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The Nitrogen and acidity story

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After listening to some advice being given to farmers recently, it has prompted me to clear things up for you about nitrogen and soil acidity. You may want to refer back to this article every time you hear some more humbug comments. Firstly, the nitrogen story.

Plants can use *both* ammonium and nitrate as nitrogen sources, and it will also take in some Urea. However, nitrate is the most common form of nitrogen a plant takes in because ammonium is positively charged and is therefore retained in soils by sticking to the negatively charged clay particles.

Nitrate has no such affinity for clay as it is also negatively charged and is therefore repelled by clay particles. Nitrate then stays in solution more, which is why a plant mainly uses this form of nitrogen, and why it can be so easily leached.

Ammonium that does get released into the soil solution becomes converted to nitrate through the process of nitrification (I'll show you what this is below).

So even though you may apply ammonium nitrogen to the soil (eg ammonium sulphate), it is often quickly converted to nitrate nitrogen through nitrification and the plant absorbs the nitrogen in this form.

When plants absorb nitrate from the soil, they quickly move it to the leaves where in the presence of energy created through the photosynthesis process, the nitrate nitrogen is converted to amino acids.

Ammonium nitrogen absorbed by the root is converted in the roots to amino acids. This occurs because ammonium is actually toxic to the plant, and in order to prevent the ammonium causing problems, it has to be converted to some non-toxic form immediately. In this case it is converted to very simple amino acids.

When adding Urea to wet soil, it quickly goes through the following reaction.

$$CO(NH_2)_2 + H_2O + \text{urease} \rightarrow 2NH_3 + CO_2$$
(urea)

Urease is an enzyme present in the soil. NH_3 is ammonia gas, and CO_2 is carbon dioxide. About 60% of the urea can be converted like this in 1-7 days.

Urease inhibitors that can be applied to urea, like Agrotain, slow down the conversion of Urea to ammonium, thus giving more time for Urea to wash into the soil and be safe from volatilisation.

So if the Urea is on the soil surface, but is damp and is in the stubble, the ammonia (NH_3) can be lost to the air – which is called ***volatilisation***. This process occurs faster in warm, alkaline and high organic matter soils – high organic matter soils have more urease floating around.

However, ammonia in water in the soil is very quickly converted into ammonium (NH_4^+) by several bugs.

This ammonium is then rapidly held onto by soil particles and is not lost. This is why as little as 2mm of rain is enough to safely wash urea into the soil and give the soil bugs a chance to convert it to ammonium before the ammonia reaches the soil surface and blows away.

In soils, ammonia (NH_3) is more rapidly converted to ammonium ions (NH_4^+) when hydrogen ions are plentiful (acidic soils - pH< 7.5). In high pH soils ammonium ions (NH_4^+) are unstable and can change back to ammonia gas (NH_3), which can be lost via volatilisation. Therefore on alkaline soils, it is critical to get the urea washed in as soon as possible.

Nitrification is the conversion of ammonium (NH_4^+) to nitrate (NO_3^-). This aerobic reaction is carried out by autotrophic bacteria. Maximum nitrification rates occur at neutral pH and high temperatures (because the bugs are happiest in these conditions).

With ammonium nitrogen, if the plant takes it up through the roots, it releases a hydrogen atom, thus increasing the soil acidity. If the ammonium is nitrified to nitrate, the four hydrogen atoms are released and therefore also increase soil acidity.

Denitrification is where nitrate (NO_3^-) is converted into nitrogen gas (N_2). This is generally lost back into the atmosphere. It occurs mostly in waterlogged soils with high levels of nitrogen.

Application timings

Before moving onto nitrogen and soil acidity, a few words about application timings of the different nitrogen forms. I have heard some say it is OK for farmers to spread ammonium sulphate out in March (dry).

If it rains weeks before sowing in May, the answer is no, I would not do that. The ammonium component will enter the soil when it rains, and most of it will be converted to nitrate.

The next big rain can then easily wash it down and out of reach for the following crop. It would be a very risky thing to do to apply it so early.

It is also risky to do on alkaline soils because if the ammonium sulphate was only washed in a few centimetres, then most of the ammonium will be lost to volatilisation by it being converted into ammonia gas.

Applying Urea in warm conditions is fraught with danger because unless it gets washed into the soil, much of it will end up as ammonia and float away.

Only apply Urea (and UAN or MaxAmFlo) in cool conditions, and preferably only when it either gets mixed into the soil at sowing, or is washed in by rain within a day or so of application.

