Nitrogen undergoes transformations in the soil, depending on the chemical composition of the nitrogen applied. While nitrate is taken up directly by plants, ammonium and urea need to be first transformed into nitrate. Transformation losses are lowest with nitrate and highest with urea.

**Nitrogen from nitrate**
Nitrate (NO₃⁻) is easily absorbed by plants at high rates. Unlike urea or ammonium, it is immediately available as a nutrient. Nitrate is highly mobile in the soil and reaches the plant roots quickly. Applying nitrogen as ammonium nitrate or calcium ammonium nitrate therefore provides an instant nutrient supply.

The negative charge of nitrate carries with it a high osmolality, which makes it a strong competitor for ion uptake. Most plants therefore prefer nitrate over ammonium.

Nitrogen from ammonium
Ammonium (NH₄⁺) is directly absorbed by plants at low rates. The positively charged ammonium ion fixes to soil minerals and is less mobile than nitrate (NO₃⁻). Plant roots therefore need to grow towards the ammonium. Most of the ammonium is transformed into nitrate by soil microbes. This nitrification process depends on temperature and takes between one and several weeks. Another part of the ammonium is immobilized by soil microbes and released only over longer periods of time, thus building up soil organic matter.

Nitrogen from urea
Plant roots do not directly absorb the uric acid form of nitrogen in significant quantities. Urea needs to be first hydrolysed to ammonium by soil enzymes, which takes between a day and a week, depending on temperature. Moisture and temperature also influence the process.

**Nitrogen transformations in the soil**

1. **Application of fertilizers**, containing mineral nitrogen as urea, ammonium, nitrate or a mix. Organic fertilizers and manure contain mostly complex organic nitrogen compounds and ammonium.
2. **Uptake of nitrate** is rapid due to the high particle mobility. Most plants therefore prefer nitrate over ammonium.
3. **Uptake of ammonium** is slower than nitrate. Ammonium is bound to clay particles in the soil and roots have to reach it. Most of the ammonium is therefore nitrified before it is taken-up by plants.
4. **Nitrification** by soil bacteria converts ammonium into nitrate in between a few days and a few weeks. Ammonium is therefore nitrified before it is taken-up by plants.
5. **Hydrolysis** of urea by soil enzymes converts urea into ammonium and CO₂ gas. Depending on temperature, hydrolysis takes a day to a week. The soil pH around the urea granules strongly increases during the process, favouring ammonia volatilization.
6. **Immobilization** of soil organic matter (and manure) releases ammonium into the soil.
7. **Leaching** of nitrate occurs mainly in winter when rainfall washes residual and mineralized nitrates below the root zone. Accurate fertilization prevents leaching during the growth period.
8. **Denitrification** is favoured by lack of oxygen (water logging). Soil bacteria convert nitrate and nitrite into gaseous nitrous oxide, nitric oxide and nitrogen. These are lost to the atmosphere.
9. **Mineralization** of soil organic matter (and manure) releases ammonium into the soil.
10. **Ammonia volatilization** occurs when ammonium is converted to ammonia and lost to the atmosphere. A high soil pH level favours conversion of ammonium to ammonia. If conversion takes place at the soil surface, losses are highest. These two conditions are met when urea is spread and not immediately incorporated.
11. **Transformation of urea**, ammonium and nitrate in the soil. Urea suffers the highest transformation losses, nitrate the lowest. UAN, a 50/50% mix of ammonium nitrate and urea, undergoes the same transformations and losses as its components.

**Figure 3:** Transformation of urea, ammonium and nitrate in the soil. Urea suffers the highest transformation losses, nitrate the lowest. UAN, a 50/50% mix of ammonium nitrate and urea, undergoes the same transformations and losses as its components.

**Figure 4:** Hydrolysis of urea leads to local alkalinization, resulting in NH₃ rather than NH₄⁺ formation and subsequent volatilization.

**Figure 5:** Nitrification in the root zone. From left to right, urea is transformed into ammonium, then into nitrate. Denitrification occurs mainly in winter when rainfall washes off residual and mineralized nitrates below the root zone. Accurate fertilization prevents leaching during the growth period.

**Figure 6:** Hydrolysis of urea results in a short-term alkalinization in the immediate vicinity of the urea grain applied. It shifts the natural balance between NH₄⁺ and NH₃ to the latter form, resulting in volatilization losses. These losses are the main reason for the lower N-efficiency observed with urea. This is also the reason why urea, whenever possible, should be incorporated into the soil immediately upon application.

In the long term, urea, as well as other sources of nitrogen, has an acidifying effect on the soil.