BIOHUB
SOLUTIONS

Solutions for today.
Benefits for generations.

BioTech Series

Nitrogen

Where science meets sustainability, and your farm's potential meets our passion.

How We Help

We know that understanding biologicals can be both confusing and overwhelming. Your solution should simple, measurable, and profitable. This is why we developed the **BioPlan**.

- Focus on testing and data to develop the best solution.
- Integrated solutions focusing on soil, nutrition, and plant health.
- Simple crop and soil monitoring providing solution accountability.
- Simple solutions providing agronomic, environmental, and economic returns.

The BioTech Series has been designed to answer some of the more technical questions you may have about our solutions. Or provide some extra information for inquisitive minds wanting to know a little more about biological strategies. When digesting the information in this booklet and others in our series, remember there is no silver bullet. No solution is the same. No challenge is the same. What is the same are the processes that BioHub team members and trained business partners follow under the BioPlan to try to formulate an integrated solution. This integrated solution can involve nutrition, plant health, biologicals, or soil ameliorants.

At BioHub Solutions, we fuse cutting-edge science and data with the wisdom of nature to deliver pioneering biological solutions to the agricultural sector. Our Australian heritage drives us to innovate for the unique challenges faced by local and global farmers, ensuring our products not only boost your bottom line but also safeguard the environment.

Take the guesswork out of biologicals by contacting one of our team or authorised business partners.

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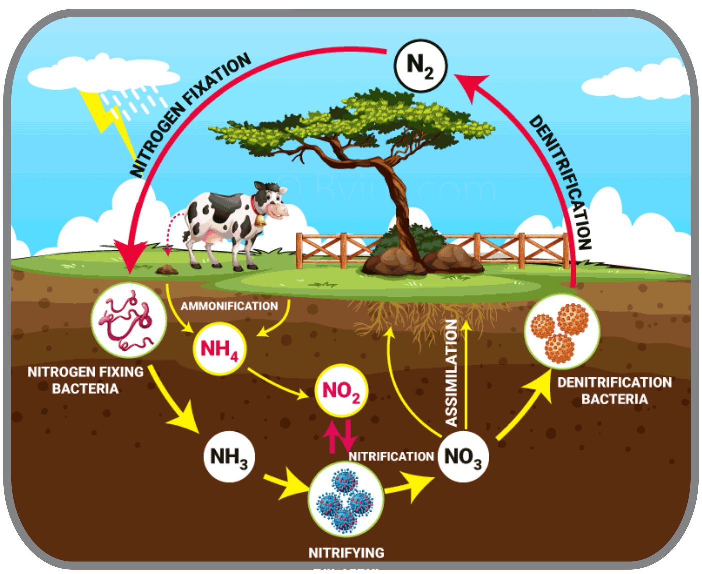
Introduction

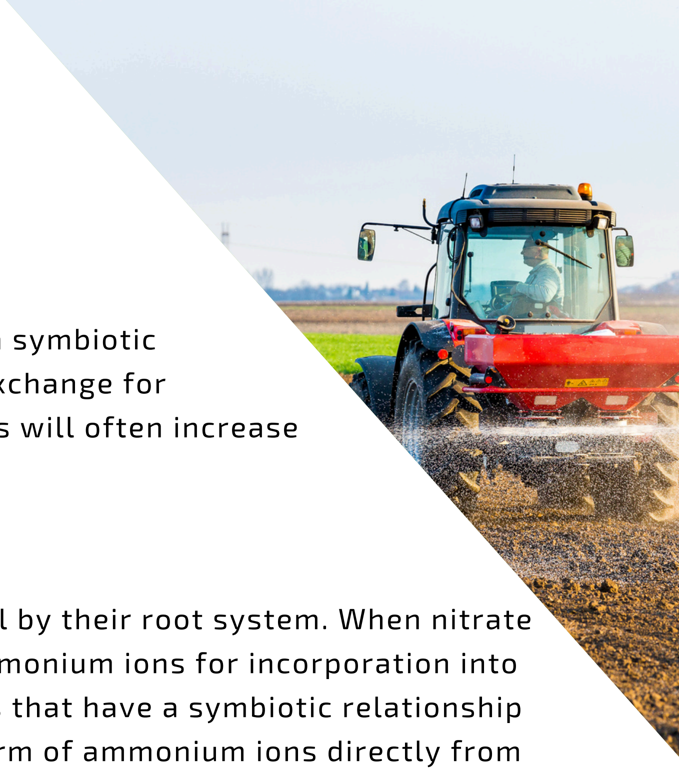
Nitrogen is present in the environment in a wide variety of chemical forms including organic nitrogen, ammonium, nitrite, nitrate, nitrous oxide, nitric oxide or inorganic nitrogen gas. Organic nitrogen may be in the form of a living organism, humus or in the intermediate products of organic matter decomposition. The processes in the nitrogen cycle is to transform nitrogen from one form to another. Many of those processes are carried out by microbes, either in their effort to harvest energy or to accumulate nitrogen in a form needed for their growth. During the various stages of the nitrogen cycle, there are also many pathways for losses.

