BASIC COTTON NUTRITION

ORGANIC MATTER AND NUTRIENT CYCLING

Organic matter provides energy to sustain the microbial activity that enables the biological cycling of nutrients between mineral and organic forms. It is also a source of plant nutrients, a site for ion exchange, a chelating agent for metal ions and confers structural integrity to the soil (see SOILpak - chapter E5).

The largest pool of most nutrients is the soil organic matter. Biological activity results in the release of nutrients (mineralisation), which are available for uptake by a crop. The crop and soil microorganisms themselves require nutrients, and convert some mineral nutrients back into organic forms (immobilisation).

The soil organic matter comprises a variety of living organisms (eg plant roots, animals, bacteria, fungi etc) and dead or decaying material (eg crop stubble, humus) from which mineral nutrients are released. Humus is composed of organic material derived from plant and animal cells. It is the end point of microbial activity and is stable and relatively resistant to further biological decomposition. Because the mineralisation process is biological, it is affected by temperature and water conditions – low temperatures and dry soil slow the mineralisation and immobilisation processes. These processes operate concurrently, cycling nutrients between the organic and mineral pools.

ORGANIC MATTER CHELATES NUTRIENTS

Chelates are complexes of organic matter and metal ions (such as zinc, iron, manganese and copper). Chelates can help maintain the supply of these nutrients in a form available to plants. If unchelated, these ions would quickly precipitate out of the soil solution to form insoluble minerals that are not available for crop uptake.

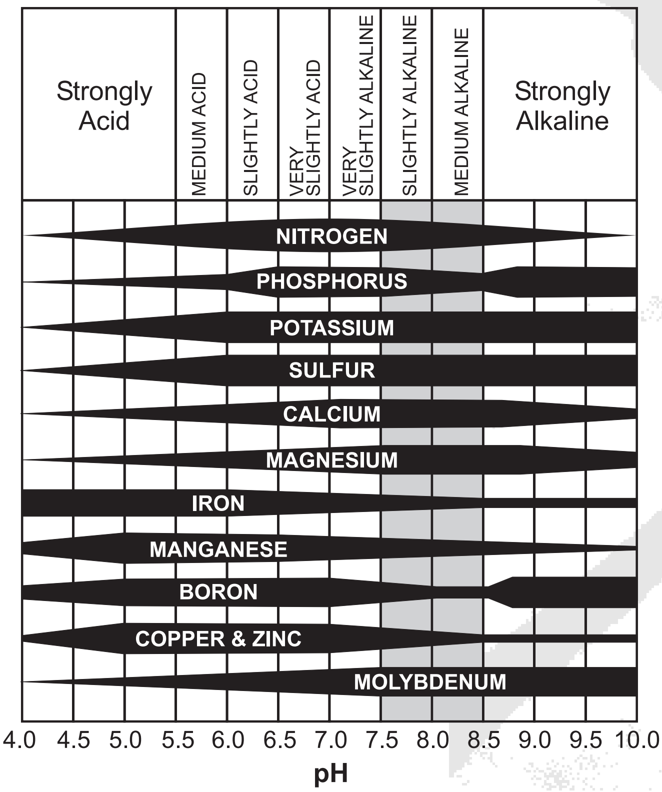
RETENTION OF NUTRIENTS IN SOIL

Clay minerals and organic matter have both positive and negative charges on their surfaces, enabling them to attract and retain both positive ions (cations or metallic ions) and negative ions (anions or non-metallic ions). Humus retains mineral nutrient ions to its charged surfaces in similar fashion to clay particles. It contributes to the cation exchange capacity (CEC) of a soil, although clay will contribute substantially more to the total CEC of the soil. Soils normally contain more negative than positive charges. Anions and cations with more than one charge (+ or –) are retained more strongly by the soil.

CATION EXCHANGE

Cation exchange capacity (CEC) is the ability of soil constituents to attract and retain cations – H^+, Al^{3+}, K^+, Na^+, Ca^{2+} and Mg^{2+}. Soils having high clay and organic matter contents will possess higher CEC than sandy soils of low organic matter content.

Figure 2-1. Soil pH influences the availability of most nutrients. The width of the bar indicates the relative availability of each nutrient as affected by soil pH (after Truog).



ANION EXCHANGE

Anion exchange also takes place on the clay minerals and organic matter (as with CEC) but anions are attracted and retained to the positively charged sites. Anions include nitrate (NO_3^-), chloride (Cl^-), phosphate (PO_4^{3-}) and sulfate (SO_4^{2-}). Anions with single charge (eg nitrate, sulfate and chloride) are more prone to leaching down the soil profile, whereas anions with multiple charges (eg phosphate - PO_4^{3-}) strongly resist leaching.

BASE SATURATION

Base saturation is defined as the total CEC occupied by the cations K^+, Na^+, Ca^{2+} and Mg^{2+}. The base saturation reflects the extent of weathering and leaching that has occurred in the soil. Base saturation is related to soil pH and is an indicator of soil fertility. The availability of the nutrient cations K^+, Na^+, Ca^{2+}, Mg^{2+} to the crop increased with higher base saturation.

