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The Nitrate Quick Test Mass Balance Tool

User Guide

Preface

The National Policy Statement for Freshwater provides direction to New Zealanders about safe-guarding the quality of our freshwater. Regional Council Land and Water plans are encouraging farmers to adopt industry agreed good management practices (GMPs) to reduce the risk of nutrients being lost from the farm, with a strong focus on nitrogen (N).

The industry-agreed GMP for nutrient management is to meet the crop's demand for nutrients. Firstly, with the supply from the soil, then with fertiliser application.

A nitrogen mass balance budget is a method to determine how much N fertiliser should be applied to the crop to achieve its potential yield. To develop the budget, estimates are required for the crop's demand for N and how much of this will be supplied by the soil.

There are two sources of plant-available N that need to be measured in the soil:

- **Immediately available N** – this is N that is already in a form that plants can take up and is measured by the mineral N test.
- **Potentially available N** (sometimes referred to as 'available N') – this is an estimate of the N supply from the mineralisation of organic N over the growing season. It is measured by the anaerobically mineralisable N (AMN) test or the recently developed hot water extractable organic N (HWEON) test.

For an effective N mass balance, **both** sources of N need to be measured.

Mineral N

The amount of mineral N in the soil can change quickly over a short period of time, especially when crops are growing quickly. It is useful to have a quick and inexpensive method for estimating soil mineral N concentrations throughout the season, so that timely fertiliser decisions can be made. Previous work in New Zealand has shown that Nitrate Quick Test strips can assist with these decisions and are a quick and cost-effective option for mineral N testing.

This guide provides guidance to growers on how to measure the soil N supply with Nitrate Quick Test strips and make an informed fertiliser decision for the crop.

Figure 1. Lettuce.

How to use this guide

This is a step by step guide on how to use the **Nitrate Quick Test Mass Balance Tool** to inform a N fertiliser decision:

- How to use the mass balance equation.
- Taking the soil sample.
- Using the Nitrate Quick Test to estimate the mineral N levels in your soil.
- Crop nutrient demands.
- Using the Nitrate Quick Test Tool.

The Nitrate Quick Test Mass Balance Tool is an easy to use electronic tool available on industry websites.

Mass balance budget

A nutrient mass balance is a useful way of determining fertiliser requirements, enabling fertiliser applications to be better matched to the crop's nutrient requirements. For N, the mass balance equation is:

N Fertiliser requirement = Crop N Demand – Soil Mineral N – Soil Organic N

Where:

1. **N Fertiliser requirement** is the amount of N to be supplied from the fertiliser. The amount of fertiliser applied depends on its N content, e.g. the N content of urea is 46%.
2. **Crop N demand** is the amount of N your crop will need to reach its **target** yield.
3. **Soil Mineral N** is a measure of how much N is immediately available for plant uptake and includes both nitrate and ammonium. The amount of ammonium in the soil is usually low, because the micro-organisms in the soil rapidly convert it to nitrate. So **the Quick Test nitrate value may be used as a proxy for soil mineral N supply at any time during the crop's growth.**
4. **Soil Organic N** is an estimate of the N that could become available to the crop as soil organic N is mineralised. This is estimated with an **Anaerobically Mineralisable N (AMN) Test or Hot Water Extractable Organic N (HWEON) Test** taken before the crop is planted.

All of these are estimates of the soil N supply, so there is a level of uncertainty to keep in mind. Regular soil testing and a consideration of the seasonal weather will enable you to get a feel for the reliability of your soil test results.

The crop's N demand relates to its planned or target yield. When working this out, the long term average yield for the crop is a good place to start. This can be reviewed throughout the season as you make assessments about the crop's growth.

Crop demand

Nitrogen is an essential nutrient for plant growth and is found in all plant cells.

The supply of N to the crop comes primarily from soluble nitrate ions which are absorbed by the plant roots as they absorb water. It is important to maintain healthy root systems by focussing on good soil structure, avoiding waterlogging and effective pest and disease management. Plants with roots affected by compaction or disease may show signs of N deficiency even when adequate N is present in the soil.

The root zone, where the roots are active, is the key management zone for reducing N losses to the environment.

Each crop has a characteristic demand for N and as the yield increases so does the demand for N.

Detailed information about the N requirements for arable and vegetable crops can be found on industry websites.

For arable crops: www.far.org.nz
For vegetable crops: www.fertiliser.org.nz/includes/download.ashx?ID=154153

Figure 2. Maize.

