PURE NUTRIENT *FACTS #2*

Protecting water, controlling leaching

REDUCING NITROGEN LOSSES

Wherever there are fertile soils, there is also some leaching. Leaching is not a new problem. While nitrate leaching from agriculture cannot be completely avoided, it can be controlled. This information details the causes of nitrate leaching and practical ways of reducing it by limiting nitrogen losses.

YARA

Knowledge grows

Avoiding nitrogen losses and leaching

Leaching is a complex problem and there is no single solution. In addition, soil organic matter builds up over many years as does mineralization. These important parameters can be changed only gradually from one year to the next. But strategies to reduce leaching exist and have been tested. Which factors should be considered?

APPLYING BEST FARMING PRACTICES

Leaching is limited when best agricultural practices are applied. Recommendations include [8]:

- Choose high yield crops that use available nitrogen efficiently
- Determine soil mineral nitrogen content by frequent sampling
- Use split application to ajust nitrogen availability to actual plant needs, ensuring rapid uptake, especially on sandy soils
- Ensure balanced nutrition (P, K, S) to optimize nitrogen uptake
- Allow for a deep and extensive root system as to utilize nitrogen more efficiently
- Apply fertilizers and manure accurately, well away from watercourses
- Consider buffer strips between agricultural land and watercourses
- Maintain green cover as long as possible to absorb excess nitrogen (cover crops, early drilling of autumn-sown crops)
- Make sure that green cover is re-established rapidly upon ploughing of set-asides and grassland
- Keep a porous soil structure to avoid surface run-off and sub-surface bypass flow on heavy soils
- Avoid application of fertilizer and manure in autumn
- Use reliable nitrogen recommendation systems, considering spatial and temporary variations of soil nitrogen supply

ADJUSTING FERTILIZER INPUT

Adjusting fertilizer input to actual plant needs is the best way to control residual nitrate and thus leaching. Nitrogen uptake varies between years, fields and crops. It depends on the soil's mineral nitrogen content, mineralization rates, yield expectations and weather conditions. Since it cannot be reliably predicted, actual plant needs should be assessed accurately and fertilization split into several adjusted applications.

Precision farming tools, such as the Yara N-Tester™ and N-Sensor™ allow plant needs to be measured on the spot and in real time. They can take into account temporal and spatial variations in soil nitrogen supply and offer precise control over fertilizer application at any time and any place. Use of these tools significantly reduces the risk of nitrogen overload and leaching [9] while maintaining optimum yield and margins.

Your local Yara agronomist is at your disposal for establishing fertilization strategies that minimize leaching while optimizing yield on your farm.

Understanding Leaching

Fertility is a matter of nitrogen, whether it comes from natural or artificial sources. But the nitrogen cycle is leaky by nature, and some nitrogen is always lost. Losses, however, are both expensive for the farmer and harmful for the environment. Farmers therefore strive to reduce such leakage.

European agriculture in general is highly efficient. What can be done to further reduce nitrogen losses and especially leaching? Which processes contribute to leaching and how can they be managed?

NITROGEN IN THE SOIL

The displacement of excess mineral nitrogen, mostly nitrate, out of the root system into the groundwater is called leaching. Where does the excess nitrate come from? Marking nitrogen with isotopes lets us trace the fate of the nitrogen from fertilizer and understand the nitrogen cycle within the soil. [1] [2] [3]. Figure 1 summarizes the soil nitrogen cycle.

Nitrogen in the soil occurs in two main forms:

- Soil organic matter contains huge amounts of nitrogen as organic compounds. These are not immediately available to plants
- Mineral nitrogen (ammonium, nitrate) is formed by mineralization of soil organic matter or directly added as mineral fertilizer. This form of nitrogen can be taken-up by plants immediately

Most of the mineral fertilizer applied is taken-up by plants, but part of it is also bound by soil microorganisms and transformed into soil organic matter. Very little actually joins the mineral nitrogen pool in the soil.

