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SOIL REFERENCE BOOKLET FOR THE BUNDABERG DISTRICT

Soil-Specific Nutrient Management Guidelines for Sugarcane Production in the Bundaberg District

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Phil Moody
and Barry Salter




SOIL-SPECIFIC NUTRIENT MANAGEMENT GUIDELINES FOR SUGARCANE PRODUCTION IN THE BUNDABERG DISTRICT

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GLOSSARY OF TECHNICAL TERMS

It is inevitable that specialist and technical words have to be used in this publication. To assist those not familiar with some of these words, we have included a list of technical terms. This can be used as a reference source whilst reading the book.

Acidic cations: Positively charged ions of aluminium and hydrogen that give the soil CEC an acid reaction. Aluminium and hydrogen are always present in large quantities in the soil but they are only present on the CEC and in the soil solution if the soil pH is below 5.5.

Acid saturation: The proportion of the soil CEC occupied by the acidic cations aluminium and hydrogen. It appears on soil tests as aluminium saturation. Low acid saturation is desirable so that more of the CEC is available for storing nutrient cations.

Acid sulphate soils: Extremely acid soils with high levels of S caused by oxidation of iron compounds in the subsoil. These soils become problematic when they are exposed to air by construction of drains or other earth work operations. Under such conditions the sulphide components of the iron compounds are converted to sulphuric acid.

Alluvial: Soils derived from recent stream deposits. These soils dominate floodplains.

Ameliorant: A substance added to soil that slowly improves its nutrient status and physical properties, usually beyond a single crop cycle. Examples are gypsum, lime and mill by-products.

Amino nitrogen: A form of nitrogen found in sugarcane juice that can increase colour in sugar. It is caused by excessive amounts of nitrogen available from the soil or from fertiliser.

Anions: Negatively charged ions such as nitrate, phosphate and sulphate.

Cations: Positively charged ions that are held on to the negatively charged sites on the soil CEC. The major cations are calcium, potassium, magnesium and sodium.

CEC (Cation Exchange Capacity): A measure of a soil's capacity to store and exchange cations. The value of the CEC is dependent on the amount and type of clay and on the amount of humus. CEC is expressed as milli-equivalents per 100 grams of soil (me%).

Clay minerals: The basic building blocks of clay. They are made from the weathered minerals in rocks and include aluminium and silicate layers as well as oxides and hydroxides. (A mineral is a naturally occurring substance that has a definite chemical composition and an ordered structure).

Colour: Soil colour refers to the colour of the soil when it is moist. A simple system using everyday terms is used in this booklet. Soil scientists use a more complicated system in which the colour is matched to a series of standard colours (Munsell Soil Colour Chart).

Compaction: A reduction in pore space in soil (meaning less air space and poorer infiltration rates) caused by machinery traffic and inappropriate tillage.

Critical level: The value for a nutrient in either a soil or leaf test above which a yield response is unlikely to occur when that nutrient is applied.

Decomposition: The breakdown of a complex substance to something simpler. The process can be caused by weathering, chemical change (increased acidification) or biological action.
Deficiency: A nutrient level below the critical level. In extreme cases a deficiency is reflected by plant symptoms such as leaf colour.

Denitrification: The conversion of the nitrate form of nitrogen to a gas. It occurs under waterlogged conditions in the presence of organic matter and suitable bacteria.

Dispersive soil: A dispersive soil usually has a high ESP which causes the soil particles to separate from each other with a resulting breakdown of soil structure.

District yield potential: This is determined from the best possible yield averaged over all soil types within a district. It is defined as the estimated highest average annual district yield (tonnes cane/hectare) multiplied by a factor of 1.2. This enables recognition of differences in the ability of districts to produce cane. The district yield potential for Bundaberg is 120 t cane / ha / year.

DTPA: Chemical used in soil analysis to extract micronutrients from the soil.

ESP (Exchangeable sodium percentage): The percentage of the CEC occupied by sodium. ESP in the topsoil of more than 5% is undesirable as is causes soil structure to breaks down.

Exchangeable nutrients: Essential nutrients (calcium, potassium, magnesium and sodium) present as cations associated with the soil CEC. They have the ability to exchange easily.

Flocculation: The grouping of clay particles which is an essential pre-requisite for the formation of good soil structure.

Horizon: A layer of soil roughly parallel to the land surface which is distinct from the layers above and/or below it. Differences are based on colour, texture, structure or some other property. Surface horizons are often not apparent in agricultural soils because of tillage operations.

Humus: Stabilised soil organic matter distinct from decomposing trash.

Jarosite: A pale yellow potassium iron sulphate mineral (main weathering product of pyrite oxidation).

Leaching: The downward movement of water through the soil and the accompanied movement of soluble nutrients and suspended clay particles.

Massive structure: A soil with no apparent structure. Such soils are very lumpy, difficult to cultivate and set hard when dry.

Micronutrient: An essential nutrient that is required in very small quantities, <10 kg/ha/year, such as copper and zinc.

Mineralisation: The breakdown of humus (stabilised organic matter) and release of nutrients especially nitrogen, sulphur and phosphorus.

Mottles: Patches of lighter or darker colour in soils often indicating the effects of poor drainage.

New land: Land in its first crop cycle of sugarcane.

Nitric K: Potassium extracted with the use of strong nitric acid. It is a crude measure of the potassium reserve in the clay minerals.

Organic matter: Carbon in the soil derived from plant matter. It is composed of carbon, hydrogen and oxygen, but also contains nitrogen, phosphorus and sulphur. In this booklet organic matter is measured as organic carbon (org C) using the Walkley-Black procedure.

Parent material: The material (rock or alluvium) from which soils have formed.

Peds: Aggregates of soil particles, usually only found in undisturbed soil.

Permeability: The ability of soil to drain water through the profile. It is dependent on pore space which is reduced by compaction.

pH: The scale that is used to measure acidity and alkalinity. A pH of 7 is neutral, less than 7 is acidic, greater than 7 is alkaline. In this booklet soil pH is the pH in a 1:5 soil: water suspension.

Plant Available Water Capacity (PAWC): The amount of water in the soil profile within the rooting zone between field capacity (full) and permanent wilting point (dry).

P-sorption: The process by which phosphorus is held tightly onto soil particle surfaces and rendered relatively unavailable to plant uptake.

Pyrite: An iron sulphide mineral often found in tidal swamps and brackish sediments. If submerged, these minerals are relatively harmless. However, when exposed through falling water levels, the pyrite will oxidise to jarosite which forms highly acidifying acid sulphate soil.

Readily Available Water (RAW): The amount of soil water within the rooting zone that can be easily accessed for plant growth. Irrigation management should aim to maintain soil moisture levels in the "readily available" range.

Sodic soil: Soils having high exchangeable sodium levels (see ESP). Such soils have a poor structure, disperse easily and are prone to erosion.

Soil profile: A vertical section through the soil showing the arrangement of soil horizons.

Soil structure: The arrangement of soil particles into aggregates (peds) and the pore spaces between them.

Soil texture: A property that depends on the relative proportions of coarse sand (2 – 0.2 mm), fine sand (0.2 - 0.02 mm), silt (0.02 - 0.002 mm) and clay (< 0.002 mm) but may be modified by organic matter or type of clay minerals.

Subsoil: Soil below the cultivated zone commonly sampled at 40 – 60 cm depth.

Topography: The shape of the landscape including height of hills, general slope and position of drainage lines.

Topsoil: The cultivated zone of soil commonly sampled at 0-20 cm depth.

Toxicity: A high level of nutrient that causes plant injury and/or reduction in growth.

Volatilisation: The loss of ammonia gas from soil, mainly associated with urea applied to the soil or trash surface.

Water holding capacity: The amount of water a soil can hold after drainage.

Waterlogging: The saturation of soil with water so that all air is excluded (anaerobic). Under these conditions denitrification can occur.

Weathering: The decomposition of minerals into different sized particles caused by carbon dioxide, water and biological processes.

INTRODUCTION

In 2003 and 2006 soil reference booklets for the Herbert and Proserpine districts respectively, entitled *Soil Specific Management Guidelines for Sugarcane Production* were produced for cane growers. Those booklets described the basic principles of soil management and presented nutrient guidelines for a range of soils. We are now in the position to present a similar booklet aimed at soil-specific nutrient management in the Bundaberg district. This is based on a methodology developed within an SRDC-funded project (Improved nutrient management in the Australian sugar industry) and research conducted in the area as part of an Envirofund project (Improved adoption of best-practice nutrient management: Bundaberg Sugar Industry).

Our philosophy is that knowledge of soils should form the basis for making management decisions on-farm. Not only does soil type influence decisions on which variety to plant and how much fertiliser to apply, but it also has an impact on the choice of tillage practices, planting techniques, drainage and irrigation requirements, and harvest scheduling. A major objective of this publication is to help growers integrate their knowledge of different soils. This includes the appearance of soils, their occurrence in the landscape, their properties and how they should be managed. Soil-specific guidelines as presented in this booklet represent a much more precise way of managing fertiliser inputs than the traditional “one size fits all” approach. It provides a benchmark against which soils and soil analyses can be compared. However, it is not intended as a substitute for on-farm soil and leaf testing. Ideally each block on the farm should be sampled every crop cycle for both soil and leaf analyses. A system of record keeping should also be implemented which records nutrient inputs, changes in soil fertility, and crop productivity and profitability.

This philosophy is particularly appropriate for the current circumstances in the Australian sugar industry. The escalating costs of fertiliser, the need to reduce production costs and mounting environmental pressures demand responsible soil and nutrient management. The guidelines in this booklet are aimed at providing best-practice soil and nutrient management for Bundaberg cane growers. Use of these will not only maintain or improve crop yields and soil fertility, but will also provide opportunities for cost reductions whilst enhancing sustainability and delivering positive environmental outcomes by minimising possible off-site nutrient movement.

CHAPTER 1

Introduction to Bundaberg soils and their properties

Sugarcane in the Bundaberg area is grown on a wide variety of soils. The range of soil properties is caused by factors such as climate, parent material, topography and the action of organisms. The rock types in the catchment influence the mineralogy and nutrient status of soils and clays that form by weathering. Through processes of erosion and sediment transport, soil material gradually moves down slope and into streams and rivers where it is mixed. During flood events sediment is deposited on floodplains. Thus the geological composition of catchment has a major bearing on the type of soils that form in floodplain locations. Time is also a critical component of soil formation. Ancient floodplains that are now above river flood levels will be affected by weathering processes and will have lower levels of soil nutrients. Knowledge of how soils form is important in understanding soil fertility, soil chemical and physical properties, and reactions between soils and fertilisers.

Soil formation and distribution

The Bundaberg area can be divided into four broad landform patterns based on geological history. These are:

1. Coastal and marine plains.
2. River alluvial plains (along the Burnett and Kolan Rivers and their tributaries).
3. Plains and low hills on sedimentary rocks.
4. Plains and low hills on basic volcanic rocks.

Coastal and marine plains consist of beach ridges, sand dunes and swales caused by wind and wave deposition. They also have large areas of marine sediments deposited during a period when the sea level was several metres higher than present. Acid sulphate soils can occur in the swales and often underlie the beach ridges. High ground water levels occur in this area and a network of drains has been constructed to lower the water table. There are two main soil groups: black sands with dark sandy topsoils overlying pale sandy subsoils, and poorly drained clays with black organic topsoils. Drainage of these poorly drained clay soils for sugarcane production has caused the sulphur compounds in these soils to oxidise and form large amounts of sulphuric acid – a common characteristic of acid sulphate soils.

The **river alluvial plains** of the Burnett and Kolan Rivers were formed by deposition of sediment from these rivers. The youngest sediments occupy the lowest part of the landscape adjacent to current stream channels. Older alluvial deposits are up to 5 m higher and were deposited when sea levels were higher than present. The floodplain soils can be grouped according to their position in the landscape. Since the coarsest sediments are quickly deposited when rivers are in flood, soils found on active levees close to the main rivers tend to be sandy and well drained. Soils dominated by finer particles occur away from the rivers in back plains and swamps. These heavy textured soils are often poorly drained due to their high clay content.

The **sedimentary rock formations** include sandstone, siltstone, mudstone, shale and conglomerate. The soils developed on these formations are related to the rock type and degree of weathering. For example, red, yellow and grey sandy loams have formed on deeply weathered coarse grained sedimentary rocks, predominantly sandstone. Similarly, red and yellow clay loams occur on deeply weathered fine grained sedimentary rocks such siltstone, mudstone and shale.

The **basic volcanic rocks** are associated with Quaternary basalt centred on the Hummock and Tertiary basalt in an area east of Gin Gin. These deposits give rise to deep red, brown and black soils with a moderate structure.

Position in the landscape

Because of the interactive effect of the soil-forming factors, the existence of soils with specific characteristics is predictable in the landscape. Soils differ according to their position in the landscape and due to the interaction between topography, geology and climate. For example, a typical sequence of soils on weathered sedimentary rocks consists of red clay loams on the upper slopes, yellow clay loams lower down, and grey sandy loams on the lower slope. On the volcanic rocks the sequence is red clays on the crest, brown clays lower down, and black cracking clays in the depressions.

Soil field properties

In recognising the existence of a range of soil types, it is possible to classify them according to complex scientific systems. However, recognition of basic soil field properties such as colour, texture, structure, depth and position in the landscape enables the separation of soils into 'user-friendly' soil types. Soil type used in combination with soil chemical properties (from soil tests) will enable growers and their advisers to make informed decisions about appropriate nutrient management strategies on-farm.

Colour

The colour of soil is determined by the amount of organic matter present, iron oxide levels and the degree of aeration / moisture content. Dark coloured soils have more organic matter than lighter-coloured soils. Well-drained soils have red or brown colours whereas poorer drainage is indicated by paler colours ranging from yellow, grading through to grey, light grey and even blue in very poorly drained soils. Bleached horizons (containing little organic matter or iron) with mottles are indicative of seasonal saturation and intense leaching. The mottles form around larger soil pores and root channels where there is some oxygen. The colours referred to in this booklet relate to soils that are moist.

Soil Texture

This is an important soil property as it affects soil structure (see below), the capacity of soil to hold air and water, the amount and availability of nutrients, and many chemical properties. Management issues such as workability, trafficability, erodibility and root development are also associated with soil texture.

Soil texture is a measure of the relative proportions of the various sized soil particles present. While the largest particles include gravel and sand, the smallest particles are referred to as clay. Silt particles are moderate in size. Soils are classified as sand, loam or clay depending on the proportions of these basic components. Clay particles, with their large surface area and negative charge, are the most reactive constituents of the soil. They give soils the ability to store positively charged nutrients such as potassium, sodium, calcium and magnesium. The fine pores between the clay particles also allow them to store large volumes of water. Actual texture (particle size distribution) can be determined in the laboratory. Alternatively, soil texture can be estimated in the field using the guidelines provided in Appendix 1.

Structure

Structure is the natural aggregation of the soil particles (sand, silt and clay) and organic matter into units called peds (aggregates). These peds can differ markedly in terms of size, shape and level of stability. Their presence in soil affects the way soils behave, the growth of plants and the manner in which we manage the soil. For instance, while some structure is essential to enable soil stability and good water-holding characteristics, large and strong structural units in the soil can prevent root penetration and negatively affect tillage operations.

Soil horizons

Soils develop different horizons or layers in their vertical sections. Horizon development varies with the type of soil parent material, organic matter, and the influence of water through leaching / flooding. Each horizon has characteristics which relate to soil colour, texture and structure that distinguish it from the horizons above and below it. Farming activities mix together the surface horizons, which we refer to as topsoil. Material below this is referred to as subsoil. In the Bundaberg cane producing soils the top 20cm is generally considered mixed topsoil and the 40-60cm depth increment is usually well within the subsoil.

Chemical Properties

Clay particles and soil organic matter are largely responsible for the chemical properties of soils due to their reactivity and their small particle size which results in a large surface area.

Cation Exchange Capacity

Cation Exchange Capacity (CEC) refers to the amount of negative charge on clay and organic matter particles that attracts positively charged chemicals called cations. The most common cations in soil are calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) and aluminium (Al). As these cations are held electrostatically, they are not easily leached but can be exchanged for other cations enabling plants to have access to them. Soils in the wetter tropical areas generally have lower CEC's than soils in cooler or drier areas as they are more highly weathered. As they become more acid due to ongoing leaching their CEC's are commonly reduced. The CEC of soils in this booklet is defined as the Effective Cation Exchange Capacity (ECEC) which is the sum of the exchangeable cations (K^+, Ca^{2+}, Mg^{2+}, Na^+, Al^{3+} and H^+) as measured in the laboratory. The ECEC is classified as very low (less than 2 me%), low (2- 4 me%), medium (4 – 8 me%) or high (more than 8 me%).

Organic Matter

Soil organic matter is derived from the breakdown of plant and animal matter. It also has the ability to attract nutrients and has a greater cation exchange capacity than a similar mass of clay. Dark colour and good structure are indicators of high organic matter. Soils in the Bundaberg district have organic C contents of up to 2.7%. Organic matter, measured as organic carbon %, improves soil structure and is a source of nitrogen (N), phosphorus (P), sulphur (S) and trace elements. There is no optimum level of organic matter, but it is best to maintain it at the highest possible level. The organic matter content of a soil is determined by the balance between inputs of organic matter forming material and the breakdown (mineralisation) of the existing stabilised soil organic matter (humus). Green harvested sugarcane inputs about 10-15 t/ha in trash and 3 t/ha in roots per year, but 80% percent of this is lost by decomposition in the first year. In soils with low clay content, organic matter is the chief store for exchangeable cations. Organic matter is a major source of N which is released by mineralisation (the process in which organic matter is broken down into its mineral components). The potential amount of N released from specific soils can be estimated using an N mineralisation index. This index is used to guide nitrogen fertiliser recommendations.

As mentioned earlier, building organic matter levels is difficult in tropical soils due to rapid decomposition rates. Breakdown of organic matter is enhanced by cultivation. Trash conservation following green cane harvesting and the use of fallow green manure crops are the major ways organic matter can be added to soil in sugarcane farming systems. Other methods of maintaining soil organic matter include reducing tillage operations, preventing soil erosion and use of imported organic matter sources such as mill mud, mud / ash and bagasse.

Acidity and soil pH

Acidity in soils is caused by excessive hydrogen (H) and aluminium (Al) ions on the cation exchange sites. Acidity is expressed in terms of pH: pH values less than 7 are acidic whilst those more than 7 are alkaline. Soil tests commonly include two measures of acidity: pH in water (pH_{water}) and pH in calcium chloride solution (pH_{CaCl2}). In this booklet we only consider pH in water. Soil pH values greater than 5.5 are desirable for plant growth in the Bundaberg district. Under acidic conditions, Al is present in its soluble form and is toxic to most plants. Fortunately, Australian sugarcane varieties are fairly tolerant to high levels of Al. However, this does not apply to legume crops which may be grown as fallow crops. Consequently regular additions of lime are essential particularly if legume crops are going to be part of a farming system on acid soils. Increased acidity (lower pH) is associated with reduced availability of N, P and S, while micro-nutrients such as copper (Cu) and zinc (Zn) will become more available.

Low pH may reduce the CEC of some soils and causes the soil CEC to be dominated by the acidic cations H^+ and Al^{3+}. This reduces the storage capacity for nutrients such as Ca, Mg and K and can be critical particularly on sandy soils with low CEC. Soil acidification is a natural process which is accelerated by the leaching of nitrate from nitrogen fertilisers and the removal of cane to the mill. Regular use of liming materials will reduce soil acidity, neutralise applied acidity arising from nitrogen fertiliser use and replace Ca and Mg (if using Mag lime or dolomite) withdrawn in the harvested crop.

Flocculation
Clay particles can remain suspended in water or they can flocculate and settle. Soils with their CEC dominated by calcium, magnesium and aluminium ions flocculate well and do not disperse easily in water. However, sodium dominated soils with an exchangeable sodium percentage (ESP) greater than 5% are unstable when wet and disperse. Clays that disperse readily fill-up pore spaces and reduce permeability to both air and water.

Sodicity, salinity and acid sulphate soils
Sodic subsoils restrict rooting depth, reduce soil water availability to roots and may increase susceptibility to surface erosion. Salinity is an issue for sugarcane grown on coastal and marine plains, and inland area where water tables are above 0.5 m causing salt accumulation in mid and lower landscape positions. Acid sulphate soils also exist in this region.

Plant nutrition

Plants require 16 elements for optimum growth. Carbon (C), hydrogen (H) and oxygen (O) are supplied from air and water. The other mineral elements can be divided into three groups: macronutrients (nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulphur (S) and magnesium (Mg)) which are required in relatively large amounts (20 – 200 kg/ha), micronutrients (iron (Fe), copper (Cu), zinc (Zn), molybdenum (Mo), manganese (Mn), boron (B), and for some plants sodium (Na)) which are required in small amounts (less than 10 kg/ha/crop). Silicon (Si), which is considered beneficial for plant growth, is required in fairly large quantities. All of these nutrients are naturally available in soils. Some soils are able to supply more of a particular nutrient than other soils. Fertilisers and soil ameliorants are used to supplement these supplies of nutrients and prevent the mining of nutrients stored in our soils.

Nitrogen (N)
Past research suggests that a crop of sugarcane requires about 1.4 kg N /tonne cane up to 100 tonnes cane per hectare and 1.0 kg N/ha thereafter. In order to achieve sustainable crop production, maximum use must be made of all the available N sources within the N cycle (Figure 1.1). To do this it is important to have an understanding of the transformations of N from one form to another.

Mineralisation of organic matter to ammonium and nitrate is on-going and the amount released depends on the amount of organic matter and microbial activity. The rate of mineralisation is also dependent on temperature and moisture and will therefore vary through the year according to climatic conditions. However, irrespective of the actual rate of mineralisation, this N is available for plant uptake and should be taken into account when nitrogen requirements are calculated. Nitrate levels fluctuate considerably in the soil. They rise substantially after cultivation in some soils (those high in organic matter) and after fertilisation. They are reduced by crop removal and after heavy rainfall (by leaching and runoff) and waterlogging (denitrification). Ammonium-N is subject to volatilisation, a loss often associated with urea applied to the surface of a trash blanket. More detail is provided on these processes in Figure 1.1.

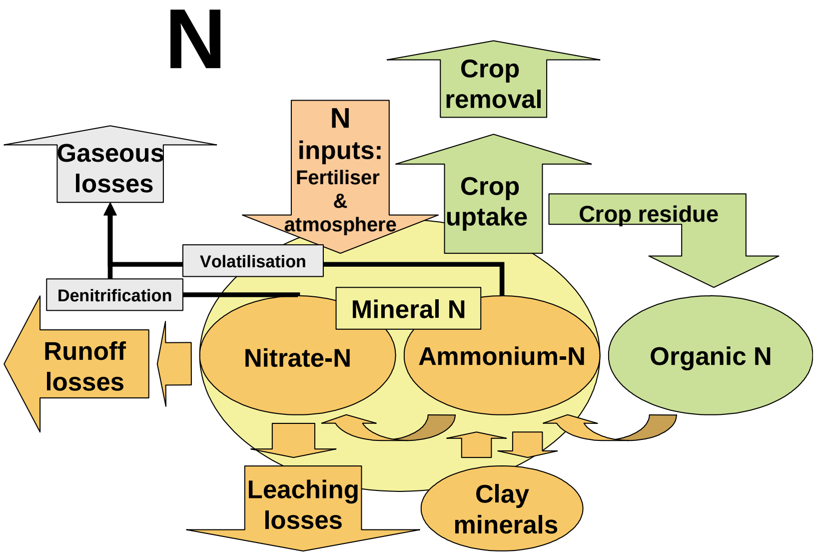

Figure 1.1 Schematic diagram of the nitrogen cycle

As it is important to minimise nitrogen losses, the following strategies are suggested:

- Apply nitrogen according to the specific requirements of different soils based on their N mineralisation index (as shown in Chapter 2).
- Reduce nitrogen losses from leaching, runoff and denitrification by splitting applications of nitrogen and avoiding applications just before the wet season.
- Reduce the potential for denitrification by improving drainage and placing fertiliser on the cane row where waterlogging is less likely.
- Reduce the potential for ammonia volatilisation when urea is applied to the surface of a trash blanket by delaying application until a cane canopy has developed. Applying the urea below the soil surface removes the possibility of losses by volatilisation but could increase the risk of loss by denitrification if waterlogging occurs.

Phosphorus (P)

Phosphorus cycles between the various forms in soil (Figure 1.2), with some forms being more readily available than others. In some soils with high clay and / or organic matter content, phosphorus is held tightly onto soil particle surfaces by a process called P sorption. More P fertiliser needs to be applied when P is strongly 'sorbed' as this P is relatively unavailable to plants. A new soil test, known as the Phosphorus Buffer Index (PBI), is now available to measure how strongly different soils sorb added phosphorus.

