Technical Information

Understanding your soils and their constraints

Where crop yield is significantly less than the potential yield, the "reasons why" need to be investigated and understood. The PIRSA SoilSmart project funded by Caring for our Country and delivered by Rural Solutions SA works with landholder groups through soil pit field days, workshops and press releases to help landholders better understand their soils, investigate soil constraints and improve production.

Soil sampling and analysis

Excavating soil pits or taking soil cores, combined with simple on-site soil tests and observations can provide useful information about soil characteristics. Laboratory analysis can support these field observations and identify productivity constraints including; effectiveness of phosphorus applications (PBI), inherent fertility and nutrient availability (Organic Carbon, Soil pH and Cation Exchange Capacity) and potential toxicities (Salinity). Soil analysis also provides the current nutrient status of the soil allowing you to calculate the nutrient application required for crop growth.

However different laboratories use different methods for testing nutrient concentrations and can use different units for expressing soil analysis results. Landholders should be aware of the tests that are appropriate for their area and know what the expected range and critical values should be.

Soil samples (at least 15 soil cores from the 0-10 cm layer) should be collected within selected soil types or precision agriculture management zones, avoiding areas that are not representative (including headlands, firebreaks, sheep camps, and old fence lines). These samples should be thoroughly mixed with 300 to 400g of this mixed sample sent for laboratory analysis. If a subsoil constraint is suspected, samples should also be taken from the 10-20 and 20-40 cm layers of the soil profile.

Key Physical Properties of Soils

Texture

Soil texture refers to the percentage of sand, silt and clay particles in the soil. This can be estimated by forming a ball of damp soil in your hand and pressing this between your thumb and finger into a ribbon of soil (http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/164615/soil-texture.pdf) (Figure 1).

The higher the clay percentage the longer the ribbon that can be formed, providing a guide to the soil texture class. Sandy soils will not easily form a bolus. Soil texture classes range from sand to heavy clay.

Sandy Soils

Sandy soils hold little water; however the water in this profile is easily accessible by plants. Common issues on sandy soils are poor fertility, water repellence and a high wind erosion risk. Water repellence occurs where waxy residues of broken down plant material coat sand particles resulting in uneven soil wetting. This impacts on crop germination and emergence, which results in reduced yields and increased wind erosion risk. Water repellence is usually found in the top five centimetres of sandy soils. The soil erosion risk can be reduced by maintaining surface cover and reducing soil disturbance (tillage).

Clay Soils

Clay soils have higher nutrient and water storage properties, however heavy clays tend to hold water so tightly that it is difficult for plants to access it. These soils can also be more difficult to work. They can have structural problems that restrict drainage leading to water logging, or can increase the risk of water erosion.

Structure

Soil structure refers to the way soil particles are arranged together. Well-structured soils enable better infiltration of rainfall, drainage and root growth. Poor soil structure can be caused by a lack of organic matter (slaking soils), clay dispersion (sodicity e.g. http://vro.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/sodic_soils) or compaction. Poorly structured soils can be subject to waterlogging, erosion and compaction.

Clay soils with high levels of exchangeable sodium (>6% of exchangeable cations) are structurally unstable and can readily disperse when wet. This can impact paddock workability and seedling emergence and increase the risk of water erosion. To test for dispersion and slaking, place a large crumb of clay distilled water or clean rainwater (not tap water which may contain chemical which may prevent dispersion) without shaking or stirring the sample. Slaking clay will slump and fall apart in the water, forming a small blob of mud on the saucer, but the water will remain clear (Figure 2). Dispersion will result in a milky layer forming around the soil crumb after 30 minutes.

