

# Nitrogen and cotton: A microbial view

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Over 100 years ago Sir William Crookes said that, “civilised nations stand in deadly peril of not having enough to eat.” His challenge was adequately met by chemist Fritz Haber and industrialist Carl Bosch. The Haber-Bosch process enabled the industrially production of nitrogen (N) based fertilisers.

Without industrially produced fertiliser it is estimated that current global agricultural productivity would be cut by one third. Despite the tremendous advantages to using N based fertilisers in agriculture it is now widely recognised that overuse can be detrimental to crop production and degrade the environment. Additionally, the cost of adding N based fertilisers is increasing.

Currently within the cotton industry there is a great deal of information being provided on better ways to use and manage N in order to maintain productivity, improve economic returns and reduce potential environmental damage.

The purpose of this article is to:

- Explain the role of soil microbes in the nitrogen cycle in cotton soils; and,
- Demonstrate that cotton cultivars influence the activity and the composition of soil microbes.

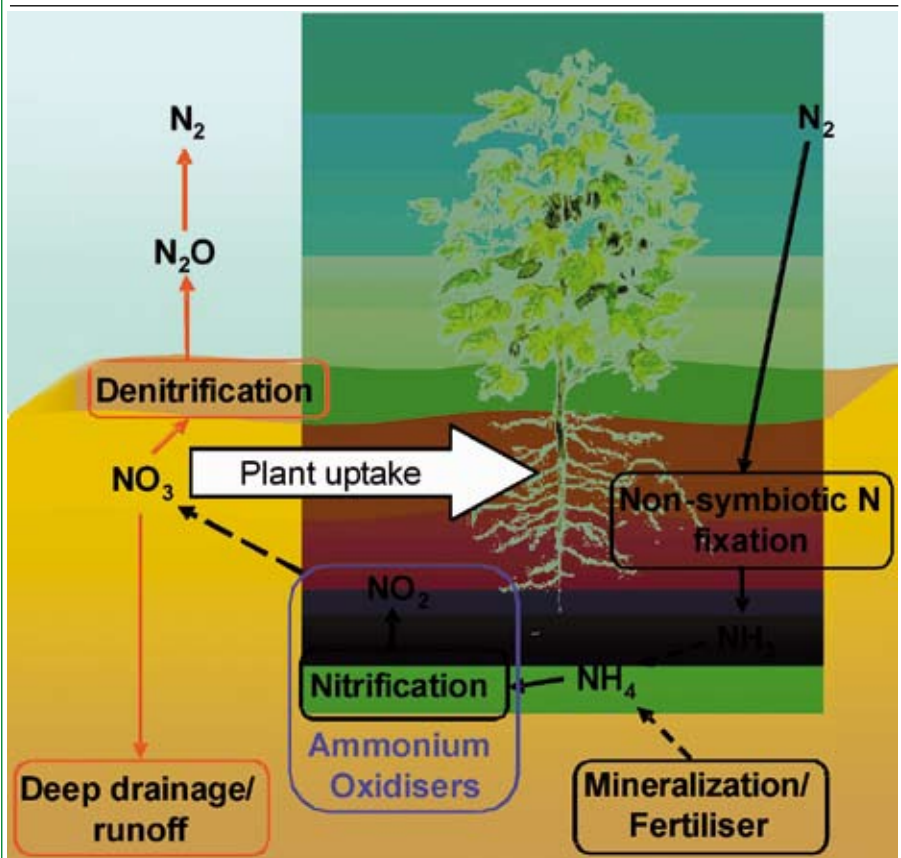
In our work, looking at the cotton cultivar-soil microbe interaction, we've assessed levels of non-symbiotic N fixation, potential nitrification rates, and populations of ammonium oxidiser (AO) bacteria (Figure 1). Our work is not complete and we are not in a position to propose altered management strategies.

But the findings are of interest to the industry as they both highlight the importance of the soil microbiology in processes involved in plant nutrition and advance our understanding of soil microbiology under cotton.