SOIL PH

Soil pH governs the equilibrium of chemical reactions in the soil. The availability of nutrients to the plant is also affected by soil pH (Figure 2-1).

Most Australian cotton is grown on cracking clays with a pH of 7.5- 8.5 - under these conditions, the availability of some micronutrients may be low. However, the application of banded fertilizers affects the soil pH in the fertilizer zone, and can temporarily alter micronutrient availability. For example, after the application of anhydrous ammonia, the pH may rise above 9. As ammonia is nitrified to nitrate, the pH in the band may fall to neutral (pH 7). This change in soil pH following the application of nitrogenous fertilizer may improve the availability of some micronutrients.

NUTRIENT SUPPLY TO THE CROP

For nutrients to be absorbed by plant roots from the soil solution, they must come in contact with the plant root surface either by:

- *Root interception:* As roots grow through the soil, they intercept and absorb the nutrient ions they encounter.
- *Mass Flow:* Water moves through the soil to the plant roots as the plant transpires. The nutrients dissolved in the soil water are carried to the root surface as a result of the mass flow of water to the plant root. Nutrients that are abundant in the soil solution (*eg* Ca^{2+} and Mg^{2+}) may be carried to the root by mass flow in sufficient quantities to satisfy the crop's requirement. In contrast, the P concentration in the soil solution is very low, so mass flow contributes a minimal amount of the P required by the crop.
- *Diffusion:* As a plant root absorbs nutrients from the surrounding soil solution, a diffusion or concentration gradient is set up. Nutrients diffuse from areas of high concentration within the soil, to the area of low concentration, near the root.

THE RHIZOSPHERE

The rhizosphere is the zone of soil surrounding the root where soil microorganisms flourish in great abundance, relative to the rest of the soil. Microorganisms proliferate here due to exudation of nutrients, sugars and other materials from the root. The rhizosphere is a zone of intense biological activity and cycling of nutrients.

MYCORRHIZAE (VAM)

Mycorrhizae (vesicular arbuscular mycorrhizae) are soil fungi that form symbiotic relationships with roots of the cotton plant. The fungi improve the supply of nutrients to the plant, which supplies carbohydrate to the fungi. The VAM form networks of fungal hyphae that grow out from the root to distances of 2 cm. This network of greatly assists the crop to take up nutrients because of the greatly increase the volume of soil explored. The uptake of P and Zn is delayed in crops poorly infected by VAM.

Long fallow disorder of cotton is associated with poor mycorrhizal colonisation, since long periods of bare, weed-free fallows or growth of non-mycorrhizal crops reduce the amount of VAM in the soil. The decline in VAM fungi has serious implications for rain grown cotton production, where it is important to fallow fields to store moisture. Inoculation with VAM is not successful. The best means of keeping VAM active in the soil is to keep crops growing in a rotation system with short fallows.

