with nitrogen-fixing microbes. However, conventional application practices of fertiliser have impaired nitrogen fixation in these microbes. In fact, approximately 40 percent of acres are over-fertilised worldwide. The microbes sense the high levels of nitrogen in soil and consequently switch off nitrogen-fixing biochemical pathways in order to conserve energy and resources.

To solve this problem, the team at Pivot Bio developed Optimised for Nutrients Technology™ (ON Technology™) that remodels the genetic behaviour of these cereal-associated nitrogen-fixing microbes. The first crop the team tested ON Technology™ with was corn. This involved identifying which microbes shared the same soil as the crop in question by collecting and analysing diverse soil samples and then creating a map of the microbiome community. Next, the team sequenced the microbiomes, exploring which microbes had both the potential to fix nitrogen and live symbiotically with corn. Finally, the team re-enabled the microbes to fix nitrogen and allow the natural process of crop fertilisation to occur, even in the presence of fertiliser. These microbes were then applied to the soil surrounding the crop as a seed treatment or in-furrow application. In the end, both the plant and microbes grew and developed in unison, living together symbiotically.

The team at Pivot Bio has developed a novel, sustainable technology that can contribute to food security and has the potential to completely revolutionise the agricultural industry

ACHIEVEMENTS OF ON TECHNOLOGY™

A major benefit of ON Technology™ is that it can supply corn with nitrogen daily throughout the corn plant's growth stages. Typically, synthetic fertiliser is applied in the autumn following harvest or in the spring before planting; however, crops greatly require nitrogen during growth and grain production. ON Technology™ can be applied when the seed is planted, growing with the plant, increasing nitrogen availability and consequently improving crop quality and yield. Interestingly, extensive field trials, performed by Dr Temme and his team at Pivot Bio revealed that ON Technology™ could supply up to 50 pounds of nitrogen per acre of corn, significantly increasing yield. This has astounding financial implications, as ON Technology™ has the potential to supply over seven million tonnes of nitrogen to corn that will not be subject to conventionally applied nitrogen leaching and denitrification concerns because the nitrogen is not applied before the plant can use it.

FUTURE RESEARCH

Overall, the team at Pivot Bio has completely revolutionised the agricultural industry, developing a novel, sustainable technology that can contribute to food security. In the future, the team aims to perform more trials to further improve the quantity of nitrogen fixed by the fine-tuned microbes. Additionally, research will be conducted on other types of cereal crops such as wheat, rice and sorghum, and the team will also investigate the ability of microbes to provide improved utilisation of other essential nutrients, such as potassium and phosphorus in crops.

Q&A

What first inspired you to develop this novel approach to crop nutrition?
While studying biomedical engineering in Iowa in the early 2000s, I got to know many farmers in the area and saw the challenges they faced, including the prohibitive costs of fertiliser. During my post-graduate studies in California, I shared a hypothesis with a colleague: What if microbes could be reprogrammed, like computer programmes, to meet specific needs? To find out, Alvin and I brought together our backgrounds in microbiology, genetics, engineering and computer programming and created Pivot Bio in 2011.

What is the advantage of Pivot Bio's nitrogen-producing microbes, as compared to historic nitrogen application processes?
Nitrogen produced through Pivot Bio's microbes significantly reduces the loss of nitrogen associated with crop production. Pivot Bio's microbes produce nitrogen for the plant to absorb on a daily basis. Microbes are not subject to leaching and denitrification, which has plagued conventional nitrogen application practices.

Why do microbes, associated with cereal crops, switch off their nitrogen-fixing biochemical pathways when exposed to high levels of fertiliser?
Decades of exposing these microbes to synthetic fertiliser have caused their natural abilities to fix nitrogen to go dormant. Using a proprietary approach, we have reawakened and amplified the ability of these microbes to fix nitrogen into forms the plant can use.

How does "Optimised for Nutrients Technology" work?
Our unique ON Technology™ uses the crop's own microbiome to produce nitrogen for the plant. Through our proprietary process of guided microbial remodelling, we identify, characterise and fine-tune microbes to realise their full potential. In other words, we unlock the genetic material naturally present in a microbe to optimise nutrient delivery. This is important because better nutrient availability improves both crop quality and yield potential.

What is your next area of focus going to be?
We are also exploring other crops, such as wheat, sorghum and rice, as well as ways to make phosphorus, potassium and other critical nutrients more available to crops. This is important as low phosphorus and potassium levels in soil lead to low crop quality, uniformity and yields.

ON technology™ could supply up to 50 pounds of nitrogen per acre of corn, which has the potential to significantly increase yields

Detail

RESEARCH OBJECTIVES

Pivot Bio, founded by Dr Temme and his colleague Alvin Tamsir, PhD, is focused on using cutting-edge science to solve agricultural problems. Pivot Bio's aim is to develop a biofertiliser that provides a better alternative for the planet, while also reducing the amount of nitrogen fertiliser used by farmers.

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COLLABORATORS

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BIO

Karsten Temme, PhD, is CEO and co-founder of Pivot Bio. He earned his PhD in bioengineering from the University of California-Berkeley, focusing on the limitless potential of microbes. Previously, Temme studied biomedical engineering at the University of Iowa. Here, he founded X-Wires, a company that brought Wi-Fi to farmers.

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ARTICLES MENTIONING PIVOT BIO:

- *Capital Press: Western Innovator: Technology puts bacteria to work* (January 12th, 2018)
- *Ag Web/Farm Journal: Is Nitrogen-Fixing Corn the Future?* (November 30th, 2017)
- *CNBC.com:* "29 startups that prove Silicon Valley innovation isn't dead" (November 14th, 2017)