The Nitrogen Cycle

Nitrogen Fixation

Nitrogen fixation commonly refers to the process of the conversion of nitrogen gas into nitrates and nitrites through atmospheric, industrial and biological processes. Atmospheric nitrogen must be processed "fixed" into a usable form before being utilised by plants. Some nitrogen is fixed by natural occurrences such as lightning strikes. However, most fixation is done by free-living or symbiotic bacteria known as diazotrophs. These bacteria have the nitrogenase enzyme that produce ammonia, which is converted by the bacteria into other organic compounds. An example of free-living bacteria is Azotobacter. Symbiotic nitrogen-fixing bacteria such as Rhizobium usually





live in the root nodules of legumes. Here they form a symbiotic relationship with the plant, producing ammonia in exchange for carbohydrates. Because of this relationship, legumes will often increase the nitrogen content of nitrogen-poor soils.

Assimilation

Plants can absorb nitrate or ammonium from the soil by their root system. When nitrate is absorbed, it is reduced to nitrite ions and then ammonium ions for incorporation into amino acids, nucleic acids, and chlorophyll. In plants that have a symbiotic relationship with rhizobia, some nitrogen is assimilated in the form of ammonium ions directly from the nodules. The plant provides amino acids to the bacteroids so ammonia assimilation is not required. In return, the bacteroids pass amino acids (with the newly fixed nitrogen) back to the plant.

Ammonification

When an animal or plant dies the initial form of nitrogen is organic. This is also the case with expelled wastes from animals. Groups of bacteria or fungi convert this form of nitrogen back into ammonium.

Nitrification

The conversion of ammonium to nitrate is performed primarily by soil-living bacteria and other nitrifying bacteria. In the primary stage of nitrification, the oxidation of ammonium is performed by bacteria such as the Nitrosomonas species, which converts ammonia to nitrites. Other bacterial species such as Nitrobacter, are responsible for the oxidation of the nitrites into nitrates. It is important for the ammonia (NH3) to be converted to nitrates or nitrites because ammonia gas is toxic to plants. Nitrates are very soluble and therefore very mobile in the soil.

Denitrification

Denitrification is the reduction of nitrates back into nitrogen gas which complete the nitrogen cycle. This process is performed by bacterial species such as Pseudomonas and Paracoccus, under anaerobic conditions. They use the nitrate as an electron acceptor in the place of oxygen during respiration. These anaerobic bacteria can also live in aerobic conditions. Denitrification happens in anaerobic conditions such as waterlogging. The denitrifying bacteria use nitrates in the soil to carry out respiration and consequently produce nitrogen gas, which is inert and unavailable to plants. Denitrification occurs in free-living microorganisms as well as obligate symbionts of anaerobic ciliates

Nitrogen Loss Pathways

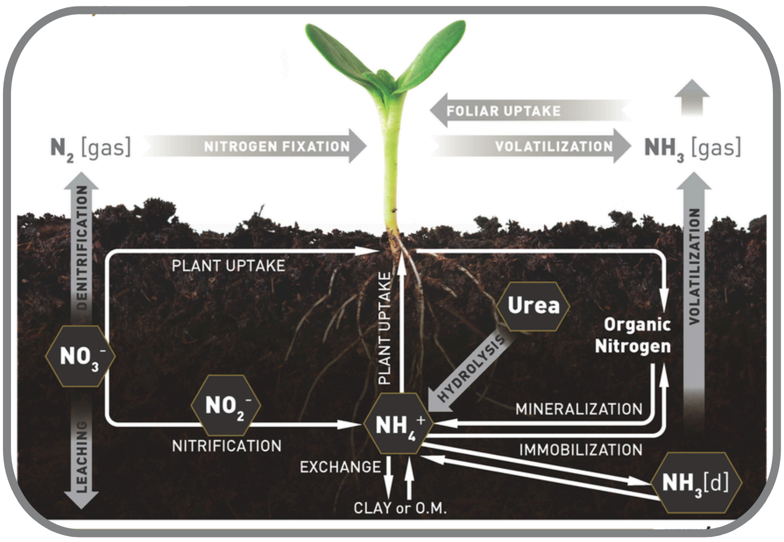
Understanding the nitrogen cycle provides an important insight into the nitrogen loss pathways. Only by understanding these two aspects of the puzzle can you then formulate a strategy to maximise nitrogen use efficiency in the paddock.

