Soil Chemistry

FACT SHEET 3

Soil chemistry is one of the three critical aspects of soil health. The chemical composition of a soil depends on the materials from which they were formed and the processes of formation. The chemistry of the soil will influence the supply of nutrients required for plant growth and production.

Soil chemical analyses

A soil chemical analysis provides a point in time measure of a dynamic system. The elements of the soil test may be used as an indicator of soil health or to inform decisions regarding the need for addition of fertiliser or other soil treatments.

A number of laboratories provide soil chemistry testing services. They all provide a relatively consistent range of analyses which will be covered here. While most provide a similar range of tests it is important to note that they often use different methods to test different features or elements (nutrients) in the soil. For this reason results from different laboratories should not be used to directly compare soil tests.

Soil chemical test results from different laboratories are often not directly comparable since they may use different testing methods

A soil chemical analysis will provide valuable information about the chemical fertility and balance of nutrients in your soil. It gives no information regarding other aspects of soil health such as soil structure or biological activity. However, the chemical composition can provide some clues about your soil's physical condition and potential biological health.

The addition of fertiliser or other soil amendments can be a significant expense. A soil chemical analysis will provide information so the appropriate treatments and rates may be applied.

Figure 1: Soil chemical analyses help you make informed decisions regarding soil treatment.

Soil chemistry tests

Organic Matter influences many of the properties of soil and is an important indicator on any soil chemical analysis. There are two common methods for analysis. The Walkley-Black method uses an acid digestion to measure the oxidisable organic carbon in a soil. Alternatively, weight loss on ignition measures the loss of weight from a dry sample when exposed to high temperature (360°C). The weight loss is correlated to oxidisable organic carbon.

It is generally accepted that organic matter, on average, consists of 57% carbon. To convert organic carbon % to organic matter multiply by 1.75. The ideal level of organic matter varies with soil type. Lighter sandier soils will have lower organic matter content than heavier clays. The ideal level in a sandy soil is greater than 2.5% and in a heavy clay over 5.5% is considered an ideal level of organic matter.

The importance of soil organic matter and relationship to soil carbon is covered in more detail in Factsheet 6 of this series.

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Soil pH is the measure of hydrogen (H+) ions in the soil solution. It is a logarithmic scale, that means a soil with a pH of 4 is 10 times more acidic than a soil with pH 5 and 100 times more acid than soil with a pH of 6.

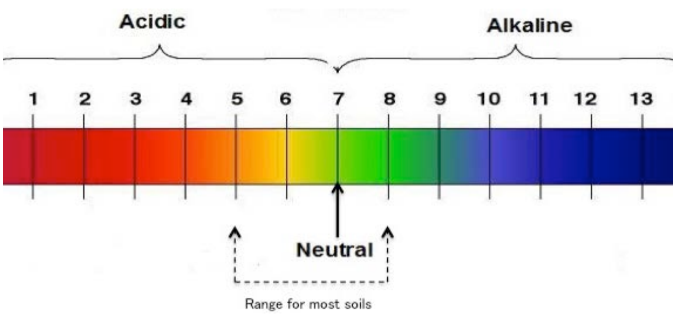

Figure 2: The pH scale ranges from 0-14 and 7 is neutral.

There are two common methods of measurement of soil pH. The $CaCl_2$ (calcium chloride) method uses a mix of 1 part soil to 5 parts 0.01M $CaCl_2$. Measured in the same ratio in distilled water the pH value for the same soil may be between 0.5 – 1.0 pH units higher than where the $CaCl_2$ method is used. Field soil pH kits give a similar result to the water measurement.

Soil pH influences the availability of other plant nutrients in the soil and biological activity. In the graph below the thicker the bar the more available the nutrient for different pH levels. The red line indicates the ideal level, pH 6-6.5 for growth of most plants.

