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SOIL REFERENCE BOOKLET FOR THE ISIS DISTRICT

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

John Panitz  
Bernard Schroeder  
Jim Sullivan  
Andrew Wood





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By

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# Foreword

Isis Landcare Group Inc. was established in June 1989 and has had a long association with the Isis sugar industry since that time. Isis Landcare has worked closely with Sugar Research Australia (SRA), formerly BSES Limited, on many projects designed to deliver sustainable land management practices in the local landscape that, at one time, had been declared an Area of Soil Erosion Hazard under the *Soil Conservation Act 1965*.

Isis Landcare and the sugar industry recognise that to protect our soils we must first provide the landholders with the knowledge and skills to change their land management practices. To this end, projects where joint cooperation has existed includes:

- Soil Conservation under Trash Retention Systems in Canelands 1995.
- Reduced Tillage Sugarcane Planting Technology for South Queensland 1997.
- Sustainable Management of Isis Red Soils 2001.
- Weeds Identification Field Day 2003.
- Precision Farming Field Day 2004.
- Soybean Manual for soybean production in a cane rotation 2005.
- Filterpress Demonstration 2005.
- Pioneering Broadscale Innovative Farming for a Sustainable Isis sugar industry 2006.
- Solving problems on a Salinity Demonstration Site 2006.

Isis Landcare values the importance of a soils reference booklet for the Isis soil types, as this useful tool will aid our farmers' understanding of the basic principles of soil and nutrient management, leading to improved management decisions on-farm. This publication is yet another in the series of SRA publications that hopefully one day will cover every canegrowing area in Queensland. This Isis Soils booklet complements the Bundaberg Soils booklet and together all soil types farmed by Isis canegrowers are covered.

SRA is to be commended for the research that has gone into producing this 'Soil-Specific Nutrient Management Guidelines for Sugarcane Production in the Isis District'.

Isis Landcare is proud to be involved in the project and encourages every grower to make good use of the resource/s to improve and protect our valuable agricultural lands and maintain soil health.



**Mark Mammino**

CHAIRMAN

**ISIS LANDCARE GROUP INC.**



**Wayne Stanley**

SECRETARY / TREASURER

# About the authors

**John Panitz** is a Principal Technician (Nutrient Management) with Sugar Research Australia based at Bundaberg. He has over 30 years working experience in an R,D&E environment and, as a Variety Officer, has made a large contribution to the plant breeding program in the Southern Region. He then held the position of Extension Officer within the Bundaberg Sugar Services group.

More recently, John has been part of the SIX EASY STEPS development and delivery team and is currently a member of the Improved Cropping Systems group investigating aspects of nutrient management, precision agriculture (PA) and crop agronomy. John brings with him a wealth of practical experience and the ability to communicate effectively across the full spectrum of people in the sugar industry.

**Dr Bernard Schroeder** is a Principal Scientist with Sugar Research Australia at Indooroopilly. He has been involved in R,D&E associated with various aspects of soil fertility and crop nutrition for about 30 years. This experience has been gained largely within the Australian and South African sugar industries.

A major part of his work has been aimed at fine-tuning the nutrient requirements for the Australian sugar industry and the development of the SIX EASY STEPS nutrient management package for sugarcane. This work has often been in collaboration with other agricultural scientists, particularly within BSES and SRDC funded projects. He is the author / co-author of a large number of publications, both technical and more industry focused.

**Jim Sullivan** was a Senior Extension Officer with BSES for 18 years and most recently in the Isis area for 12 years. Previously, Jim was a Soil Conservation Officer with the then QDPI and was based in that position in the Isis district for a number of years.

In addition to a good technical knowledge of sugar cane production, he has a sound background in soils, and in particular, the soils of the Coastal Burnett cane growing area, including the Isis district. Jim currently works as a consultant in the Isis cane supply district.

**Dr Andrew Wood** worked as a Research Agronomist for over 30 years in the Herbert River district. He is now based at Millaa Millaa but continues to consult within the sugar industry. In addition to a good general knowledge of sugarcane production, he has been largely responsible for mapping soils in the Herbert sugarcane district at a scale of 1:5000. This is unparalleled in any other sugarcane growing region in Australia.

Andrew has been the project leader of a number of projects covering aspects of sugarcane production which were funded by various organisations (SRDC, CRC Sugar, Envirofund, etc). He is the author or co-author of a large number of scientific papers, books and reports.