Volatilisation

Volatilisation is one of the most commonly recognised forms of nitrogen loss in agriculture. Fertilisers such as urea are applied to the soil surface first dissolves into solution, then is hydrolysed into ammonium and bicarbonate ions with the help of the urease enzyme. If this ammonia is near to the soil surface, it can come out of solution as a gas and be lost from the soil via ammonia volatilisation.

Soil moisture content at the time of application is important to preventing this loss. The preference is for moist soils that are not too dry nor not too wet when spreading nitrogen products. Field-measured volatilisation studies in the Australian grains industry have primarily focused on losses from surface applications of urea. Reported ammonia volatilisation losses from N applied to Australian cropping soils ranged from 0.1–34% (median of 6.7%) (Barton et al. 2022), which is similar to global averages of 6–19.5%, although the global range extends up to 65% (Ma et al. 2020). Average losses of ammonia from surface application of animal manures tend to be higher (23% global median) (Bouwman et al. 2002), but there is limited Australian data. Denmead et al. (2020) found 12% loss during summer grazing of pasture, but only 1% during winter.

Ammonia volatilisation losses typically occur over a period of 1–2 weeks after application but can be prolonged by dry weather or cut short by wet weather. Ammonia



volatilisation risk is higher where urea is applied to a wet soil that is drying, than to a dry soil that is rained on. A wet soil dissolves the urea and commences hydrolysis but does not move the ammonium into the soil. In contrast, urea that is spread may sit undissolved on a dry soil until rainfall or heavy dew dissolves and, if in sufficient intensity, washes the dissolved urea down into the soil profile. Clay and carbon content in soils help to absorb ammonium and reduce the amount of ammonium/ammonia available to be lost. Low clay soils with low organic matter are more at risk of ammonia being lost. The risk of volatilisation loss diminishes with time as the ammonium is nitrified to nitrate or taken up by plants.

A nitrogen loss pathway that is rarely discussed are losses from the crop itself. While plants can 'absorb' ammonia from the air they can also lose nitrogen. Ammonia also escapes from plant matter during leaf senescence, residue decomposition or stubble burning, with the amount lost linked to the N content in the residues. Incorporating residues into the soil can reduce losses.

Nitrification

Nitrification refers to the conversion of ammonium to nitrate by several groups of soil bacteria. This process involves multiple steps and gaseous compounds which can leak out of the soil and are then lost to the atmosphere. In most instances, the total amount of nitrogen lost during the nitrification process is minimal, typically <1% of applied N.

Denitrification

Denitrification is a process that describes the reduction of nitrate to dinitrogen. This reduction process is carried out by bacterial and/or fungal organisms in oxygen deprived environments. Denitrification can be a significant loss pathway in poorly drained or flooded soils where more than 70% of the soil pores are filled with water. It can also occur in drier soils where aggregate pores have inadequate air.

Directly measured denitrification losses from Australian dryland cropping soils ranged from 0–54% of applied fertiliser N (median, 28%) (Barton et al. 2022). Greatest losses occurred where N fertiliser was applied to clay soils as a pre-plant operation. Similarly, studies of pre-plant nitrogen fertiliser application ahead of irrigated cotton reported losses of up to 92% of applied nitrogen after above-average rainfall in the fallow period (Humphreys et al. 1990).

Nitrous Oxide

Nitrous oxide emissions can come from a range of soil biological and chemical processes. Microbial nitrification and denitrification considered to be the main sources.

The median annual nitrous oxide emissions from Australian dryland grain cropping soils across many studies was 0.19 kg N/ha (range: 0–48 kg N/ha) (Barton et al. 2022). This represents a median loss of 0.2% of applied nitrogen fertiliser, with losses of up to 1.8% reported. Most losses of nitrous oxide from fertiliser applications occur during the early crop stage between fertiliser application and crop uptake. The loss can be increased if rainfall events leads to waterlogging conditions. Otherwise, nitrous oxide emissions during a dryland cropping are typically very low with occasional short spikes following rainfall events. After harvest, crop residue breakdown can also contribute to nitrous oxide emissions, particularly from crops containing higher nitrogen contents.

Leaching

With the focus on crop yields, nitrogen rates have increased in many crops. Soluble forms of nitrogen may move past the usable root zone through leaching. Given the environmental impact of this nitrogen,it has become a concern around significant areas such as waterways. Nitrate is considered the most susceptible form for leaching, but organic forms may also leach. Leaching on deep sands in Western Australia range from 4–72 kg N/ha (Barton et al. 2022). Losses from applied fertiliser were 1.2% of applied nitrogen in a southeast Australia study. Long-term studies illustrated that under zero tillage, stubble burning, and fertiliser applied that potential losses were equivalent to 30% of the applied nitrogen (Turpin et al. 1998).

