Nitrogen Losses Due to Heavy Rain

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This spring’s heavy rains have created the ideal conditions for higher nitrogen losses. Indeed, high precipitation increases deep nitrate leaching, particularly in lighter soils, while waterlogged soils promote denitrification, especially in heavy soils. Loamy soils are equally affected by both processes. In wet soils, without a doubt, denitrification leads to the largest nitrogen losses. As demonstrated by the Logiag studies completed in 2003 and by the results obtained in 2005 at the Synagri/Demers Testing Station under conditions similar to those experienced in 2013 and now in 2015, increasing nitrogen supply from 20 to 30 kg/ha post-emergence for corn and cereals will largely palliate the lack of nitrogen due to denitrification and leaching.

This recommendation especially applies to fields in which all the nitrogen was applied during pre-planting, planting, and very early in post-emergence applications (before the collar of the 4th leaf is visible), which happens too often. We highly recommend a review of fertilization programs for all cultures: adding nitrogen if an application is still planned, and possibly planning an additional application if all the nitrogen initially planned was applied already. If the quantities to apply are too small for the equipment, these specific conditions may call for adding water to liquid fertilizers or diluting solid fertilizers. This recommendation is valid even if controlled-release nitrogen (all technologies) was used, because both applied nitrogen and nitrogen released by organic matter can be lost through leaching and denitrification.

Leaching: Loss of Nitrogen Downward

Under normal conditions, leaching is the main cause of nitrogen loss, after collection by plants. Opposite to positive ammonium ($NH_4^+$), negative nitrates ($NO_3^-$) not held by organic matter or clay, both negative, move almost freely in the soil and are easily leached, i.e., washed deeper in the ground by heavy rains and made less accessible to roots.
With heavy rainfall, leaching accelerates significantly, particularly in light soils (CEC<12), in which the water percolation rate is higher. One inch of precipitation on already-moist soil will wash nitrates 12" down in sandy soils and 4" down in clay soils. Depending on the depth to which nitrates are leached, a certain deeper amount of nitrates will be available as the roots grow and dig in the ground. Major rains subsequently raising the groundwater will help raise some of these leached nitrates. In compacted soils, leaching will be limited, as the water percolation rate is lower. However, nitrates left on the surface in waterlogged soil are prone to denitrification.

### Denitrification: Loss of Nitrogen Upward

In waterlogged soil, nitrates are converted to nitrogen oxides and elemental nitrogen, both gaseous and volatile. Nitrogen oxides (NOₓ) include nitrogen monoxide (NO) and nitrogen dioxide (NO₂). This nitrate reduction into gaseous nitrogen is called *denitrification* and occurs mostly in the first cm of the ground.

Denitrification is the main cause of nitrogen loss in extremely humid conditions, especially in loamy and clay soils (CEC>12). Nitrates from every source of nitrogen are affected: synthetic fertilizers, manure, liquid manure, green manure, compost, organic matter, etc. When oxygen in the soil is limited by the excessive water filling the soil pores (called *anaerobic conditions*), some anaerobic bacteria and facultative anaerobic bacteria use the oxygen combined with nitrates, causing gaseous nitrogen to form that is then released in the atmosphere. Denitrification happens only if the oxygen level is too low for the bacteria’s needs, which occurs when soils are waterlogged.

Denitrification uses easily degradable organic matter as an energy source. The more abundant the organic matter (manure, crop residues, or green manures) on the surface, the greater the denitrification (and resultant nitrogen losses). Carbon resulting from root activity, especially in cereals and corn during spring, also increases the denitrification rate.

Heavy soils and compacted soils are more prone to denitrification. Denitrification increases rapidly in moist soils from 8 °C, which is a much cooler temperature than the one required for plants to grow, for soil organic nitrogen mineralization to happen, and for the nitrification of urea and ammonium. Denitrification is insubstantial in soils with a pH under 5.0, and happens faster in soils that are too wet with a pH above 5.6.

Denitrification promotes nitrite formation (NO₂⁻). Furthermore, nitrites’ chemical reactions transform urea into volatile gaseous elemental nitrogen, further increasing nitrogen loss during excessively wet periods. To occur, this chemical reaction does not require any microorganisms, or poor humidity or temperatures conditions; rather, a high nitrite level in wet soils promotes it. If conditions are good, an important supply of urea post-emergence may account for more losses by denitrification.
Consequences of Leaching and Denitrification in Wet Soil

The amount of nitrogen lost through leaching and denitrification depends on farming practices and soil conditions. Loss can be particularly high in moist soils with significant nitrogen supply during planting, or when urea is lightly incorporated in the soil or left on the surface. Nitrate losses ranging from 10 to 35 kg/ha have been measured. The use of nitrogen sources in the form of ammonium (NH₄⁺) rather than nitrate (NO₃⁻) and urea (NH₂) limits denitrification losses. Using only the nitrogen quantity needed during planting and providing enough of it for the post-emergence application can reduce the risk of denitrification between May and June.

Nitrogen losses by nitrate leaching or denitrification can greatly increase during extended periods in which the ground remains too wet. This can result in a significant nitrogen deficiency for all cultures, whether sowed or planted early or late, as extended extremely humid conditions reduce the total nitrogen balance. For straw cereals and corn, this lack of nitrogen may occur at a critical moment of their development, i.e., at the ear formation at the 4th-to-6th leaf stage for corn, and at 29 on the Zadoks scale for straw cereals. For corn, an early nitrogen deficiency in August could lead to a steep drop in yield and grain quality.

![Nitrogen deficiency in August in maize due to insufficient nitrogen supply in June or high nitrogen losses.](image)

Diagnostic Tools Available

When weather conditions are poor, it is very important for the producer to effectively control all the factors he or she can, including good nitrogen fertilization adjusted to actual conditions. Tissue samples collected early and soil samples analyzed in laboratories to detect nitrogen deficiencies and identify the soil nitrate level (NO₃⁻) are inexpensive, accurate, and effective tools to modify nitrogen fertilization according to the conditions specific to each field, and to avoid significantly reduced yields and crop qualities.

Nitrate losses are highly mobile in soil. To know the level of nitrogen available to crops, soil sampling at a depth of 30 cm (12 inches) is required. Each section of 10 cm (4 inches) is sent separately to the laboratory: 0-10 cm (0-4 inches), 11-20 cm (5-8 inches), and 21-30 cm (9-12 inches). Soil nitrate analysis will allow for a post-emergence nitrogen application readjustment, or suggest that an application be performed if it was not planned in the initial fertilization program. In this way, harmful nitrogen deficiencies will be avoided during grain filling of cereals, corn, potatoes, root vegetables, apples, etc.

The soil sample should be taken from the most representative portions of the field. Since the results from the higher and lower portions of the field can differ greatly, these should be sampled separately. Nitrogen release after the nitrate analysis and nitrogen application will significantly vary depending on the soil type, the organic matter ratio, and the pH. In fields where soil types vary greatly, nitrate tests are not as effective unless several samples are collected based on the soil texture variances, and nitrogen dosage can be adjusted from one sampled area to another.