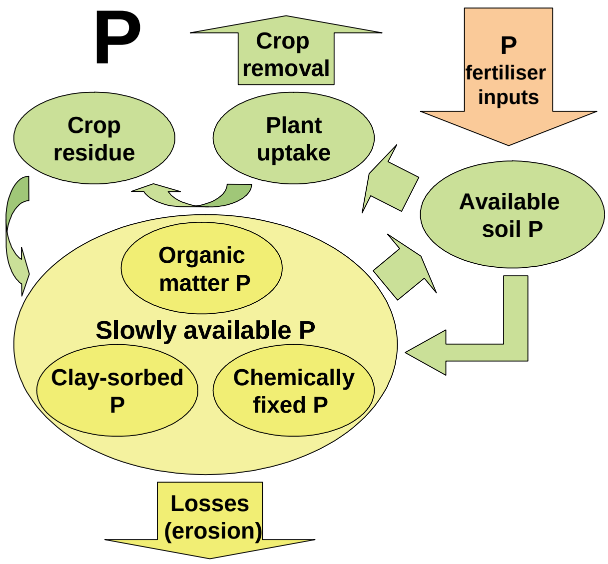

Figure 1.2 Soil phosphorus cycle

Potassium (K)
Sugarcane needs potassium in large quantities mainly for the maintenance of water balance. On average 150 kg K/ha is removed each year in the cane harvested and sent to the mill. Plants luxury feed on potassium where surplus is available. Potassium is present in a number of distinct forms within soils. A schematic diagram of the potassium cycle is shown in Figure 1.3.

Lattice K is part of the clay structure and in some soils can represent a major part of the total K in the soil and provide a source of plant available K. Slowly available non-exchangeable K exists in some K minerals and this can also act as a source of exchangeable and solution K (plant available forms). Potassium losses are possible with leaching of exchangeable and soil solution K, particularly from sandy soils and by erosion, which results in losses of lattice and non-exchangeable K reserves.

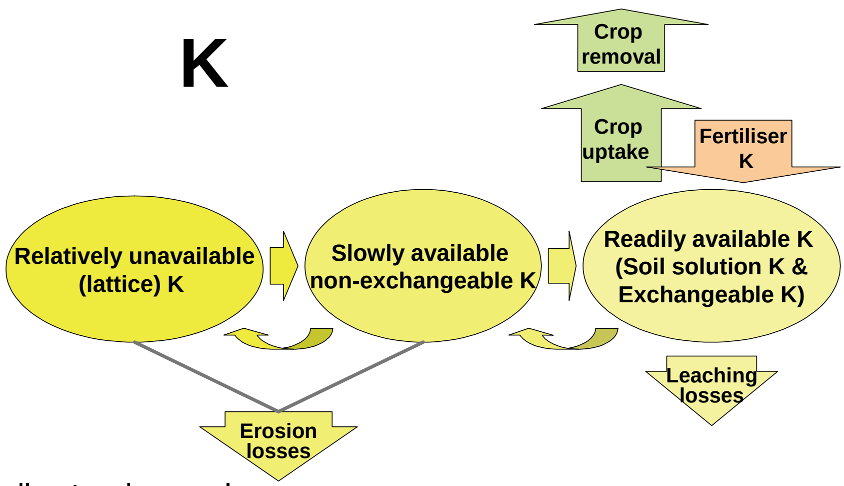

Figure 1.3 Soil potassium cycle

Calcium (Ca)
Calcium is essential for cane growth and for cell wall development. It is taken up as a positively charged cation from the soil solution. Soil reserves of Ca, which are held on the CEC, are supplemented by additions of liming materials and by gypsum. A cane crop removes about 30 kg Ca/ha/year but when applying lime, considerably more Ca than this is applied because of the need to control soil acidity.

Magnesium (Mg)
Magnesium is essential for plant photosynthesis, as it is the main mineral constituent of chlorophyll. Like calcium, it is taken up from the soil solution and from the CEC, and total uptake is similar to calcium.

Sodium (Na)
Sodium is required in very small amounts for the maintenance of plant water balance. It is stored on the CEC and can be taken up from the soil solution by plants. Sodium is readily supplied from rainfall, particularly in coastal areas. It can have a detrimental effect on soil structure even at low levels (ESP of around 5%) and at higher levels (ESP above 15%) can restrict plant growth and root development.

Sulphur (S)
Sugarcane requires sulphur in relatively large amounts of about 25 kg S/ha/year, which is used for plant structure and growth. Plants take up sulphur as sulphate which is more mobile in soils than phosphate and is therefore subject to leaching. Consequently fertilising may need to supply more than that harvested in the crop. The main store of sulphur in soils is organic matter. The release of sulphur from the mineralisation of soil organic matter should be allowed for when developing fertiliser recommendations. Other natural sources of sulphur are rainfall and irrigation.

Micro-nutrients

Micronutrients are taken up by cane in much smaller quantities than the nutrients already mentioned and are generally regulators of plant growth. Both copper (Cu) and zinc (Zn) have been shown to be deficient in some Bundaberg soils, particularly low organic matter sandy soils, whereas iron (Fe) and manganese (Mn) are usually well supplied. Little is known about the status of molybdenum (Mo) and boron (B) in Bundaberg soils.

Silicon

Deficiencies of silicon (Si) have been detected in Bundaberg, particularly on very sandy soils on sedimentary rocks.

CHAPTER 2

Principles for determining nutrient management guidelines

When developing nutrient management guidelines for the different soil types in the Bundaberg district the following factors were taken into account:

- Crop yield potential.
- Nutrients removed in the harvested crop.
- Nutrients returned to the soil in trash, fallow crops and mill by-products.
- Nutrients released by the mineralisation of soil organic matter.
- Nutrients released by the weathering of soil minerals.
- Nutrients fixed (held tightly) on soil particle surfaces.
- Soil acidity.
- Critical levels of nutrients as determined by soil analysis.
- The balance and interactions of different nutrients, particularly those on the soil CEC.
- The risk of nutrient loss processes occurring.

A wide range of soil physical and chemical properties were used to assist this process. These data were obtained from the analysis of samples taken from the soil reference sites and from a DNR report on Bundaberg soils. They were used to produce the bar graphs for each soil type in Chapter 3 and include:

- Soil particle size distribution, particularly clay % (soil texture).
- Soil organic carbon % (a measure of organic matter).
- Nitrogen mineralisation index (a measure of the amount of N released from the breakdown of soil organic matter).
- Soil pH (a measure of soil acidity).
- Cation exchange capacity (CEC).
- Exchangeable K, Ca, Mg and Na (cations held on the soil CEC).
- Nitric K (a crude measure of K reserves).
- Exchangeable sodium percentage or ESP (the % of the CEC occupied by sodium).
- Exchange acidity (a measure of acidic cations held on the CEC).
- Acid saturation (% of the CEC occupied by acidic cations).
- BSES and Colwell P (indices of available phosphorus).
- Phosphorus Buffer Index - PBI (a measure of the degree to which added P is held tightly onto soil particle surfaces and is unavailable for plant uptake).
- Sulphur, copper and zinc.

Nitrogen (see Wood and others, 2003; Schroeder and others, 2006)
Nitrogen guidelines are now based on a combination of **district yield potential** and **soil N mineralisation index**. The district yield potential is determined from the best possible yield averaged over all soil types within a district and is defined as the estimated highest average annual district cane yield (tonnes cane/ha) multiplied by a factor of 1.2. The district yield potential for Bundaberg is 120 tonnes cane/ha (estimated highest average annual yield of 100 tonnes cane/ha multiplied by 1.2). This concept of district yield potential recognises differences in the ability of districts and regions to produce cane. For example, the Burdekin region with its fertile soils, higher temperatures and access to water, has a higher yield potential than many other districts.

The district yield potential is used to establish the base N application rate according to an estimate, previously developed by CSIRO scientists. Accordingly, 1.4 kg N per tonne of cane is required up to a cane yield of 100 tonnes/ha and 1 kg N per tonne/ha thereafter. With the new approach however, inputs are adjusted according to the N mineralisation index, which is based on soil organic carbon (%) and is related to soil colour. Generally the darker the soil, the more organic matter is present. Seven N mineralisation index classes are recognised (very low, low, moderately low, moderate, moderately high, high and very high). With the district yield potential for the Bundaberg district set at 120 tonnes cane/hectare, the baseline N application rate is 160 kg N/ha. Adjustment to take account of the contribution of N from the soil organic matter (according to the N mineralisation index) results in a set of guidelines for N fertiliser inputs as shown in Table 2.1. If a sub-district or farm **consistently** produces higher yields than the district yield potential, the baseline N application rate should be adjusted upward by 1 kg N per tonne of cane above the district yield potential. For example, if the average yield on a farm in the Bundaberg district, calculated over a ten year period, is 130 tonnes cane/hectare, then the baseline N application rate should be set at 170 kg N/ha. The N application rates based on the soil organic carbon would then be 10 kg N/ha greater than those shown in Table 2.1. The N application rates for replant or ratoon cane, in this case, would be 170 kg N/ha for soils with organic carbon content of < 0.4%. Where the organic carbon content exceeded 2.4%, the appropriate N application rate would be 110 kg N/ha. Conversely, if a sub-district or farm **consistently** produces lower yields than the district yield potential, the baseline N application rate should be decreased using the same approach.

Table 2.1 – N mineralisation index and suggested nitrogen rates for replant and ratoon crops
(see Schroeder and Wood, 2001)

N mineralisation index	Organic Carbon %	Suggested N rate for replant and ratoons
VL	<0.4	160
L	0.4 - 0.8	150
ML	0.8 - 1.2	140
M	1.2 - 1.6	130
MH	1.6 - 2.0	120
H	2.0 - 2.4	110
VH	>2.4	100

After determining the appropriate N application rate in this way, further discounting is required to recognise the contributions of other sources of N. These sources include N from legume fallow crops, harvested legume crops and application of mill by-products and nitrogen remaining in soil after small crop production.

Determining N application rates for sugarcane following legume fallows (see Bell and other, 2003; Garside and Bell, 2001)
Unlike N held in soil organic matter, legume N is readily available for plant uptake and should be treated the same way as fertiliser nitrogen for the purposes of calculating nitrogen requirement. Information published by scientists working in the Yield Decline Joint Venture has provided details on how to estimate the amount of legume N being returned to the soil from a legume crop. The amount of N available to the succeeding sugarcane crop will be dependent on the type of legume, how well it was grown and whether the grain was harvested. A summary of the calculations for various legume fallows is shown in Table 2.2. This information can then be used to adjust the amount of nitrogen fertiliser required for the different soils following different legume fallows. The values shown in **BOLD** in Table 2.2 are used as examples in Table 2.3.

Table 2.2 - Calculation of N contribution from a fallow legume as supplied by the Sugar Yield Decline Joint venture (see Schroeder and others, 2005)

Legume crop	Fallow crop dry mass (t/ha)	N (%)	Total N contribution (kg N/ha)	N contribution if grain harvested (kg/ha)
Soybean	8	3.5	360	120
	6		**270**	**90**
	4		180	60
	2		90	30
Peanut*	8	3	n/a	125
	6			100
	4			65
	2			25
Cowpea	8	2.8	290	100
	6		220	75
	4		145	50
	2		**70**	25
Lablab	8	2.3	240	80
	6		180	60
	4		120	40
	2		60	20

* MJ Bell, 2007

Table 2.3 – Effect of fallow management on N requirement (see Schroeder and others, 2005)

Crop	N mineralisation index						
	VL	L	ML	M	MH	H	VH
Replant cane and ratoon after replant	160	150	140	130	120	110	100
Plant cane after a grass/bare fallow	140	130	120	110	100	90	80
Plant cane after a poor legume crop (e.g. 2 t/ha cowpea green manure: N rate minus **70** kg N/ha)	90	80	70	60	50	40	30
Plant cane after a good legume crop (e.g. 6 t/ha soybean: N rate minus **270** kg N/ha)	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Plant cane after a good legume crop harvested for grain (e.g.6 t/ha soybean: N rate minus **90** kg N/ha)	70	60	50	40	30	20	10
First ratoon after a good legume crop*	160	150	140	130	120	110	100
Second ratoon after a good soybean/cowpea crop	160	150	140	130	120	110	100

***** Data from the Yield Decline Joint Venture and BSES trials suggest that N applied to the first ratoon sugarcane crop after a good legume crop can possibly be reduced. The reduction in N applied will depend on several factors which include legume residue management, soil type, climate and tillage practices.

Modifying N application rates for sugarcane where mill by-products have been used

The amount of N applied needs to be discounted for up to 3 years after application of mill by-products. The amount of N to be subtracted from N application rates following the use of mud and mud/ash mixture is as follows:

Product	Application rate	To be subtracted from the appropriate N application rate		
		Plant crop	First ratoon	Second ratoon
Mill Mud	150 wet t/ha	80 kg N/ha	40 kg N/ha	20 kg N/ha
Mud/Ash	150 wet t/ha	50 kg N/ha	20 kg N/ha	10 kg N/ha

Adjustments of N rates following small crops

Unlike the situation following a legume crop, soil testing for mineral N (ammonium and nitrate) is appropriate when assessing the amount of residual N in a block following the harvest of a rotational small crop. This is often worthwhile as the amount of N can be substantial due to the relatively high fertiliser applications that are used with small crops and the fact that the fertiliser N is sometimes not fully utilised by these crops. Soil samples for this purpose should be taken after the small crop is harvested but before the cane is planted.

It should be noted that soils usually contain some mineral N (due to ongoing mineralisation of organic matter and normal residual sources). Hence the ammonium and nitrate N soil test values will reflect both this 'normal' mineral N and any additional N remaining after the small crop. It is therefore important to subtract the 'normal' mineral N from the soil test before determining appropriate N applications for sugarcane after a small crop. 'Normal' mineral N generally increases with organic C and the N mineralisation index as shown in Table 2.4.

Table 2.4 - Estimate of the residual N found in soil before the plant crop
(see Schroeder and others, 2005)

N mineralisation Index	VL	L	ML	M	MH	H	VH
Soil Org C (%)	0 - 0.4	0.4 - 0.8	0.8 - 1.2	1.2 - 1.6	1.6 - 2.0	2.0 - 2.4	>2.4
Estimate of mineral N (mg/kg)	5	10	14	18	20	22	24

To determine the amount of additional residual N in the soil (in mg/kg or ppm), subtract the appropriate value in Table 2.4 from the combined soil nitrate and ammonium N indicated in the soil test report. The resulting number is then multiplied by a factor of 2 (to allow for soil bulk density and a depth of 0 - 20 cm) to convert it to kg N/ha. This amount needs to be subtracted from the suggested N application rate in Table 2.1 to determine the fertiliser N requirement.

For example: A crop of zucchinis have recently been harvested from a block which is to be planted to sugarcane. A soil test indicates that the soil has an organic C content of 1.17% and the presence of 38 mg/kg nitrate N and 6 mg/kg ammonium N. What is the appropriate N fertiliser application rate?

- From Table 2.1, a soil with 1.17% organic carbon has a suggested N rate of 140 kg N/ha (N mineralisation index is moderately low (ML)).
- Mineral N (nitrate and ammonium) = 38 + 6 = 44 mg/kg.
- Additional residual N = 44 - 14 (from Table 2.4) = 30 mg/kg. This is then multiplied by 2 to give 60 kg N/ha.
- Appropriate N application rate = 140 - 60 = 80 kg N/ha.

Phosphorus

Two techniques are used to decide how much P fertiliser is required. Firstly a BSES critical level is used to determine the quantity of P fertiliser required. This is then modified by the soil's ability to fix added P (P sorption), which determines how much of the fertiliser P will be available to the crop. The P sorption class of each soil is based on the Phosphorus Buffer Index (PBI) which is measured in the laboratory (Table 2.5). It can also be estimated from the clay % and organic matter content of a particular soil (Table 2.6).

Table 2.5 - P sorption classes based on PBI (see Burkitt, 2000)

P sorption class	PBI
Low	< 140
Moderate	140 - 280
High	> 280

Table 2.6 - P sorption classes based on Org C (%) and texture class
(see Wood and others, 2003)

% Org C	**Sand** (<24% clay)	**Loam** (24-36% clay)	**Clay** (>36% clay)
<0.6 %	Low	Low	Moderate
0.6 - 1.2 %	Low	Moderate	Moderate
1.2 - 1.8 %	Moderate	High	High
>1.8%	High	High	High

Clay % is not given on most soil tests but can be estimated from a soil texture determination. If that is not available then an estimate of texture can be made from the cation exchange capacity of the soil as shown in Table 2.7.

Table 2.7 - Estimate of soil texture class from CEC

CEC (me%)	**Texture class**
<4	Sand
4 - 8	Loam
>8	Clay

Currently, some older sugarcane areas do not require any P fertiliser due to their long history of P fertilisation. New land, on the other hand, is often deficient in available P with BSES P values less than 5 and requires P fertiliser in the first crop cycle (Table 2.8). The guidelines in Table 2.8 are based on a combination and subsequent re-interpretation of information supplied by Calcino (1994), Bramley and Wood (2000) and Burkitt and others (2000).

Table 2.8 - Phosphorus guidelines for old and new land (see Schroeder and others, 2006)

BSES P in soil test (mg/kg)	**P sorption class**	**Suggested phosphorus application** (kg/ha)	
>60	All	Nil P for at least 2 crop cycles	
50 - 60	All	Nil P for 1 crop cycle	
		Plant	**Ratoon**
40 - 50	Low	20	0
	Moderate	20	5
	High	20	10
30 - 40	Low	20	10
	Moderate	20	15
	High	20	20
20 - 30	Low	20	10
	Moderate	20	20
	High	30	25
10 - 20	Low	30	15
	Moderate	30	20
	High	40	30
5 -10	Low	30	20
	Moderate	40	30
	High	50	40
<5	Low	40	20
	Moderate	60	30
	High	80	40

Discounts should be made where mill by-products have been used, because they are a source of P.

Mud and Mud/ash mixture (applied at 150 wet t/ha)
Apply nil P for at least 2 crop cycles

Potassium

Potassium fertiliser guidelines are based on two measures of soil potassium: readily available or exchangeable K (potassium in the soil solution and on the CEC) and reserve or nitric K (slowly available, non-exchangeable potassium).

The maximum recommended K rate for Bundaberg is 120 kg K/ha which is slightly less than the amount of K removed in the harvested sugarcane crop when trash is retained. This upper limit on K applied is to avoid luxury consumption of K by the crop (resulting in reduced juice quality) and leaching losses on low CEC soils. It is justified by the relatively high K reserves on some soils that slowly but continuously become available, although these are rare in the Bundaberg district. Hence, fallow plant requires less K than replant or ratoons.

Soil critical levels for exchangeable K are dependent on clay content and soils are assigned into one of three textural classes: sand (<24% clay); loam (24 - 36% clay); and clay (>36% clay). Potassium fertiliser recommendations can then be derived as shown in Table 2.9.

Table 2.9 - Potassium fertiliser guidelines
(see Wood and Schroeder, 2004)

Plant (kg/ha K)						
Nitric K (me%)	Exchangeable K (me%)					
	< 0.20	0.20 - 0.25	0.26 - 0.30	0.31 - 0.35	0.36 - 0.40	> 0.40
< 0.70	100 (sand)	80 (sand)	50 (sand)	50 (sand)	Nil (sand)	Nil
	120 (loam)	100 (loam)	80 (loam)	50 (loam)	Nil (loam)	
	120 (clay)	120 (clay)	100 (clay)	80 (clay)	50 (clay)	
> 0.70	80 (sand)	50 (sand)	Nil (sand)	Nil (sand)	Nil (sand)	
	100 (loam)	80 (loam)	50 (loam)	Nil (loam)	Nil (loam)	
	100 (clay)	100 (clay)	80 (clay)	50 (clay)	Nil (clay)	

Replant & Ratoon (kg/ha K)						
Nitric K (me%)	Exchangeable K (me%)					
	< 0.26	0.26 - 0.30	0.31 - 0.35	0.36 - 0.40	0.41 - 0.45	> 0.45
< 0.70	120 (sand)	100 (sand)	80 (sand)	50 (sand)	Nil (sand)	Nil
	120 (loam)	100 (loam)	100 (loam)	80 (loam)	50 (loam)	
	120 (clay)	100 (clay)	100 (clay)	100 (clay)	80 (clay)	
> 0.70	100 (sand)	80 (sand)	50 (sand)	Nil (sand)	Nil (sand)	
	100 (loam)	100 (loam)	80 (loam)	50 (loam)	Nil (loam)	
	100 (clay)	100 (clay)	100 (clay)	80 (clay)	50 (clay)	

Discounts should be made where mill by-products have been used, because they are sources of K.

Product	Application rate	To be subtracted from the appropriate K application rate	
		Plant crop	First ratoon
Mill Mud	150 wet t/ha	40 kg K/ha	Nil
Mud/Ash	150 wet t/ha	120 kg K/ha	120 kg K/ha

Sulphur
As the mineralisation of soil organic matter is a source of sulphur, S fertilising guidelines are based on the nitrogen mineralisation index. Soils are placed in one of three N mineralisation classes and then soil sulphate critical levels are used to calculate sulphur fertiliser rates (Table 2.10). Discounts should be made where mill by-products have been used, because they supply S.

Table 2.10 - Sulphur fertiliser guidelines (kg S/ha) for plant and ratoon crops

Sulphate S (mg/kg)	N mineralisation index		
	VL - L	ML - M	MH - H
<5	25	20	15
5-10	15	10	5
11-15	10	5	0
>15	0	0	0

Product	Application Rate	To be subtracted from the appropriate S application rate		
		Plant crop	First ratoon	Second ratoon
Mill Mud	150 wet t/ha	10 kg S/ha	10 kg S/ha	10 kg S/ha
Mud/Ash	150 wet t/ha	10 kg S/ha	10 kg S/ha	nil

Lime (See Aitken, 2000; Nelson and others, 2000; Wood and others, 2003)
Lime is used to neutralise soil acidity and to supply calcium. Soils are constantly being acidified through the use of nitrogen fertiliser, removal of nutrients in the harvested crop and by leaching of nitrate. Maintenance applications of about 2 tonnes lime/ha each crop cycle are needed to neutralise this effect. The more N fertiliser is used, the greater is the lime requirement. In addition, some forms of nitrogen fertiliser acidify more than others (ammonium sulphate acidifies more than urea which acidifies more than calcium ammonium nitrate). Some soil tests include liming estimates to a target pH of 5.5, 6.0 and 6.5. The liming estimate aimed at a soil pH of 5.5 should be used where available, otherwise the guidelines in Table 2.11 can be applied. Lime is recommended when soil pH falls below 5.5 (Table 2.11) and when exchangeable Ca is below the critical value of 1.5 me% (Table 2.12). Discounts are necessary where mill by-products have been used.

Table 2.11 - Lime guidelines for acid soils (when pH_{water} <5.5)

CEC (me%)	Suggested lime application (tonnes/ha)
<2.0	1.25
2.0 - 4.0	2.5
4.0 - 8.0	4
>8.0	5

Table 2.12 – Ag lime guidelines based on exchangeable Ca
(adapted from Calcino and others, 2000)

Ca (me%)	Suggested lime application (tonnes/ha)
> 0.2	3
0.2 - 0.4	2.5
0.4 - 0.6	2
0.6 - 0.8	1.5
0.8 - 1.1	1
1.1 - 1.5	0.5

Mud or mud/ash mixture (applied at 150 wet t/ha)
Subtract 2 t/ha Ag Lime from next application

Magnesium

Magnesium guidelines are based on soil critical levels for exchangeable magnesium (Table 2.13). Whilst a magnesium level of 10-20% of CEC is desirable, levels of over 50% of CEC can occur on some soils. This may affect soil physical properties, making the soils prone to hard-setting and possibly causing germination difficulties. However, subsequent growth does not appear to be affected, provided all nutrients are above their critical levels and soil pH is above 5.5.

Table 2.13 - Magnesium guidelines for plant crops (adapted from Calcino, 1994)

Soil test (me% Mg)	<0.05	0.06-0.10	0.11-0.15	0.16-0.20	0.21-0.25	>0.25
Mg rate (kg/ha)	150	125	100	75	50	0

Sodium

Sodium does not need to be applied to sugarcane but needs to be reduced when the exchangeable sodium percentage (ESP) is above 5% of the CEC in the topsoil. Where this occurs it is suggested that subsoil samples be taken to determine ESP in the soil profile and specialist advice be sought on possible remedial activities. Gypsum is the normal ameliorant for sodic soils because it is relatively soluble. However lime is an alternative on acidic soils. Rates of application are dependent on exchangeable sodium percentage (ESP). Guidelines are provided in Table 2.14.

Table 2.14 - Gypsum requirement for sodic soils (see Nelson, 2000)

ESP (%)	Gypsum rate (tonnes/ha)
<5	0
5 - 10	2
10 -15	4
>15	6

Micronutrients

Copper and zinc guidelines are based on previously determined soil critical values (Table 2.15). The BSES zinc test is appropriate for acidic soils. The DTPA soil test should be used if soil pH is greater than 6.5. In this booklet, only DTPA results have been reported. Copper and zinc are most often required on low CEC and very sandy soils. Leaf analysis is also a suitable method of diagnosing whether micro-nutrient applications are required. Heavy applications of ag lime may induce deficiencies, particularly of zinc, when micronutrient levels are marginal.