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- Isis LandCare and Burnett Catchment Care Association for their financial support.

# Glossary

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 at significant levels 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.

**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.

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

**Back plain:** An elevated area often found between a river bank crest and the back swamp.

**Back swamp:** A low lying area some distance from current river or streams. These areas tend to be the lowest part of the landscape.

**Basalt:** A dark igneous rock composed of fine grained alkaline material.

**Base saturation:** The proportion of the soil CEC occupied by the basic cations calcium, magnesium, potassium and sodium. In some soils the base saturation is quite high with possible effects on certain relative cation (e.g.  $K^+$ ) availability.

**Cations:** Positively charged ions that are held on 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.

**Conglomerate:** A rock composed of rounded water worn pebbles or rock fragments cemented into a matrix of sand, silt, clay and mixtures of other materials.

**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 nitrate to nitrogen 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 clay 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 amongst districts in their ability to produce cane.

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

**Duplex soils:** A soil with a relatively permeable topsoil, abruptly overlying a very slowly permeable subsoil.

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

**Exchangeable nutrients:** 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 as distinct from decomposing trash.

**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.

**Mudstone:** A sedimentary rock consisting mainly of clay material that is present in a consolidated form.

**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.

**Peat:** A dark soil consisting of partially decomposed organic matter.

**Peds:** Aggregates of soil particles, usually only found in undisturbed soil, or below the compaction layer.

**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).

**Plastic limit:** The lowest soil moisture content at which a soil is capable of being moulded or deformed permanently by pressure.

**Potential acid sulphate soils:** Soils that contain sulphides which have the potential to generate sulphuric acid if disturbed (drained, excavated, etc) and exposed to air.

**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 to air 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.

**Sandstone:** A sedimentary rock consisting mainly of grains of quartz that are present in a consolidated form.

**Shale:** Fine grained sedimentary rock formed in layers by the consolidation of sand, silt and mud.

**Siltstone:** Fine grained consolidated rock composed of silt-sized particles.

**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 the 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 or element 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

This booklet deals with soils of the Isis district and complements the Bundaberg soils reference booklet which was printed in 2007. The area that this booklet encompasses is the Isis cane growing district between the Elliott and Isis Rivers, as well as the Gin Gin and Wallaville cane growing areas west of Bullyard. A soils map for the Isis cane growing district is included as a useful reference for readers of this booklet.

These booklets describe the basic principles of soil management and presents nutrient guidelines for the major cane growing soils. The soil-specific nutrient management guidelines in the Bundaberg and Isis booklets are based on a methodology developed within an earlier research project.

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 Isis 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 Isis and Bundaberg soils and their properties

Sugarcane in the Isis and Bundaberg areas 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 a 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 Isis and Bundaberg areas can be divided into four broad landform patterns based on geological history. These are:

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

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

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. These are found in the Alloway, Gooburrum and Farnsfield areas. Similarly, red and yellow clay loams occur on deeply weathered fine grained sedimentary rocks such as siltstone, mudstone and shale.

The **river alluvial plains** of the Burnett, Kolan, Elliott and Gregory 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. Examples of these soils are commonly found in the Wallaville area.

**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. Potentially 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. Commonly found in coastal areas around Moore Park, Fairymead, Burnett Heads and Elliott Heads.

### 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, 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 a soil profile may include rocks and gravel, sand grains are the largest particles that contribute to soil texture.

Silt particles are intermediate in size. The smallest particles are referred to as clay. 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 Isis / Bundaberg cane producing soils the top 20 cm is generally considered mixed topsoil and the 40-60 cm 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 is 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 Isis / Bundaberg district have organic C contents of

up to 2.7%, but usually range from 1.0% to 1.5%. 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% 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 ( $\text{pH}_{\text{water}}$ ) and pH in calcium chloride solution ( $\text{pH}_{\text{CaCl}_2}$ ). In this booklet we only consider pH in water. Soil pH values greater than 5.5 are desirable for sugarcane growth in the Isis / Bundaberg district, where soils are naturally acidic. Under acidic conditions, Al is present in its soluble form and is toxic to most plants. Fortunately, Australian sugarcane varieties are fairly tolerant of 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. Soybeans require pH values greater than 6. 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  $\text{H}^+$  and  $\text{Al}^{3+}$ . 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 areas 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 is 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)