Figure 1. Hand texturing soil samples in the field

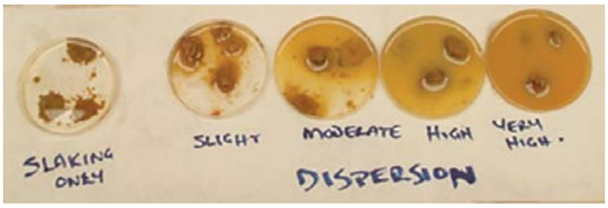

Figure 2. Field dispersion of a number of clay samples

Applying gypsum addresses sodicity by replacing sodium ions with calcium ions that hold the clay structure together. However slaking soils often do not respond to gypsum applications, requiring reduced soil disturbance and increased soil organic carbon to improve soil structure. The application of gypsum to saline soils is not recommended as the sodium is unlikely to be displaced under saline conditions.

Soil Colour

Soils which are dark in colour usually contain high organic carbon levels and are often more fertile. Sandy soils can often have a lighter coloured (bleached) layer below the darker organic surface layer, which can indicate leaching of organic matter and nutrients through the profile. Soils with bright colours (particularly red) indicate good aeration and moderately good drainage whilst grey coloured clay soils (sometimes with orange/yellow mottles) indicate poor drainage. Lighter (pale) red or off-white colours down the profile may be related to the presence of soil carbonates (lime) which can reduce the availability of nutrients.

Key Chemical Properties of Soils

Soil pH and Carbonates

Soil pH (the acidity/alkalinity of soil) can provide an indication of nutrient availability and affect the way in which agricultural products react in the soil. Soil pH can be quickly estimated using a field soil pH test kit but a more accurate figure can be acquired by sending a sample for laboratory analysis. When sending samples for laboratory analysis results may come back with two values for soil pH. These are pH(H_20) measured in a 1:5 soil:water solution and pH($CaCl_2$), where a small amount of calcium chloride has been added to the soil:water solution prior to testing. The addition of calcium chloride to the solution is to reduce the influence of seasonal soil moisture variations on soil pH. As such pH($CaCl_2$) is a more accurate indication of the "true" pH of the soil and is are usually 0.5 to 1.0 unit lower than the pH(H_20) value.

Acidic soils, with pH less than 5.5 ($CaCl_2$), may have low available levels of magnesium, copper and zinc and may be high in toxic elements such as aluminium. Low soil pH can be addressed through the application of lime (calcium carbonate) to the soil.

Alkaline soils, with pH above 8 ($CaCl_2$), may indicate the presence of high amounts of calcium carbonate which can reduce the availability of phosphorous, zinc, manganese and copper. Carbonates can be tested for in the field by observing the reaction (fizz) from the application of a weak solution (1:10 dilution of hydrochloric acid) to the soil sample. Highly alkaline soils (pH levels greater than 8.5) indicate the presence of toxic substances such as sodium bicarbonate. Sodium is often associated with boron in soils. Clays with a very high pH can be high in lime, salinity and boron.

Organic Carbon (%)

Organic carbon is an indicator of plant production. It also supports increased production as it provides the food source for soil biology, and aids in improving soil structure, water holding capacity and nutrient retention. High organic carbon levels are generally good, however, can also indicate low levels of biological activity due to acidity or water logging.

Cation Exchange Capacity (CEC)

Cation exchange capacity is a measure of the soils ability to attract, hold and exchange nutrients (usually in the form of positively charged particles called cations). It is associated with the amount and type of clay and organic carbon and to a lesser extent soil pH. Generally, the higher the CEC the higher the potential fertility of the soils and the reduced leaching of nutrients. Very low CEC values (<5meq+/100g) are an indication of low inherent fertility and are commonly a characteristic of sandy soils and some acidic soils. However, the presence of salts, gypsum or carbonate (lime) can lead to over estimation of exchangeable cations resulting in CEC values that are higher than in other soils in the same texture class.

Macro and Micronutrients (Major nutrients and Trace Elements)

Plants require 19 chemical elements for adequate plant growth, these are referred to as plant nutrients. Macro nutrients (Nitrogen, Phosphorus, Potassium and Sulphur) are required in higher quantities than micro nutrients (also referred to as trace elements and including Iron, Copper, Zinc, Manganese, Molybdenum). Despite the different quantities of each nutrient required for plant growth, crops will only perform to the potential of their most limiting nutrient.