Manure contains mainly organic nitrogen compounds, except for slurry, which also contains some mineral nitrogen. Manure therefore basically increases soil organic matter. It needs to be mineralized first before it can be taken-up by plants.

Leaching occurs when mobile nitrate from the mineral nitrogen pool is washed out of the root zone by heavy rainfall. This is more likely to happen on sandy soils than on heavy clay soils. In the latter, nitrate is denitrified before it can be leached.

NITROGEN AND AGRICULTURE

The European Nitrogen Assessment [7] has revealed generally stabilizing or decreasing nitrogen surpluses from agriculture in most European countries. However, due to the slow response time of aquifers, high nitrate levels will not be absorbed quickly. Further efforts are required, especially in some areas where nitrate levels remain high.

Nitrate in watercourses and groundwater is undesirable. Elevated concentrations of nitrate contribute to the eutrophication of surface and coastal waters.

High nitrogen surpluses are generally related to high livestock concentrations, whereas nitrogen surpluses in agricultural regions are comparatively low [6]. In agricultural production, nitrate leaching basically depends on the amount of unused mineral nitrogen in the soil at risk of loss and the amount of drainage that carries that nitrogen away to waters. The more rainfall there is, the more nitrate can be leached, but the more it will be diluted as well.

Dilution by rainfall is an important aspect since the limit of 50 mg NO_3/l set by the European Union is a concentration, not the amount leached. In wet regions with heavy rainfall, higher amounts of nitrate might be leached without breaching the limits. In dry regions with less rain, however, even small natural leaching losses might exceed authorized limits.

SEASONAL ASPECTS

Mineral nitrogen fertilizer applied in spring is mainly absorbed by plants during the growing season. In addition, capillary rise, caused by high levels of soil evaporation during spring and summer, as well as lower levels of precipitation, prevent rainfall from reaching the water table.

After the growing season, however, soil microbes continue to metabolize organic matter, producing mineral nitrogen. This is no longer taken-up by plants and builds up in the soil as residual nitrate. It can be leached in winter, when percolating rainfall recharges the water table. Leaching during the growing season is an exceptional situation [8]. The situation is explained in figure 2.

The risk of nitrate leaching increase with

- High nitrate concentration in the soil after harvest
- Low water retention by the soil,
- High rain fall
- Long fallow periods

1. Nitrate is mobile in the soil and rapidly absorbed by plants. Ammonium has limited mobility is and not at risk of leaching.

2. Soil microbes compete with plants for nitrogen and immobilize part of it as soil organic matter. This nitrogen is not lost, but needs to be mineralized first before it can be taken up by plants. Some of the immobilized nitrogen is mineralized during the growing season, but some is mineralized only in subsequent seasons. Split application ensures rapid uptake of available nitrogen by plants and thus reduces immobilization.

3. With good agricultural practice, only a very small portion of applied fertilizer nitrogen can be found in the residual nitrate pool upon harvesting.

4. Manure contains nitrogen mainly as organic compounds, building up soil organic matter. This nitrogen is not immediately available.

5. Manure, especially slurry, also contains some mineral nitrogen, mainly as ammonium. The part of mineral nitrogen in manure depends on its sources.

6. Mineralization of soil organic matter contributes to soil nitrogen supply. Mineralization rates are variable and can exceed 300 kg/ha for grassland. After harvest, however, microbes find optimum conditions in humid and warm autumn soil. Since there are no more plants to take up the nitrate produced, it is prone to leaching.

7. During the growth period, mineralized nitrogen contributes to plant uptake. Determining soil nitrogen supply accurately by sampling or precision farming tools avoids over-fertilization and reduces leaching.

8. The water table is recharged by rainfall during autumn and winter. This is the time when most of the residual nitrate is leached. During spring and summer, little rain is available and evaporation from the plough layer counteracts leaching. Keeping the residual nitrate pool as small as possible is the best strategy against leaching.