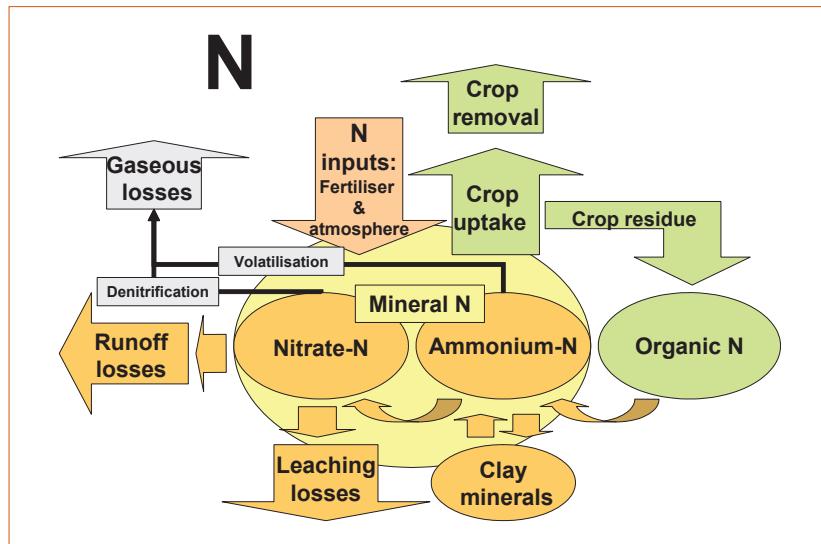
Past research suggests that a crop of sugarcane requires about 1.4 kg N/tonne cane up to 100 tonnes cane per hectare and 1.0 kg N/ha thereafter. In order to achieve sustainable crop production, maximum use must be made of all the available N sources within the N cycle (**Figure 1.1**). To do this it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

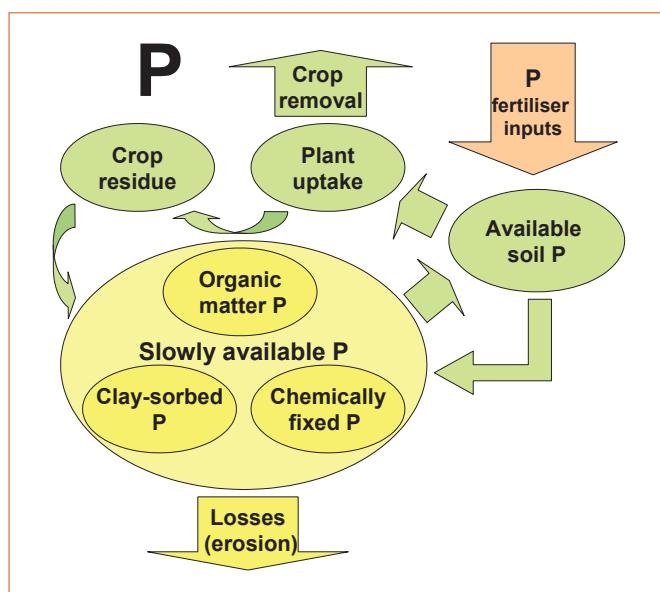
Figure 1.1: Schematic diagram of the nitrogen cycle.



### 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.

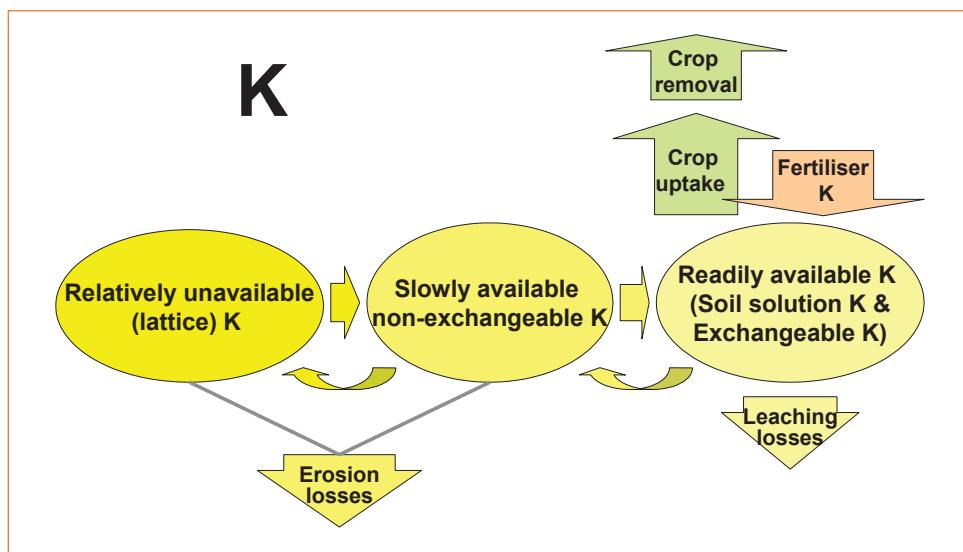


## Potassium (K)

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 Isis 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 Isis soils.