Nitrogen supply from the soil

Soil N levels are dynamic. The N cycle has ongoing immobilisation and mineralisation processes which either lock up N into organic forms or release it into soluble plant available forms.

In the mineralisation process, N is converted from the organic form to mineral forms through the decomposition of organic soil compounds by microbial activity. The soluble mineral forms of N comprise of only 2–3% of the total soil N, and only these soluble forms are available to the plant.

There are two groups of tests that provide information about the availability of N for the crop, and each group provides different information about the soil N supply.

1. Mineral Nitrogen (MinN) Tests
MinN or Deep Soil Mineral N tests, measure the inorganic or mineral N fractions in freshly collected soil. These mineral fractions are nitrate (NO_3-) and ammonium (NH_4+), which are immediately available to the plant. In most cultivated cropping soils, nitrate is the predominant form of mineral N (> 90%) unless urea or an ammonium-based fertiliser (e.g. calcium ammonium nitrate) have been applied recently, then ammonium levels may be elevated.

Soil samples collected for Mineral N tests can be submitted to the laboratory for testing or tested on farm with the Nitrate Quick Test strips.

Samples must be chilled, but not frozen, to prevent mineralisation occurring while in transit to the lab. Ensure samples are < 4°C when they arrive at the lab.

It is important to note that when comparing laboratory Mineral N values with Nitrate Quick Test Strip readings, laboratory results are often expressed as Nitrate-Nitrogen (amount of N in the nitrate ion with the oxygen component removed), whereas Nitrate Quick Test results are expressed as Nitrate (which includes the oxygen component). Dividing the Nitrate Quick Test result by 4.43 will convert Nitrate to Nitrate-Nitrogen.

2. Anaerobically Mineralisable N (AMN) Test or Hot Water Extractable Organic N (HWEON) Test
These are a laboratory-based estimate of the amount of N that could be mineralised from the organic matter in the soil over the growing season. The AMN test is also sometimes referred to as the Available Nitrogen (AN) test.

The actual amount of N that becomes available depends on the soil's mineralisation processes. These processes are largely dependent on soil temperature, moisture and pH.

Testing the soil for nitrogen

Regular soil testing is important, especially in the crop's active root zone. Management of nutrients where the roots are active is the key to reducing N losses during drainage events. For most arable and vegetable crops the majority of roots actively taking up nutrients are in the top 60 cm, with the densest concentration of roots in the 0-30 cm zone.

In combined arable and pastoral systems there are times when the soil will have high residual fertility. The first crop following the pastoral phase in these systems is likely to need minimal amounts of inorganic fertiliser applied to reach its yield.

High mineral N situations include:

- Recently cultivated long-term pastures;
- Paddocks that have been intensely grazed, e.g. following winter dairy grazing;
- Paddocks where the previous crop did not reach its planned yield;
- Paddocks where a large amount of crop residues with a high N content (e.g. trimmings and leaf residues from brassicas) has recently been returned to the soil.

It is important to test fertility levels in these soils before the next crop in the rotation is established so that an efficient fertiliser plan can be developed.

Soil sampling methodology and equipment

Equipment

- A 15 cm corer for basic soil tests and/or an auger/corer for deep mineral N tests (up to 60 cm depth).
- Buckets for mixing the samples in order to produce a homogenous sub-sample.
- 4 mm sieve (most garden sieves can be used).
- Sample bags that seal.
- Labels and a water-resistant pen.
- Chilly bin with ice or cooler bags.

A spade or trowel can be used for the sampling, but make sure the sample is representative of the whole soil profile for the sample depth being measured.

Timing

The best time to collect a soil sample for mineral N analysis is in the week prior to base, planting or side dress N fertiliser applications.

- The longer the period between sampling and fertiliser application, the less useful the mineral N test result will be for informing a N mass balance. This is because inorganic N may be lost in drainage if there is a big rainfall event or soil concentrations may change quickly if a crop is growing rapidly. One of the main benefits of Nitrate Quick Test strips is that the results from the soil test are available within a couple of hours, so testing can be carried out on the same day as the fertiliser application if required.

For AMN testing, the best time to collect a sample is after harvest and before the ground work for the next crop is started.

- The standard turnaround time for this test at commercial laboratories is 3 to 10 days. For the N mass balance, samples for AMN analysis would only need to be taken once (before crop establishment) to give an estimate of potential N supply from mineralisation of organic N.