Table 2.15 - Copper and zinc guidelines
(see Calcino and others, 2000)

Micronutrient	Soil test value	Suggested application rate
DTPA soil test		
Copper	<0.2 mg Cu/kg	10 kg Cu/ha once per crop cycle
Zinc	<0.3 mg Zn/kg	10 kg Zn/ha once per crop cycle
BSES zinc test		
Zinc	<0.6 mg Zn/kg	10 kg Zn/ha once per crop cycle

Silicon
Two soil tests are appropriate for assessing silicon deficiencies. These are based on calcium chloride extractable Si and dilute sulphuric acid extractable Si. The latter is sometimes referred to as BSES-Si. Ameliorants are only required if both of the Si test values are low (Table 2.16). Leaf analysis is appropriate for assessing whether crops have been able to take up adequate amounts of Si.

Table 2.16 - Silicon guidelines for plant cane
(Calcino and others, 2000; Berthelsen and others, 1999)

	Sulphuric acid (0.005M)		Calcium chloride (0.01M)	Rating	Suggested application rate
Si (mg/kg)	<70	and	<10	Low	Calcium silicate @ 4 t/ha; **or** Cement @ 3t/ha **or** Mill mud/ash @ 150 wet t/ha

CHAPTER 3

Description of Bundaberg sugarcane soils and guidelines for their management

This chapter presents information on the location, appearance, properties and management requirements of the main soils producing cane in the Bundaberg district. The 80 soil mapping units described in the DNR Land Resource Bulletin (DNRQ980142) for the Bundaberg district have been condensed into 17 different soil groups based on colour and texture (Table 3.1) These groups have been further condensed into nine productivity classes based on average cane yields (Table 3.1; Figure 3.1).

Table 3.1 - Classification and grouping of Bundaberg cane producing soils.
An asterisk indicates the mapping units that were selected as representative of the soil group.
Page numbers indicate where descriptions of particular soils can be found in this booklet.

Productivity group	Soil groups and brief description	Mapping unit	Australian Soil Classification	Page
Volcanic	Red volcanic (red structured clay soil on basalt)	Woongarra*	Red Ferrosol	24
		Chin	Red Ferrosol	
		Childers	Red Ferrosol	
	Brown volcanic (brown structured clay soil on basalt)	Telegraph*	Brown Ferrosol	26
		Ashgrove	Redoxic Hydrosol	
		Seaview	Black Ferrosol	
		Hummock	Brown Vertosol	
		Berren	Brown Dermosol	
		Corfield	Brown Dermosol	
		Hillend	Brown Dermosol	
Clay	Black clay (black cracking clay on basalt)	Rubyanna*	Aquic Vertosol	28
		Maroondan*	Black Vertosol	30
		Windermere	Brown Ferrosol	
	Grey clay (grey cracking clay)	Walla*	Grey Vertosol	32
		Bucca*-	Grey Vertosol	34
		Hinkler	Black Vertosol	
Clay loam	Red clay loam (loamy topsoil over a red subsoil)	Oakwood*	Red Kandosol	36
		Otoo*	Red Dermosol	38
		Howes*	Red Dermosol	40
		Watalgan	Red Dermosol	
		Gibson	Red Kandosol	
	Yellow clay loam (loamy topsoil over a yellow subsoil)	Kepnock*	Yellow Dermosol	42
		Gillen	Yellow Kandosol	
		Calavos	Brown Dermosol	
		Bingera	Redoxic Hydrosol	
		Cedars	Brown Dermosol	
		Bungadoo	Yellow Dermosol	
Grey loam	Grey clay loam (loamy topsoil over a grey clay subsoil)	Takoka	Leptic Tenosol	
	Grey sandy loam (sandy topsoil over a grey clay subsoil)	Alloway*	Redoxic Hydrosol	44
		Clayton*	Redoxic Hydrosol	46
		Peep	Grey Sodosol	
		Woco	Grey Kurosol	

Continued on next page

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Productivity group	**Soil groups and brief description**	**Mapping unit**	**Australian Soil Classification**	**Page**
Sandy loam	Red sandy loam (sandy topsoil over a red subsoil)	Gooburrum*	Red Dermosol	48
		Farnsfield	Red Kandosol	
		Pocket	Red Kandosol	
	Yellow sandy loam (sandy topsoil over a yellow subsoil)	Meadowvale*	Yellow Dermosol	50
		Isis	Yellow Dermosol	
		Woolmer	Yellow Dermosol	
		Littabella	Yellow Kandosol	
Sand	Grey sand (grey sandy topsoil over a grey sandy subsoil)	Quart*	Yellow Kandosol	52
		Wallum	Redoxic Hydrosol	
		Winfield	Redoxic Hydrosol	
		Theodolite	Redoxic Hydrosol	
	Dark sand (dark sandy topsoil over a sandy subsoil)	Mahogany*	Redoxic Hydrosol	54
		Rothchild	Brown Kandosol	
		Kinkuna	Aquic Podosol	
Coastal	Black sand (black to brown sandy topsoil over a grey/mottled sandy subsoil; podzol)	Colvin*	Semiaquic Podosol	56
		Moore Park	Aquic Podosol	
		Summervile	Grey Sodosol	
		Beelbi	Orthic Tenosol	
		Coonar	Aquic Podosol	
		Toogum	Aquic Podosol	
		Woodgate	Aquic Podosol	
		Tantitha	Orthic Tenosol	
	Humic gley (black topsoil over a grey / mottled clay subsoil)	Fairymead*	Redoxic Hydrosol	58
		Fairydale	Redoxic Hydrosol	
		Whymere	Redoxic Hydrosol	
		Booloongie	Redoxic Hydrosol	
Sodic	Grey forest soil (sandy to loamy topsoil with sodic clay subsoil)	Auburn*	Grey Sodosol	60
		Kolan*	Grey Kurosol	62
		Givelda	Yellow Sodosol	
		Moorland	Red Sodosol	
		Crossing	Grey Sodosol	
		Avondale	Grey Sodosol	
		Turpin	Grey Sodosol	
		Tirroan	Grey Sodosol	
		Brooweena	Grey Sodosol	
		Norville	Grey Sodosol	
		Qunaba	Grey Sodosol	
		Gall	Grey Sodosol	
	Ti tree soil (wet soils with sodic texture contrast)	Robur	Redoxic Hydrosol	
		Kolbore	Redoxic Hydrosol	
		Kalah	Redoxic Hydrosol	
Alluvial	Alluvial (brown and black loamy topsoil on alluvium)	Gahan*	Brown Dermosol	64
		Burnett	Brown Dermosol	
		Flagstone	Brown Dermosol	
		Sugarmill	Redoxic Hydrosol	
		Barubbra	Orthic Tenosol	
		Boyne	Red Dermosol	

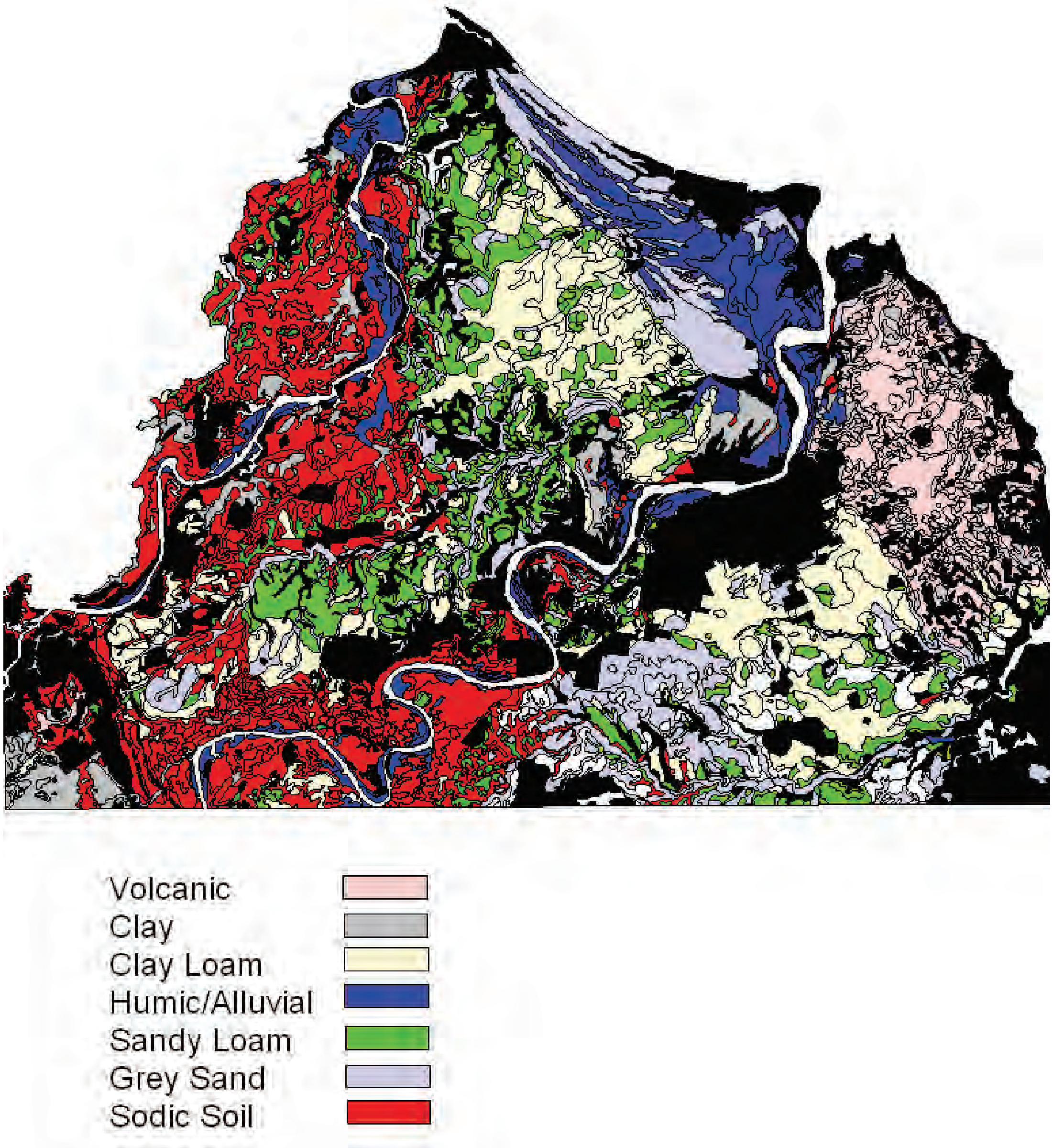


Figure 3.1 - Map of the Bundaberg district showing productivity groups mapped at a scale of 1:50,000

Location of soils

Each soil is found in a particular part of the landscape. Three landscape sections covering different parts of the Bundaberg landscape are shown in Figures 3.2, 3.3 and 3.4. They illustrate where each soil group occurs and its relationship to the river system and different topographic features.

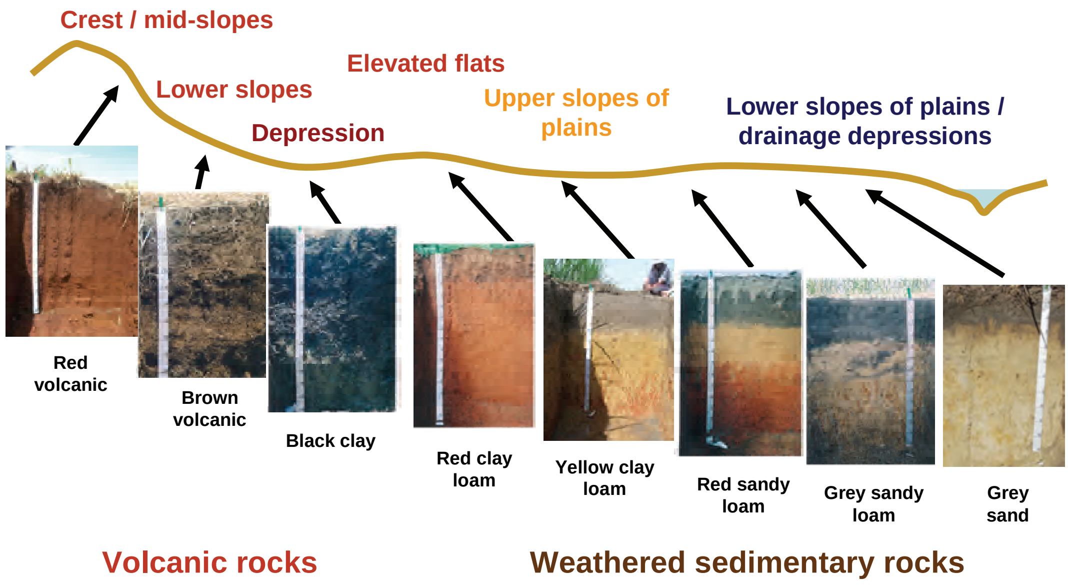


Figure 3.2 - Typical Bundaberg landscape between the Hummock and Elliot River.

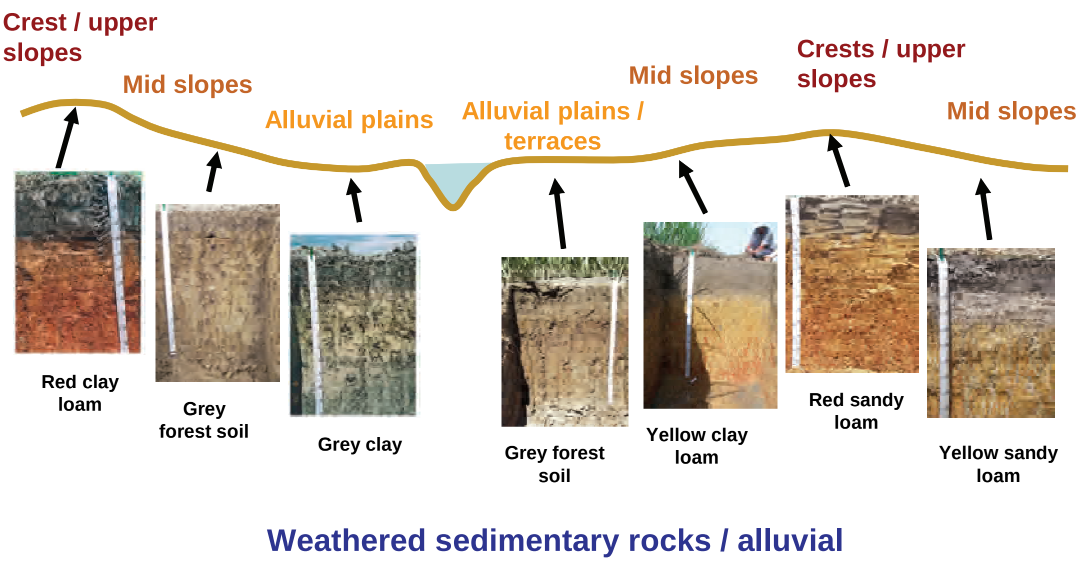


Figure 3.3 - Typical Bundaberg landscape in areas north and south of the Kolan River.

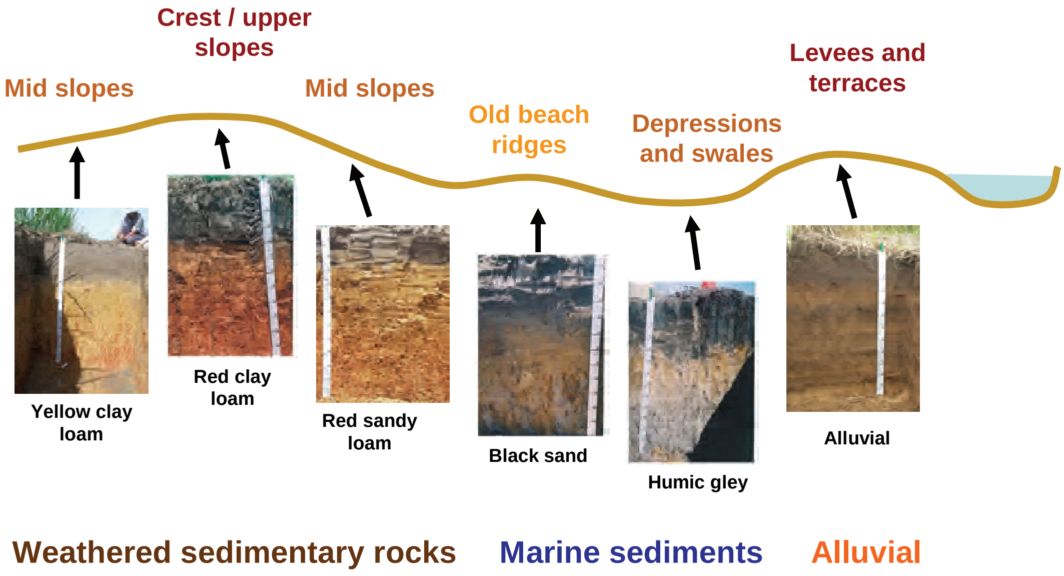


Figure 3.4 - Typical Bundaberg landscape in the Fairymead area.

Soil reference sites

Twenty one soil reference sites representative of the major soil groups were established and are indicated by asterisks in Table 3.1. Profiles were excavated for describing field appearance of each soil type. Representative topsoil (0 - 20 cm) and subsoil (40 - 60 cm) samples were taken from the surrounding cane area. These samples were analysed in laboratories for a range of chemical and physical properties.

In the rest of this chapter, information on the occurrence, formation, field appearance and chemical and physical properties of these 21 soils are provided in a two-page format. Bar graphs are used to represent the soil analytical data on a scale from very low to very high for each reference site and for similar soils sampled in the DNR study. Guidelines are given for the management of nutrient applications, tillage, water and environmental risks. Nutrient management guidelines are provided for different crop classes, such as fallow plant, replant and ratoons. However specific nutrient guidelines following the use of legume crops and mill by-products are not included and readers need to refer to the information in Chapter 2. The nutrient management guidelines are for the reference sites. They are only intended to be used as a guide for nutrient inputs when recent soil and / or leaf tests are not available for specific blocks.

Woongarra (Wo) - Red Volcanic

Red structured clay soil on basalt

Productivity class: Volcanic

Occurrence: Woongarra soils occur on the upper and mid slopes in the vicinity of the Hummock which has volcanic origins. These soils occupy about 7% of the sugarcane area in the Bundaberg district. They have some of the longest cropping history in the region. The coastal areas around the Hummock generally receive higher rainfall than the areas to the west.

Formation:
Woongarra soils are formed *in situ* from weathering basalt. Most Woongarra soils are found within a few kilometres of the Hummock.

Woongarra soil profile

Woongarra soil in the vicinity of the Hummock

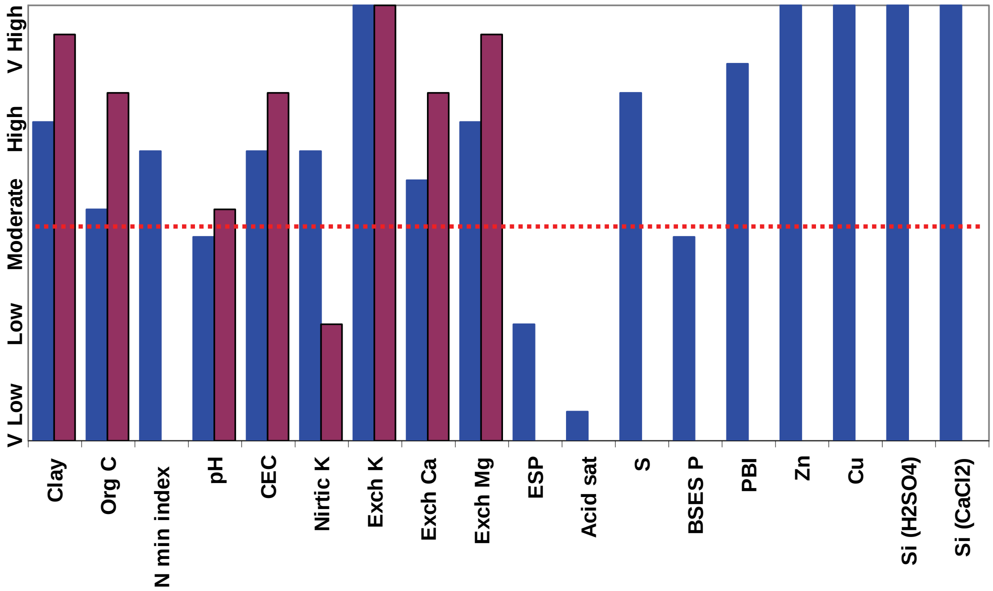
Field appearance:
Topsoils are structured reddish brown clay loams. Subsoils exhibit a more intense red colour than the topsoils (because of lower organic matter content) and are heavier in texture. Basalt boulders are occasionally present in the subsoil and may move to the surface layers with tillage.

Similar soils:
Chin (Ch) and Childers (Cd) which occupy very small sections of the sugarcane growing area.

Physical properties:
These soils are highly permeable and well drained. Rooting depths are often in excess of 1m. These soils have well-developed structure, but may compact if excessively cultivated when wet.

Chemical properties:
These soils have a relatively high nutrient status. The CEC is relatively high and consistent with the clay texture. The organic matter content is moderately high resulting in moderately high N mineralization potential. Although the exchange complex is dominated by calcium and magnesium, potassium is still very well supplied. Potassium reserves are also relatively high. Magnesium values are often higher than calcium on soils irrigated with magnesic groundwater. The PBI values indicate relatively high P sorbing capacity. The P status of these soils needs to be monitored because BSES P values are variable and range from moderate to high according to history of fertiliser applications. Sulphur is generally well supplied. Silicon and micronutrients levels are high.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0	100	20	0	0	0	0	0
Replant	0	120	20	0	0	0	0	0
Ratoon	0	120	20	0	0	0	0	0

Tillage and water management:

These soils are easily tilled and produce a good seedbed. If tilled when too wet, they are prone to compaction, and will produce large clods. Green cane trash blanketing will assist in moisture retention. Overhead irrigation is recommended for these soils because of their high permeability. These soils have a high water-holding capacity.

Environmental risk management:

In the crop rows, most water movement occurs as drainage. Nitrogen fertiliser applications should be split to reduce the risk of nitrate leaching. There is also potential for off-site movement of suspended sediment down compacted traffic lanes following high intensity rainfall events. In particular, these soils are susceptible to erosion on slopes. This can be controlled by making use of minimum tillage, trash blanketing, contour farming and grassed headlands / drains.

Telegraph (Tg) - Brown Volcanic

Brown structured clay soil on basalt

Productivity class: Volcanic

Occurrence: Telegraph soils occur on the lower slopes of the Hummock and surrounding area. They occupy about 2% of the sugarcane area in the Bundaberg district. The coastal areas around the Hummock generally receive higher rainfall than the areas to the west.

Formation:

Telegraph soils are formed *in situ* from weathering basalt. Most Telegraph soils are found within a few kilometres of the Hummock, and occur in mid- to lower-slope positions. They have a long history of sugarcane production.

Telegraph soil profile

Telegraph soil on lower basaltic slopes at Qunaba

Field appearance:

Topsoils are structured brown clay loams. Subsoils are lighter brown in colour than the topsoils, but have heavier textures. Basalt boulders are frequently present in the subsoil.

Similar soils:

Ashgrove (Ag) and Seaview (Sw) which occupy about 1% each of the sugarcane growing area.

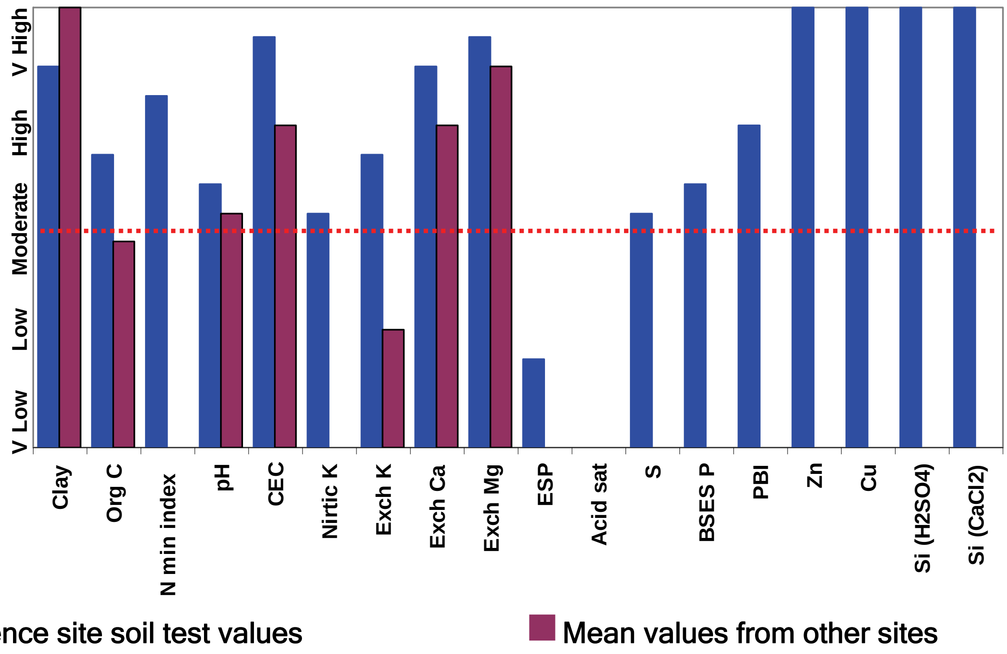
Physical properties:

These soils are moderately permeable but tend to be less well-drained than the red volcanic soils because of their position in the landscape. Rooting depth is often in excess of 1m. These soils have well-developed structure, but may compact if excessively cultivated when wet.