## **Silicon**

Deficiencies of silicon (Si) have been detected in Isis and 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 Isis and Bundaberg districts 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 DNR reports on Isis and 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 Isis / 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 Isis / 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 Isis / 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	< 0.40	160
L	0.41-0.80	150
ML	0.81-1.20	140
M	1.21-1.60	130
MH	1.61-2.00	120
H	2.01-2.40	110
VH	> 2.40	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 others, 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	3.0	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 crops	160	150	140	130	120	110	100
Ratoon crops	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 legume 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
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 P 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)
< 0.60 %	Low	Low	Moderate
0.61-1.20 %	Low	Moderate	Moderate
1.21-1.80 %	Moderate	Moderate	High
> 1.80%	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 (meq/100g)	Texture class
< 4.0	Sand
4.1-8.0	Loam
> 8.0	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	
40-50	Low	Plant	Ratoon
	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/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 Isis / 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 and Isis districts. 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 (meq/100g)	Exchangeable K (meq/100g)						
	< 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)	Nil	
	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 (meq/100g)	Exchangeable K (meq/100g)						
	< 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)	Nil	
	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
Mud/Ash	150 wet t/ha	120 kg K/ha	nil

## 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
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  $\text{pH}_{\text{water}} < 5.5$ ).

CEC (meq/100g)	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*).

Soil Ca (meq/100g)	Suggested lime application (tonnes/ha)
> 0.2	3.0
0.2-0.4	2.5
0.4-0.6	2.0
0.6-0.8	1.5
0.8-1.1	1.0
1.1-1.5	0.5

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 Mg (meq/100g)	< 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 HCl 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
<b>DTPA soil test</b>		
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
<b>HCl zinc test</b>		
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. 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, 2001; Berthelsen and others, 1999*).

	Si (Sulphuric acid)		Si (CaCl <sub>2</sub> )	Suggested application rate
Si (mg/kg)	< 70	and	< 10	Calcium silicate @ 4 t/ha or Cement @ 3 t/ha or Mill mud/ash @ 150 wet t/ha

# Chapter 3

## Description of Isis 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 Isis / Bundaberg district. The soil mapping units described in the DNR Land Resource Bulletin (DNRQ980142) for the Isis / Bundaberg district have been condensed into 16 different soil groups based on colour and texture (**Table 3.1**).

**Table 3.1:** Classification and grouping of Isis/Bundaberg cane producing soils.

\* An asterisk indicates the mapping units that were selected as representative of the soil group.

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	
		Chin	Red Ferrosol	
		Childers*	<b>Red Ferrosol</b>	30
	Brown volcanic (brown structured clay soil on basalt)	Telegraph	Brown Ferrosol	
		Ashgrove	Redoxic Hydrosol	
		Seaview	Black Ferrosol	
		Hummock	Brown Vertosol	
		Berren	Brown Dermosol	
		Corfield	Brown Dermosol	
		Hillend	Brown Dermosol	
		Doolbi*	<b>Brown Dermosol</b>	34

Productivity group	Soil groups and brief description	Mapping unit	Australian Soil Classification	Page
Clay	Black clay (black cracking clay on basalt)	Rubyanna	Aquic Vertosol	
		Maroondan*	<b>Black Vertosol</b>	48
		Windermere	Brown Ferrosol	
	Grey clay (grey cracking clay)	Walla*	<b>Grey Vertosol</b>	52
		Bucca	Grey Vertosol	
		Hinkler	Black Vertosol	
Clay loam	Red clay loam (loamy topsoil over a red subsoil)	Oakwood	Red Kandosol	
		Otoo	Red Dermosol	
		Howes*	<b>Red Dermosol</b>	40
		Watalgan	Red Dermosol	
		Gibson	Red Kandosol	
	Yellow clay loam (loamy topsoil over a yellow subsoil)	Kepnock*	<b>Yellow Dermosol</b>	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*	<b>Redoxic Hydrosol</b>	24
		Clayton	Redoxic Hydrosol	
		Peep	Grey Sodosol	
		Woco	Grey Kurosol	
Sandy loam	Red sandy loam (sandy topsoil over a red subsoil)	Gooburrum*	<b>Red Dermosol</b>	38
		Farnsfield	Red Kandosol	
		Pocket	Red Kandosol	
	Yellow sandy loam (sandy topsoil over a yellow subsoil)	Meadowvale	Yellow Dermosol	
		Isis	Yellow Dermosol	
		Woolmer*	<b>Yellow Dermosol</b>	54
		Littabella	Yellow Kandosol	