Avoid soil sampling immediately after a fertiliser application with urea or ammonium compounds.

- The Nitrate Quick Test strips do not measure ammonium-N and the test results will under-estimate the plant available N if ammonium is in the soil sample. In most situations, nitrate is the predominant form of soil mineral N and this means that Quick Test nitrate is an effective proxy for plant available N.

Sampling

- Collect 15 to 20 cores across the paddock. Develop a pattern of sampling that can be repeated and record where the sampling points are, with GPS or visual cues, so that the sampling pattern can be repeated in subsequent years.
- Avoid atypical areas such as gateways and headlands and old stock camps and fire sites. If there are a number of different soil types within the paddock, sample from each soil-type area separately.
- For bed crops (e.g. onions, lettuce, brassicas), avoid taking samples from the inter-rows or wheel tracks where crop root growth is usually restricted.
- Banded applications of fertiliser result in a more concentrated nutrient zone close to the plant rows. If a soil test is required for a side dressing decision, take half the cores from the banding zone and the other half from outside this area (aim to take more samples e.g. 15 samples from each zone as banding fertiliser increases variability in soil testing). The sample will represent the average fertility across the area in question.
- Allow at least 10 days after the application of nitrogenous fertilisers to reduce the risk of high ammonium concentrations in the sample. Increase this time to at least two weeks in winter, particularly if ammonium-based products are being used (e.g. CAN). Avoid sampling when soils are waterlogged.
- Collect samples to a minimum depth of 60 cm. For shallow rooting crops, e.g. lettuces and onions, only a 30 cm sample depth is necessary. It can be useful to keep the different depth increments separate (i.e. 0-15 cm, 15-30 cm, 30-60 cm) as this gives an indication of where the available nutrients are in the soil profile. Nutrients at depth are not available to shallow rooting crops or those that are just establishing.

Preparing the soil for testing

- After collecting the soil cores, mix them thoroughly and sieve them to less than 4 mm to break-down the soil clods. This enables the nitrate in the soil to be fully extracted by the calcium chloride in the testing process.

Soil samples should be kept chilled until they can be tested. Use a chilly-bin with ice packs and a water-resistant pen for labelling.

Figure 3. Soil sampling.

Using the Nitrate Quick Test strips

How do the strips work?

The Nitrate Quick Test strips are similar to the litmus strips used for pH testing but are coated with a chemical that changes colour when it reacts with nitrate. A simple colorimetric scale is used to quantify the nitrate concentration in the soil sample. This is in mg nitrate/litre of soil solution.

Equipment for setting up your strip test "lab"

- Spoon or spatula.
- Storage rack for tubes.
- 50 ml plastic extraction tubes (10 ml graduations).
- MQuant® Nitrate Test Strips (0 - 500 mg/L NO_3).
- M Calcium chloride solution (1.47 g of calcium chloride dihydrate in 1 L of bottled spring water or rainwater. Note, if requested Lab Supplies will weigh out 10 lots of calcium chloride for you, otherwise if you are stuck, use a quarter teaspoon from a set of measuring spoons and level the calcium chloride with the top of the spoon with the back of a knife.
- Stop watch.

The tubes, rack, strips and calcium chloride can be purchased as a kit. Details on where to obtain these are provided in Appendix 1.

The Nitrate Quick Test process

The testing process starts with a set of in-field soil samples, collected as described on pages 7-9.

Method

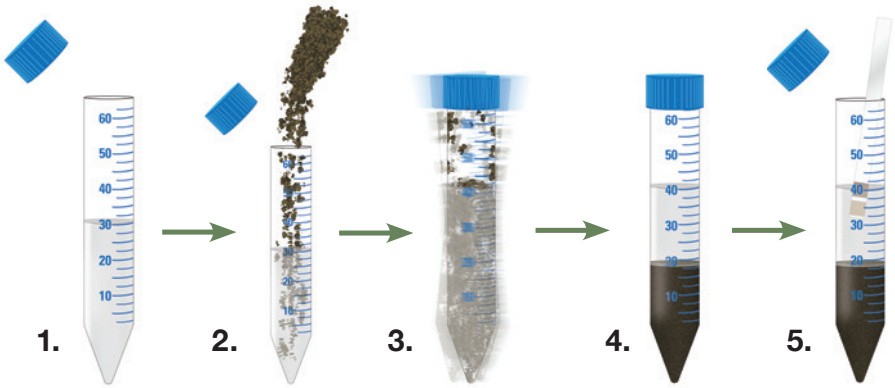


Figure 4. The Nitrate Quick Test Analytical Protocol method steps 1-5.