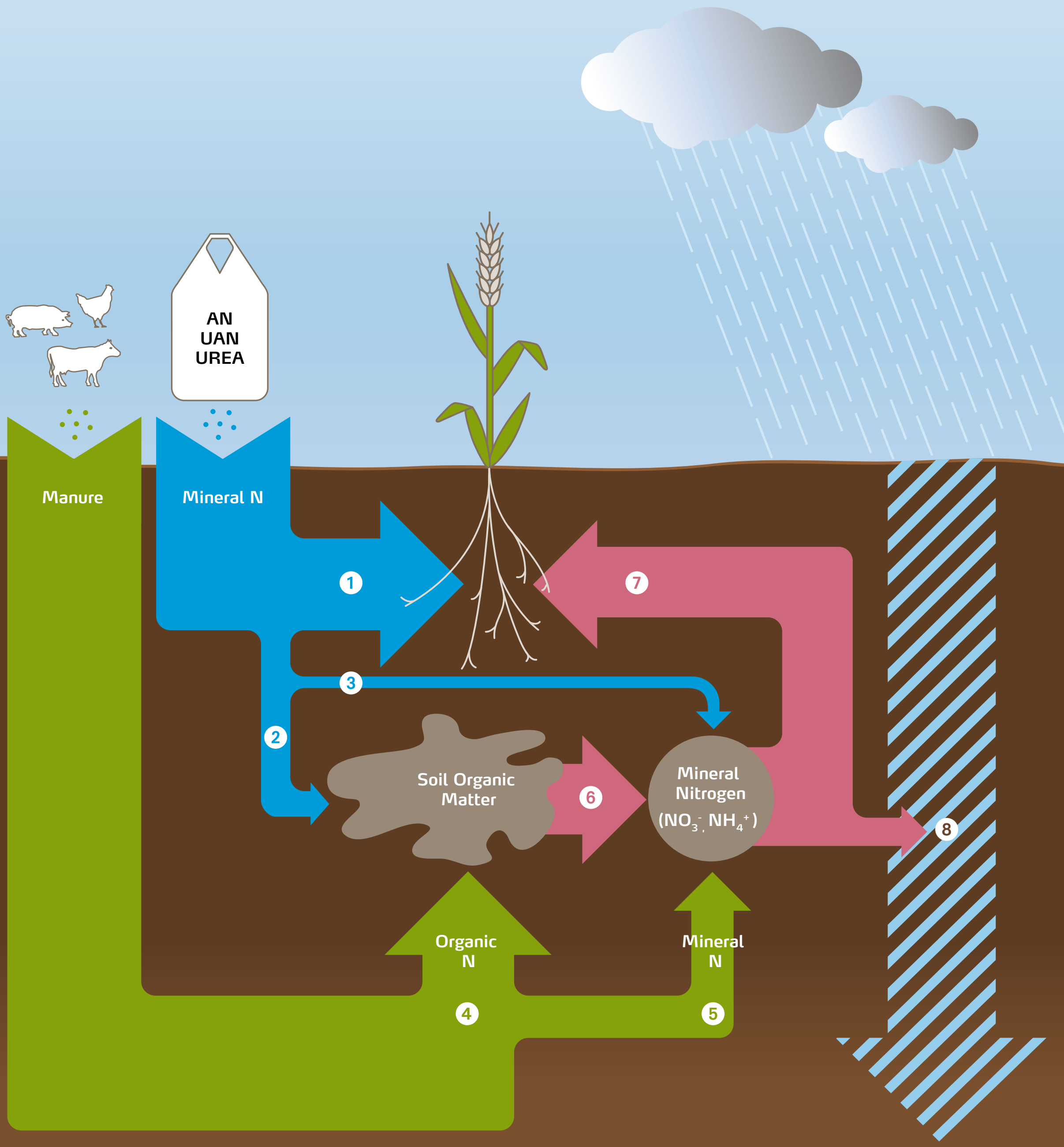

Figure 1: The nitrogen cycle in the soil relevant for leaching. Adapted from [1] [3] [8].