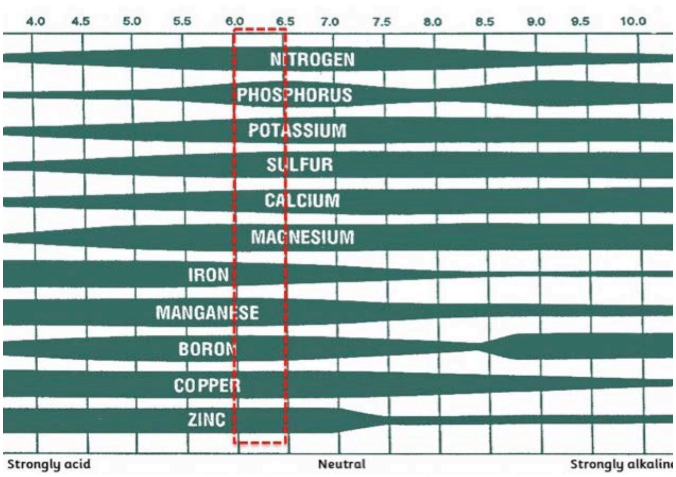

Figure 3: Influence of pH on plant nutrient availability.

Electrical conductivity (EC) is a measure of the ability of a saturated soil water extract to pass an electric current. It is also a measure of salinity. The EC will increase with salt concentration. An EC measure of <2 dS/m is considered ideal and generally soils with an EC over 4 dS/m are defined as saline.

Soil nutrients

Plant available nutrients are present in the soil solution (soil water) and are most often taken up by plants in ionic form. Nutrients in the ionic form carry an electrical charge which may be positive or negative. Positively charges ions are called cations and negatively charged ions are called anions.

Table 1: Examples of common soil nutrients and ionic form.

Cations - positive charge		Anions – negative charge	
Potassium	K^+	Nitrate	NO_3^-
Ammonium	NH_4^+	Sulphate	SO_4^{2-}
Calcium	Ca^{2+}	Phosphate	PO_4^{3-}
Magnesium	Mg^{2+}		
Aluminium	Al^{3+}		

Traditional soil testing reports provide values for plant available nutrients, those present in the soil solution and available for plant uptake. They also report on exchangeable cations. Positively charged ions bound to the negatively charged surface of clay and organic matter.

Exchangeable cations and Cation Exchange Capacity (CEC) of soil is covered in more detail in Factsheet 4 of this series.

The available and exchangeable pools of nutrients represent a relatively small proportion of the total nutrients present in a soil. Since these are the most often reported pools presented in soil chemical tests they will be the focus of discussion here.

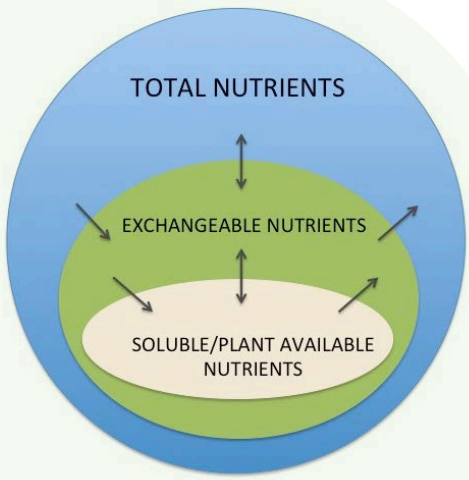

Figure 2: The pH scale ranges from 0-14 and 7 is neutral.

Phosphorus (P) is often reported using a range of methodologies, representing the use of different extracts to mimic the soil solution. The Morgan test is a mild extract and indicates the most readily available phosphorus pool. Colwell and Olsen P tests use a bicarbonate extract and are suitable for alkaline soils (pH >7). Colwell tests should also report a phosphorus buffer index (PBI) for adequate interpretation.

The PBI indicates the extent to which the soil can absorb P. Soils with a high PBI value (clay) will require the addition of more P to increase available P than soils with a low PBI.

Bray analyses use a carbonic acid extract and are suitable for more acidic soils (pH<7). The Bray 1 test indicates readily plant available P and the stronger Bray 2 extract also includes the acid soluble pool. Check your soil test report and method used to compare adequate levels in your soil. The ideal levels will likely also vary according to land use or crop type.

Nitrogen (N) is very dynamic in the soil. Between 95 and 98% of soil N occurs in organic form and is mineralised by microbes. It is reported as the negatively charged NO3- ion and positive NH4+ ion, both plant available, on most soil tests.

Sulphur (S) is most commonly tested using the KCl 40 method and a range of between 8-10mg/kg is considered adequate.

Potassium (K) although included as a base cation, K may also be reported separately on the soil test using a range of extraction methods. Depending on the extraction method, an adequate range for K is usually between 60-120mg/kg depending on soil type.