Always check the $CaCl_2$ extract solution with a strip to ensure there is no 'background' nitrate.

1. Begin with **30 ml $CaCl_2$** solution.
2. Add 10 ml of sieved soil to give a total volume of **40 ml**.
3. Shake vigorously for **1-2 minutes**.
4. Allow the soil to settle (**about 30 minutes**).
5. Dip the test strip in for **2 seconds** then remove it.

Reading the strip colour

1. Allow the colour to develop for exactly one minute.
2. Compare the colour to the nitrate concentration scale on the container .
3. **Use the NO_3- scale – the top row of numbers. This shows concentrations from 0 to 500 mg/L**.
4. Record the result.

Figure 5. Comparing the colour on the strip with the scale on the test strip bottle. The recommended product is from Merck (MQuant® 0 – 500 ppm strips).

If the test strip colour falls in between a colour range, you will need to estimate the concentration based on closest colour range. For example, if the reading is between 25 and 50 mg/L NO_3- but closest to 50 mg/L, a value of 40 would be appropriate.

The concentration result is in mg/L. This needs to be converted to a more useful measure relating the nitrate concentration in the test solution to an amount of nitrate in the soil.

Some people are not confident that they will be able to assess the strip colour and get an accurate result. An alternative to making an assessment by eye is to download the **MQuant® StripScan** app to your phone and purchase a nitrate reference card, (refer Appendix 1).

Note: Clay soils may take a long time to settle
Settling times in clay soils can be slow. If you find this happens for your samples put the tubes in the fridge and leave them overnight. It is important to chill them to minimise microbial activity and mineralisation. Measure the nitrate in the morning.

The MQuant® StripScan and nitrate reference card

The simplest way to determine the nitrate concentration in your soil solution is to use the MQuant® phone app and reference card. These work together to guide you through the test timing and colour analysis.

1. Prepare the soil sample.
2. Start the app and get your MQuant® nitrate test strip and reference card ready.
3. Test your sample with the test strip.
4. Press the nitrate icon on the app as soon as you have removed the test strip from the solution to start the timer, then place the test strip on the reference card and wait for the colour to develop.
5. When the countdown is complete align the camera so that the app can take an image.
6. Record the result.

The app is available on the App Store for iPhone or Google Play for free. However the reference card must be purchased in order to use the app. (refer to Appendix 1).

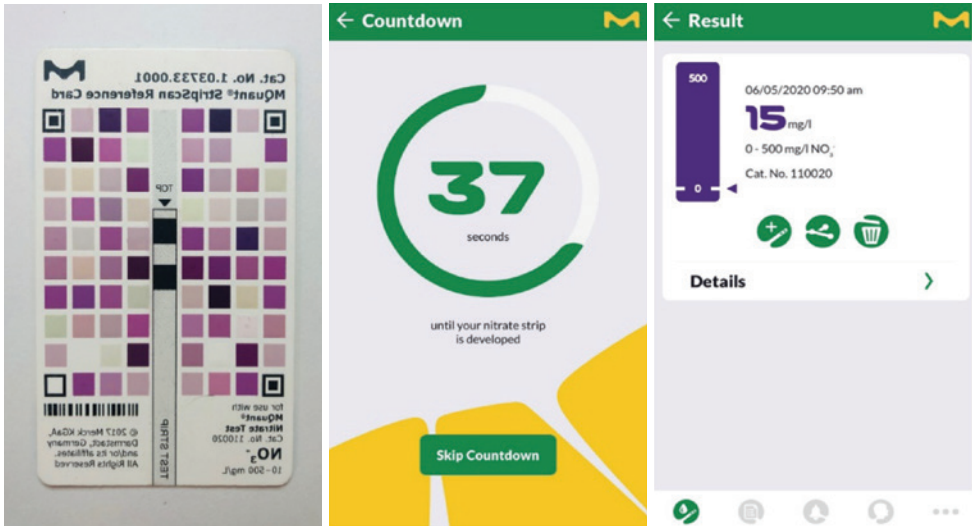


Figure 6. MQuant® reference card and phone app.

How to work out how much nitrate is in your soil

There are two ways to work out how much nitrate is in your soil.