Chemical properties:

These soils have a high soil fertility status. The organic matter content and N mineralisation potential are high. CEC values tend to be higher than the red volcanic soils, with much of the exchange complex dominated by calcium and magnesium. The K status (reserve and exchangeable K) of these soils tends to be lower than that of the red volcanics, although the high exchangeable K levels in the reference site reflect local use of dunder. BSES P values are moderate, but can vary according to fertiliser histories of individual blocks. PBI values of these soils indicate moderate P sorbing capacities. Soil pH values tend towards neutral. Sulphur is generally well supplied, as are micronutrients and silicon.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0	90	20	0	0	0	0	0
Replant	0	110	20	0	0	0	0	0
Ratoon	0	110	5	0	0	0	0	0

Tillage and water management:
These soils are easily tilled and produce a good seedbed. However they are prone to compaction if in-field activities are carried out in wet conditions. Minimising tillage and traffic in such conditions will reduce the risk of compaction. Because of their low position in the landscape, these soils may be intermittently waterlogged. Green cane trash blanketing is recommended for maintenance of soil organic matter, but may prolong periods of excessive soil moisture and reduce soil temperatures. Overhead irrigation is recommended for these soils because of their high permeability. Plant available water capacity is moderate.

Environmental risk management:
Loss of nitrogen by denitrification is a risk due to intermittent water-logging. Strategies to reduce these losses include mound planting, placement of nitrogen fertiliser into the mound and split fertiliser applications. On sloping land there is a potential risk of off-site sediment movement, and erosion control methods (contour farming, grassed waterways and headlands) should be practised. Minimum tillage will help prevent soil erosion on slopes.

Rubyanna (Ra) - Black Clay

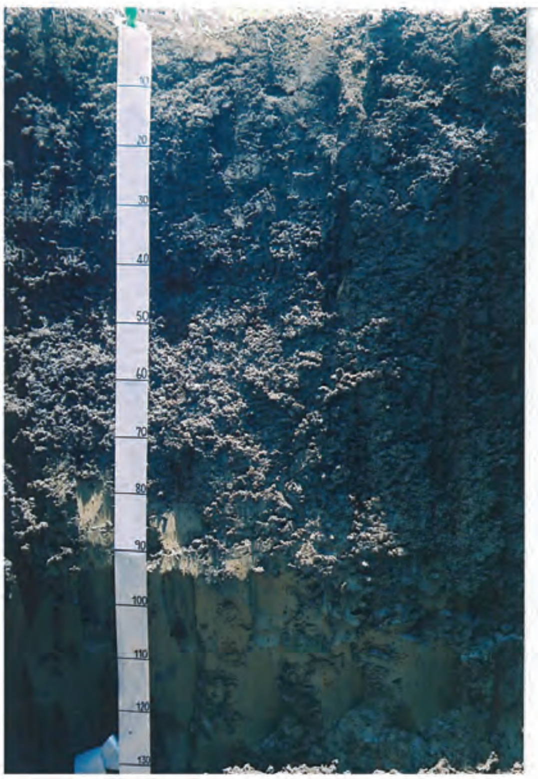
Black cracking clay on basalt

Productivity class: Clay

Occurrence: Rubyanna soils occur in low lying areas around the Hummock. These soils occupy about 2% of the sugarcane area in the Bundaberg district. The coastal areas around the Hummock generally receive higher rainfall than the areas to the west.

Formation:
Rubyanna soils are formed *in situ* from weathering basalt. Most Rubyanna soils are found within a few kilometres of the Hummock, and occur in drainage lines, low lying flats and depressions.

Rubyanna soil in the Qunaba area.



Rubyanna soil profile

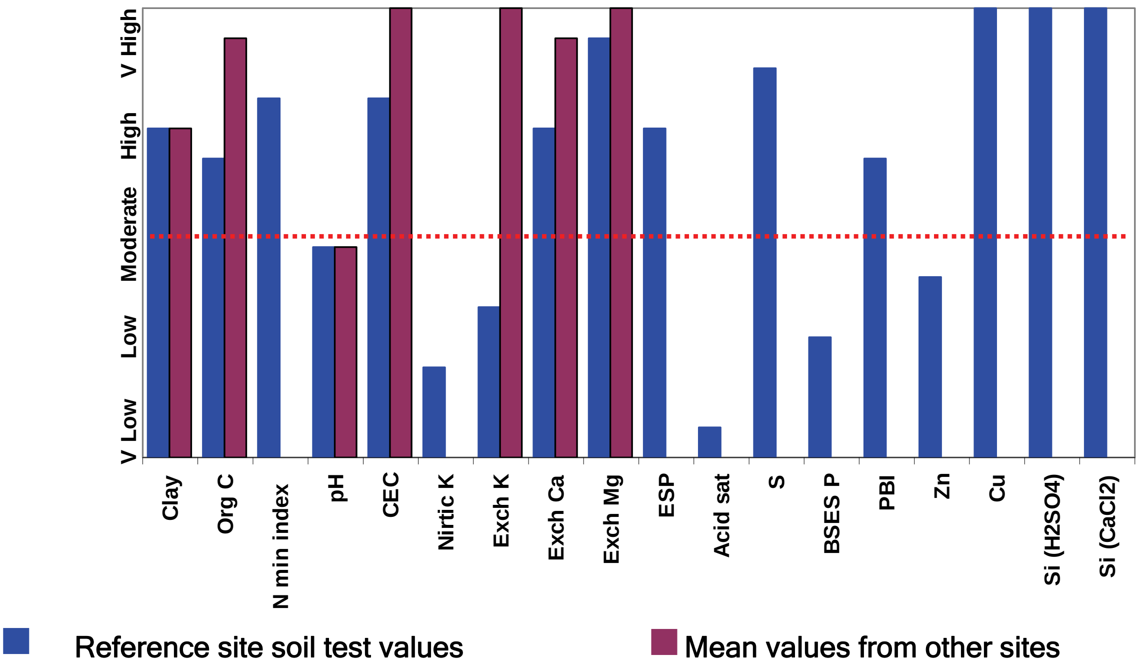
Field appearance: Topsoils are dark in colour with a clay texture. Yellow mottles occur in heavy grey subsoils. Stones and boulders may be present on the surface.

Similar soils:
Maroondan (Mr) soils occupy about 3% of the sugarcane growing area. Windemere (Wi) soils are also found in small pockets in the vicinity of the Hummock.

Physical properties:
Soils are imperfectly drained with frequent water-logging. Rooting depth is restricted because of the heavy clay subsoil and probably does not exceed 60 cm.

Chemical properties:
These soils have a moderate nutrient status. The organic carbon content and N mineralisation potential are high. Topsoils and subsoils have relatively high CECs that are dominated by calcium and magnesium. Potassium reserves are low, as are exchangeable K values in the reference site. Sodic conditions may occur due to relatively high exchangeable Na values which increase with depth, such as in the reference site. Phosphorus status and P-sorbing capacity are moderate. There is no evidence of micro-nutrient or silicon deficiencies.

Reference site and grower soil sample median analysis data:



Nutrient management guidelines based on the reference site data:

Crop situation	Gypsum t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	4	90	20	120	0	0	0	0
Replant	4	110	20	120	0	0	0	0
Ratoon	0	110	20	120	0	0	0	0

Tillage and water management:
It is difficult to obtain a good tilth with these soils and there is a restricted moisture range for effective tillage. Cultivating these soils when too wet will cause smearing. When too dry, ‘clods’ will form. Compaction can be reduced by adopting controlled traffic. Green cane trash blanketing is recommended for maintenance of soil organic matter, but may prolong excessive soil moisture and reduce soil temperature. Furrow irrigation is recommended for these soils because of their low permeability. Short irrigation duration times should be used to take advantage of rapid water entry when surface cracks are visible. Drains may be necessary to intercept water and to improve on-site drainage. Plant available water capacity is moderate to moderately high. These soils may be excavated to form small on-farm water storages.

Environmental risk management:
Loss of nitrogen by denitrification is a risk due to prolonged water-logging. Strategies to reduce these losses include drainage lines, mound planting, placement of nitrogen fertiliser into the mound and split fertiliser applications.

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Maroondan (Mr) - Black Clay

Black cracking clay on basalt

Productivity class: Clay

Occurrence: Maroondan soils occur on crests, slopes and low lying flats east of Gin Gin. They occupy about 3% of the sugarcane area in the Bundaberg district.

Formation:
Maroondah soils are developed on Tertiary volcanic rocks, including Gin Gin Basalt.

Maroondan soil profile

Maroondan soil in the Wallaville area

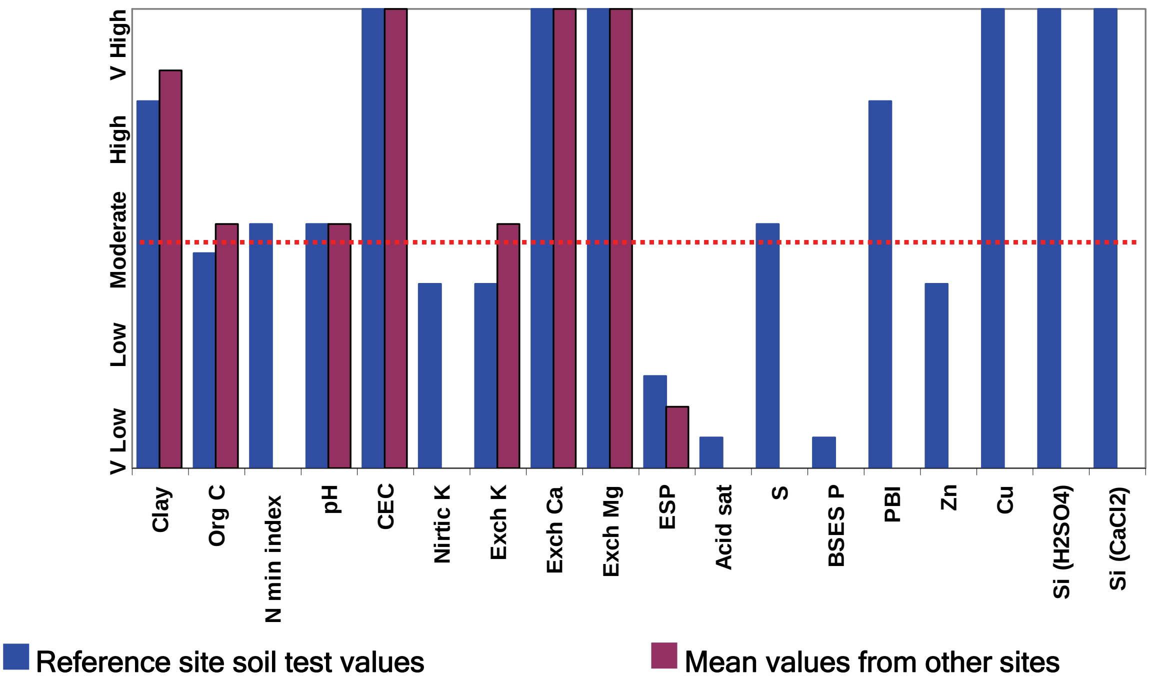
Field appearance: Topsoils are heavy black clays which exhibit self-mulching properties. They overlie black medium to heavy clay subsoils. Stones and boulders may occur in the surface layers of these soils.

Similar soils:
Rubyanna (Ra) soils occupy about 2% of the sugarcane growing area. Windermere (Wi) soils are also found in small pockets in the vicinity of the Hummock.

Physical properties:
These soils have self-mulching surfaces. They have low permeability and are poorly drained at depth. They are prone to compaction if cultivated or subjected to heavy traffic when too wet. These soils are strongly adhesive.

Chemical properties:
These soils have a relatively high nutrient status. Organic carbon content and N mineralisation potential are moderate. CECs in the top and subsoils are very high. The exchange complex is dominated by calcium and magnesium, but sodium increases with depth giving rise to sodic conditions in deeper sections of the soil profile. Potassium reserves and exchangeable K are moderate. Although the reference site had a very low BSES P value, the P status of these soils can vary considerably according to fertiliser application histories. Topsoils have moderate P-sorbing capacities. Micro-nutrients levels, especially Zn, may be marginal on these soils.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0	110	40	100	5	0	0	0
Replant	0	130	40	100	5	0	0	0
Ratoon	0	130	30	100	5	0	0	0

Tillage and water management:
A narrow range of moisture conditions exists for in-field operations. Under ideal moisture conditions, relatively good tilth can be achieved. However smearing will occur if the soil is cultivated when too wet, and clods will be produced if it is too dry. Compaction by machinery can be confined to the inter-row by adopting controlled traffic. Green cane trash blanketing is not widely practiced on these soils because they remain wet and cold for too long. These soils are suited to both overhead and furrow irrigation, but infiltration rates are low except when soils are dry. Plant available water capacity is moderately low.

Environmental risk management:
When these soils occur on slopes, erosion control measures such as contour farming, grassed waterways and headlands should be practiced. Where these soils occur in low-lying parts of the landscape, loss of nitrogen by denitrification is a risk due to prolonged water-logging. Strategies to reduce these losses include drainage, mound planting, placement of nitrogen fertiliser into the mound and split fertiliser applications.

Walla (Wl) - Grey Clay

Grey cracking clay

Productivity class: Clay

Occurrence: Walla soils occupy about 1% of the sugarcane area in the Bundaberg district. They are found on older alluvial plains in gently sloping positions and drainage depressions of the Burnett and Kolan Rivers and local streams.

Formation:
Walla soils are formed on older alluvia in back swamp areas of the Burnett and Kolan Rivers.

Walla soil profile

Walla soil in the Tegege area

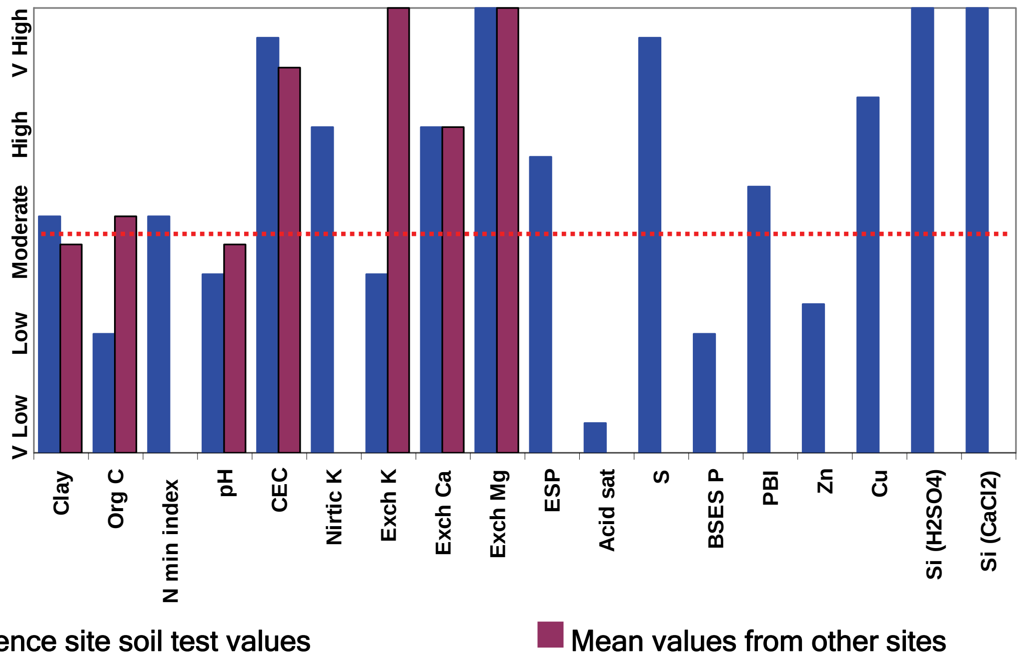
Field appearance: Topsoils are grey-brown in colour overlying grey subsoils. Yellow mottles occur frequently in the sub-soils.

Similar soils:
Bucca (Bc) soils occupy about 2% of the sugarcane growing area. Small sections of Hinkler (Hk) soils are found in the area north of the Burnett River.

Physical properties:
Surface crusting occurs in these hard-setting soils. They are very slowly permeable and are poorly drained. They are prone to compaction if cultivated or subjected to heavy traffic when too wet. Rooting depth can be restricted due to intermittent waterlogging.

Chemical properties:
These soils have a moderate to high fertility. The CEC and exchangeable cations increase markedly with depth consistent with increases in clay content. The organic carbon content and N mineralisation potential are moderate. Topsoils have a relatively high CEC which is dominated by Ca and Mg. Potassium reserves are relatively high. Exchangeable K can vary from moderate to high. Topsoils have low P-sorbing capacities. BSES P levels are often moderate to low, reflecting different fertiliser histories. Sulphur values are generally satisfactory. Although the reference site has a sodic topsoil (high ESP), Walla soils generally have non-sodic topsoils but strongly sodic subsoils.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime* t/ha	Gypsum* t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	5	4	120	20	80	0	0	0	0
Replant	5	4	140	20	100	0	0	0	0
Ratoon	0	0	140	10	100	0	0	0	0

* If more than one ameliorant is suggested, then application rates need to be rationalized. In this case gypsum is not required if lime is used.

Tillage and water management:
It is difficult to obtain a good tilth with these soils and there is a restricted moisture range for access and cultivation. Cultivating these soils when too wet will cause smearing, or clods if too dry. Compaction by machinery can be confined to the inter-row by adopting controlled traffic. The plant available water capacities of the topsoils are moderate. Furrow irrigation is recommended for these soils because of their low permeability. Short irrigation duration times should be used to take advantage of rapid water entry when surface cracks are visible. Surface gypsum application will reduce surface sealing. Ripping performed in combination with gypsum applications will have a positive effect on water infiltration and the water-holding capacity of the upper subsoil.

Environmental risk management:
Loss of nitrogen by denitrification is a risk due to intermittent waterlogging. Strategies to reduce these losses include drainage lines, mound planting, placement of nitrogen fertiliser into the mound and split fertiliser applications.

Bucca (Bc) - Grey Clay

Grey cracking clay

Productivity class: Clay

Occurrence: Bucca soils occupy about 2% of the sugarcane area in the Bundaberg district and are found on the crests and hill slopes north of the Kolan River.

Formation:
Bucca soils are developed on moderately weathered sedimentary rocks in areas with hills and slopes in relative proximity to the river.

Bucca soil profile

Bucca soil in the Bucca area

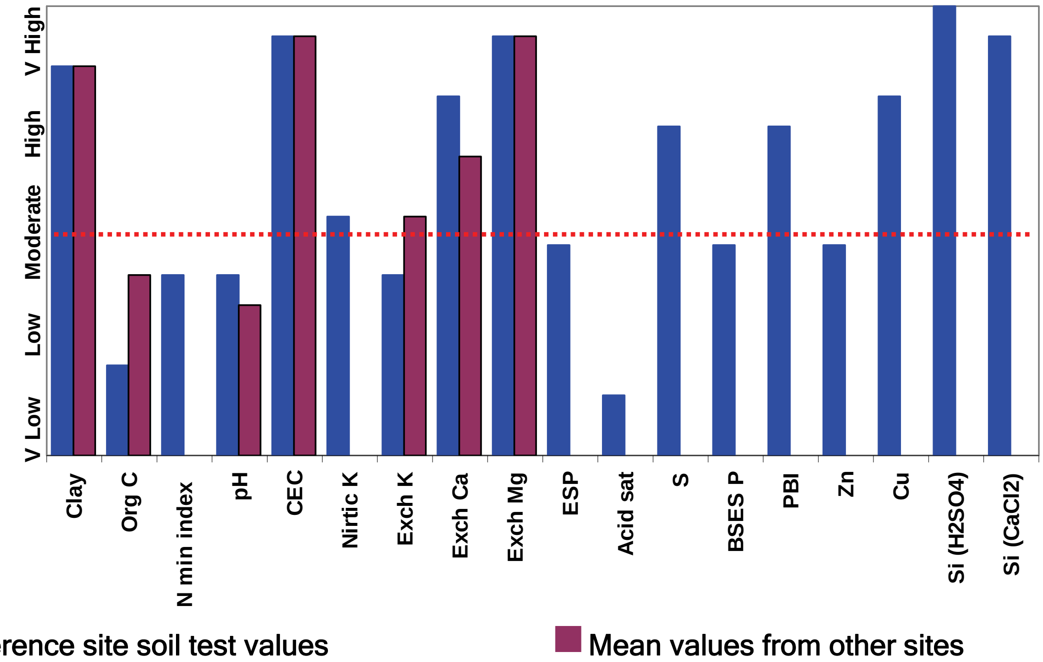
Field appearance:
Bucca soils have brown to grey clay topsoils and grey medium to heavy clay subsoils with red mottles. The subsoils have moderate structure.

Similar soils:
Walla (Wl) soils occupy about 1% of the sugarcane growing area. Small sections of Hinkler (Hk) soils are found north of the Burnett River.

Physical properties:
These soils are moderately permeable but imperfectly drained. The subsoil is intermittently waterlogged where the soil occurs in lower landscape positions. Rooting depth is typically up to 1 m.

Chemical properties:
These soils have a low to moderate fertility status. The organic carbon content and N mineralisation potential are moderately low. The CEC of the topsoils is relatively high, with the exchange complexes dominated by calcium and magnesium. The CEC values increase with depth. The subsoils are usually strongly sodic. Potassium reserves and exchangeable K are moderate. High levels of exchangeable Al can occur where soils have not been adequately limed. Sulphur values are generally satisfactory. Topsoils have moderate P-sorbing capacities. BSES P values are variable and reflect different P application histories. There is no evidence of widespread micro-nutrient deficiencies.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime* t/ha	Gypsum* t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	5	2	110	20	80	0	0	0	0
Replant	5	2	130	20	100	0	0	0	0
Ratoon	0	0	130	15	100	0	0	0	0

* If more than one ameliorant is suggested, then application rates need to be rationalized. Gypsum is not required if lime is used.

Tillage and water management:

It is difficult to obtain a good tilth with these soils and there is a restricted moisture range for access and cultivation. Compaction by machinery can be confined to the inter-row by adopting controlled traffic. These soils often occur in undulating landscapes, and overhead rather than flood irrigation should be used. Irrigation events should be frequent and of short duration to avoid waterlogging. Plant available water capacity is moderate.

Environmental risk management:

Where these soils occur on slopes, they are prone to erosion. Unless erosion controls, such as contour planting, are implemented, there is a risk of off-site movement of sediments and attached nutrients. Where intermittent waterlogging occurs after fertiliser application, denitrification is possible.

Oakwood (Ok) - Red Clay Loam

Loamy topsoil over a red subsoil

Productivity class: Clay loam

Occurrence: Oakwood soils occur on the crests, upper slopes of rises and elevated plains. They occupy about 6% of the sugarcane area in the Bundaberg district.

Formation:
Oakwood soils are developed on deeply weathered fine grained sedimentary rocks.

Oakwood soil profile

Oakwood soil in the Three Chain Rd area

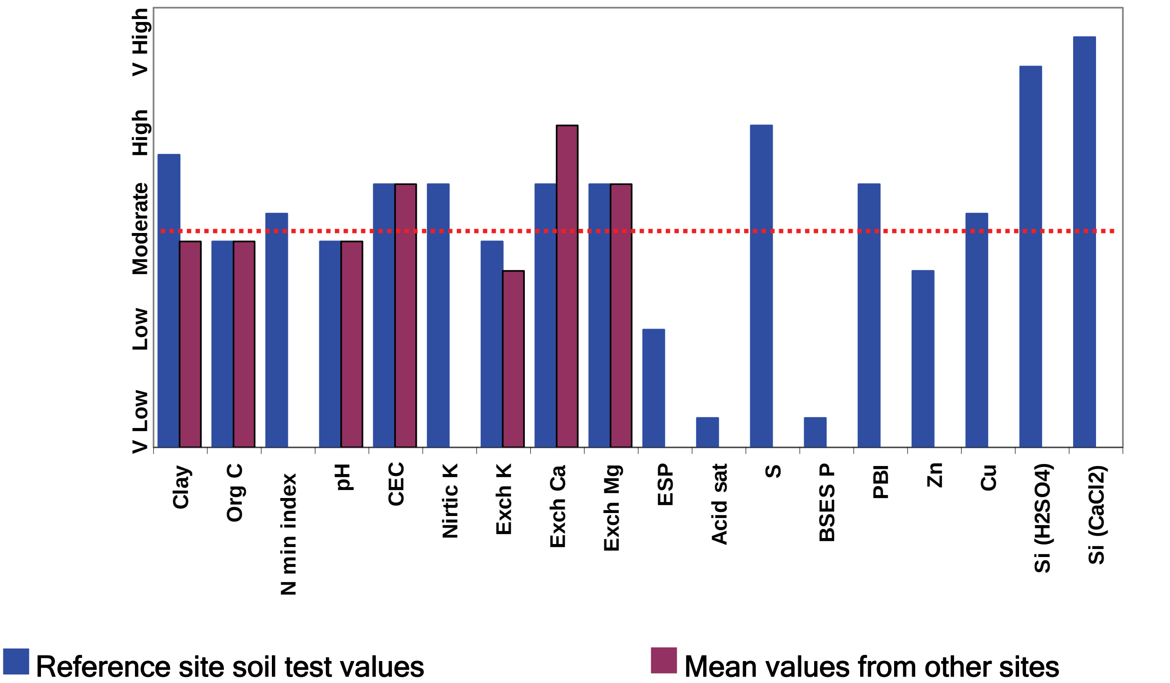
Field appearance:
Topsoils are brown loams to clay loams. Subsoils are red clay loam to light clay with a massive structure.