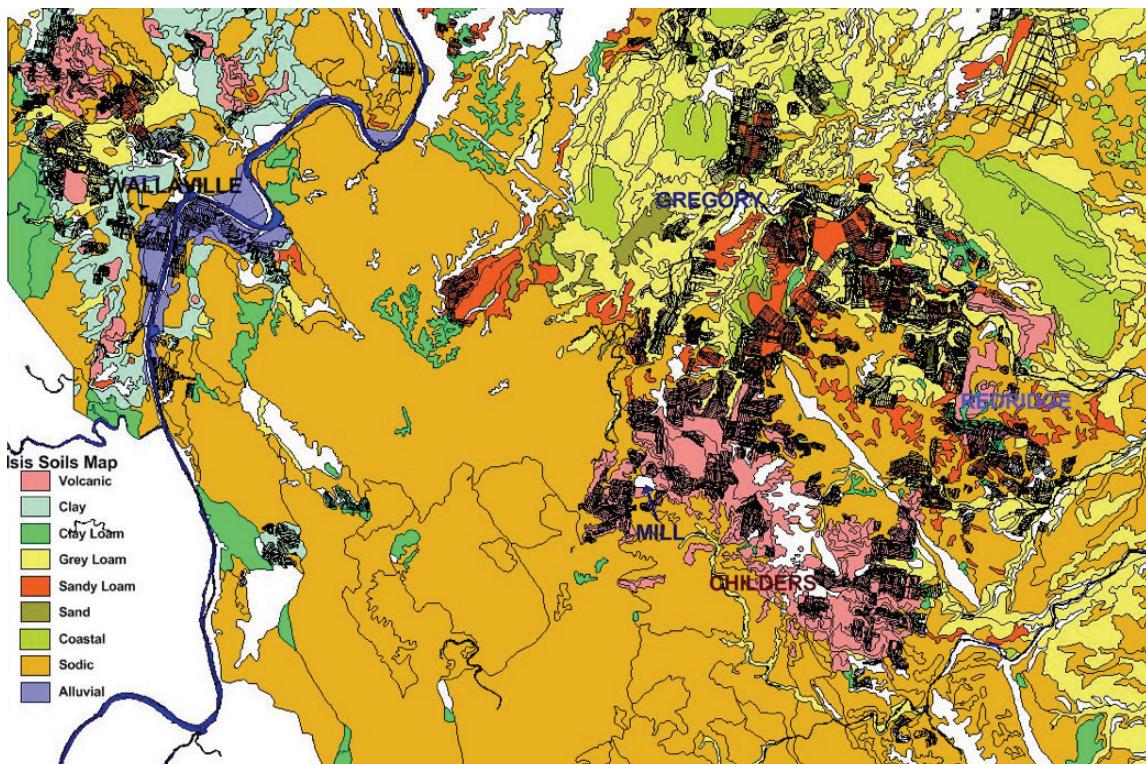
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Productivity group	Soil groups and brief description	Mapping unit	Australian Soil Classification	Page
Sand	Grey sand (grey sandy topsoil over a grey sandy subsoil)	Quart*	Yellow Kandosol	50
		Wallum	Redoxic Hydrosol	
		Winfield	Redoxic Hydrosol	
		Theodolite	Redoxic Hydrosol	
	Dark sand (dark sandy topsoil over a sandy subsoil)	Mahogany*	Redoxic Hydrosol	46
		Rothchild	Brown Kandosol	
		Kinkuna	Aquic Podosol	
Coastal	Black sand (black to brown sandy topsoil over a grey/mottled sandy subsoil; podzol)	Colvin*	Semiaquic Podosol	32
		Moore Park	Aquic Podosol	
		Summerville	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	
		Fairydale	Redoxic Hydrosol	
		Whymere	Redoxic Hydrosol	
		Booloongie	Redoxic Hydrosol	