Base cations – calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) and aluminium (Al) are reported separately on the soil test as a percentage of the cation exchange capacity (CEC) of the soil. This characteristic of the soil will be covered in more detail in Factsheet 4 of this series. As a guide the ideal percentage contribution of each to the total CEC are; Ca between 60-75%, Mg between 10-20%, K between 3-8%, Na between 0.5-3% and Al as low as possible.

Your soil chemical report should provide a guide to ideal levels of each element for your soil type.

Trace element extraction procedures vary between laboratories and elements. The ideal levels of each element will also vary depending on the crop. Review your soil test report to identify the ideal levels for each trace element in your soil.

The role of nutrients in the plant

There are 14 soil nutrients considered essential for plant growth, each perform critical roles in plant growth and development. A summary of the action of each element is provided in the tables below. Note that while carbon, hydrogen and oxygen are also essential for plant growth they are not considered plant nutrients.

Table 1: The role of the key macronutrients in plant growth.

NUTRIENT	FEATURES AND ROLE IN THE PLANT
Nitrogen	Most abundant element needed for plant growth Essential for photosynthesis & protein formation
Phosphorus	Essential for energy formation Stimulates early growth Essential for pollination, seed formation and viability
Sulphur	Important in protein production, formation of chlorophyll, vitamins Involved in energy processes Role in taste of fruit & vegetables
Calcium	Role in most metabolic processes Critical for plant structure, soil biology, movement of nutrients Most elements carried to plant in association with Ca
Magnesium	Essential for photosynthesis and seed germination Production of carbohydrates, amino acids, sugars, fats, vitamins etc. Enzyme activation
Potassium	Important for stem strength, fruit size and quality Disease resistance Regulates enzyme reactions
Sodium	Essential for osmosis - water movement in and out of plant cells

Table 2: The role of the key micronutrients in plant growth.

NUTRIENT	FEATURES AND ROLE IN THE PLANT
Zinc	Needed for P uptake, energy production and water uptake
Manganese	Required for N and CO2 uptake, stalk strength & seed germination
Iron	Essential for chlorophyll function
Copper	Role in photosynthesis, respiration and enzyme processes Assists protein and carbohydrate metabolism Disease resistance
Boron	Creates sap pressure, movement of sugars around plants and roots Regulates cell division Salt absorption, water use, N uptake, pollination and seed set Disease resistance, plant resilience
Molybdenum	Protein production
Silicon	Improves photosynthesis Strengthens plants Increased drought tolerance

Other trace elements have important roles in various aspects of plant growth but those listed in the table above are the most commonly reported trace elements on soil tests.

Calculating nutrient requirements

The nutrient levels present in a soil are most often reported in mg/kg soil. The cations, in particular calcium, are a special case and are covered in Factsheet 4 of this series. To calculate the amount of any fertiliser product to be added to the soil the units need to be converted to kg/ha.

Conversion units

1% = 10,000 ppm = 10,000 mg/kg

1 ppm = 1 mg/kg

1 kg/ha = 2.24 mg/kg

Step 1

To address a deficiency (or excess) in any nutrient subtract the amount present in your soil from the ideal levels indicated by the laboratory report for each element.

Step 2

Convert the difference in mg/kg reported on the soil test to kg/ha required by multiplying by 2.24.

Step 3

Investigate the range of products available which contain the elements identified as deficient in your soil. Be aware of the different amounts of each element the different forms of an element in different products as well as associated elements and amounts present. The short and long term availability of elements in different products may vary.

Step 4

Calculate the amount of a product needed to be applied to correct the deficiency.

Step 5

Select the appropriate product for your soil and consider your soil treatment budget.

Example - Sulphur deficiency:

Sulphur present = 4.9 mg/kg Desired level = 8 mg/kg

Deficiency = 3.1 mg/kg x 2.24 = 7 kg/ha S required

Product examples

Gypsum = 19% S (+23% Ca) = 7 ÷ 0.19 = 37 kg/ha

Single super = 11% S (+9% P) = 7 ÷ 0.11 = 64 kg/ha

This is the third of a series of 12 Factsheets which cover a range of topics regarding soil health and effective function of soil processes.

More Information

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