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Salinity and sodicity — what's the difference?

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Salinity and sodicity can be major problems in some Australian farming situations. The recent CRDC sponsored forum on these topics attracted a lot of interest and a number of articles will appear in The Australian Cottongrower in this and future issues. But there is often confusion about what the terms actually mean.

Why should cotton growers have a basic understanding of soil chemistry?

Typically 1.5 tonnes per hectare of salt are deposited in the root zone each time an irrigated cotton crop is grown. Much higher values can occur where bore water is used rather than river water. If there is no deep drainage, cotton crops (and associated rotation crops) may begin to suffer adverse affects from this salinity.

And if the salt imported via the irrigation water is sodium dominated, the soil could eventually become more prone to waterlogging because of subsoil sodicity.

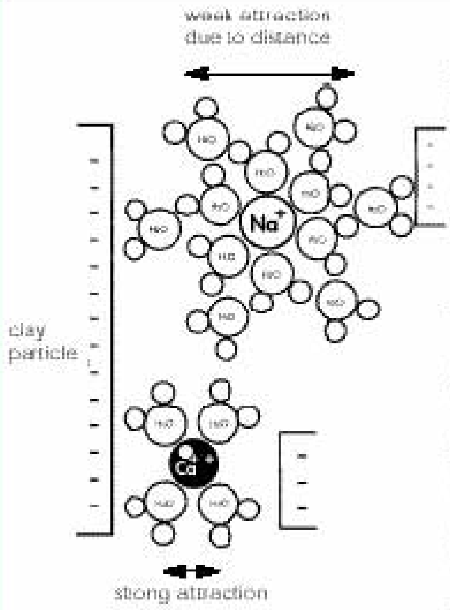
Much of the soil used for cotton production in Australia was naturally sodic before development. The source of the sodium causing these problems apparently was wind-blown material, deposited during severe droughts prior to European settlement.

When it comes to correcting some of these soil problems, farmers can spend a lot of money for little result if they — or their advisors — don't have a sound idea of what they are dealing with.

Some of the commercially available products for sodic soil improvement give 'poor value for money.' For example, lime-based calcium products for soil structure improvement are almost insoluble when the pH of the soil is high. Gypsum is a very effective ameliorant for sodic soil, although it may contain unwanted impurities if produced as an industrial by-product.

To deal with these potential problems, cotton growers — particularly those who use irrigation water — are encouraged to learn more about the

FIGURE 1: Strength of attraction of common soil cations



Na^+: Strongly hydrated ions such as sodium are surrounded by a shell of water which effectively increases their distance from the surface of the particle and decreases the attractive electrical force acting on the ion.

Mg^{2+}: Magnesium is also a highly hydrated ion like sodium, so despite its double positive charge it is held more weakly than calcium due to its distance from the surface.

Ca^{2+}: Calcium is not as strongly hydrated as sodium or magnesium; therefore, the calcium ions are held closer to the surface with consequently greater attraction. The double positive charge also leads to greater attraction.

soil chemistry issues outlined below.

What is a saline soil?

When a soil is referred to as being saline, we are talking about an excess of soluble salts in the soil solution. The soil solution is the liquid located between aggregates of soil. Soil aggregates consist of bound particles of clay, silt, sand and organic matter.

If the concentration of salts in the soil solution exceeds the salt concentration inside plant roots, water tends to move out of the roots via a process called osmosis. This creates an effect referred to as “chemical drought” — plants wilt because of a shortage of water, even though the soil remains moist.

Examples of salts are sodium chloride (common table salt) and calcium sulphate (gypsum). The components of solid sodium chloride (positively charged sodium cations and negatively charged chloride anions) dissociate when added to water — that is, the salt dissolves.

Sodium chloride dissolves easily when added to water, and produces a very concentrated electrolyte solution. Gypsum is only sparingly soluble. Lime (calcium carbonate) is only slightly soluble in water, and becomes even less soluble as the soil becomes more alkaline.

What is a sodic soil?