Similar soils:
This soil has similar properties to the Otoo (Ot), Watalgan (Wt) and Howes (Hs) soils which occupy about 5%, 3% and 1% of the sugarcane growing area respectively.

Physical properties:
These soils are permeable and well-drained. They are prone to hardsetting and can be subject to erosion depending on the slope.

Chemical properties:
These soils have a moderately low to moderate fertility status and range from being strongly acid to neutral. The organic carbon content, N mineralisation potential and CEC of the topsoils are moderate, as are the K reserves. Exchangeable K values can vary according to cropping histories. Topsoils have low P-sorbing capacities. BSES P and sulphur values vary according to past fertiliser histories. Micronutrients, especially Zn, need to be monitored as marginal / deficient levels have been recorded at some locations.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0	110	30	80	0	0	0	0
Replant	0	130	30	100	0	0	0	0
Ratoon	0	130	20	100	0	0	0	0

Tillage and water management:
These soils are prone to hardsetting, but compaction can be restricted to the inter-row with controlled traffic. Green cane trash blanketing will improve soil structure, tilth and soil porosity. These soils are permeable and have good drainage. If flood irrigated, U-shaped furrows are most suitable with medium flow rates. Spray or trickle irrigation may help reduce losses to deep drainage. Plant available water capacity is moderate.

Environmental risk management:
Loss of nitrogen by leaching could occur with excessive rainfall or high irrigation rates. Fertiliser applications should be split to reduce the risk of leaching. Where these soils occur on slopes, they are prone to erosion. This can be minimised with grassed headlands and waterways, minimum tillage and green cane trash blanketing.

Otoo (Ot) - Red Clay Loam

Loamy topsoil over a red subsoil

Productivity class: Clay loam

Occurrence: Otoo soils occur on plains, crests, and slopes. They occupy about 5% of the sugarcane area in the Bundaberg district.

Formation:
Otoo soils are developed on deeply weathered fine grained sedimentary rocks.

Otoo soil profile

Otoo soil in the Gooburrum area

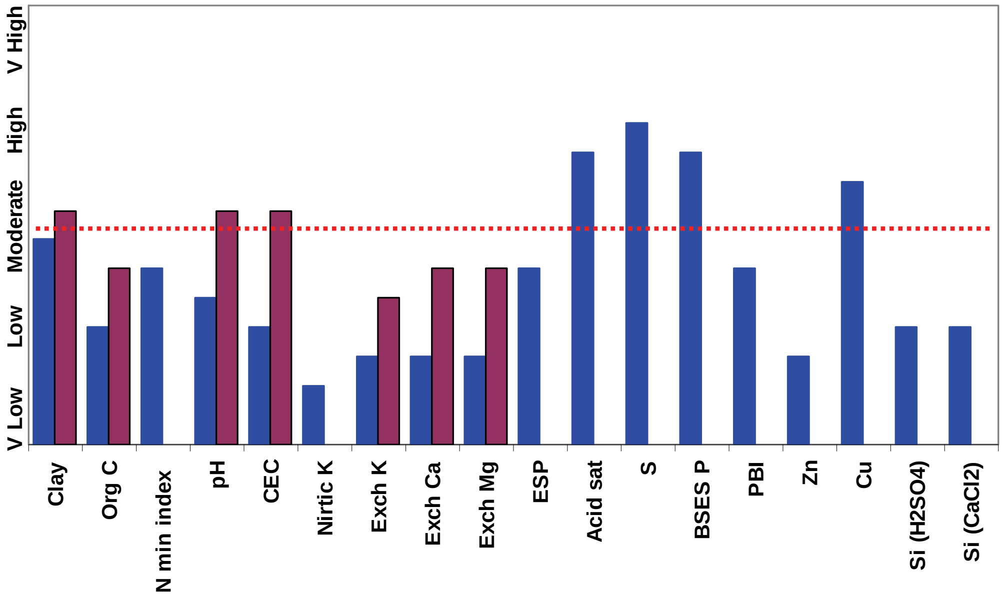
Field appearance:
Topsoils are brown sandy clay loams to clay loams. Subsoils are yellow to brown light clays over mottled red clays.

Similar soils:
This soil has similar properties to the Oakwood (Ok), Watalgan (Wt) and Howes (Hs) soils.

Physical properties:
These soils are moderately permeable. They range from being well drained to moderately well drained.

Chemical properties:
These soils have a low fertility status and soil pH values range from strongly acid to neutral. The organic carbon content and N mineralisation potential are moderately low. The CEC of the topsoil is low to moderate. Acid saturation values of up to 60% have been measured at some sites. The K reserves and exchangeable K values are generally low. Topsoils have low P-sorbing capacities. A relatively wide range of BSES P values reflects different fertiliser histories. Sulphur values range from low to satisfactory depending on previous fertiliser applications. Micronutrients, especially Zn, need to be monitored as marginal / deficient levels have been measured on samples from various locations.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	4	120	0	100	0	75	0	10
Replant	0	140	0	120	0	75	0	10
Ratoon	0	140	0	120	0	0	0	0

Tillage and water management:
These soils are prone to hardsetting and compaction can be restricted to inter-rows with controlled traffic. Green cane trash blanketing and application of other organic amendments can improve soil structure, tilth and soil porosity. These soils are permeable and are moderate to well drained. Laser levelling may be useful for improving surface drainage where the topography is flat. If flood irrigated, U-shaped furrows are most suitable with medium flow rates. Plant available water capacity is moderate to moderately low.

Environmental risk management:
Loss of nitrogen by denitrification is not usually a factor except when heavy rain or flooding occurs shortly after N application. Erosion preventative measures are recommended where these soils occur on slopes.

Howes (Hs) - Red Clay Loam

Loamy topsoil over a red subsoil

Productivity class: Clay loam

Occurrence: Howes soils occur on the crests and upper slopes of rises and on elevated plains. They are most often found on the plains at South Kolan and occupy about 1% of the sugarcane area in the Bundaberg district.

Formation:
Howes soils are developed on deeply weathered fine grained sedimentary rocks.

Howes soil profile

Howes soil in the South Kolan area

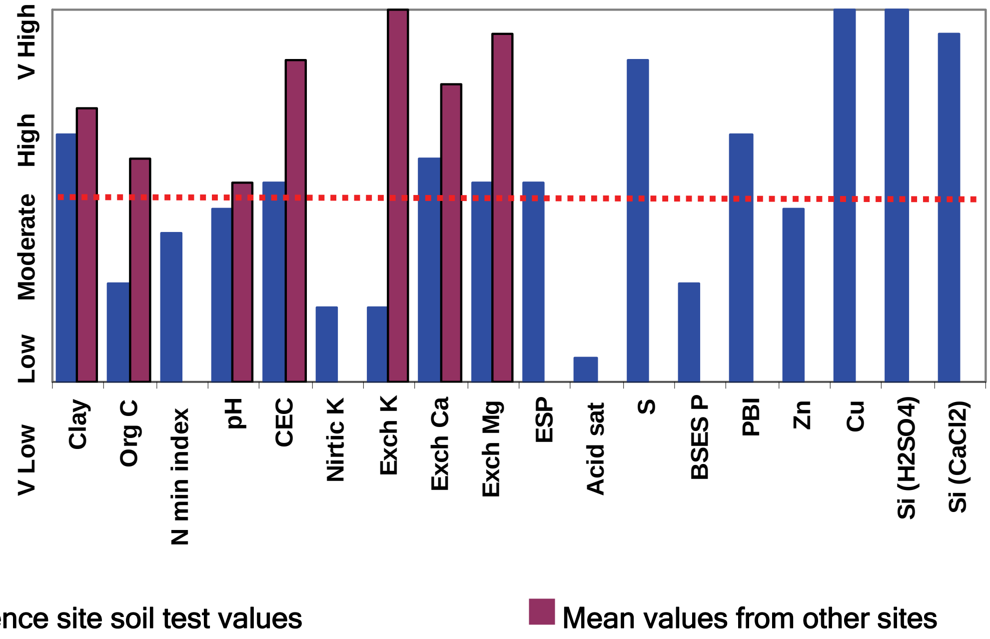
Field appearance:
Topsoils are red to brown light clays. Subsoils are mottled yellowish red grading to red with depth and are light to medium structured clays.

Similar soils:
This soil has similar properties to the Oakwood (Ok), Otoo (Ot) and Watalgan (W soils.

Physical properties:
These soils are permeable and well-drained. They are prone to hardsetting and may erode depending on the slope.

Chemical properties:
These soils have a moderate to moderately high fertility status. They range from being acidic to neutral. The organic carbon percentage and N mineralisation potential of the topsoils are moderately low. The CEC ranges from moderate to moderately high. The K reserves are low, but exchangeable K values range from low to moderate. Topsoils can be slightly sodic, but ESP increases with depth. Topsoils have moderate P-sorbing capacities. BSES P values are generally moderate, but vary according to past fertiliser histories. There is generally no evidence of micronutrient deficiencies. Silicon is adequately supplied.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Gypsum t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn Kg/ha
Fallow plant	2	120	20	120	0	0	0	0
Replant	2	140	20	120	0	0	0	0
Ratoon	0	140	20	120	0	0	0	0

Tillage and water management:
These soils are prone to hardsetting. Compaction by machinery can be confined to the inter-row by adopting controlled traffic. Green cane trash blanketing and the application of organic amendments can improve soil structure, tilth and soil porosity. These soils are permeable and have good drainage. Overhead irrigation is recommended to reduce losses to deep drainage. If flood irrigated, U-shaped furrows are most suitable with medium flow rates. Plant available water capacity is moderate.

Environmental risk management:
Loss of nitrogen by denitrification is not usually a factor except when heavy rain or flooding occurs shortly after N application. Loss of nitrate by leaching is possible and fertiliser applications should be split to reduce this risk.

Kepnock (Kp) - Yellow Clay Loam
Loamy topsoil over a mottled yellow subsoil

Productivity class: Clay loam

Occurrence: Kepnock soils occur on the mid to lower slopes of rises and plains. They occupy about 15% of the sugarcane area in the Bundaberg district.

Formation:
Kepnock soils are developed on deeply weathered fine grained sedimentary rocks.

Kepnock soil profile

Kepnock soil in the Three Chain Rd area

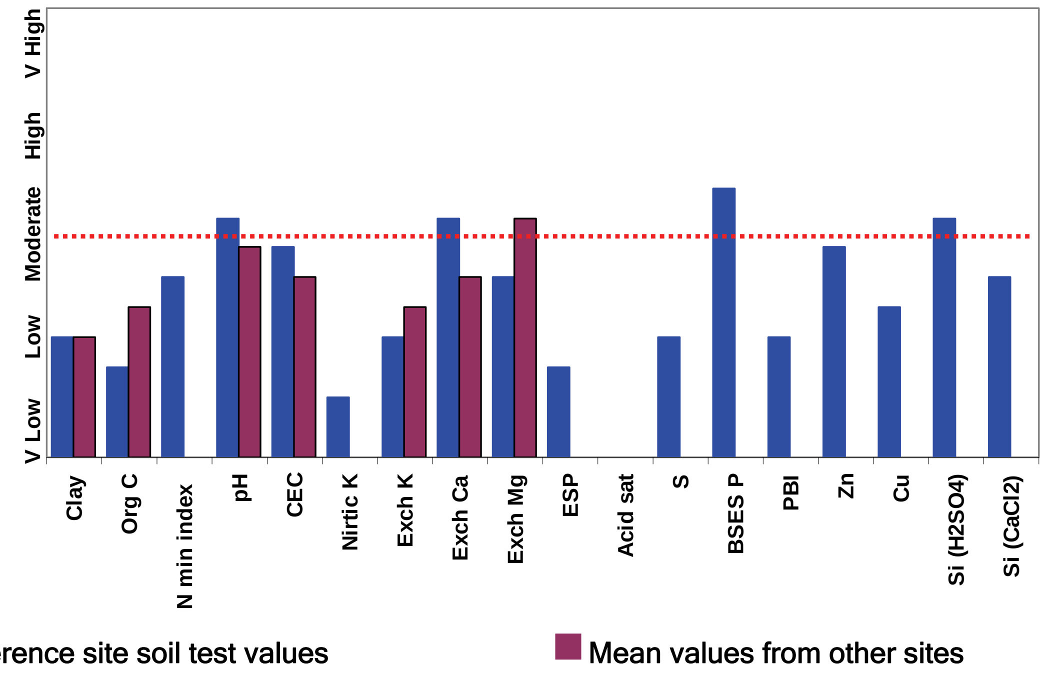
Field appearance:
Topsoils are grey loams to clay loams. Subsoils have a bleached A2 horizon overlying mottled yellow, light to medium clays with reddish iron / manganese nodules at depth.

Similar soils:
This soil has similar properties to the Gillen (Gi), Calavos (Ca) and Cedars (Cr) soils each of which occupy small sections of the sugarcane growing area.

Physical properties:
These soils are moderately permeable and moderately well-drained. They are prone to hardsetting and can be subject to erosion depending on the slope.

Chemical properties:
These soils have a low to moderate fertility status and range from neutral to strongly acid. The organic carbon percentage, N mineralisation potential and CEC of the topsoils are low to moderately low, as are the K reserves and exchangeable K values. Topsoils have low P-sorbing capacities. BSES P can vary according to past fertiliser histories. Sulphur values are generally low. Micronutrients need to be monitored as low to marginal levels have been recorded at some locations.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0	130	20	100	15	0	0	0
Replant	0	150	20	120	15	0	0	0
Ratoon	0	150	0	120	15	0	0	0

Tillage and water management:

These soils are prone to hardsetting and compaction can be confined to inter-rows with controlled traffic. Green cane trash blanketing and the application of organic amendments can improve soil structure, tilth and soil porosity. If flood irrigated, U-shaped furrows are most suitable with medium flow rates. Overhead or trickle irrigation may help reduce losses to deep drainage. Plant available water capacity is moderate but is lower in the subsoil due to the presence of nodules.

Environmental risk management:

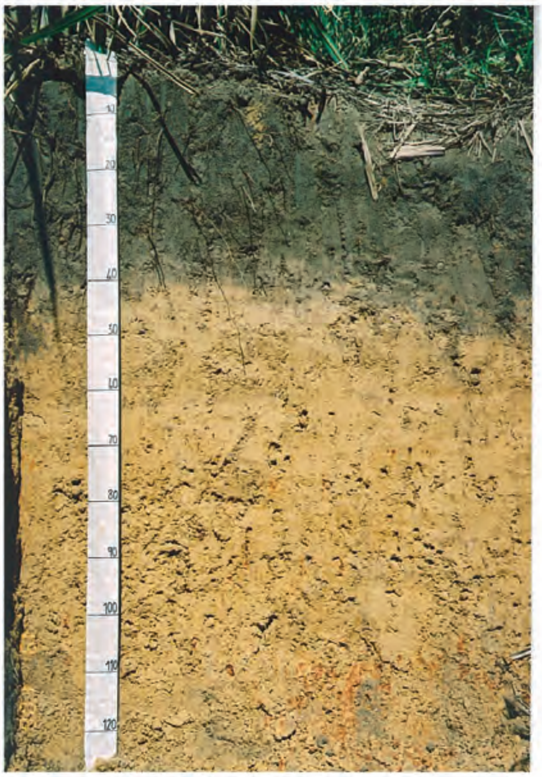
Loss of nitrogen by leaching and / or denitrification could occur with excessive rainfall or high irrigation rates soon after fertiliser application. To reduce these risks fertiliser applications should be split. Cultivation of steeper slopes should be avoided. Grassed headlands and drains, green cane trash blanketing and minimum tillage should be used to reduce the risk of erosion.

Alloway (Al) - Grey Sandy Loam
Sandy topsoil over a yellowish grey clay subsoil

Productivity class: Grey loam

Occurrence: Alloway soils occur on gently sloping plains, drainage depressions and lower slopes of rises. They occupy about 4% of the sugarcane area in the Bundaberg district.

Formation:
Alloway soils are developed on deeply weathered fine grained sedimentary rocks.


Alloway soil profile


Alloway soil in the Wises Rd area

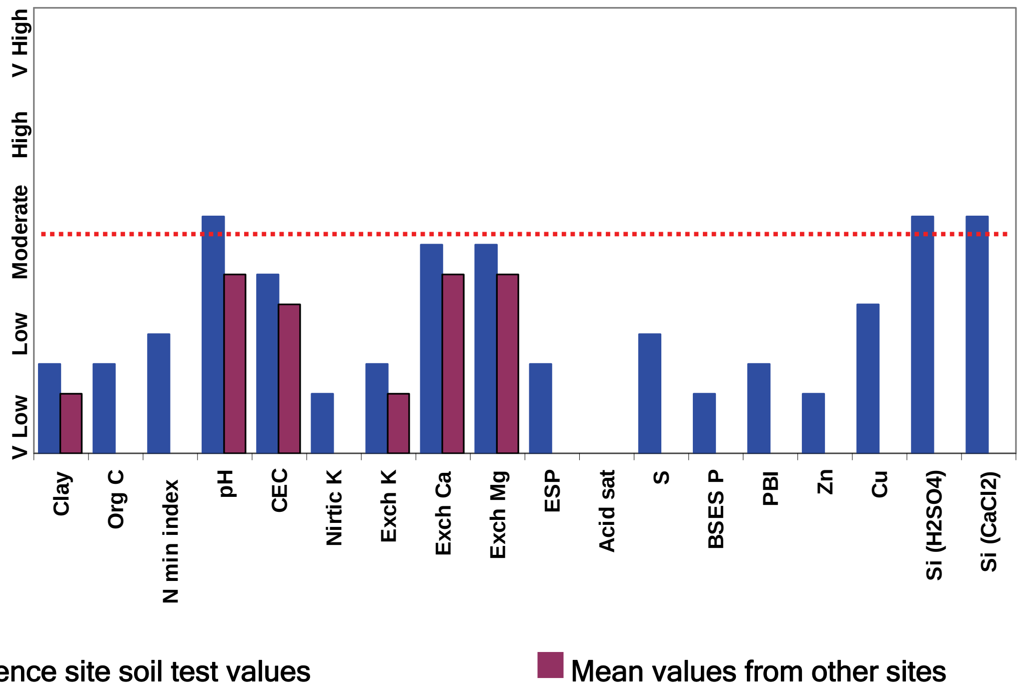
Field appearance:
Topsoils are grey loamy sands to sandy loams with bleached A2 horizons. Subsoils are grey to yellow sandy clay loams to sandy light clays with red mottles at depth.

Similar soils:
This soil has similar properties to the Clayton (Cl), Peep (Pp) and Woco (Wo) soils which each occupy small sections of the sugarcane growing area.

Physical properties:
These soils are imperfectly drained, but they have low plant available water capacity due to their sandy nature.

Chemical properties:
These soils have a low fertility status and have low nutrient retention due to low CEC and organic matter content. They are acid to neutral depending on their liming histories. Due to their sandy nature soil pH can be increased with relatively small amounts of lime. The organic carbon, N mineralisation index and CEC of the topsoil are low, as are the K reserves and exchangeable K values. Topsoils have low P-sorbing capacities. BSES P varies according to past fertiliser history. Sulphur values are usually low. Monitoring of micronutrients is needed because they are often low. Although the reference site silicon values are satisfactory, lower levels can be encountered in these soils.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0	130	30	100	15	0	0	10
Replant	0	150	30	120	15	0	0	10
Ratoon	0	150	15	120	15	0	0	0

Tillage and water management:
Drainage is advisable to reduce the effects of waterlogging. Green cane trash blanketing and the application of organic amendments can improve soil structure, tilth, soil porosity and plant available water capacity. Overhead irrigation should be practised with frequent light irrigations to reduce the incidence of waterlogging. Plant available water capacity is low.

Environmental risk management:
Loss of nitrogen by denitrification can occur during periods of excessive rainfall or waterlogging. To reduce this risk, mound planting should be considered and fertiliser applications should be split. Due to the low P sorbing capacity of the topsoil and proximity to watercourses, there is a risk of off-site movement of sediment and phosphate.

Clayton (Cl) - Grey Sandy Loam
Sandy topsoil over a grey clay subsoil

Productivity class: Grey loam

Occurrence: Clayton soils occur on lower slopes and depressions in the landscape. They occupy about 3% of the sugarcane area in the Bundaberg district.

Formation:
Clayton soils are developed on deeply weathered coarse grained sedimentary rocks.


Clayton soil profile


Clayton soil in the Three Chain Rd area

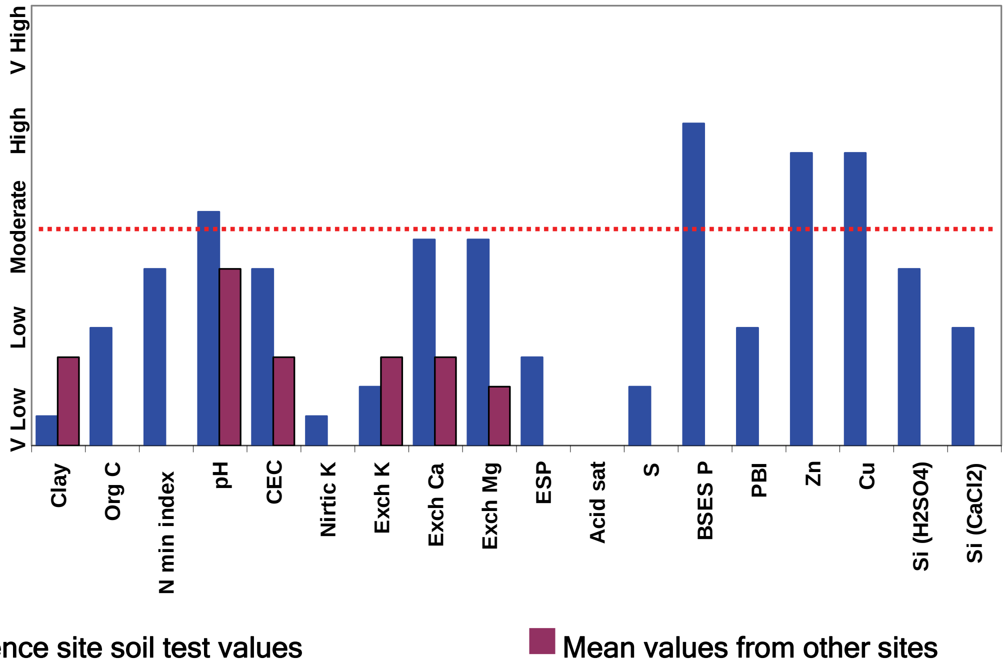
Field appearance:
Topsoils are grey fine sandy loams to loams with bleached A2 horizons. Subsoils are mottled grey, light to medium clays.

Similar soils:
This soil has similar properties to the Alloway (Al), Peep (Pp) and Woco (Wo) soils which each occupy small sections of the sugarcane growing area.

Physical properties:
These soils are poorly drained and can be waterlogged for several months. They have low plant available water holding capacities.

Chemical properties:
These soils have a low fertility status and have low nutrient retention due to low CEC and organic matter contents. They are acid to neutral depending on their liming histories. Due to their sandy nature, soil pH can be increased with relatively small amounts of lime. The organic carbon, N mineralisation index and CEC of the topsoils are low, as are the K reserves and exchangeable K values. Exchangeable calcium can be low but is adequate in the reference site, possibly due to liming. Topsoils have low P-sorbing capacities. BSES P can vary according to past fertiliser history. Sulphur values are often low. Although the micronutrient levels for the reference site are adequate, they can be below critical values in some profiles and should be monitored. Silicon should also be monitored as low levels are often associated with these soils.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0	120	0	80	20	0	0	0
Replant	0	140	0	100	20	0	0	0
Ratoon	0	140	0	100	20	0	0	0

As the Si values for the reference site are both below the critical values, the application of a silicon amendment is recommended.

Tillage and water management:

Surface and subsurface drainage is advisable to reduce the effects of waterlogging. Green cane trash blanketing and the application of organic amendments can improve soil structure, tilth, soil porosity and plant available water capacity. If irrigation is practiced, frequent light applications of overhead irrigation are suggested to avoid waterlogging. Plant available water capacity is low.