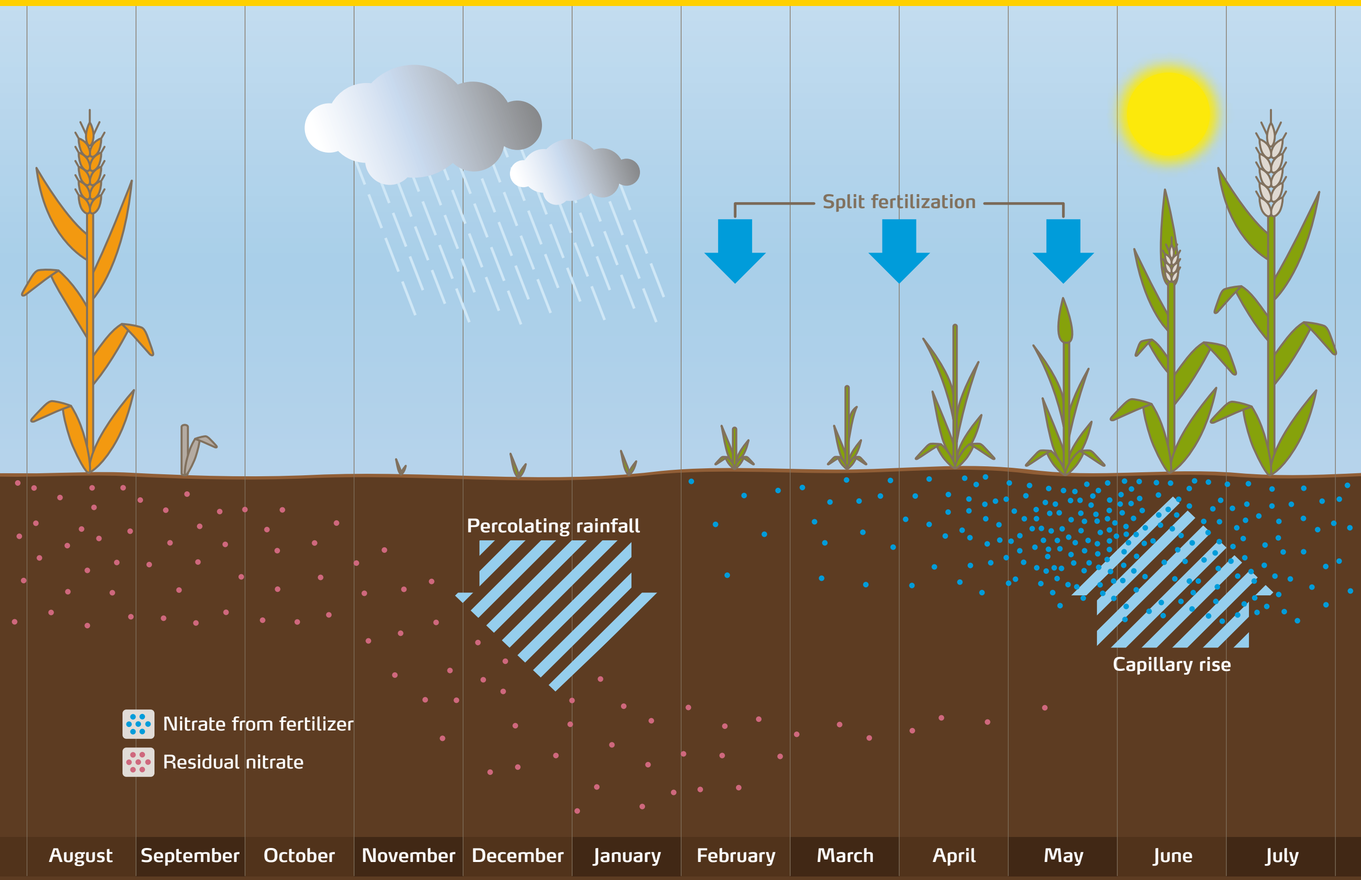

Figure 2: Nitrogen from mineral fertilizer is rapidly taken-up by plants during the growth period. In addition, evaporation and capillary rise prevent nitrogen to reach the water table in spring and summer. Leaching therefore generally occurs during the fallow period when percolating rain fall washes residual and some freshly mineralized nitrate out of the root zone.