A sodic soil has too much sodium associated with the negatively charged clay particles. Too much sodium leads to excessive swelling of the soil, which may result in a structural collapse referred to as dispersion. Dispersion is the separation of soil aggregates into the component sand, silt and clay particles.

Dispersive soil is very prone to waterlogging, which can greatly reduce the profitability of cotton growing enterprises. When dry, dispersive soil tends to be too hard for roots and seedlings to penetrate.

Clay particles in soil used for cotton production generally have a negative charge. Like the same ends of two magnets, they will repel each other if moved close together. The clay particles are held together to form aggregates by the presence of positively charged cations (such as sodium or calcium) in the space between the particles.

But sodium ions have only half the positive charge of calcium ions, so the bonds between the clay particles are only weak if the space between them is dominated by sodium ions. Another problem with sodium ions is that they attract, because of their large size, a swarm of water molecules that push the clay particles even further apart and reduce the attractive forces.

The bonds between the clay particles are stronger, and dispersion is reduced, when sodium ions are displaced by calcium ions. Magnesium, despite having a double-positive charge, is less effective than calcium as a binding agent because it also attracts a large swarm of water molecules.

These processes are shown diagrammatically in Figure E4-6 in SOILpak for cotton growers, third edition (Figure 1).

Salinity vs sodicity

The strength of the bond between clay particles is reduced if the salinity of the solution between the soil aggregates is too low. When low salinity water is present in the soil solution — such as just after heavy rain — water tends to move (by the process of osmosis) from the soil solution into the space between clay particles, causing excessive swelling and dispersion. Conversely, the application of saline water will improve soil structure, even if sodium ions lie between the clay particles, but crops usually are unable to take advantage of this situation because of the “chemical drought” effect described earlier.

Gypsum improves soil structural stability by providing a mildly saline soil solution that is not strong enough to adversely affect water uptake by most crops, but which restricts the movement of water molecules into the space between clay particles. Gypsum also contains calcium, which displaces sodium and magnesium from the exchange sites between clay particles.

Where soil pH is below about 6.5 (measured in calcium chloride solution), the use of lime or a gypsum/lime blend may be the most effective and profitable way of dealing with a sodicity problem.

The key factors to monitor when improving soil structural stability are exchangeable sodium and electrolyte concentration. Exchangeable magnesium is important, although on Australian cotton soil there is usually a strong correlation between this factor and exchangeable sodium. Information about cation exchange capacity (CEC) and pH also is needed when designing gypsum/lime/salinity abatement strategies.

Hardsetting soil

Hardsetting soil is prone to soil structural collapse when water is applied, but lacks the shrink-swell potential to regenerate a desirable soil structure via cracking as it is dried. Other hardening processes such as ‘reversible silicate bonding’ may also be involved.

The role of organic matter

Once a soil has been stabilised by calcium ions and an appropriate amount of electrolyte, further stabilisation can be achieved by the addition of organic matter.

In terms of structural improvement, soil with a poor shrink-swell potential has a greater need for organic matter than high-CEC soil. On hardsetting soil, organic matter protects the soil from disruptive forces such as raindrop impact, and provides food for structure-enhancing soil fauna such as earthworms, ants and fungi.

Other soil factors that need to be optimised

The benefits of a farm management program that improves soil structural stability and optimises soil salinity will not be fully realised unless the following issues are dealt with simultaneously.

- Compaction damage from farm machinery and/ livestock needs to be repaired (either by ‘biological deep loosening’ using shrink-swell processes, or with deep tillage), and further damage should be prevented by using modern machinery guidance systems.

- In fields that are too flat, high raised beds are important for the control of near-surface waterlogging.

- Soil and plant tissue testing should be carried out regularly to ensure that there are no deficiencies and/or toxicities of essential nutrients.

- Monitor ‘soil biological health’ so that the risk of soil-borne disease is minimised.

For more information, see SOILpak for cotton growers, third edition (www.cotton.pi.csiro.au/Publicat/Soil).