Technical Note

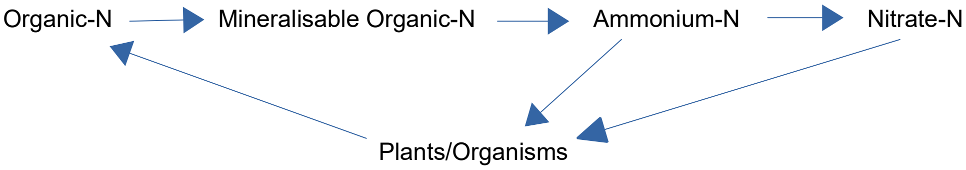
UNDERSTANDING SOIL NITROGEN TESTS

Introduction

Chemical analysis of New Zealand topsoils typically shows that up to 5000 kg of nitrogen (N) is present per hectare. About 98% of the total soil N exists as a component of organic matter called the organic nitrogen fraction, which includes humus and soil organisms. In organic forms, soil nitrogen is insoluble, unavailable to plants and described as immobilised.

Soluble (or immediately plant available) nitrogen comprises only 2–3 % of the total soil nitrogen and exists as ammonium (NH_4^+) or nitrate (NO_3^-) ions, called the mineral nitrogen fraction. Nitrogen is converted from organic to mineral forms, ammonium-N and nitrate-N, through the decomposition of organic soil compounds. This process is referred to as ‘mineralisation’.

Mineral nitrogen is constantly being ‘taken up’ by plants and organisms (as NO_3-N and NH_4-N) and converted to protein, or is lost by leaching (as NO_3-N). As plants and organisms die and their organic mass is subject to decomposition, nitrogen is eventually released as ammonium and subsequently converted to nitrate in a continuous process referred to as the ‘Nitrogen Cycle’.



Fertilizer inputs, fixation of N by legumes, urea excreted in urine, leaching, product removal and volatilisation of nitrogen as ammonia and nitrogenous oxides affects the equilibrium between organically fixed and plant available mineral N. Between 50 and 150 kg N per ha can be mineralised annually from organic matter and crop residues depending on soil conditions.

Soil N Tests at Hill Labs

- **Mineral N** (ammonium-N and nitrate-N) is extracted from soils as-received (preferentially submitted immediately to the laboratory or refrigerated to less than 4ºC). Low temperature inhibits the decomposition of organic matter. Otherwise, microbial activity and mineralisation of organic matter would continue in the soil sample until it is analysed. The Mineral N test would then be an inaccurate estimation of the amount of ammonium-N and nitrate-N in the sampled area.

- **Potentially Available N (AN) or Anaerobic Mineralisable N (AMN)** is determined by anaerobic incubation of the soil sample for 7 days at 40ºC followed by the extraction and measurement of ammonium-N produced (value includes mineral N present). Warm temperature accelerates the rate of microbial activity and the rate of conversion of organic matter N to ammonium-N. Under the anaerobic conditions of the laboratory test, conversion of ammonium-N to nitrate-N does not occur.

  Only a small proportion of the total organic-N is mineralised (typically about 3 %) since the majority of organic compounds are large polymeric molecules that are resistant to decay. The properties of the organic material and the particular combination of type and quantity of microorganisms present will determine the amount of ammonium-N released during incubation. The amount of ammonium-N released is dependant on the amount and type of organic matter present.

- **Hot Water Extractable Organic Nitrogen (HWEON)**

  A new test introduced in December, 2019 the Hot Water Extractable Organic Nitrogen (HWEON) test has been shown by researchers to be a very good test to derive the potentially mineralisable Nitrogen (PMN) in soils, to aid with Nitrogen fertiliser decisions for crop soils. This new test (HWEON) is thought to be an improvement on the AN/AMN tests described above. Ongoing research will be undertaken to demonstrate this, and may result in replacement of the AN/AMN test in the future.

  Results are reported as Hot Water Extractable Organic Nitrogen (mg/kg) and also calculated to PMN (mg/kg). An additional calculated result as PMN kgN/ha is also available, using the client supplied sample depth (assumes 150mm if no depth provided) and the lab volume weight as a proxy for field bulk density. The PMN profile (PMNp) is required for this additional reporting expression. N.B. If a field bulk density is known or estimated (from soil type & depth), this figure should be substituted for the lab volume weight value.

  - PMN (kgN/ha) = PMN (mg/kg) x sampling depth (mm) x volume weight (g/ml) x 0.01

- **Total Nitrogen (tN)**

  This test measures the total Nitrogen in the soil by way of the Dumas combustion method. This measure includes Nitrogen that is unavailable to the plant but is useful in determination of Carbon: Nitrogen ratios. In some cases, tN can be used as an input value in decision support tools where field-calibration for the land-use has been carried out by research.