Do not panic about 15C days when you are topdressing Urea. The rate of volatilisation is minimal, as you can see from the following tables. The volatility of urea depends to a great extent on soil temperature and soil pH.

Table 1. Percent of surface-added urea volatilised as ammonia at different temperatures and days on the surface.

	Temperature (°C)			
Days	7 °C	16 °C	24 °C	32 °C
	(% of added N volatilised)			
0	0	0	0	0
2	0	0	1	2
4	2	2	4	5
6	5	6	7	10
8	5	7	12	19
10	6	10	14	20

Urea was added on a silt loam soil at 100 kgN/ha.

Table 2. Percent of surface-added urea volatilised as ammonia at various soil pH levels and days on the surface.

	Soil pH (in water)					
Days	5.0	5.5	6.0	6.5	7.0	7.5
	(% of added N volatilised)					
0	0	0	0	0	0	0
2	0	0	0	0	1	5
4	1	2	5	10	18	20
6	4	5	7	11	23	30
8	8	9	12	18	30	33
10	8	10	13	22	40	44

Urea added on silt loam soil at 100kgN/ha.

Nitrogen and soil acidity

There are a few things to remember about soil acidity.

One is that leaching of nitrogen causes acidification. Another is that adding ammonium increases soil acidity (deceases soil pH), and adding nitrate will decrease acidity (increases the soil pH).

The final point is that soil acidity is the concentration of hydrogen ions in solution, on a negative logarithmic scale. Therefore lots of hydrogen ions is acidic; a low pH. The logarithmic scale also means that a pH of 3.0 is 10 times more acidic than 4.0.

Table 3 is taken out of the "Wheat Book" produced by the WA Agriculture Department.

What it shows is that for every unit of nitrogen added as ammonium, you need 3.6kg of lime just to maintain the pH. If the ammonium leaches, you need 7.2kg lime.

To clarify the leaching part, if you apply nitrate to the soil at 5cm, and then rain washes it down to 30cm where the plant then picks it up, the net effect is to decrease the pH in the 5cm region, and increase the pH around the 30cm region. There is no net acidification from 0-30cm, just a stratification of acidity.

When nitrate is used continuously, the soil tends to become more alkaline. This is because when a plant takes up nitrate, it releases bicarbonate from the roots into the soil.

If you can remember school chemistry, everything must stay balanced with charges, so a plant taking up a negatively charged nitrate ion must balance that by releasing a negatively charged ion, in this case it is bicarbonate.

(Bicarbonate) $HCO_3^- + H^+ \dashrightarrow H_2CO_3 \dashrightarrow H_2O + CO_2$

Bicarbonates are negatively charged and tend to react with hydrogen ions to produce carbon dioxide and water. The consumption of hydrogen ions raises pH.

Ammonium nitrogen tends to result in the acidification of the soil because when ammonium is taken up, the plant roots release hydrogen ions into the soil solution.

Also, as ammonium is turned into nitrate through nitrification, all of the hydrogen ions are replaced by oxygen. The hydrogens are released into the solution. So over time ammonium fertilised areas will become more acidic.

As urea releases ammonium ions in the soil, it creates basic soil conditions in a localized area around the urea pellet.

However, the ammonium that is converted into nitrate causes some acidity. As long as there is no leaching, the net effect of adding urea is neutral. It does not acidify the soil unless there is some leaching.

Ammonia gas is also neutral on acidity because as it is converted to

Table 3: Acidification potential of nitrogen fertilisers – first number is if there is NO leaching. The 2nd is if the nitrogen is leached.

Fertiliser	N form	Acidification Kg lime/kg N
Urea	Urea	0 to 3.6
Ammonia	Ammonia	0 to 3.6
CAN	Nitrate	– 3.6 to 0
Ammonium Sulphate	Ammonium	3.6 to 7.2
DAP	Ammonium	3.6 to 7.2
MAP	Ammonium	3.6 to 7.2
Agras	Ammonium	3.6 to 7.2

ammonium, it takes a hydrogen ion out of the soil, but when it is taken up by the plant, or is converted to nitrate, hydrogen ions are released. As long as there is no leaching, the net acidity effect is zero.

What you need to realise is that if you are in a high rainfall, high yielding scenario, then you will need to add about 1t/ha of lime every 4-5 years, just to keep the pH level stable. You will need to add even more to increase the pH.

Aim to have your pH levels around 5.0 in $CaCl_2$. Do not wait until they are 4.5 or less if at all possible.

Lower rainfall and lower yield potential areas do not need to add lime as often because there is less leaching, and less nitrogen is applied.