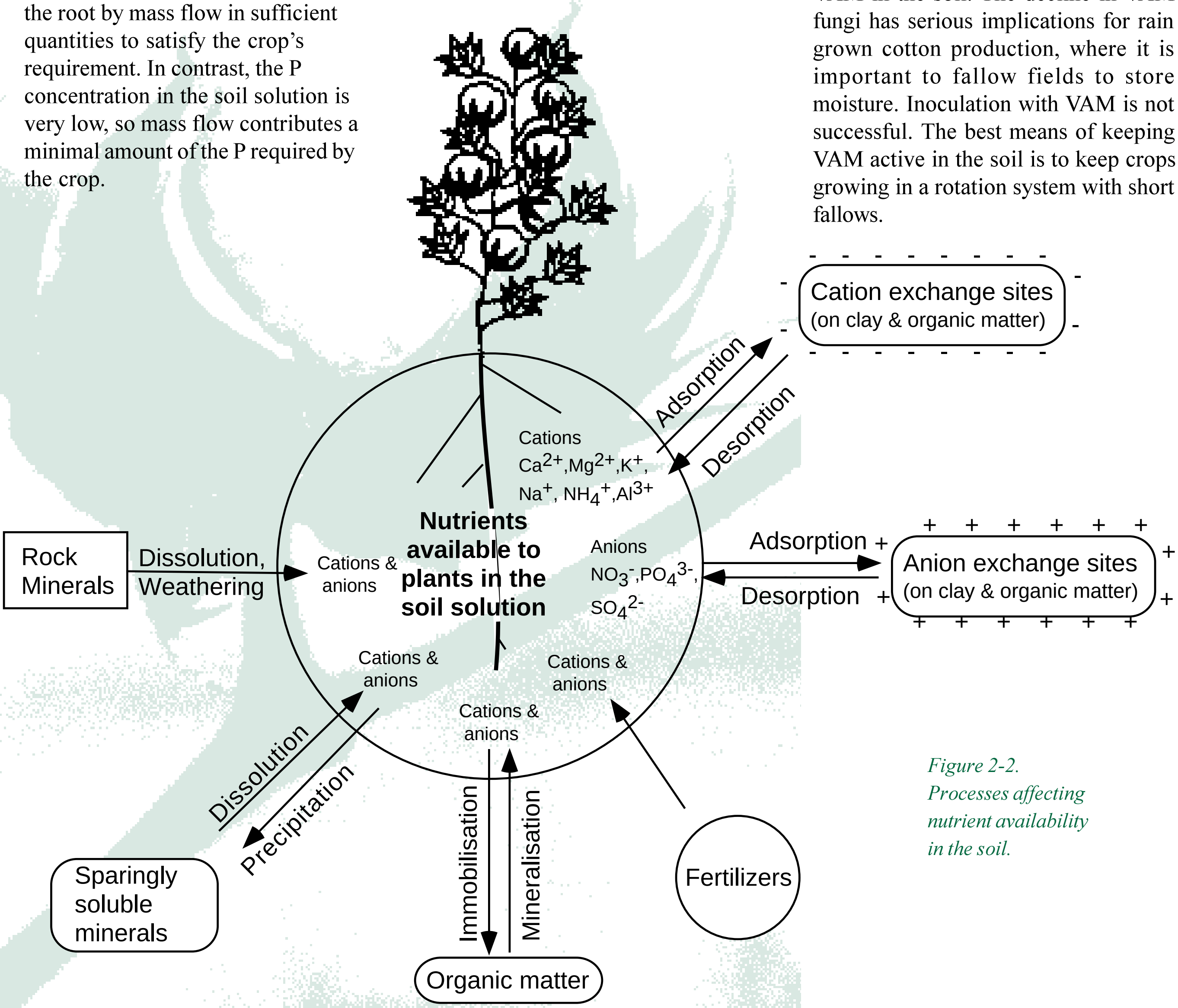


Figure 2-2. Processes affecting nutrient availability in the soil.

NUTRIENT UPTAKE BY COTTON

Cotton takes up nutrients as cations and anions from the water held between soil particles - the soil solution. The plant must expend a considerable amount of energy to take up nutrients. Nutrients are normally in much greater concentration in the plant tissue than in the soil solution. Only a small fraction of the total nutrient content of the soil is found in the soil solution. As nutrients are removed from the soil solution, they are replaced from labile forms held within the soil, which include:

- organic matter
- low solubility minerals
- cation and anion exchange sites on clay particles and organic matter

Processes that release nutrients into the soil solution are usually reversible. Where high concentrations of a nutrient exist in the soil solution (especially after fertilizer application) that nutrient may be precipitated as an insoluble mineral, making it unavailable to the crop until the soil solution becomes depleted (see Figure 2-2). NUTRIpak will outline the processes that apply to individual nutrients in following sections.

FACTORS INFLUENCING NUTRIENT UPTAKE BY COTTON

Nutrient uptake may be restricted where:

- a deficiency of one nutrient will reduce the uptake of other nutrients by limiting crop growth
- nutrient uptake slows as the crop matures and are cycled from vegetative to reproductive organs within the plant
- oxygen is required to maintain metabolic processes including nutrient uptake, hence waterlogging will slow nutrient uptake
- poor soil physical structure (ie compaction) or chemical toxicities in the soil (eg salinity or sodicity) may limit root and shoot growth and nutrient uptake, even where sufficient nutrients are available

Carbon, oxygen and hydrogen make up 90% of the plant's dry matter, but are not considered to be mineral nutrients. In cotton farming systems, deficiencies of N, P, K, S, Mg, B, Zn, Fe and Cu have been identified. The relative concentrations of each nutrient at various stages of growth are listed in the ***Interpretation of soil, petiole and leaf analyses*** chapter of this manual.

NUTRIENT DISTRIBUTION WITHIN THE PLANT

Nutrients vary in their mobility within a plant. Some nutrients have very low mobility and deficiency is seen in new growth. Deficiencies of highly mobile nutrients within the plant are observed in the older growth (Table 2-1).

It is therefore imperative to sample the youngest mature leaf (fully expanded leaf) (normally 5^{th} leaf from the terminal) when assessing crop nutrient status (see section on ***leaf and petiole analysis*** in this manual).

The cotton plant can take up nutrients quickly, as demand requires. The highest demand period for most nutrients occurs from flowering to boll fill (ie during the period of fastest growth). Nutrients are stored in leaf tissue and other organs until required by the developing bolls. Storage is important to provide nutrients to the crop in periods when crop uptake is reduced (eg cloudy weather, waterlogging episodes). This is especially significant for N, P and K where the supply of these nutrients may not be able to meet the demand (eg potassium at boll fill and the premature senescence syndrome). *See the chapter on Premature Senescence in this manual.*

Table 2-1. Nutrient mobility in the plant defines where plant tissues express deficiency symptoms.

Mineral Nutrient	Nutrient mobility within plant	Plant organ where deficiency symptoms usually appear
N, P, K, Mg	High	old leaves
S	Low	Young leaves
Fe, Zn, Cu, Mo	very low	Young leaves
B, Ca	extremely low	Young leaves and terminal