The impact of mineral fertilizer

Leaching can be a major problem in areas with high livestock, causing important nitrate surpluses that are hard to control. Mineral nitrogen fertilizer, however, when accurately tailored to plant needs, does not contribute to leaching. Adjusting application rates to the economic optimum is the best strategy, both from an environmental and an economic point of view.

THE ECONOMIC OPTIMUM

Since it is the residual nitrate in the soil after harvesting that causes leaching, rather than the fertilizer applied in spring, it is important to reduce this residual nitrate pool.

Figure 3 shows the impact of fertilizer application rates on residual nitrogen levels in the soil. Residual nitrogen remains stable up to a certain threshold of fertilizer application. If the threshold is exceeded, residual nitrate levels in the soil rise sharply. Lower fertilization rates do not reduce residual nitrogen, but drastically diminish grain yield [5].

It is not surprising that this threshold coincides with the economic optimum: Applying more nitrogen than the plant can take up doesn't make sense, neither economically, nor environmentally. Tailoring nitrogen application exactly to plant needs reduces the risk of leaching while optimizing grain yield.

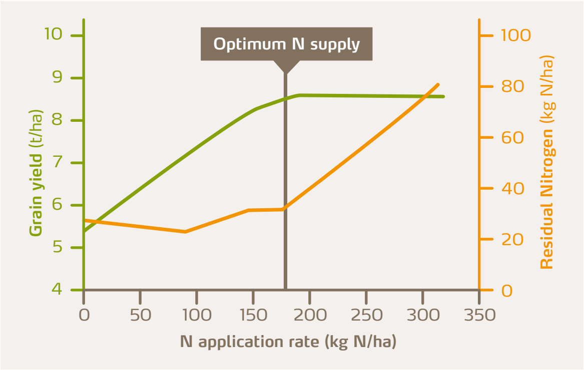

Figure 3: Below the optimum N supply, the residual nitrogen in the soil after harvesting (and thus the risk of leaching) is independent from application rates [5].

Optimizing yield, preserving the environment

Nitrate-based fertilizers - such as ammonium nitrate, calcium ammonium nitrate and NPK-based compounds - are pure nutrients offering the required precision, efficiency and reliability to meet the agronomic and environmental imperatives of sustainable agriculture. Yara nitrate-based fertilizers and precision farming tools reduce leaching and are the natural choice for farmers who care for the environment.

UREA OR AN?

Almost all nitrogen fertilizer, whether applied as Urea, AN or AHL, is ultimately transformed into nitrate before being taken up by plants. Leaching, therefore, is independent of the nitrogen form applied. Differences can be observed, however, during, or immediately after, spreading:

- A majority of field trials reveal higher efficiency of nitrates, resulting in lower N surpluses and reduced risk of leaching.
- The spreading accuracy of AN is higher than that of Urea, due to higher bulk density and lower concentration. Application of AN can therefore be matched to plant needs with higher precision, avoiding local over- or under-fertilization.
- Urea is non-ionic and thus mobile. It is susceptible to leaching and runoff by heavy rainfall upon spreading. Urease inhibitors delay hydrolysis and therefore tend to exacerbate the problem. Environmental conditions (low soil temperature, lack of moisture) can have similar effects.
- Higher volatilization losses observed with Urea are usually compensated by higher dosage. Since volatilization cannot be predicted, this help-along significantly increases the risk of over-fertilization and leaching.

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For further information about nitrate fertilizers, get the complete nitrate fertilizer brochure from www.yara.com

ABOUT YARA

Yara International ASA is an international company headquartered in Oslo, Norway. As the world's largest supplier of mineral fertilizers for more than a century, we help to provide food and renewable energy for a growing world population.

Yara provides quality products, knowledge and advice to farmers. Please do not hesitate to contact one of our local agronomists for further information.

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