1. Use the soil correction factors and follow the calculation example below, or
2. Use the Nitrate Quick Test Mass Balance Tool (refer to page 15).

The soil correction table

The results in this table have been validated for New Zealand cropping soils as part of the project's science programme.

Follow these steps to identify your soil correction factor.

1. Identify the texture of your soil. If this is not known, roll a small lump in your hand use the "feel method". https://soils.landcareresearch.co.nz/understanding-soils/get-dirty/#st
2. Determine how dry the soil is at the time of testing.
   - A 'dry' soil will crumble and not form a ball.
   - A 'moist' soil will form a ball that is not overly wet, unless it is sandy.
   - A 'wet' soil forms a ball which releases moisture when squeezed.
3. Select the correction factor for your soil from the table.

Soil Correction Table

Texture	Dry	Moist	Wet
Clay	1.8	1.5	1.3
Clay loam	1.7	1.4	1.3
Loam	2.0	1.5	1.3
Loamy sand	1.8	1.5	1.4
Sand	1.8	1.5	1.4
Sandy clay	1.8	1.4	1.3
Sandy clay loam	1.9	1.6	1.4
Sandy loam	2.1	1.8	1.5
Silt	1.9	1.4	1.3
Silt loam	1.7	1.4	1.3
Silty clay	1.9	1.6	1.4
Silty clay loam	1.9	1.5	1.4

4. Follow the calculation example to work out how much nitrate is in your soil

Calculation example:
The calculation converts the nitrate concentration from an amount in solution (mg NO_3-/L) to an amount in the soil (mg NO_3-N/kg dry soil).

In our example the soil that has been sampled is a **moist silt loam**. From the correction table the correction factor is **1.4**. Following extraction, the Nitrate Quick Test strip gives a NO_3- reading of **25 mg/L.**

To convert to **an amount in the soil** divide this value by the relevant correction factor from the table: **25 mg/L ÷1.4 = 17.9 mg NO3-N/kg dry soil**

To convert to **an amount in the field** (kg N/ha), multiply the soil value by the sample depth factor and the field bulk density.

The sample depth factor is the sample depth/10. In this example **15 cm** sample depth/10 = **1.5**

The bulk density is a characteristic of the soil type. In this example the bulk density is **1.05 g/cm^3**. If the bulk density is unknown use a value of 1.0.

The calculation is: **17.9 mg NO_3-N/kg dry soil** x **1.5** x **1.05** = **28 kg N/ha** in the 0-15 cm soil depth profile.

The Nitrate Quick Test Mass Balance Tool - Using it for your soil

The Quick Test Mass Balance Tool is an interactive web-page **that does the calculation for you**.

The tool uses the N mass balance equation to estimate the N fertiliser requirement for specific crops at the time of soil testing.

- **Crop N demand** (in season and total) is estimated using a N uptake curve for the crop which is dependent on yield potential.
- **Soil mineral N supply** is estimated from Nitrate Quick Test results.
- **Nitrogen supply from mineralisation of organic N** is estimated from the **AMN** or **HWEON test** or, if this isn't available, a default value based on land management history.

The tool is freely available on the FAR website: www.far.org.nz

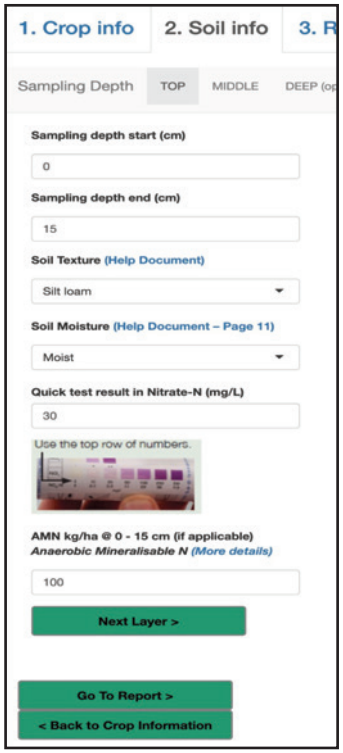
Instructions for using the tool

The Crop Information page

1. Select paddock Status.
   a. Fallow – use if paddock is in a fallow state or if only wanting to determine the level of plant available N.
   b. Cropping – use to estimate specific crop N requirements.
2. Select farm system.
3. Select crop type – if crop is not available, use the fallow function to determine current plant available N levels.
4. Enter planting, sampling and next sampling dates.
5. Enter predicted target yield.
6. Enter paddock name for reference.