Soil tests provide information on the levels of each of these elements available in the soil and enable management of fertiliser application to address deficiencies. But, the status of some nutrients is highly variable depending on soil moisture and temperature. Results must be interpreted in relation with other soil data including texture, pH, CEC and the levels of other nutrients as well as paddock history and knowledge of the production capacity of particular paddocks. If the potential of your soil is limiting due to factors other than nutrition, no amount of fertiliser will lift the yield beyond that potential.

It is strongly recommended that soil test results should be discussed with your agronomic consultant or fertiliser supplier when making decisions based on test results.

Phosphorus

Phosphorus requirements will be based on crop yield, stocking rate, production targets as well as soil phosphorus status. When applied as a granular fertiliser phosphorus dissolves rapidly and is then subject to a range of processes in the soil. These include combining with other soil elements (such as iron and aluminium), adsorption to clay and organic carbon particles and leaching. The Phosphorus Buffering Index (PBI) analysis can support soil phosphorus analyses by providing an indicator of phosphorus "tie up" and leaching potential. Higher PBI levels (greater than 150-200 PBI units) indicate potential for a significant proportion of phosphorus applied to be unavailable to plants, while very low PBI values (below 40 PBI units) indicate that there may be potential for phosphorus to leach (these soils generally have low soil phosphorus levels as well).

Nitrogen

Soil nitrogen figures should be used as a guide only as these can change can change quickly with changes in soil temperatures and moisture. Nitrate levels less than 5 mg/kg are consider low, however nitrogen applications should be determined by yield expectations, crop type, soil type, rainfall, past and present management factors etc. Deep soil nitrate testing is the preferred testing as nitrate is highly soluble and can be leached deeper into profiles.

Micro Nutrients (Trace Elements)

Soil test interpretation for trace element deficiencies is difficult as critical concentrations vary between soil types and plants. Availability also varies through the season. Provided the growth status of the plant is not significantly constrained by other factors (e.g. low rainfall) plant tissue analysis can be useful in determining trace element deficiencies. Availability of trace elements will vary depending on a range of factors including; carbonate levels, soil texture, and soil moisture.

Soil Toxicities

There are a number of chemical properties that can be detrimental to plant growth. The impact of Dryland Salinity results from salts in rising ground water tables ending up in the soil. This type of soil salinity often results from the clearance of deep rooted perennial vegetation. It can be managed by either using the water in the topsoil before it reaches the water table (through revegetation or high water use perennial pastures) or lowering the ground water table at the discharge point through improved drainage. Areas which are not influenced by shallow water tables but that have high levels of salt present in the soil profile from historical deposition/regolith weathering are referred to as Dry Saline Land (or "Magnesia patch"). These salts move up and down in the soil profile depending on the level of seasonal rainfall (leaching) and evaporation (capillary rise or "wicking").

Soil salinity can be measured using a salinity meter and a soil-water mixture of 1 part soil to 5 parts water. The electrical conductivity (EC) of the 1:5 soil/water suspensions is measured (dS/m). The reading is then multiplied by a texture based conversion factor to give an estimate of electrical conductivity (ECe). Where ECe is less than 4 dS/m yields will be impacted only on sensitive crops. ECe values above 4 dS/m will affect the yield of many crop species.

Boron

Boron toxicity can occur in dryland cereals where boron levels exceed 15 mg/kg (ppm) and in sensitive crops when exceeding 5 mg/kg. High boron levels are often present at the same depth in the soil profile as elevated levels of carbonates and salinity. This gives an indication of the historic rainfall and depth to which these salts were leached in the soil profile.

Aluminium

High levels of extractable aluminium in soil tests are closely related to soil pH, with low pH (less than 5.0 $CaCl_2$) releasing aluminium in an active form into the soil. Soil test values greater than 4 mg/kg can damage developing plant roots. Increasing the pH of acid soils through the application of lime will make aluminium unavailable for uptake by plant roots.

Reference/Acknowledgements

Modified from: Masters, B., Davenport, D. and Crawford, M. (2013) "SoilSMART: Understanding Your Soils" Field Day Handout, Rural Solutions SA.