Factors affecting Mineral N levels in soil

- **Temperature:** Mineralisation or decomposition of organic matter and conversion of nitrogen to ammonium and nitrate are processes dependant on the activity of microorganisms. This starts at about 4 – 5ºC and reaches a maximum at between 30 to 40ºC. Between 20 and 30ºC the rate of mineralisation can more than double, from about 3.4 to 7.5 % of the total organic N during one growing season. Nitrate-N levels increase as the soil warms up after winter, accumulate in the soil during summer drought conditions and decrease with the onset of winter as soils become cold and the risk of leaching increases.
- **Crop type**: Nitrogen that is ‘fixed’ by legumes in root nodules contributes to the soil N pool by sloughing-off dead nodules, excretion of nitrogen-containing organic compounds from the nodules and from decomposition of dead roots. Since nitrogen is the most mobile of the essential plant nutrients and is subject to gains and losses through natural processes, farm management practices can utilise mineral N fluctuations within and between seasons. Crop residues from early harvested crops can be cultivated into the soil before the onset of low winter temperatures to release mineral nitrogen for utilisation by autumn sown crops.
- **Soil texture:** Higher levels of nitrate are retained in clay soils compared to loamy soils, with sandy soils retaining the lowest concentrations. The risk of nitrate leaching is highest in sandy soils. Leaching on clay soils is less prominent with nitrate being retained in the surface soil layers. Clay soils generally contain more organic matter and humus with a higher organic-N reserve than sandy soils. This may be due to the higher water holding capacity of clay type soils and faster plant growth rates, which increase the supply of organic matter to the soil.
- **Organic matter:** Studies have shown that soils with a carbon content <2 % have half the nitrogen reserve compared to soils with >10 % carbon. This confirms that the mineralisation potential of soils increases with increasing organic matter content. The standard conversion factor between soil carbon and soil organic matter is to multiply carbon by 1.72.
- **Soil depth:** The conversion rate of ammonium-N to nitrate-N described as ‘nitrification’ decreases with soil depth and is linked to decreasing soil temperatures lower in the soil profile. This reaction also is ‘aerobic’, requiring oxygen, so anaerobic conditions in the soil restrict nitrate-N build-up. Subsoil is more likely to be compacted and anaerobic than topsoil.
- **pH:** The rate of nitrification increases with increasing pH. Lime applied to soil to increase the pH, stimulates the microbial population and also the enzymes involved in the nitrification process. In pasture soils where lime is surface applied, and very slow to increase the pH of subsurface soil layers, nitrification in the topsoil is substantially faster than in the subsoil.
- **Freezing and thawing:** Small increases in mineral-N have been observed upon freezing and thawing of soil samples. This increase has been attributed to a flush in microbial activity following the decomposition of dead microbial cells (killed by freezing and thawing) and organic material exposed by rupturing of soil aggregates. On New Zealand soils with relatively high organic-N contents this effect is negligible.
- **Nitrogen volatilisation:** Loss of nitrogen as gaseous compounds from the soil takes place when nitrate is converted to NO, NO_2 and N_2 through the process of denitrification, especially under anaerobic conditions due to soil compaction and/or waterlogging.

  Ammonia gas (NH_3) may be lost from surface application of urea as urine (particularly from dairy cows) or fertiliser.

  Loss of nitrogen from volatilisation can have a significant effect on mineral N budgets.
- **Nitrification inhibitors:** Various nitrification inhibitors can be used to slow down the conversion of ammonium-N to nitrate-N. These inhibitors can have the beneficial effect of decreasing the quantity of nitrate leaching into the water table and nitrate in run-off water ending up in streams and waterways. DCD is the nitrification inhibitor used in New Zealand and has been shown to significantly reduce the conversion from ammonium-N to nitrate-N. When testing for mineral N levels in soils, any use of nitrification inhibitors over the area sampled should be documented, as this will affect the interpretation of test results.
- **Cultivation:** Aeration of soils through cultivation speeds up the rate of organic matter mineralisation and the supply of mineral nitrogen for the subsequent crop. Repeated cultivation for two or more seasons rapidly decreases the ability of the soil to provide N from the organic-N pool. Typical test results, for available N in the assumed 0 – 15 cm soil layer, for pasture vary between 100 and 280 kg/ha compared to continuous cropping where the available N can drop to as low as 50 kg/ha.

Interpretation

- **Mineral N** is reported in mg/kg as ammonium-N and nitrate-N separately and totalled. By utilising the volume weight of the soil and the sampling depth, the amount of mineral N present in the soil per hectare can be calculated. Although the volume weight determined in the laboratory is not the same as the field bulk density of uncultivated soil, this calculation can be used to obtain some indication of seasonal variability.

  Mineral N (kg/ha) = Mineral N (mg/kg) x sampling depth (mm) x volume weight (g/mL) x 0.01

  N.B. If a field bulk density is known or estimated (from soil type & depth), this figure should be substituted for the lab volume weight value.

- **Potentially Available N** is reported as kg/ha with a default sampling depth of 15 cm (150mm). If the soil sample represents a different soil layer the result should be adjusted proportionately.

  It is advisable to sample well drained soils to depths below the surface soil layer especially where root development is present in the subsoil since nitrogen below the surface 0 - 7.5 or 0 - 15 cm layers can also be plant available and should be accounted for in nutrient budgets. If it is established that either insignificant or substantial quantities of N are present in the subsoil, an appropriate sampling regime can be adopted for future use.

Conclusion

- Nitrogen is the most mobile essential plant nutrient, with numerous factors affecting transformation processes and distribution of nitrogen in the soil.
- Hill Labs tests for mineral N that represents the immediately plant available nitrogen. Anaerobically mineralisable N represents the amount of potentially plant available nitrogen
- A new method to derive the potentially mineralisable N in soil, using the Hot Water Extractable Organic N test has been introduced in December 2019.
- Soil samples should be submitted immediately after collection (or chilled <4ºC) for the Mineral N test, to prevent mineralisation in transit. Freezing may be required if transit overnight is necessary, but should be avoided if possible.
- It is unlikely that nitrogen levels would stay the same from one season to another since seasonal climatic differences, farming practices and crop removal will affect residual soil nitrogen levels and the ability of the soil to provide plant available nitrogen.

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