# Free-living bacteria lift soil nitrogen supply

Biological nitrogen fixation is usually associated with symbiotic Rhizobium-legume systems. But as this article shows, there is a wealth of free-living bacteria in soils across Australia that are capable of fixing significant atmospheric nitrogen in the absence of legumes, using crop residues and root exudates as an energy source.

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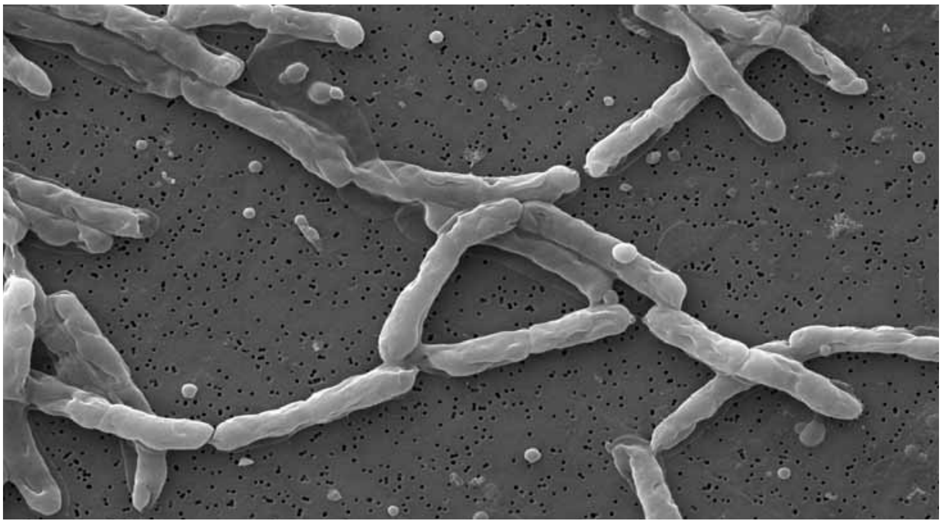
Non-symbiotic nitrogen fixation can contribute significant plant-available nitrogen per hectare per year to intensive farming systems.

For example, in an intensive wheat rotation at Avon, South Australia, non-symbiotic nitrogen fixation contributed 20 kilograms per hectare per year, which met 30–50 per cent of the long-term nitrogen needs of this system.

With the potential for non-symbiotic nitrogen fixation to provide a significant amount of farming system nitrogen, a better awareness and understanding of the role of non-symbiotic nitrogen fixation could enable improved targeting of nitrogen fertiliser inputs across a range of farming systems.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*Biological nitrogen fixation is critical as it provides a source of fixed nitrogen for plant growth that is non-polluting and not dependent on inorganic nitrogen fertilisers produced from fossil fuel use. Pictured is the non-symbiotic nitrogen fixing bacterium Azospirrillum, which is found in cropping soils across Australia.*

## Nitrogen-fixers widespread

CSIRO research indicates non-symbiotic nitrogen fixation bacteria occur in all soils throughout southern Australia, regardless of soil type or land use.

Populations are generally higher in clay soils than sandy soils but land use appears to have the largest impact on the size of these populations. For example, populations are higher in paddocks under crops with high carbon-to-nitrogen ratios such as wheat, oat, rice, sorghum and millet.

### At a glance

- Non-symbiotic nitrogen fixing bacteria can contribute significant amounts of nitrogen to cropping soils.
- Unlike symbiotic nitrogen fixers, non-symbiotic nitrogen fixing bacteria must find their own energy source to convert nitrogen gas to ammonia.
- Stubble retention, reduced tillage and in some cases intensive cropping provide the high carbon, low nitrogen conditions required by non-symbiotic nitrogen fixing bacteria.

Free-living nitrogen fixers represent a range of bacteria including saprophytes living on plant residues, bacteria living in close association with the rhizosphere of plant roots and bacteria which live entirely within plants (endophytes).

Bacteria such as *Azotobacter* and *Azospirrillum* (pictured) live in aerobic conditions whereas others such as *Clostridium pasteurianum* must live in oxygen-free (anaerobic) conditions.

## Stubble retention is critical

Due to the low levels of biologically available organic carbon in Australian soils, significant amounts of non-symbiotic nitrogen fixation can occur only near decomposing crop residues or in the area close to crop roots called the rhizosphere.

Stubble retention and reduced tillage provide a high-carbon, low-nitrogen environment during summer and autumn, enabling optimum activity of non-symbiotic nitrogen fixation.

## Energy hungry

Nitrogen fixation requires an enzyme called nitrogenase, which converts gaseous nitrogen into the more available nitrogen form — ammonia.

Nitrogenase activity consumes large amounts of energy. Symbiotic nitrogen fixing bacteria receive energy from the host legume but free-living bacteria must find their own source of energy within the soil. Nitrogenase requires the products of about 20 genes for its synthesis and activity. These genes are not expressed if sufficient fixed nitrogen is available in the environment. This means the activity of non-symbiotic nitrogen fixation bacteria in systems with crop residues containing high available nitrogen (such as legumes) is relatively low.

## Oxygen-free conditions required

Nitrogenase activity is deactivated in the presence of oxygen and all nitrogen-fixing bacteria (free-living and symbiotic) must therefore operate within oxygen-free (anaerobic) conditions.

Free-living nitrogen fixers that exist only in aerobic (oxygen) conditions have evolved a specialised biochemical pathway to keep oxygen at very low levels within their cells.

## Moisture and temperature

The highest rate of non-symbiotic nitrogen fixation occurs at soil moisture contents close to or higher than field capacity.

In areas with high summer rainfall such as northern New South Wales, significant nitrogen fixation rates of 25–35kg/ha have been measured.

The combination of moisture and warm temperatures in these areas promotes the bacterial activity.

In contrast, the usually low soil moisture levels of cropping areas in southern and Western Australia during summer often limits free-living nitrogen fixation in these areas.

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