Environmental risk management:

Loss of nitrogen by denitrification can occur during periods of excessive rainfall or waterlogging. To reduce this risk, mound planting should be considered and fertiliser applications should be split. Due to low P sorbing capacities and proximity to watercourses and drainage, there is a risk of off-site movement of sediment and dissolved phosphate.

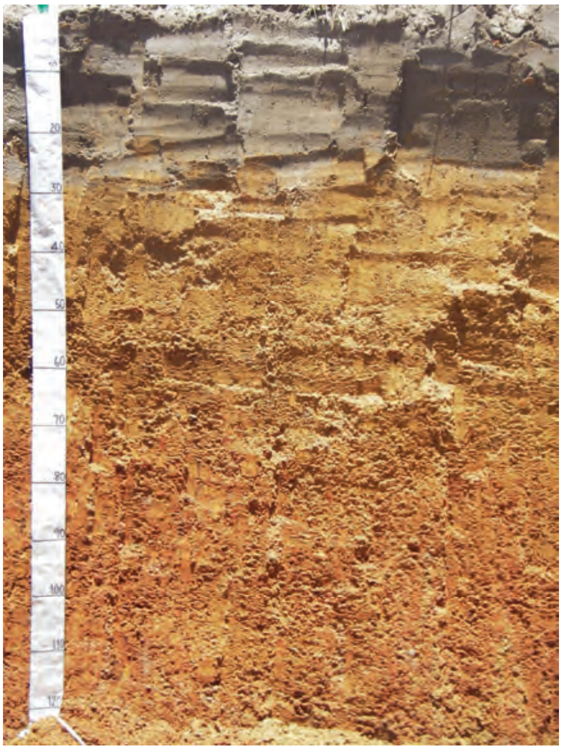
Gooburrum (Gb) - Red Sandy Loam

Sandy topsoil over a red subsoil

Productivity class: Sandy loam

Occurrence: Gooburrum soils occur on crests and upper and mid slopes of rises. They occupy about 5% of the sugarcane area in the Bundaberg district.

Formation:
Gooburrum soils have formed on deeply weathered coarse grained sedimentary rocks.



Gooburrum soil profile

Gooburrum soil near Rosedale Rd

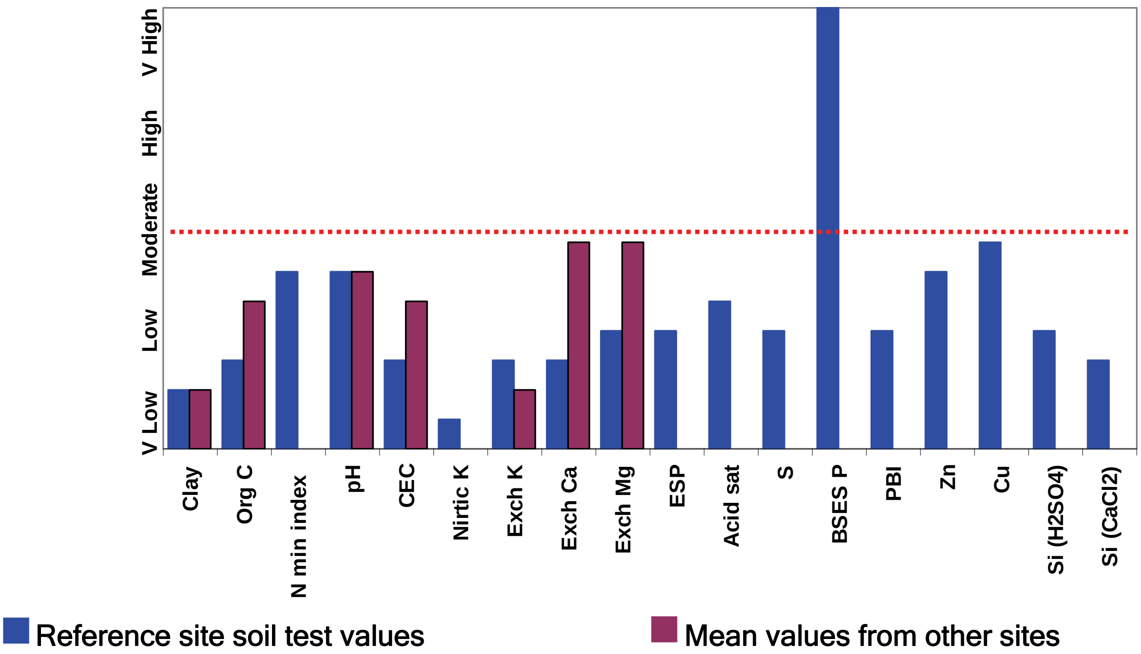
Field appearance:
Topsoils are brown to dark grey brown loamy sands to sandy clay loams with weak structure. They overlie red sandy clay loam to clay loam subsoils. Subsoils have a blocky structure.

Similar soils:
This soil has similar properties to the Farnsfield (Ff) and Pocket (Pk) soils which occupy small sections of the sugarcane area.

Physical properties:
These soils are deep and well-drained. They are prone to erosion on slopes.

Chemical properties:
These soils have a low to moderate fertility status and range from neutral to strongly acid. The organic carbon content, N mineralisation potential and CEC of the topsoils are low to moderately low, as are the K reserves and exchangeable K values. Topsoils have low P-sorbing capacities. BSES P values vary according to past fertiliser histories. In the case of the reference site, the BSES P is high reflecting excessive applications of P. Sulphur, calcium and magnesium values can be low. Micronutrients need to be monitored as low to marginal levels have been recorded at some locations. Silicon levels should be monitored as low values have been recorded at some sites.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	2.5	130	0	100	15	50	0	0
Replant	2.5	150	0	120	15	50	0	0
Ratoon	0	150	0	120	15	0	0	0

As the Si values for the reference site are both below the critical values, the application of a silicon amendment is recommended.

Tillage and water management:

Overhead or trickle irrigation should be used to reduce deep drainage. If flood irrigated, V-shaped furrows are most suitable with small but frequent applications. Green cane trash blanketing and the application of organic amendments can improve soil structure, tilth, soil porosity and plant available water capacity, with the latter generally low. Minimum tillage and controlled traffic are recommended for these soils.

Environmental risk management:

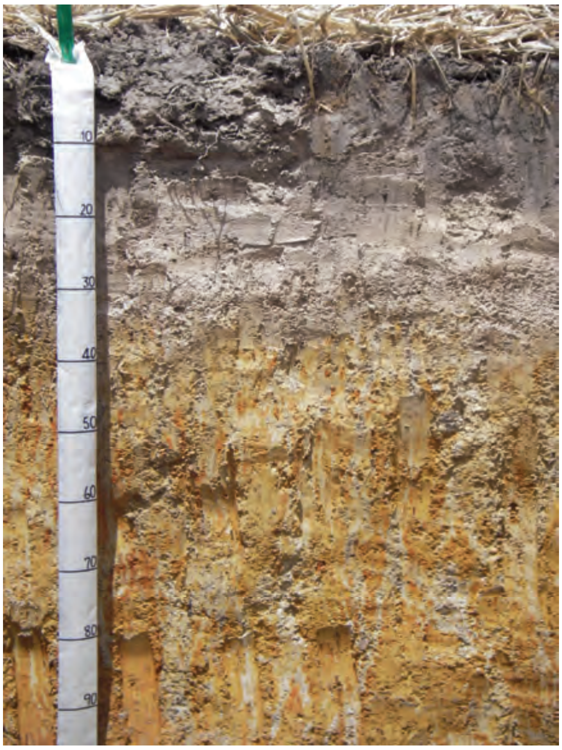
Loss of nitrate by leaching can occur during periods of excessive rainfall or irrigation. To reduce this risk, fertiliser applications should be split. Erosion control measures, including contour planting and grassed waterways should be implemented on sloping land.

Meadowvale (Md) - Yellow Sandy Loam
Sandy topsoil over a yellow subsoil

Productivity class: Sandy loam

Occurrence: Meadowvale soils occur on mid slopes. They occupy about 5% of the sugarcane area in the Bundaberg district.

Formation:
Meadowvale soils have formed on deeply weathered coarse grained sedimentary rocks.



Meadowvale soil profile


Meadowvale soil in the Moorlands Rd area

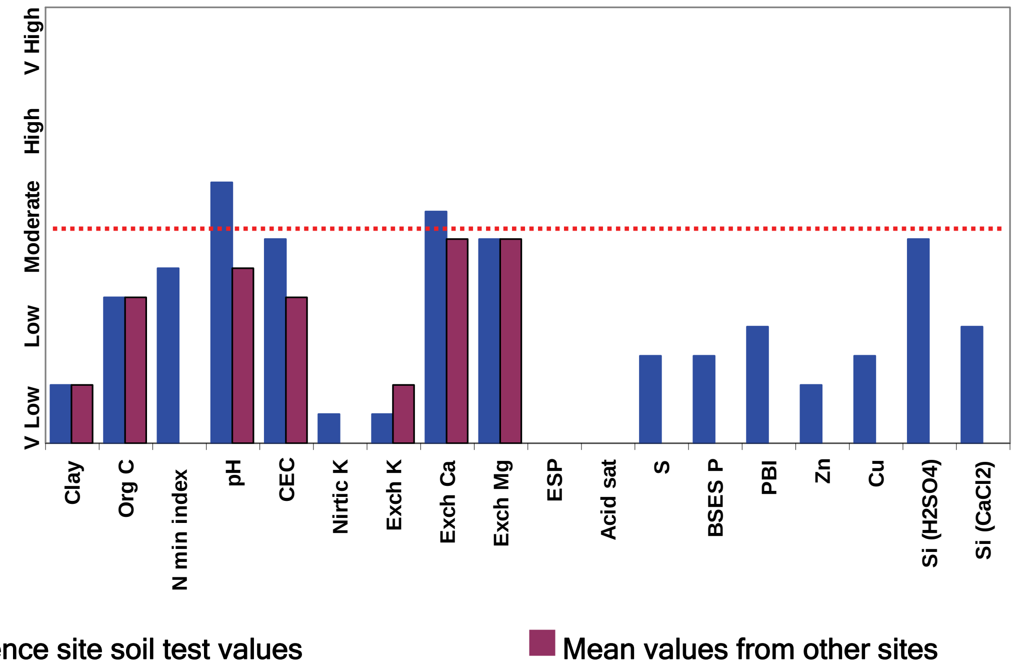
Field appearance:
Topsoils are grey loamy sands to sandy loams over bleached A2 horizons. The subsoils are massive mottled yellow to brown sandy clays to medium clays.

Similar soils:
This soil has similar properties to the Isis (Is), Woolmer (Wr) and Littabella (Lt) soils which occupy small sections of the sugarcane area.

Physical properties:
These soils are moderately permeable and imperfectly drained. The subsoil is intermittently waterlogged. Rooting depth is typically up to 1m.

Chemical properties:
These soils have a low to moderately low fertility status and range from neutral to strongly acid. The organic carbon content, N mineralisation potential and CEC of the topsoils are low to moderately low. K reserves and exchangeable K values are low. Topsoils have low P-sorbing capacities. BSES P is often low, but varies according to past fertiliser histories. Sulphur values are generally low. Micronutrients need to be monitored as low to marginal levels have been recorded at some locations. Silicon levels should also be monitored as low values have been recorded at some sites.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0	120	30	100	20	0	10	10
Replant	0	140	30	120	20	0	10	10
Ratoon	0	140	15	120	20	0	0	0

As the Si values for the reference site are both below the critical values, the application of a silicon amendment is recommended.

Tillage and water management:

If irrigation is practiced, frequent light applications of water using overhead irrigations are suggested to avoid waterlogging. Green cane trash blanketing and the application of organic amendments can improve soil structure, tilth, soil porosity and plant available water capacity. Minimum tillage and controlled traffic are recommended for these soils. Plant available water capacity is moderate.

Environmental risk management:

Loss of nitrate by denitrification can occur during periods of excessive rainfall or irrigation. To reduce this risk, fertiliser applications should be split. In addition, good surface drainage should be used to reduce ponding after rainfall. Erosion control measures should be implemented on sloping sites.

Quart (Qr) - Grey Sand

Grey sandy topsoil over a grey sandy subsoil

Productivity class: Sand

Occurrence: Quart soils occur on very gently sloping areas north of the Elliott River. They occupy about 2% of the sugarcane area in the Bundaberg district.

Formation:
Quart soils have formed on deeply weathered coarse grained sedimentary rocks.

Quart soil profile

Quart soil north of the Elliott River

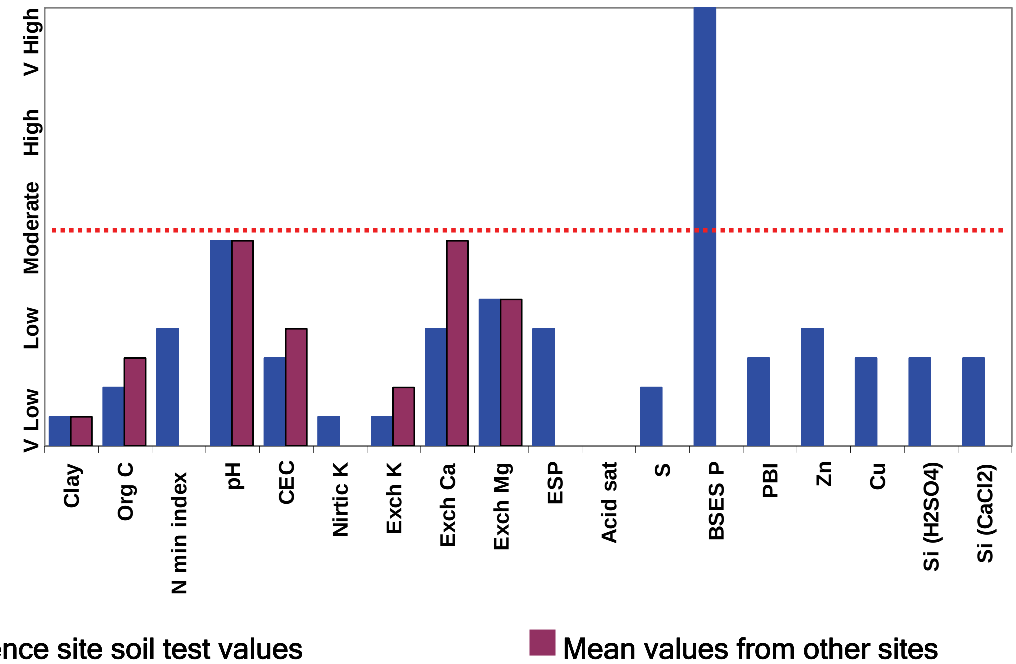
Field appearance:
Topsoils are grey loamy sands to sandy loams over bleached A2 horizons. They overlie pale yellow to grey sandy loam to sandy clay loams. Soils have little structure.

Similar soils:
This soil has similar properties to the Wallum (Wm), Winfield (Wf) and Theodolite (Th) soils which are more poorly drained.

Physical properties:
These soils are deep, very sandy and imperfectly drained. Their sandy nature contributes to their very weak structure.

Chemical properties:
These soils have a low fertility status and range from neutral to acid. The organic carbon content, N mineralisation potential and CEC of the topsoils are all low. K reserves and exchangeable K values are very low. Topsoils have low P-sorbing capacities. BSES P values reflect past fertiliser histories. In the case of the reference site the BSES P is high suggesting excessive P applications in the past. Sulphur, calcium and magnesium values are all low. Micronutrients and silicon need to be monitored as they are generally low.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	1.5	130	0	100	25	0	10	0
Replant	1.5	150	0	120	25	0	10	0
Ratoon	0	150	0	120	25	0	0	0

As the Si values for the reference site are both below the critical values, the application of a silicon amendment is recommended.

Tillage and water management:

Frequent light overhead irrigations should be used due to the sandy nature of the soil and the very low plant available water capacity. Green cane trash blanketing and the application of organic amendments can improve soil structure, tilth, soil porosity and plant available water capacity. Minimum tillage and controlled traffic are recommended for these soils.

Environmental risk management:

Loss of nitrate by leaching can occur during periods of excessive rainfall or irrigation. To reduce this risk, it is strongly recommended that fertiliser applications be split. Due to the proximity of waterways and streams, there is a risk of offsite movement of P particularly due to the low P sorbing capacity of these soils. Erosion control measures should be implemented on sloping sites.

Mahogany (Mh) - Dark Sand

Dark sandy topsoil over a sandy subsoil

Productivity class: Sand

Occurrence: Mahogany soils occur in depressions and on gentle lower slopes. They occupy about 2% of the sugarcane area in the Bundaberg district.

Formation:
Mahogany soils have formed on deeply weathered coarse grained sedimentary rocks.

Mahogany soil profile

Mahogany soil in the Three Chain Rd area

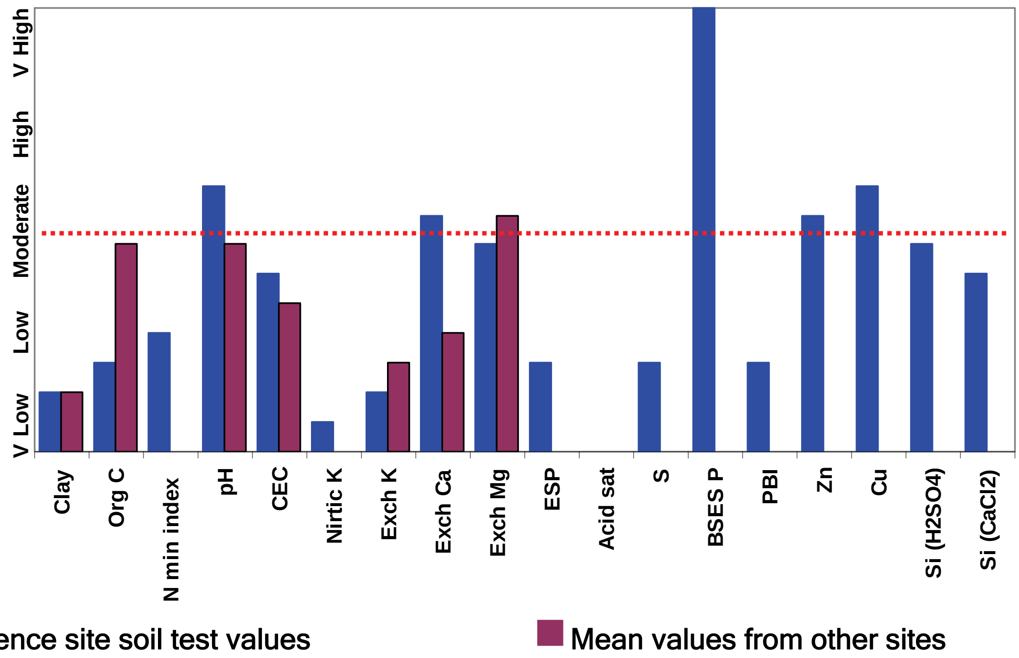
Field appearance:
Topsoils are dark grey to black sands to sandy loams. They overlie a bleached A2 horizon. Subsoils are grey mottled sandy clay loams to sandy clays with massive structure.

Similar soils:
This soil has similar properties to the Rothchild (Rt) and Kinkuna (Kn). Both are minor soils in the sugarcane area.

Physical properties:
These soils are deep, sandy and poorly drained. Their sandy nature contributes to their very weak structure.

Chemical properties:
These soils have a moderately low fertility status and pH values range from neutral to strongly acid. The organic carbon content, N mineralisation potential and CEC of the topsoils are low to moderately low, as are the K reserves and exchangeable K values. Topsoils have low P-sorbing capacities. BSES P varies according to fertiliser histories and, in the case of the reference site, the BSES P is very high reflecting excessive P applications in the past. Sulphur values are generally low. Micronutrients and silicon need to be monitored as low to marginal levels have been recorded at some locations.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P Kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn Kg/ha
Fallow plant	0	130	20	100	25	0	0	0
Replant	0	150	20	120	25	0	0	0
Ratoon	0	150	0	120	25	0	0	0

Tillage and water management:

Frequent light overhead irrigations should be used due to the sandy nature of the soil. Trickle irrigation is the most efficient method of irrigating these soils. Green cane trash blanketing or the application of organic amendments can improve soil structure, tilth, soil porosity and plant available water capacity. Plant available water capacity is low. Minimum tillage and controlled traffic are recommended for these soils.

Environmental risk management:

Loss of nitrate by leaching can occur during periods of excessive rainfall or irrigation. To reduce this risk, it is strongly recommended that fertiliser applications be split. Due to the proximity of waterways and streams, there is a risk of offsite movement of P particularly due to the low P-sorbing capacity of these soils. Erosion control measures should be implemented on sloping sites.

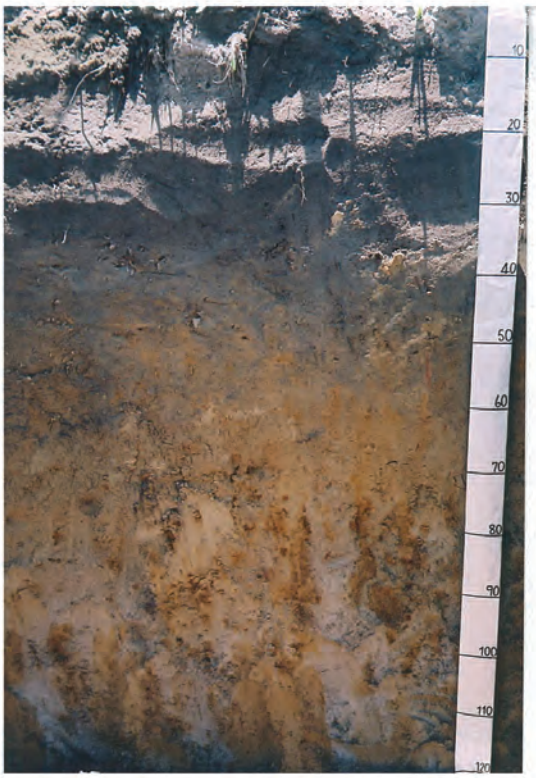
Colvin (Cv) - Black Sand

Black to brown sandy topsoil over a grey mottled sandy subsoil

Productivity class: Coastal

Occurrence: Colvin soils occur on old beach ridge formations in the marine plains between Fairymead and Moore Park. They occupy about 3% of the sugarcane area in the Bundaberg district.

Formation:
Colvin soils have formed on deep sandy beach ridges.



Colvin soil profile

Colvin soil in the Gooburrum area

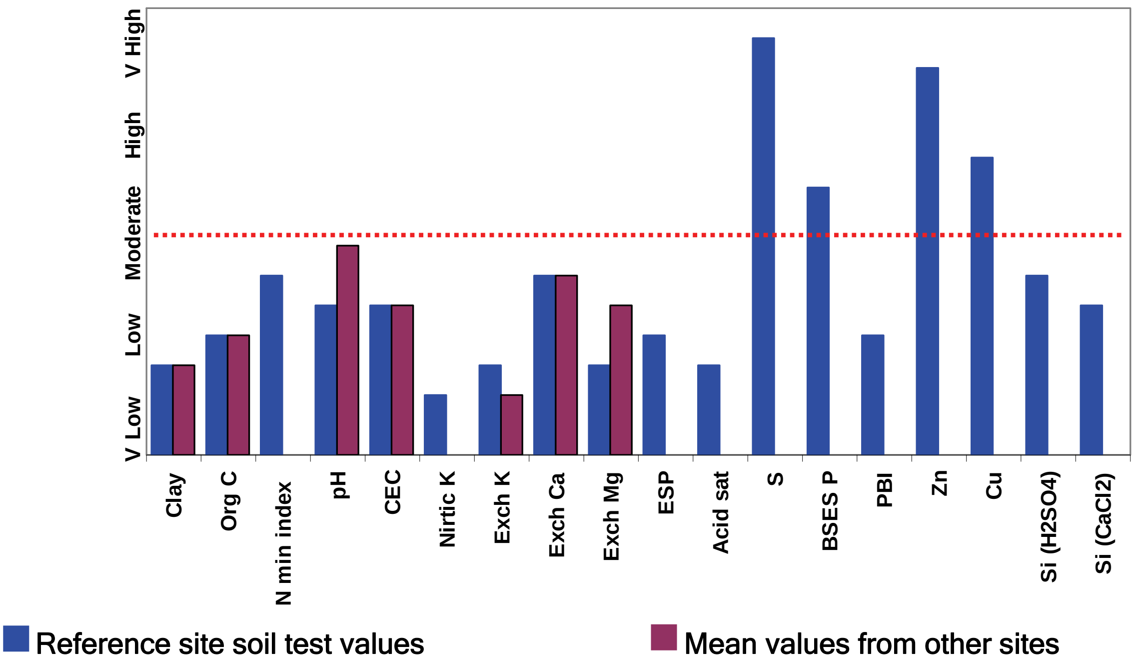
Field appearance:
Topsoils are dark grey to black loamy sands to sandy loams. They overlie brown to yellow sand to sandy loam subsoils with mottles.

Similar soils:
There are seven other soils with similar characteristics as indicated in Table 3.1. These include Moore Park (Mp) and Tantitha (Tt).