Runoff and/or Erosion

Water and wind erosion can result in losses of both organic and inorganic nitrogen. Nitrogen from organic matter and fertiliser is generally concentrated at the soil surface and this is where most soil erosion loss occurs.

In wind erosion of cultivated bare soils, the smaller particles are removed in dust and these small particles carry away 16 times more N than was present in the soil it was derived from (Leys and McTainsh 1994). Water erosion can be minimised by maintaining ground cover, improving soil structure , and creating contours to control water flow. In a central Queensland study, sediment loss from a Vertosol under zero tillage was 1.2 t/ha compared to 4 t/ha under conventional tillage practice. The calculated loss was 8 kg N/ha, which was two thirds of the total N loss and 20% of the fertiliser N applied (Murphy et al. 2013). In a southern Qld Vertosol under annual winter cropping, soil movement of 61 t/ha/yr under bare summer fallow was reduced to 2.1 t/ha/yr under zero tillage (Freebairn and Wockner 1986).

Nitrogen Management Options

Nitrogen is one of the most mobile elements in our soil and as such there are several pathways for its loss. The most common nitrogen product utilised in agriculture now is urea, a product that has been available for decades. The answer to date has been to investigate a nitrogen ceiling for growers to abide to in order to reduce the impact on the environment. The purpose of this article is not to suggest that the science is wrong, nor that we should not be setting a nitrogen use level. There is no silver bullet, yet we are looking for one. This BioTech article will outlines three simple factors with nitrogen that you should be considering this season and every season.

Listen to the Plant

Because nitrogen is mobile you need to understand the plant's ability to uptake the product. This is generally done through the root system (except for foliar application). Yet how many of you have looked at the root system after harvest? A healthy root system can uptake nutrients more efficiently, access water, survive excessive rainfall events and thus regulate plant health. If you have a poor root system, applying high rates of nitrogen less often will only leads to leaching past the effective root zone. In this case you will need to devise a plan for smaller amounts more often, which has its efficiency benefits as well. The depth of the root system will also be able to give you a strategy for nitrogen use during excessive rainfall events. A deeper root system, the more nitrogen is retained by the plant after irrigation or rainfall. Match application rates to what the plant can uptake efficiently.

Measure, Measure, Measure

This is the cornerstone of BioHub Solutions' BioPlan. The key is to utilise as many easy measurement systems as possible at your disposal. With regards to soil tests, be careful not to just focus on the surface measurements. If you know how deep roots are going, then invest in a deep soil test as well. It takes the guesswork out of what your plant can access later in the season and reduce the risk of over applying nitrogen which can leach out of the profile. Leaf tests are being utilised by many farms. This is a great way to see what you plant is doing now. When used in conjunction with soil tests they can be a very effective proactive tool for the season, rather than waiting for deficiencies to appear in the crop. Moisture meters can also be a very good tool for nitrogen management. If you understand how nitrogen moves through your profile, moisture meters can aid in understanding where your applications are with regards to your root structure.

Nitrogen Efficiency Products

Urea is currently the dominant nitrogen product supplied in the marketplace. It is simple to obtain and yet it is also an old technology with inherent limitations. In the marketplace there are several technologies available that can improve the uptake of nitrogen or reduce the losses. Some can be directly applied to established products, whist other are standalone products.

Urea efficiency products have been available for several years now. Most are coated products that are applied directly to the granule, either coating the outside or embedding into the granule. Some products reduce volatilisation, slow breakdown of the granule, reduce/increase the activity of microbes involved in breakdown the granule, or provide a carbon source to reduce leaching.

Urea Ammonium Nitrate (UAN) is an increasingly popular form of nitrogen. It is a high analysis liquid containing all three forms of nitrogen. It does however suffer some of the inefficiencies of urea. Like urea there are currently several options in the marketplace focusing on reducing the loss pathways of this product.

As well as additives there have been an increase in other products designed to improve the efficiencies within the nitrogen processes. Most of these to date have been centred around biology and other related technologies.

So why look at these products? The two main reasons are cost and flexibility. Enhanced efficiency products mean that you can utilise less product to maintain your current yield levels. This is because less of the nitrogen is lost through the various avenues. The amount of this reduction will be dependent upon the manufacturer's literature. Be sure to check the data. In addition, check how the product works, as this will have a direct effect on your operations and how it can be utilised. Flexibility is also an understated by-product of this solution. If you could grow your current crop with less nitrogen and are meeting the current legislative requirements, it means that your potential to grow higher yield crops when more favourable conditions presents itself. This provides a nitrogen flexibility that has never been explored in our industry to date.

By investigating the three simple steps and you will be well on your way to potentially improving your nutritional use efficiency this season. Worst case you will begin to understand further what is going on in your soil and your crops, which isn't such a bad thing?

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