## Non-symbiotic N fixation

This is the process of fixation of gaseous nitrogen ( $N_2$ ) from the air into the soil. It is similar to the N fixation process that occurs with the legume/Rhizobium association, but this biological N fixation is largely responsible for maintaining a natural nitrogen balance in non-fertilised systems. Bacteria capable of carrying out non-symbiotic N fixation are ubiquitous within the soil

**FIGURE 1: Schematic of some of the processes involved in the nitrogen cycle, which appear to be influenced by cotton cultivar selection**



Black boxes and arrows indicate plant beneficial process whilst red boxes and arrows indicate potential sources of loss of N from the system.

and belong to a number of genera including Clostridium, Azotobacter, Azospirillum and Klebsiella.

The grey vertisol soils we have investigated under cotton crops all show the capability to fix  $N_2$  via this process of non-symbiotic fixation. The rate of this fixation appears to vary with conditions and cotton cultivar (Figure 2).

We have measured it as high as two kg  $N_2$  per hectare per day when soil and environmental conditions are optimum. Non-symbiotic N fixation is unlikely to provide sufficient N for a high yielding cotton crop, but could supply 40–60 kg  $N_2$  per hectare per cotton crop. But the potential to manipulate this process to supply any proportion of the crop's nutrition is largely unexplored.

## Nitrification

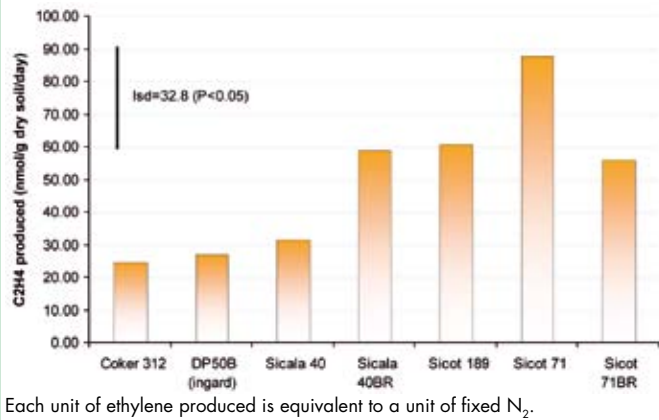
The mineralisation of plant and other organic residues finishes with the formation of ammonium ( $NH_4^+$ ). This ammonium, the most reduced form of inorganic nitrogen, then serves as the starting point for the process of nitrification, which results in its oxidation to nitrite ( $NO_2^-$ ) and finally nitrate ( $NO_3^-$ ).

The conversion of ammonium and other inorganic mineral forms of N to nitrate is often seen as a problem in agricultural systems because nitrate is highly mobile and can be lost from the rooting zone as water drains out of the profile.

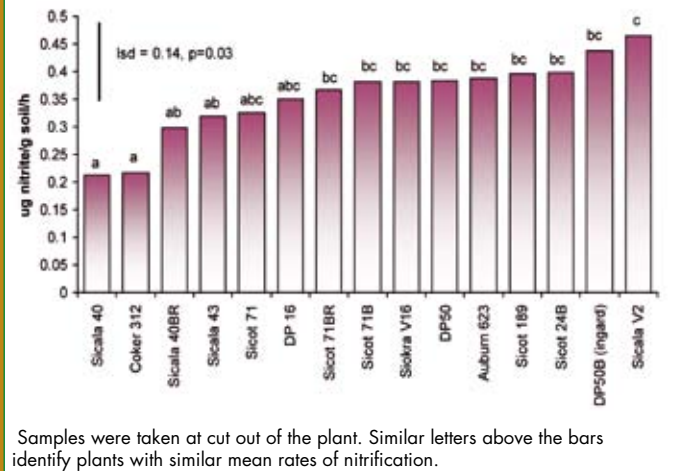
Nitrate is also used by many microbes, when oxygen is limited, to remain active. This tends to occur under wet soil condi-