Physical properties:
These soils are deep, very sandy and imperfectly drained, with a fluctuating water table. Due to their sandy nature, structure in the topsoil is very weak.

Chemical properties:
These soils have a low to moderately low fertility status and are often acidic. The organic carbon content, N mineralisation potential and CEC of the topsoils are low to moderately low. K reserves and exchangeable K are low, as are exchangeable Mg values. Topsoils have low P-sorbing capacities. BSES P varies according to fertiliser histories. Sulphur values are generally low but also vary due to past fertiliser applications. Micronutrients and silicon need to be monitored as low to marginal levels are possible.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn Kg/ha
Fallow plant	2.5	120	20	100	0	75	0	0
Replant	2.5	140	20	120	0	75	0	0
Ratoon	0	140	0	120	0	0	0	0

As the Si values for the reference site are both below the critical values, the application of a silicon amendment is recommended.

Tillage and water management:

Surface and subsurface drainage is advisable to reduce the effects of potential waterlogging. Green cane trash blanketing and the application of organic amendments can improve plant available water capacity which is low. Frequent light irrigations using either overhead or trickle are the most efficient ways of irrigating these soils. Green cane trash blanketing will also improve soil structure, tilth and soil porosity. Minimum tillage and controlled traffic are recommended for these soils.

Environmental risk management:

Loss of nitrate by denitrification can occur during periods of excessive rainfall which may result in a perched water table. Nitrate can also be lost by leaching due to the sandy nature of these soils. To reduce these risks, it is recommended that fertiliser applications be split.

Fairymead (Fm) - Humic Gley

Black topsoil over a grey mottled clay subsoil

Productivity class: Coastal

Occurrence: Fairymead soils occur on marine sediments in depressions and swales between beach ridges in the area from Moore Park to Fairymead. They occupy about 2% of the sugarcane area in the Bundaberg district.

Formation:
Fairymead soils have formed on deep marine sediments.

Fairymead soil profile

Fairymead soil in the Moore Park area

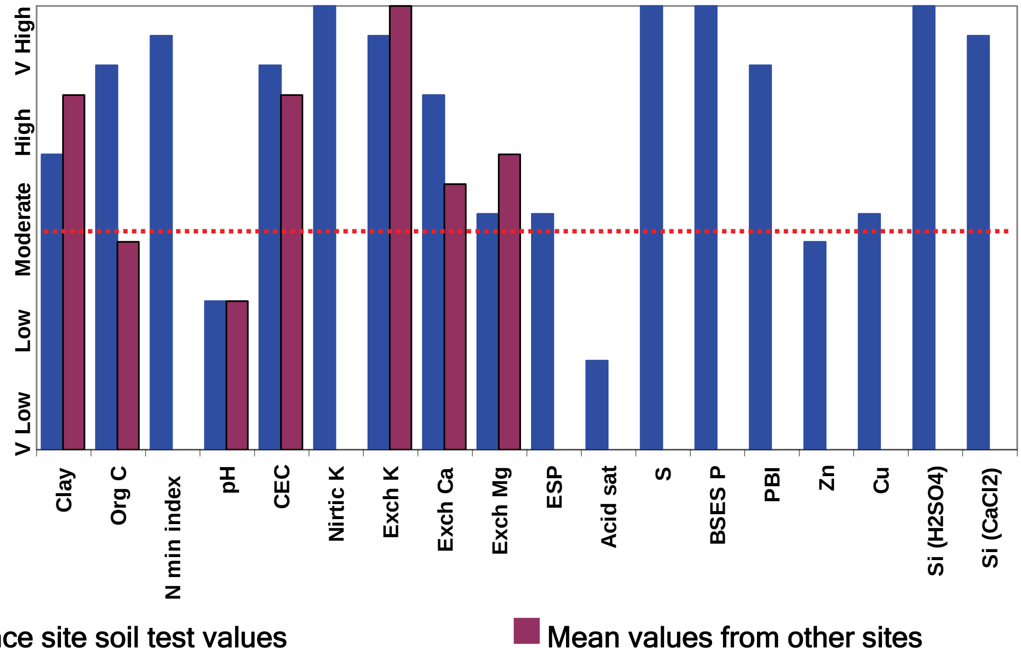
Field appearance:
Topsoils are black clay loams to light clays. They overlie mottled grey light to medium clay subsoils with common occurrences of jarosite and pyrite.

Similar soils:
This soil has similar properties to the Fairydale (Fd), Whymere (Wy) and Booloongie (Bo) soils.

Physical properties:
These soils are deep and poorly drained with high water tables. Drainage of these soils has lowered water tables resulting in the oxidation of pyrite to jarosite. High water tables may still occur after heavy rainfall.

Chemical properties:
These soils have a moderate to high fertility status and are usually strongly acid due to their acid sulphate characteristics. The organic carbon content, N mineralisation potential and CEC of the topsoils are high. K reserves, exchangeable K, Ca and Mg are high. Topsoils have high P-sorbing capacities. BSES P varies according to fertiliser histories. In the case of the reference site, the BSES P is very high reflecting excessive applications of P in the past. Sulphur, silicon and micronutrients are generally well supplied.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime* t/ha	Gypsum* t/ha	N** kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	5	2	130	0	0	0	0	0	0
Replant	5	2	150	0	0	0	0	0	0
Ratoon	0	0	150	0	0	0	0	0	0

* If more than one ameliorant is suggested, then application rates need to be rationalised

** Based on the organic C content and N mineralisation index, this soil required 80 and 100 kg N/ha for plant and ratoon cane respectively. However due to suspected N losses by denitrification, the N fertiliser application rates have been increased to meet the expected yield potential.

Tillage and water management:

Drainage of these soils is essential to lower water tables, but fluctuating ground water levels are still an issue. Dewatering to lower the perched water table may be necessary particularly during wet periods. However, care should be taken not to lower the water table below the pyritic layers otherwise acid leakage will occur into drains. Access onto these soils is restricted to dry periods and controlled traffic and minimum tillage are recommended. Green cane trash blanketing is not advisable as it prevents surface horizons from drying out.

Environmental risk management:

Loss of nitrate by denitrification is a constant risk. Split fertiliser applications would reduce this risk, but are often impracticable due to limited access onto these soils during wet periods. Mound planting is therefore suggested to minimise N losses by denitrification. Frequent large applications of lime are essential to ameliorate the acid sulphate conditions.

Auburn (Ab) - Grey Forest Soil

Sandy to loamy topsoil over a sodic clay subsoil

Productivity class: Sodic

Occurrence: Auburn soils occur on old alluvial deposits on plains and terraces near the Kolan River. They occupy about 5% of the sugarcane area in the Bundaberg district.

Formation:
Auburn soils have formed over a long period on deep alluvial deposits resulting in distinct horizons within the profile.

Auburn soil profile

Auburn soil at Moorlands

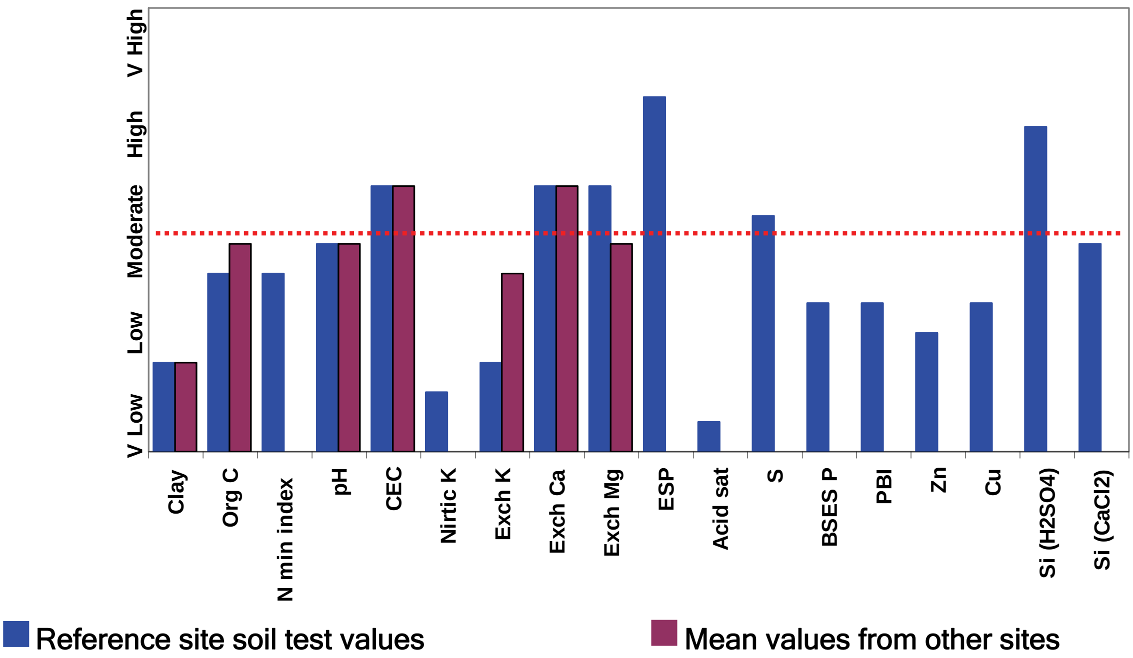
Field appearance:
Topsoils are dark grey to grey, fine sandy clay loams to silty clay loams. Subsoils are frequently mottled brown or grey medium to heavy clays.

Similar soils:
This soil has similar properties to the Kolan (Ko) and Givelda (Gv) soils together with nine other soils listed in Table 3.1.

Physical properties:
These soils are imperfectly drained with intermittent high water tables. Rooting depth is limited by the strongly sodic subsoils.

Chemical properties:
These soils have a moderately low to moderate fertility status and range from neutral to acid. The organic carbon content, N mineralisation potential and CEC of the topsoils are moderate. K reserves are low, but exchangeable K values are moderately low to moderate. Although exchangeable Ca and Mg values are moderate, exchangeable sodium percentage (ESP) values are high. Topsoils have low P-sorbing capacities. BSES P varies according to fertiliser histories. Sulphur and micronutrients levels are generally satisfactory.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Gypsum t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	6	110	20	120	5	0	0	0
Replant	6	110	20	120	5	0	0	0
Ratoon	0	130	10	120	5	0	0	0

Tillage and water management:
These soils are very challenging and require careful management. Rooting depth and plant available water capacity are limited by high sodicity and salt levels at shallow depths. Internal drainage is poor and surface horizons are often hardsetting. Access is difficult during wet periods, yet improved drainage is difficult due to their low position in the landscape. Deep ripping combined with gypsum application may improve permeability and available water capacity. Green cane trash blanketing and the application of organic amendments can improve soil structure, tilth, porosity and plant available water capacity. Frequent but small irrigations are advisable due to the limited infiltration.

Environmental risk management:
Loss of nitrate by denitrification can occur during periods of excessive rainfall which may result in a perched water table. To reduce this risk, it is recommended that fertiliser applications be split. However this will not always be possible due to the limited periods of access onto these sodic soils.

Kolan (Ko) - Grey Forest Soil

Sandy to loamy topsoil with sodic clay subsoil

Productivity class: Sodic

Occurrence: Kolan soils occur on crests and hill slopes in areas north and south of the Kolan River to the west of Bundaberg. They occupy about 6% of the sugarcane area in the Bundaberg district.

Formation:
Kolan soils occur on moderately weathered sedimentary rocks.

Kolan soil profile

Kolan soil in the Tegege area

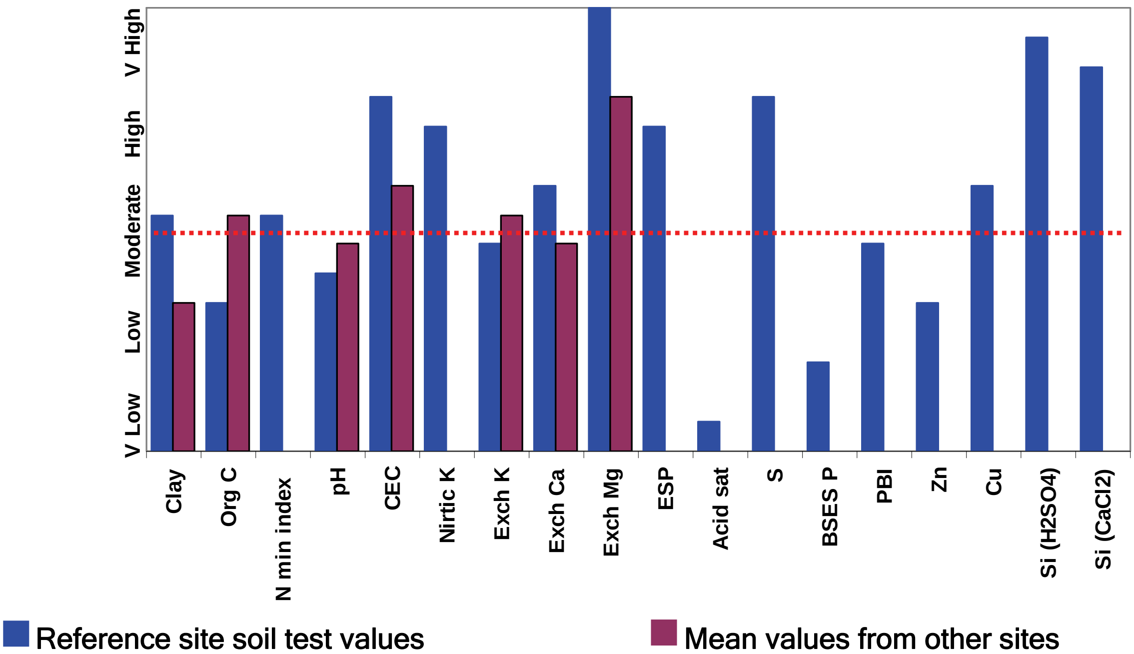
Field appearance:
Topsoils are dark grey loams or sandy clay loam. They overlie mottled grey to brown medium to heavy clay sodic subsoil. There are mottles at depth.

Similar soils:
This soil has similar properties to the Auburn (Ab) and Givelda (Gv) soils.

Physical properties:
These soils are deep, with poor internal drainage and seasonal high water tables. They have limited rooting depth due to high sodicity.

Chemical properties:
These soils have a moderate fertility status and range from neutral to acid. The organic carbon content, N mineralisation potential and CEC of the topsoils are low to moderate. K reserves and exchangeable K values are moderate. Topsoils have low P-sorbing capacities. BSES P varies according to fertiliser histories. The BSES P value for the reference site is however low. Sulphur and micronutrient values are generally satisfactory.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime* t/ha	Gypsum* t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	5	4	120	30	50	0	0	0	0
Replant	5	4	140	30	100	0	0	0	0
Ratoon	0	0	140	15	100	0	0	0	0

* If more than one ameliorant is suggested, then application rates need to be rationalized. Gypsum will have a more rapid effect in improving structure and flocculation but will not reduce acidity.

Tillage and water management:

Deep ripping in conjunction with gypsum applications will improve water penetration and plant available water capacity which is generally low. It is difficult to obtain good tilth with these soils and there is a restricted moisture range for access and cultivation. Compaction by machinery can be limited by adopting controlled traffic. Irrigation events should be frequent and of a short duration as water penetration is limited. Overhead irrigation is the preferred method of water application. Laser levelling may be useful for improving surface drainage where the topography is flat, although care should be taken not to remove topsoil as this will bring the highly sodic horizons closer to the surface.

Environmental risk management:

Loss of nitrate by denitrification is a risk and can be reduced by splitting nitrogen applications. However, access for the second fertiliser application may be difficult in wet years.

Gahan (Gh) – Alluvial Soil

Brown and black loamy soil on alluvium

Productivity class: Alluvial

Occurrence: Gahan soils occur on recent alluvial deposits along the levees and terraces adjacent to the Burnett and Kolan rivers. They occupy about 2% of the sugarcane area in the Bundaberg district.

Formation:
Gahan soils are formed on young layered alluvium.

Gahan soil profile

Gahan soil in the Fairymead area

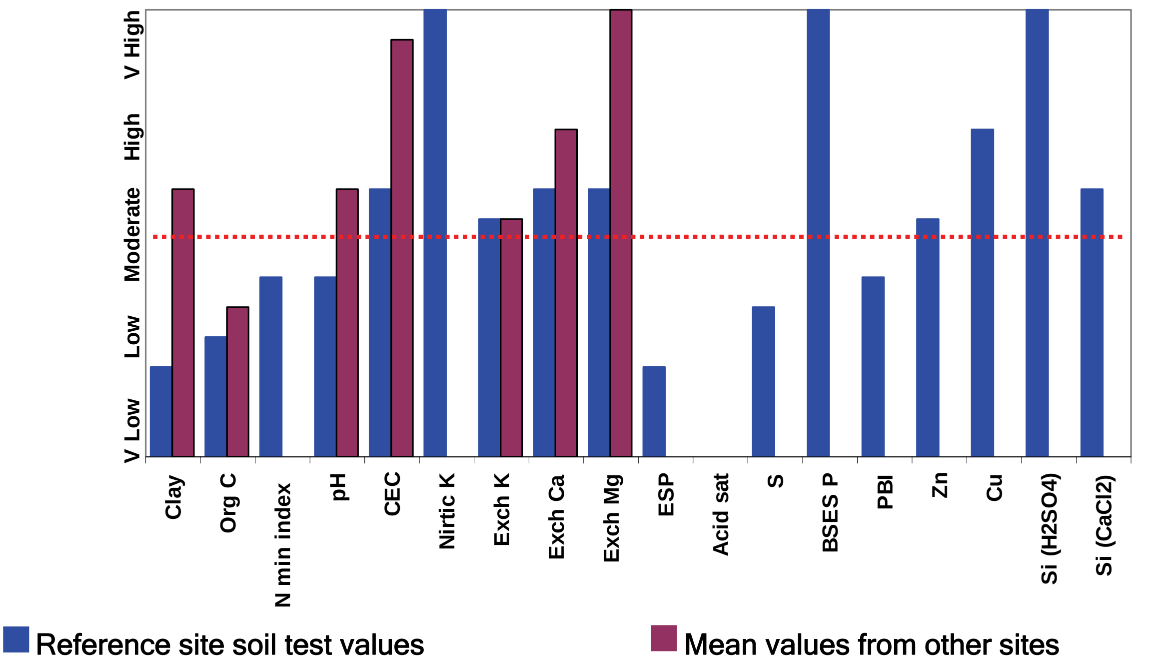
Field appearance:
Topsoils are black to brown loams. They overlie brown sandy subsoils. These soils exhibit distinctive layering caused by deposition during flood events.

Similar soils:
This soil has similar properties to the Burnett (Bn) and Flagstone (Fs).

Physical properties:
The lower layers of these soils are highly permeable. These soils are too young to have much structure. Because of their stratified nature it is difficult generalise about their physical properties as sandy layers can alternate with heavier textured material.

Chemical properties:
These soils do not have a uniform fertility status because of the nature of the depositional material. However, they are usually quite fertile for cropping. They range from being neutral to acid. The organic carbon content and N mineralisation potential are moderate. The CEC of the topsoils can be relatively high. The K reserves are often high whilst exchangeable K values are usually moderate. Topsoils have low P-sorbing capacities. BSES P varies according to fertiliser histories and the origin of deposited soil. Sulphur should be monitored as levels are sometimes low. Micronutrients are generally satisfactory.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0	120	0	0	10	0	0	0
Replant	0	140	0	50	10	0	0	0
Ratoon	0	140	0	50	10	0	0	0

Tillage and water management:

These soils are easily tilled and produce a good seed bed. Overhead irrigation is essential because of their high permeability. They require more frequent irrigation as plant available water capacity is reduced due to the presence of sandy layers in the profile. These soils are well suited to minimum tillage and controlled traffic.

Environmental risk management:

Flooding occasionally occurs on lower terraces and drainage depressions. Early harvest and split applications of nitrogen are recommended to reduce the risk of loss of nitrate by leaching. Green cane harvest and trash blanketing is recommended to retain moisture and reduce off-site movement of sediment. Grassed headlands and waterways will also assist in reducing offsite sediment and nutrient movement.

CHAPTER 4

Nutrient requirements for specific blocks of sugarcane

The guidelines for managing nutrient inputs according to soil type (Chapter 3) should be refined for specific blocks of cane by making use of some important tools such as soil testing, leaf analysis, juice analysis, and an integrated nutrient management package.

Soil testing

Soil testing provides useful information about the chemical (and some physical) properties of a soil and serves as a basis for determining specific nutrient inputs for a particular block of sugarcane. There are four important steps involved in this process. Each of these needs to be carried out with care to ensure meaningful results.

Step 1. Sample collection

Collect soil samples according to the guidelines provided in Appendix 2.

Step 2. Sample analysis

Submit samples to a reputable laboratory for analysis.

Step 3. Interpretation of results and calculating nutrient inputs

Ensure sound interpretation of the results and appropriate fertiliser recommendations by having an understanding of the basic process and getting advice from capable advisers such as extension officers.

Step 4. Fertiliser applications

Apply fertilisers at the appropriate rates and keep records of nutrient inputs.

Interpretation of soil test values

With the exception of N, soil tests are interpreted by comparing the actual soil analysis data with established critical values. As shown in Figure 4.1, a critical value for a particular nutrient is that soil test value above which any further yield response to the applied nutrient is unlikely.

Soil test results therefore indicate those nutrients which are present in adequate quantities (and are readily available to the crop), and those nutrients which are lacking (and need to be applied). As indicated in Chapter 2 nitrogen requirement is based on the yield potential for the district and the N mineralisation index, which depends on the organic carbon content (%) of the soil. Actual soil test values are interpreted by using the information provided in Chapter 2.

An example of a soil test report (Figure 4.2) shows the numerical soil test values from a commercial laboratory (column 2) and a representation of these values within the range from low (deficient) to excess/toxic. These values are used to assess the amount of each nutrient required by the crop for optimum production.

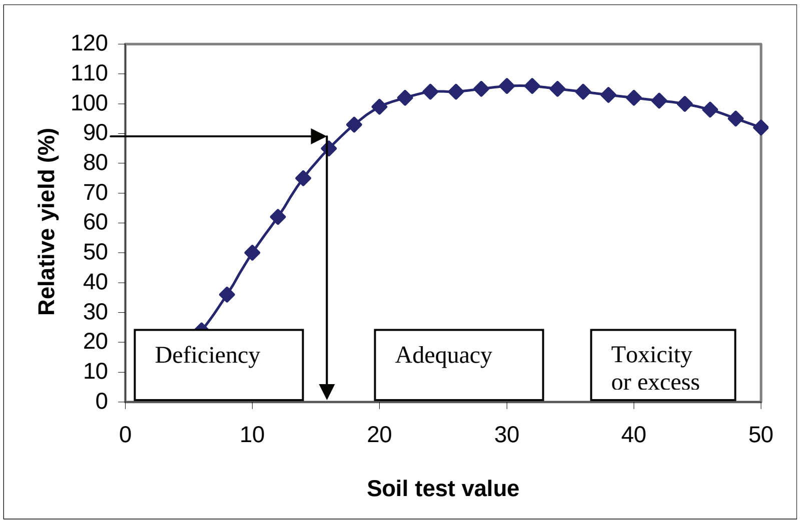


Figure 4.1 An example of a nutrient response curve for sugarcane.

Soil test report							
Trading Name: Bloggs & Bloggs		**Field Name:** Block 1					
Location: Bundaberg District		**Section of Field:** A					
Contact Name: Joe Bloggs		**GPS Latitude:**			**GPS Longitude:**		
Work Phone:		**Sample type:**			**Depth:** 0-20 cm		
Adviser:		**Lab Report Number:**			**Sampling Date:**		
Phone:		**Crop:** Sugarcane					
		Stage: Plough-out/Replant			**Target Yield:** 120 tonnes/ha		
		Low	<Optimum	Satisfactory	>Opt/ Norm	High	Excess/ Toxic
pH (1:5 water)	4.9	■					
Electr. Conduct dS/m	0.03			■			
Organic C (%)	0.73	■					
Sulphate S (MCP) mg/kg	6	■					
P (BSES) mg/kg	22		■				
K (Nitric) me%	0.18	■					
K (Amm. Acetate) me%	0.11	■					
Ca (Amm. Acetate) me%	0.60		■				
Mg(Amm.Acetate) me%	0.21		■				
Aluminium (KCl) me%	0.80				■		
Na (Amm. Acetate) me%	0.04	■					
Copper (DTPA) mg/kg	0.45			■			
Zinc (DTPA) mg/kg	0.2	■					
Zinc (HCl) mg/kg	0.4	■					
Mn (DTPA) mg/kg	15			■			
Silicon ($CaCl_2$) mg/kg	4	■					
Silicon (BSES) mg/kg	36	■					
ECEC me%	1.76		■				
Aluminium saturation %	45					■	
Sodium % of cations (ESP)	2.3	■					
Phos. Buffer Index (PBI)	38	■					
Colour (Munsell)	Grey Brown						
Texture	Sandy Loam						

Figure 4.2 Example of a soil test report from a commercial laboratory.