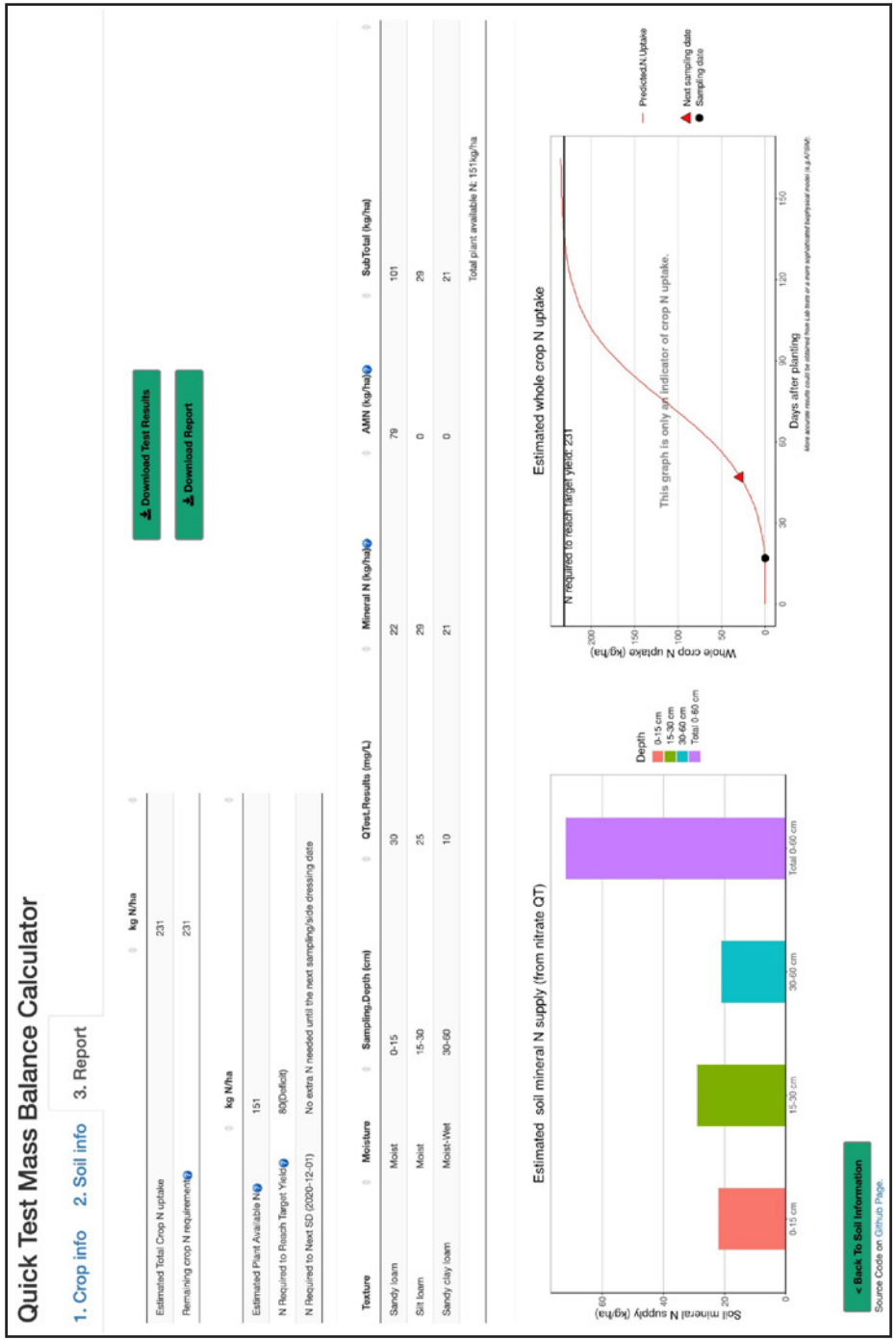
The Soil Information page

1. Enter sampling depth start (cm).
2. Enter sampling depth end (cm).
3. Select soil texture – a ‘Help Document’ is available to accurately determine your soil texture.
4. Select soil moisture - a ‘Help Document’ is available to accurately determine your soil moisture.
5. Enter Nitrate Quick Test result.
6. Enter AMN or HWEON value if available – if not available, leave this cell blank and the app will provide a default value based on the farming system selected.
7. Repeat steps 1-5 for ‘middle’ and ‘deep’ depths if being analysed.



