NITROGEN

Key points
- Nitrogen (N) is needed for crop growth in larger quantities than any other nutrient.
- Nitrate ($\text{NO}_3^-$) is the highly mobile form of inorganic nitrogen in both the soil and the plant.
- Sandy soils in high rainfall areas are most susceptible to nitrate loss through leaching.
- Soil testing and nitrogen models will help determine seasonal nitrogen requirements.

Background
Over 98% of all nitrogen (N) present in the soil is in an organic form, which is mineralised by microbes into inorganic forms (2% of all N) such as nitrate and ammonia. Mineralisation occurs throughout the growing season providing a steady, continuous supply of nitrogen to the crop.

The positive charged ammonium ion ($\text{NH}_4^+$) is immobile in soil, does not leach, and is an intermediary in the conversion of organic-N to nitrate ($\text{NO}_3^-$). Nitrate on the other hand has a negative charge and is highly mobile in the soil. This mobility provides a nitrogen source that moves readily towards plant roots, but can also be leached out of reach of the plant root system (figure 1). Nitrate is used by the plant to make precursors to plant proteins.

Deficiency symptoms
As proteins make up much of the content of cells, nitrogen is needed in greater quantity than any other mineral nutrient. Nitrogen plays an essential role in the production of chlorophyll, and any deficiency is displayed as yellowing leaves and reduced tillering (figure 2). This ultimately leads to reduced crop yields.

Figure 2: Nitrogen deficiency symptoms in wheat plants (right) (Snowball and Robson, 1988).

Nitrogen is highly mobile within the growing plant allowing it to re-mobilise and move to tissues that can use it more effectively. As a result, older leaves tend to exhibit nitrogen deficiency symptoms first.
Yield potential and nitrogen requirement
Nitrogen requirement of cereal crops is driven by yield potential, where every tonne of grain produced requires 40–50 kg-N/ha. Cereal crops access nitrogen from 3 major pools:

**Stable Organic Nitrogen** (SON) is released slowly throughout the season, and is by far the largest nitrogen source in the soil. Approximately 2% of SON becomes available to crops during the season.

**Residue Organic Nitrogen** (RON) is mineralised rapidly into NH$_4^+$ and NO$_3^-$, and is highest following legume crops.

**Fertiliser Nitrogen** is applied to a crop by growers where the above sources cannot meet the needs of the crop.

Due to the number of different nitrogen sources accessible to the crop, it is best to use models to gauge nitrogen status in the soil. Most current models measure the following soil and crop attributes to determine soil nitrogen status/requirement:

- Yield potential—determines nitrogen demand of the crop.
- Total organic carbon (%)—gives indication of potential SON contribution.
- Rotation—characteristic of the last legume crop (RON).
- Soil type—gives indication of the potential for leaching.
- Rainfall—determines RON breakdown and contribution to leaching.

Models that use this information are SYN (Select Your Nitrogen) from the Department of Agriculture and Food, Western Australia, and NuLogic from the commercial fertiliser company CSBP.

Protein and maximum yield
A simple method to determine whether the correct nitrogen regime was used is to measure grain protein following harvest. The optimum protein percentage in wheat grain varies between cultivars, however it is a useful tool for auditing nitrogen budgets. Increasing N rates to achieve protein levels above these thresholds results in lower economic responses, as protein payments and yield do not offset the extra cost of nitrogen. Conversely, if crops consistently achieve protein levels below these levels, they are forgoing optimum yield potential.

Soil testing
In the past, Western Australian growers have had little reason to test for NO$_3^-$ and NH$_4^+$ in the soil, as little mineral nitrogen is present in the soil over summer. However, in some years summer rain results in mineral-N release and soil testing helps in determining the worth of this available nitrogen. This can be viewed as a pre-emergent application and can be a significant N source in some years; however it is also prone to leaching if heavy rainfall occurs before crop establishment.

Leaching
Once organic-N is converted to nitrate it is prone to leaching, particularly in sandy textured soils in high rainfall zones where soil compaction problems slow root growth. Other subsoil constraints, such as soil acidity, may also reduce the efficiency of uptake of NO$_3^-$ by the crop. Finer textured soils (e.g. red loams) are less likely to suffer significant NO$_3^-$ to leaching, allowing efficient use of available nitrogen.

Timing of application
Grain yield improvements are mainly caused by increased tiller numbers and grains per ear, both of which are determined early in the life of a wheat plant. This places importance on a sufficient supply of nitrogen during crop emergence and establishment. Due to potential leaching, nitrogen use efficiency on sandy soils can be improved by delaying fertiliser application until the crops roots system is adequately developed. This can be 3–4 weeks after germination.

Later nitrogen applications can also have yield benefits through increased tiller survival, leaf duration and photosynthetic area. Delaying application however, reduces the chance that economic response to nitrogen will be achieved. An advantage of late applications (115 node visible) is that growers have a better idea of yield potential before applying the nitrogen.