Appropriate nutrient inputs for this soil test report are calculated as follows (using the guidelines in Chapter 2):

Nitrogen

N requirement is **150 kg N/ha** because the N mineralisation index is LOW due to an Org C (%) value of 0.73%. This requirement is appropriate for replant cane and ratoon cane after replant, but is modified according to the effect of fallow management or the use of ameliorants such as mill mud and/or mill ash. If, for example, the plant cane followed a grass/bare/poor legume fallow, the plant crop N requirement is **130 kg N/ha.**

Phosphorus

P requirement for plant cane is **20 kg P/ha** because the BSES P value is 22 mg/kg and the P sorption class is LOW as indicated by a PBI of 38. If a PBI value was not available, P sorption could also have been estimated as being LOW using texture and % Org C (texture is described as loamy sand i.e. a low clay content (< 24% clay) and an organic C (%) value of 0.73%). Maintenance dressings of P at a rate of **10 kg P/ha** are also required in subsequent ratoon crops in this case. As clay content is not normally reported in soil tests it is reasonable to use an approximate clay content determined from the ECEC (Table 2.4) or using the 'soil texturing' method described in Appendix 1.

Potassium

K requirement is **100 kg K/ha** because the Nitric K value is less than 0.7 me%, the texture is described as a sand (< 24 % clay) and an exchangeable K value of 0.11 me%. **120 kg K/ha** is needed for each ratoon crop.

Sulphur

S requirement is **15 kg S/ha** for the plant and all ratoon crops because the soil sulphur value is 6 mg/kg and the N mineralisation index is known to be LOW (as described above).

Magnesium

Mg requirement is **50 kg Mg/ha** for the plant and all ratoon crops because the exch. Mg value is 0.21 me%.

Copper and zinc

Although leaf analysis is the preferred means of determining micronutrient requirements, the soil tests indicate that zinc is required (**10 kg Zn/ha**) because both the DTPA and BSES zinc values are less than the critical values shown in Table 2.15.

Silicon

Silicon is required because both soil tests (BSES and $CaCl_2$) are below the respective critical values shown in Table 2.16. Si can be applied as calcium silicate (4 t/ha) **or** cement (3 t/ha) **or** mill mud/ash (150 wet t/ha).

Lime

Lime requirement is **1.25 t/ha** based on the soil pH(water) as the value is below 5.5 and the cation exchange capacity is 1.76 me% (which is a low CEC). However exchangeable Ca is 0.6 me% and hence the lime requirement determined from Table 2.12 is **2 t/ha**.

A summary of the nutrient requirement for the entire crop cycle in this example (Plant crop and three successive ratoons) is as follows:

Crop	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Zn (kg/ha)	Si (as mill mud/ash (t/ha)	Lime prior to planting (t/ha)
Replant cane	150	20	100	15	10	150	2
Ratoon crops	150	10	120	15	10	-	-

Leaf analysis

Leaf sampling offers an appropriate means of checking on the adequacy of fertiliser recommendations and nutrient inputs to a block of sugarcane. It allows adjustment of fertiliser rates in the subsequent crop (or in the current crop if the cane was young enough at the time of sampling). It also allows possible nutrient problems associated with 'poor cane' to be identified and is an important tool for monitoring nutrient trends at different scales (cane block, farm and region). Leaf sampling instructions are supplied in Appendix 3.

Leaf analysis results are interpreted according to the third leaf critical values shown in Table 4.1. It should be noted that third leaf N values decrease as the season progresses.

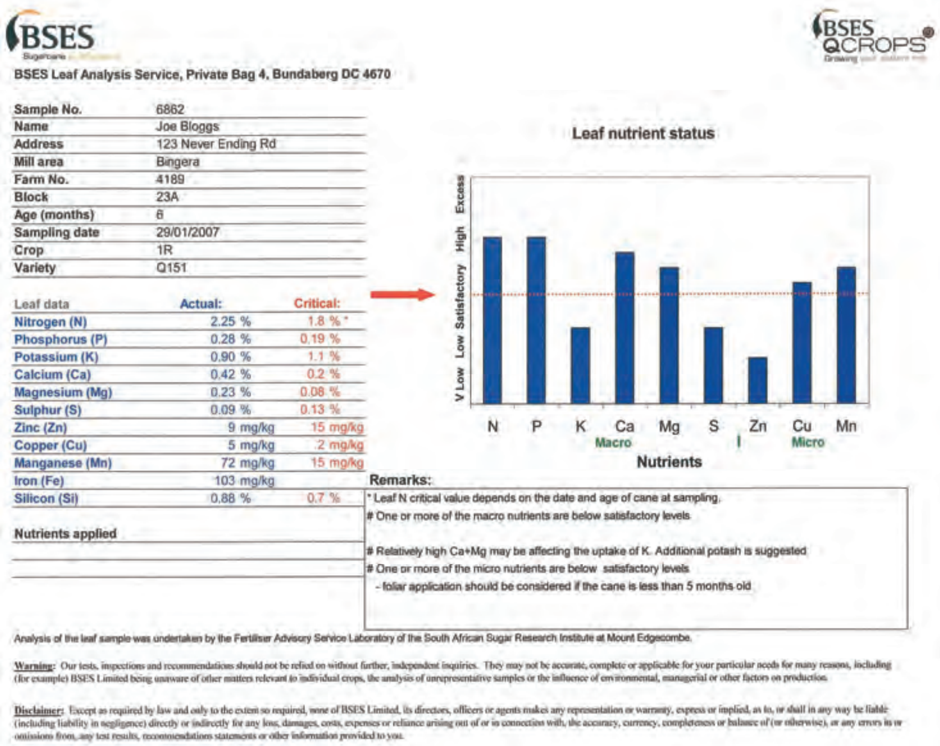
Table 4.1 - Third leaf nutrient critical values for sugarcane

Nutrient	Month of sampling	Third leaf critical nutrient value (%)
N	Nov - mid Jan	1.9 %
	Mid Jan - Feb	1.8 %
	Mar - May	1.7 %
P	Nov - May	0.19 %
K		1.1 %
Ca		0.2 %
Mg		0.08 %
S		0.13 %
Cu		2 mg/kg
Zn		15 mg/kg
Mn		15 mg/kg
Si		0.7 %

Leaf analysis data and third leaf critical values are incorporated in reports from the BSES Leaf Analysis Service. The reports include a bar-graph representation of values to assist growers in identifying the nutrient status of their crop. An example of a leaf analysis report is shown in Figure 4.3. Apart from showing the actual analysis data and appropriate critical values for the full range of nutrients, the bar graphs provide an easy to understand interpretation, with the red dotted line indicating satisfactory levels. Statements below the bar-graph add to this interpretation.

In this example, the leaf analysis results are alerting Mr Bloggs to the following:

- The third leaf N value is high. This reflects the relatively high N fertiliser application rate (170 kg N /ha). Less N fertiliser should be applied next season.
- The third leaf P, Ca, Mg, Cu and Mn values are all satisfactory.
- The third leaf K value is low and reflects the relatively low K fertiliser rate (60 kg
- K /ha). Joe should consider applying additional K next season.
- The third leaf S value is slightly low. DAP (diammonium phosphate) which is currently used at planting does not contain sulphur. Joe should apply fertiliser mixtures that contain some sulphur in order to replace the S removed by the crop.
- The third leaf Zn value is very low. Had the cane been younger at the time of sampling, Joe could possibly have considered a foliar application of 1% zinc sulphate solution (300 litres/ha). Next season he should consider either applying zinc fertiliser (to the soil) or a foliar application of zinc sulphate when the cane is about 3 months old.



BSES Leaf Analysis Service, Private Bag 4, Bundaberg DC 4670

Sample No.	6862
Name	Joe Bloggs
Address	123 Never Ending Rd
Mill area	Bingera
Farm No.	4189
Block	23A
Age (months)	6
Sampling date	29/01/2007
Crop	1R
Variety	Q151

Leaf data	Actual:	Critical:
Nitrogen (N)	2.25 %	1.8 % *
Phosphorus (P)	0.28 %	0.19 %
Potassium (K)	0.90 %	1.1 %
Calcium (Ca)	0.42 %	0.2 %
Magnesium (Mg)	0.23 %	0.08 %
Sulphur (S)	0.09 %	0.13 %
Zinc (Zn)	9 mg/kg	15 mg/kg
Copper (Cu)	5 mg/kg	2 mg/kg
Manganese (Mn)	72 mg/kg	15 mg/kg
Iron (Fe)	103 mg/kg	
Silicon (Si)	0.88 %	0.7 %

Nutrients applied

Remarks:

* Leaf N critical value depends on the date and age of cane at sampling.
# One or more of the macro nutrients are below satisfactory levels
# Relatively high Ca+Mg may be affecting the uptake of K. Additional potash is suggested
# One or more of the micro nutrients are below satisfactory levels
- foliar application should be considered if the cane is less than 5 months old

Analysis of the leaf sample was undertaken by the Fertiliser Advisory Service Laboratory of the South African Sugar Research Institute at Mount Edgecombe.

Warning: Our tests, inspections and recommendations should not be relied on without further, independent inquiries. They may not be accurate, complete or applicable for your particular needs for many reasons, including (for example) BSES Limited being unaware of other matters relevant to individual crops, the analysis of unrepresentative samples or the influence of environmental, managerial or other factors on production.

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Figure 4.3 Example of a leaf analysis report

Juice analysis

Juice analysis has been proposed as a means of identifying nutrient imbalances in sugarcane. For instance, it has been reported that amino N levels in cane juice are indicative of high N application rates and also contribute to increased colour in sugar. However, the absence of critical values for N and other nutrients have not enabled this technique to be used for developing routine fertiliser recommendations.

Integrated nutrient management

Analytical results for a single soil or leaf sample are of limited value. Of much more benefit is the concept of integrated nutrient management which includes the use of a range of different activities for determining nutrient inputs to a particular cane block. In brief the integrated nutrient package consists of six steps:

1. Knowing which soils occur in each block of your farm
2. Understanding the properties of each soil and the nutrient processes and loss pathways likely top occur in each soil.
3. Regular soil testing (blocks should be sampled before every crop cycle).
4. Developing a plan of fertiliser applications for each block covering a whole crop cycle (covering a plant crop and at least three successive ratoons). This can be achieved using knowledge of the nutrient requirement of each soil and implementing soil/site specific fertiliser recommendations.
5. Using leaf analysis as a check on the adequacy of fertiliser recommendations (enabling modifications to the fertiliser plans).
6. Maintaining a good record keeping system which enables informed decisions to be made based on block histories and longer-term nutrient management strategies.

Implementation of this system on-farm will lead to best practice nutrient management and sustainable sugarcane production.

CHAPTER 5

Concluding remarks

Soils are complex physical, chemical and biological systems which store and release nutrients for crop growth and are not simply for holding up plants. The amount and rate of release of nutrients from different soils and the reactions between soils and fertilisers need to be taken into account when developing nutrient guidelines. This complexity is appreciated by cane growers in the Bundaberg District who have an excellent understanding of the different soil types occurring on their farms and recognise that different management practices are appropriate for different soils. The information presented in this booklet is intended to reinforce this local soil knowledge and provide an easily understood system for soil and nutrient management. It focuses much more than current systems on the chemical, physical and biological properties of different soils.

Our new philosophy focuses on the management of different soils to enhance their ability to store and supply a wide range of nutrients to the crop. It emphasises the importance of improving levels of soil organic matter and has the long term goal of improving soil fertility through the enhancement of natural soil processes and nutrient cycles. It differs from current approaches in the following ways:

- Lime is recommended for the amelioration of soil acidity even though many soils are well supplied with calcium.
- Our nutrient management guidelines take into account the release of N, P and S in the soil through the mineralisation of soil organic matter. Our N guidelines in particular are lower than previous recommendations. This is particularly important given current concerns regarding elevated levels of nitrate in the waters of the Great Barrier Reef lagoon.
- We recognise that soils differ in their capacity to sorb added P fertiliser and render it less available to sugarcane crops. We therefore interpret the standard BSES P test somewhat differently for different soils.
- Our K guidelines are broadly similar to previous recommendations but take into account differences in soil texture. They are higher than previous K application rates and recognise the low exchangeable K levels in nearly all Bundaberg soils. They can be justified by the fact that we have not been replacing crop removal of K and have thus been exploiting soil K reserves.

We hope that this booklet will improve the local awareness and understanding of different soils and how they can be managed for sustainable sugarcane production. Whilst growers can use the management guidelines directly for their different soils, the booklet also explains the way in which the nutrient management guidelines have been derived so that growers can make informed judgements on how to manage their soils. It also provides guidelines for interpreting soil and leaf analyses. We hope this will encourage growers to make greater use of these important nutrient management tools.

APPENDIX 1

How to determine soil texture

The texture of a soil is defined as the relative proportions of sand, silt and clay particles in the soil. In the laboratory, the particle size distribution is determined by measuring the percentages of each of these particles in a particular soil. In the field, the field texture grade of a soil (sand, sandy loam, loam, clay loam, silty clay loam, clay, etc) can be estimated by observing the behaviour of a small handful of soil, moistened with enough water to ensure that a ball (bolus) can be formed with kneading and then pressed between thumb and forefinger to produce a ribbon. The texture is determined by noting certain characteristics of the moistened soil and comparing the length of this ribbon (mm) with the ranges indicated in the following table.


Forming the ball (bolus) of soil and pressing it into a ribbon

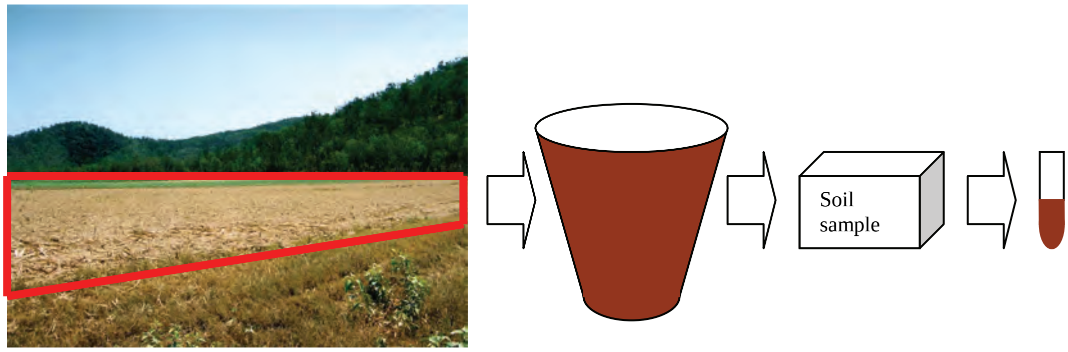
Simplified guide to determining soil texture.

Characteristics of the soil bolus and ribbon	Length of the ribbon (mm)	Textural grade	Approximate clay %
Sandy feel, no coherence with single grains sticking to fingers	Nil	Sand	0 - 10
Sandy feel, slight coherence, with discolouration of fingers	5-15	Loamy sand	5 - 15
Sandy feel, slight coherence	15-25	Sandy loam	10 - 20
Spongy, greasy feel, with coherence, but no obvious sandiness of silkiness.	25	Loam	10 - 24
Smooth, silky feel, with distinct coherence	25	Silt loam	10 - 24
Sandy feel but with distinct coherence	25-40	Sandy clay loam	20 - 30
Smooth feel with strong coherence and no obvious sand grains	40-50	Clay loam	25 - 40
Smooth, silky feel with distinct coherence	40-50	Silty clay loam	25 - 40
Easily moulded with sandy feel	50-75	Sandy clay	25 - 50
Easily moulded with smooth and silky feel	50-75	Light clay / silty clay	35 - 45
Easily moulded (like plasticine), smooth feel, but with resistance to shearing.	+75	Medium / heavy clay	> 45

APPENDIX 2

How to take a soil sample

Soil tests in the laboratory are carried out on a 10 g sample which is taken from about 500 g of soil submitted to the laboratory. Usually this 500 g sample is a sub-sample of about 10 kg of soil which ideally should be sampled from a block of cane (average 2 hectare area) which contains about 6 000 tonnes of soil in the plough layer.

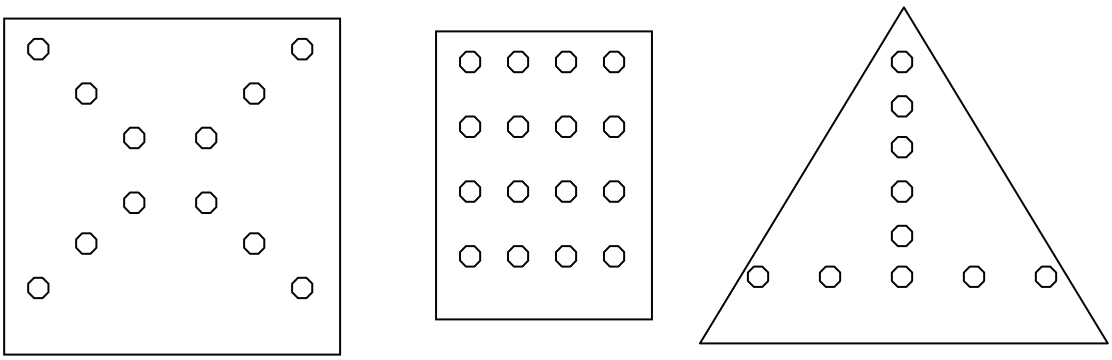


Soil: 6 000 tonnes 5-10 kg 500g 10g

The ten grams of soil analysed in the laboratory is a sub-sample of the soil sample collected in the field and represents around 1.6 parts per billion. In view of this it is extremely important that a soil sample is representative of the volume of soil from which it is collected. This is achieved by collecting adequate soil from the block being sampled using a standard procedure.

Soil sampling procedure

- Determine the area that is to be sampled. Ensure that the area (or block) being sampled does not exceed 2 or 3 hectares and that it is relatively uniform in soil type. In large blocks consider taking multiple samples and if a block consists of more than one distinct soil types sample each separately. Avoid sampling areas that differ in terms of crop growth or where large amounts of mill mud or other ameliorants have been dumped. Again, sample such areas separately if necessary.
- Sampling is traditionally undertaken using an auger (either a turning auger or a soil coring tube) to a depth of 20 cm.
- At least 10 or 12 ‘augerings’ should be collected from the area, using a zig-zag or grid pattern. The basic principle is that more ‘augerings’ are better than less.



Some suggested sampling patterns within cane blocks of different shapes.

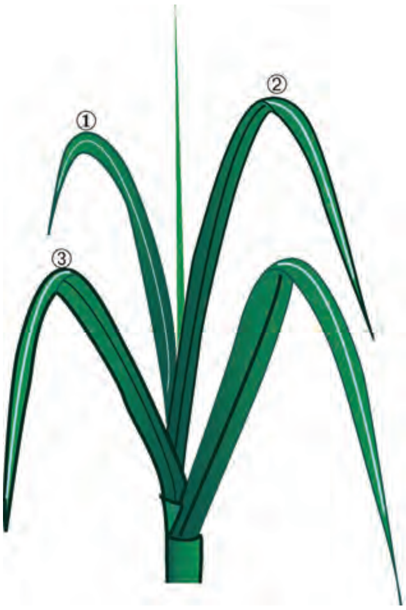
- Whilst there is some debate as to where soil samples should be taken in relation to the cane row or inter-row, we suggest that all samples be taken from the shoulder of the cane row, approximately mid way between the centre of the cane row and the centre of the inter-row. By following this rule you will avoid sampling the highly compacted centre of the inter-space where there are likely to be fewer roots. You will also avoid sampling the centre of the cane row where you are likely to encounter the cane stool and/or residual plant cane fertiliser.
- If possible, take soil samples in the last ratoon crop just after harvest. You should then have sufficient time to apply lime and/or soil ameliorants to the fallow, well before planting.
- All sub-samples should be collected in a good-quality plastic bag or a clean plastic bucket to form a single composite sample. After collection, the soil should be mixed thoroughly to ensure uniformity of the sample.
- Preferably the complete sample should be dispatched to a reputable laboratory for analysis. If the sample is too cumbersome, however, a portion (500g- 1kg) should be sub-sampled for analysis. Ideally this should occur after air-drying and initial sieving. However, such facilities are not always available. Assistance may be obtained from BSES or Sugar Services Bundaberg.
- Supply as many details as possible on a label and on the sample bag itself to ensure that the sample can be easily identified, and that meaningful interpretation of the results is possible.

Remember: Care should be taken to ensure that the sample is not contaminated. Cleanliness is most important. Always ensure that the auger is cleaned between sampling different blocks, that any buckets used are clean and that new plastic bags are used. Do not use a soil sampler or shovel made from galvanised iron or a bucket with a galvanised handle if the soil is to be hand-mixed, otherwise zinc contamination could occur.

APPENDIX 3

How to take a leaf sample

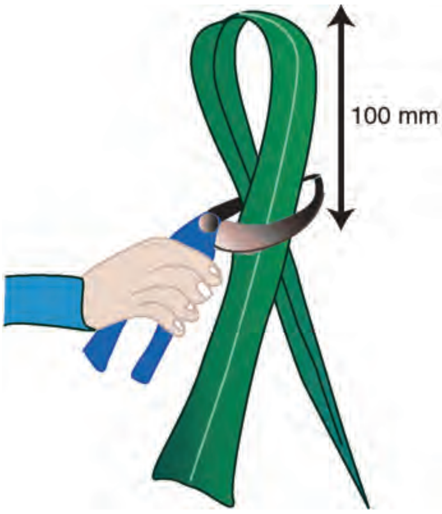
Step 1

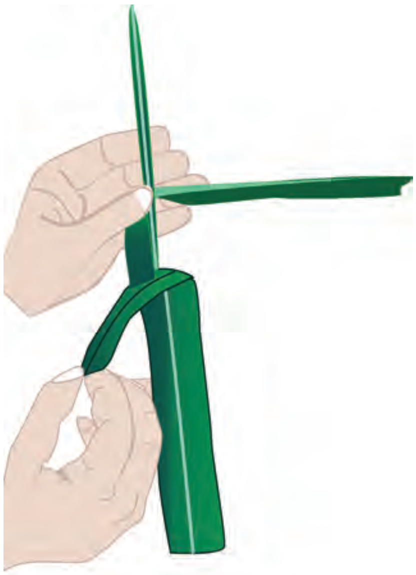


- Select leaves from stalks of average height.
- Sample the third leaf from the top of the stalk (as shown on the diagram). Counting from the top of the plant, the first leaf is the one that is more than half-unrolled. The third leaf usually corresponds to the top visible dewlap.
- Collect 30 - 40 leaves at random from across the entire block of sugarcane being sampled.

Step 2

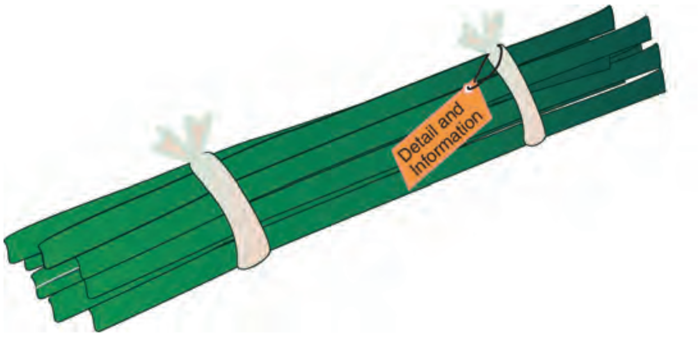
- Fold the leaves in half (top to base) and cut a 100-200 mm length from these folded leaves (giving a total 200-300 mm section of each leaf). Retain these middle 200-300 mm sections of the leaf blades and discard the remaining top and bottom sections.
- Strip out & discard the midrib from each 200-300 mm section.





Step 3

- Bundle the leaf strips together and attach a completed BSES



- Place the sample in a cool environment (polystyrene cooler) until it can be dried in an oven (at about 60^{0}C) or in a dry well-ventilated area.
- Once the sample is dry, place it in a clean paper bag or envelope, and send it to:

  BSES Leaf Analysis Service
  Ashfield Road / Private Bag 4
  Bundaberg DC
  Qld 4670

To ensure meaningful interpretation of the analysis results, make sure that the following guidelines are adhered to:

- Cane is sampled during the prescribed leaf-sampling season (December to April).
- Cane is the correct age (3-7 months) at the time of sampling.
- Cane has been growing vigorously during the month prior to sampling.
- Cane is not affected by moisture stress at the time of sampling.
- Cane is also unaffected by any other factors, such as disease, insect damage, etc.
- Six weeks has passed since fertiliser applications.

It is important that leaves are sampled correctly and that all the details requested on the BSES Leaf Analysis Service labels be supplied as accurately as possible. This will enable meaningful interpretation of the analysis results.

Labels and brown paper packets are available from BSES Experiment Stations and Extension Offices. If you would like to make use of this facility or get more information regarding leaf analysis, please contact you local Extension Officer, Sugar Services Bundaberg or BSES Bundaberg (4155 7400).

FURTHER READING

The material covered in this booklet includes information drawn from various sources. This expertise and knowledge is gratefully acknowledged, particularly in relation to the following publications and/or reports. The list also provides details of some further reading options.

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