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**FIGURE 2: Measures of the rate of non-symbiotic free N<sub>2</sub> fixation, based on ethylene (C<sub>2</sub>H<sub>4</sub>) production, as assessed for replicated 10 g samples of rhizosphere soil from different cotton cultivars around the time of defoliation**



**FIGURE 3: Rates of nitrification, as measured by the rate of conversion of ammonium sulphate to nitrite, by rhizosphere soil samples from a number of cotton cultivars**



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tions and is responsible for denitrification, which leads to the loss of N from the soil as N<sub>2</sub>O, a potent greenhouse gas.

But there is also evidence that the existence of N as nitrate in cotton soils is de-

sirable. While plants have the potential to take up N in a number of forms through their root systems, some research highlights a preference for nitrate uptake, over ammonium, in both Pima and Acala cottons.

The alkaline grey clays used in much of the Australian cotton production system demonstrate rapid rates of nitrification. But the nitrate this produces is preferentially immobilised over ammonium by the microbial component of the soil, which assimilate it into their cells, thereby reducing potential for losses to leaching and denitrification.

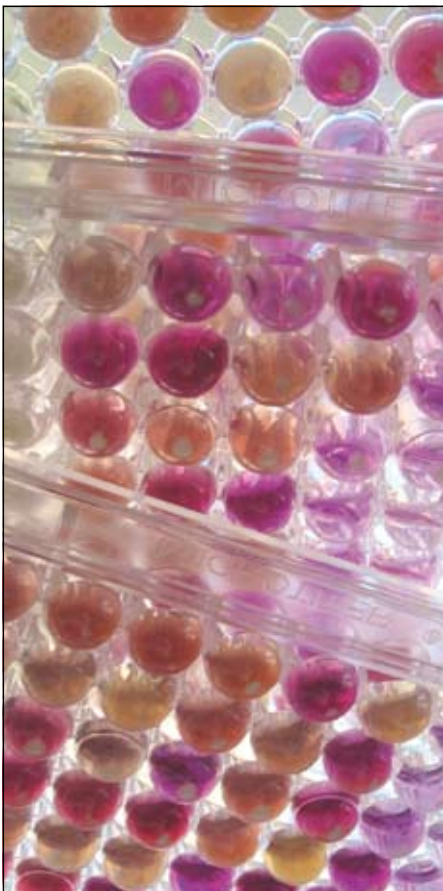
In the laboratory we measure the potential for nitrification as the conversion of ammonium (added to soil as ammonium

sulphate) to nitrite. The increase in the amount of nitrite produced is monitored over time as a measure of potential rates of nitrification (Figure 3).

Again a cultivar difference is observed in this process. Although the underlying reasons for this are unknown, differences in the rates of nitrification would suggest that the levels of nitrate in the soil under cultivars differs and could have implications for both plant and microbial uptake (immobilisation) in the rhizosphere and/or the potential for the loss of N from the system, depending on environmental conditions.