The Report page

- **Estimated total crop N uptake**: this is the N required to achieve the target yield.
- **Remaining crop N requirement**: this is the N required from sampling date to harvest date.
- Estimated plant-available N: the sum of mineral N + AMN (that is potentially available between sampling date and harvest date).
- N required to reach target yield: if the ‘deficit’ is greater than 70 kg N/ha, consider split applications. If there is a ‘surplus’ avoid applying N and re-test at a later date.
- N required until next side dressing: N required from sampling date until next side dressing.



Note: The tool estimates the N supply from the organic pool (AMN value (kg/ha)) for the period between the most recent quick test sampling and harvest date.

- If you hover the cursor over the '?' an explanation will appear.
- If there is a 'deficit' of N to reach target yield, but no N is required until next side dressing, then this is due to sufficient plant available N to meet crop requirement in the interim. Avoiding application during this period will help to reduce potential N losses. Re-test at a later date.
- 'Estimated soil mineral N supply' and 'estimated whole crop N uptake' are depicted in the graphs.
- Test results can be downloaded in an Excel file by clicking the 'Download Test Results' button.
- A report can be generated for record keeping by clicking the 'Download Report' button.

Developing a nitrogen fertiliser plan

This simple tool has been developed to give growers an indication of the potential N uptake of certain crops based on the supply of N from the soil, however a number of important factors have not been accounted for. These include climate, location, variety, time of sowing/ planting and known soil constraints.

The tool's **estimated total crop N uptake** is the starting point for the development of a fertiliser plan and the other factors that influence the crop's performance must be considered.

In the tool, the calculation for the crop's demand for N is based on the minimum amount needed to reach the target yield. This promotes the most efficient use of fertiliser and minimises the risk of over-fertilisation. However, it assumes that your crop takes up 100% of the added N fertiliser. In practice this does not occur, as there are many factors that reduce the efficiency of applied fertiliser to less than 100%.

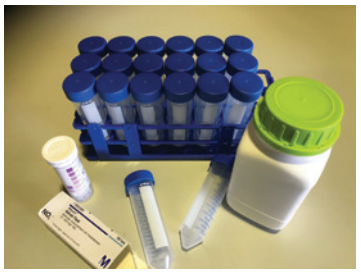
N uptake efficiency is variable. It can be as high as 80% when fertiliser is applied little and often, as in fertigation systems, but can be less than 50% when large applications of fertiliser are applied to crops with shallow root systems. Uptake efficiency reduces when environmental and management factors lead to leaching, denitification or volatalisation and can be affected by the way the fertiliser is applied. For example, broadcasting can be less efficient than banding if some fertiliser is spread onto areas that are not accessible to roots e.g. wheel-tracks or unplanted headlands, this is particularly relevant in crops with small/ shallow root systems.

The tool cannot account for the numerous factors that affect the uptake efficiency of applied N fertiliser, and for simplicity, the tool's recommendation is based on the best-case scenario of 100% fertiliser uptake. Growers may choose to adjust the tool's recommendation if they know of factors that may reduce the uptake efficiency in their situation.

The Quick Test approach is simple and cheap to do, so it is possible to monitor soil mineral N levels during the growing season in order to match crop N demand with soil N supply. This approach helps to reduce the risk of potential N leaching and also helps to ensure that sufficient N is being supplied to maximise crop growth.

Appendix 1

Nitrate Quick Test kits and reference strips



Test kits and StripScan reference card can be purchased from Lab Supply Ltd.

Test kit includes:

- A tube rack,
- 20 extract tubes,
- A container of 100 MQuant® Nitrate Test Strips,
- 500 g Calcium chloride dihydrate.

The cost for the kit at the time of writing this Guide was $189.75 including GST and delivery (rural areas included). To find the kits enter www.labsupply.co.nz/nitrate-test-kit into your browser, or enter 'CHENITRATE-N' into the search box on the lab supply website. Items may also be purchased individually.

StripScan Reference Card for the measurement of MQuant® Nitrate Test

Cost for the StripScan reference card at the time of writing this Guide was $84.80 excluding GST and delivery (reference: MER103733)

Contact details

Website: www.labsupply.co.nz
Email contact: info@labsupply.co.nz
Tel: 0800 522 787

MQuant® StripScan App

The app is available on the App Store for iPhone or Google Play for free. However, the reference card must be purchased in order to use the app.

Acknowledgements

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