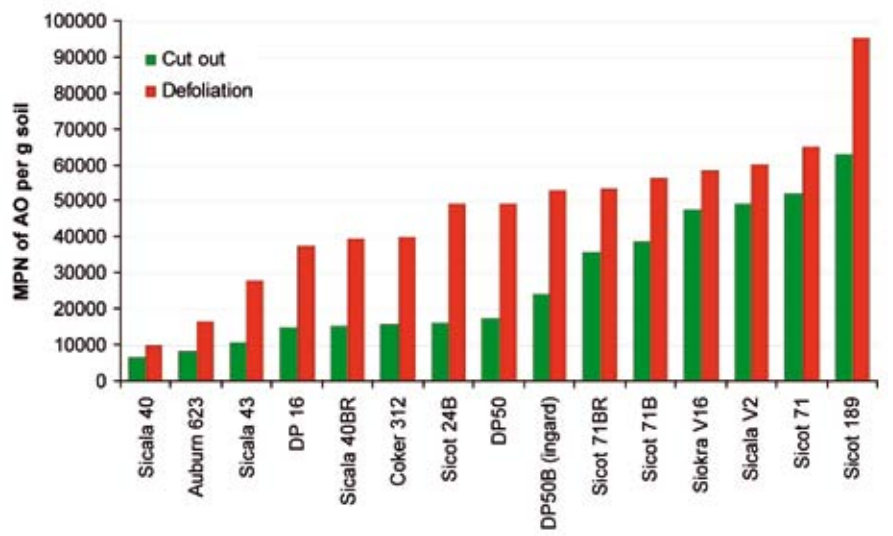
**Ammonium oxidisers**

The processes of nitrogen fixation and decomposition of organic matter generate



Picture of 96 well plates developed for the assessment of MPN of AO bacterial populations with Griess reagent after a three week incubation.

**FIGURE 4: The most probable number (MPN) of ammonium oxidiser bacteria recovered from the rhizosphere soil of several cotton cultivars at cut out and defoliation**



Different recoveries were seen at the two periods of assessment, but there is a similar trend.

much of the soil's nitrogen by making ammonium. Similarly, applied fertilisers are often ammonium based formulations.

The nitrification of this soil ammonium to nitrite is carried out by bacteria known as ammonium oxidisers (AO) or nitrifying bacteria. The role of these bacteria is therefore very important in determining the forms of N present in the soil and its potential fate.

As is the case with N-fixation and nitrification rates, there are differences among cotton cultivars in the abundance of AO bacteria associated with their roots (Figure 4).

### SUMMING UP

- In soil it is the microbiology that is central to the processes involved in nutrient cycling, including N.
- Cotton cultivars are influencing processes involved in N cycling in the soil in close proximity to their root systems by manipulating the associated microbiology.
- Currently we do not know if the differences between cultivars in non-symbiotic N fixation, nitrification and ammonium oxidation rates are the result of changes in activity or structure of the rhizosphere microbial community. If cultivars are producing different quantities of root exudates then this might be expected to influence the populations and overall activity of the microbiota.
- Further, if the quality or chemical nature of the exudates is different then the composition of the rhizosphere microbial population may also be altered. It is likely, however, that both factors will be involved in a more complex relationship that also encompasses subtle differences in plant rooting and the soil environment.
- In the future, there may be potential to improve N use efficiency through cultivar selection to enhance N cycling microbiota. But the current best practise would be to follow the advice of your agronomist.
- Less time between up front fertiliser applications and planting, application of more of the crop N requirement in season, and the introduction of legumes and particularly green manured legumes are all generally considered to be good management practices to adopt.

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## Winner of Round Table education award

A prestigious national Award for 'Best Collaboration with a Regional Focus' has been taken out by the Cotton Catchment Communities CRC (Cotton CRC) "Summer Scholarship Program".

Lisa Paul, Secretary of the Department of Education, Science and Training, presented the Business/Higher Education Round Table (BHERT) Award to Cotton CRC Chief Scientist, Professor Peter Gregg, during a gala awards ceremony in Sydney. This BHERT award reflects recognition by the chief executives of major Australian corporations, research organisations and the Vice Chancellors of Australian Universities.

The Cotton CRC "Summer Scholarship Program" provides new dimensions and opportunities for undergraduate students studying agriculture or related sciences at University. Students gain eight weeks paid work during their summer holidays, combining experience in a regional location and collaboration with a "real" scientist.

This enables scientists to expand their current projects by investigating smaller yet novel aspects of their science

Professor Gregg said that since the course began in 2000, 45 scholarships have been provided to motivated university students to conduct pilot projects.

This innovative education program has helped overcome the major problem of attracting future graduates as employees and postgraduate students to study in regional locations



Lisa Paul presents the award to Peter Gregg.

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