Continued

Productivity group	Soil groups and brief description	Mapping unit	Australian Soil Classification	Page
Sodic	Grey forest soil (sandy to loamy topsoil with sodic clay subsoil)	Auburn	Grey Sodosol	
		Kolan*	<b>Grey Kurosol</b>	44
		Givelda	Yellow Sodosol	
		Moorland	Red Sodosol	
		Crossing	Grey Sodosol	
		Avondale*	Grey Sodosol	
		Turpin	Grey Sodosol	
		Tirroan	Grey Sodosol	
		Brooweenaa	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	
		Burnett*	<b>Brown Dermosol</b>	28
		Flagstone*	<b>Brown Dermosol</b>	36
		Sugarmill	Redoxic Hydrosol	
		Barubbra	Orthic Tenosol	
		Boyne	Red Dermosol	

Figure 3.1: Soils map for the Isis District.



### Location of soils

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

Sixteen 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.

### Occurrence and properties of soil types

In the rest of this chapter, information on the occurrence, formation, field appearance and chemical and physical properties of these 16 soils are provided in a two-page format. Bar graphs are used to compare the properties of soil types (blue bars) with mean values for all soil samples from the Isis District (maroon bars). Nutrient management guidelines are for the reference sites with provision for the different crop classes such as fallow plant, replant and ratoons. 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. 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**. General management guidelines cover tillage, water and environmental risks.

Figure 3.2: Typical Isis landscape between the Gregory River and South Isis.

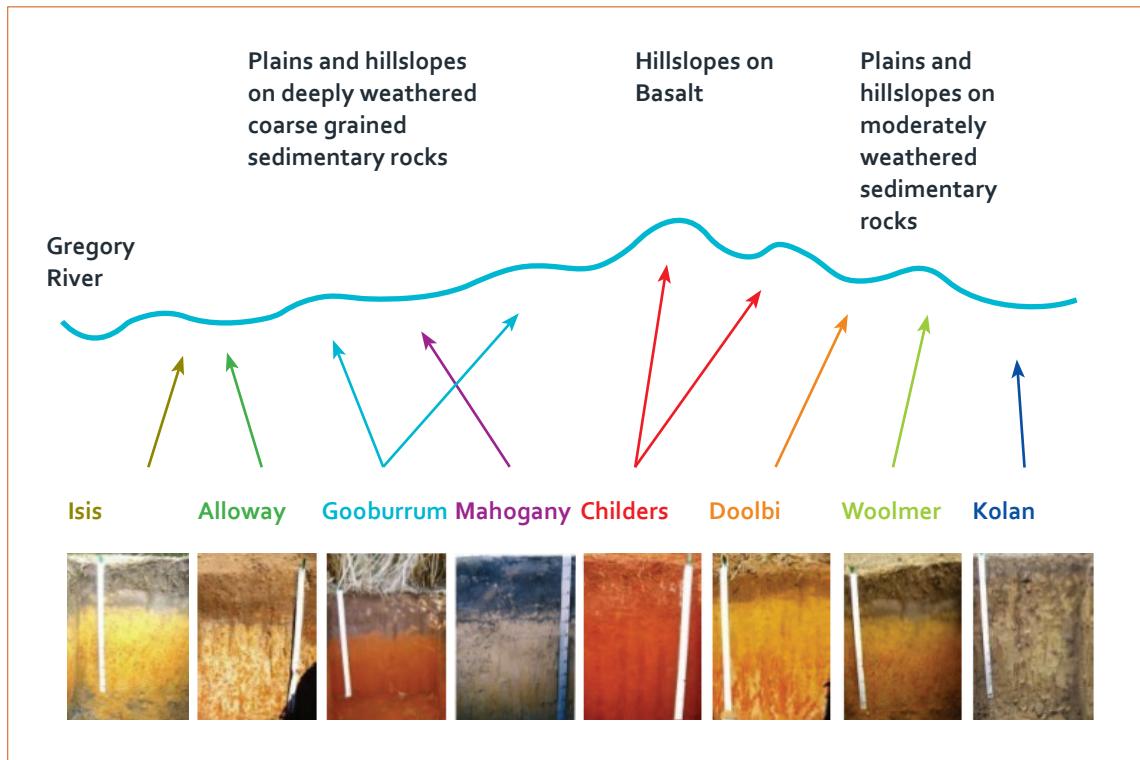
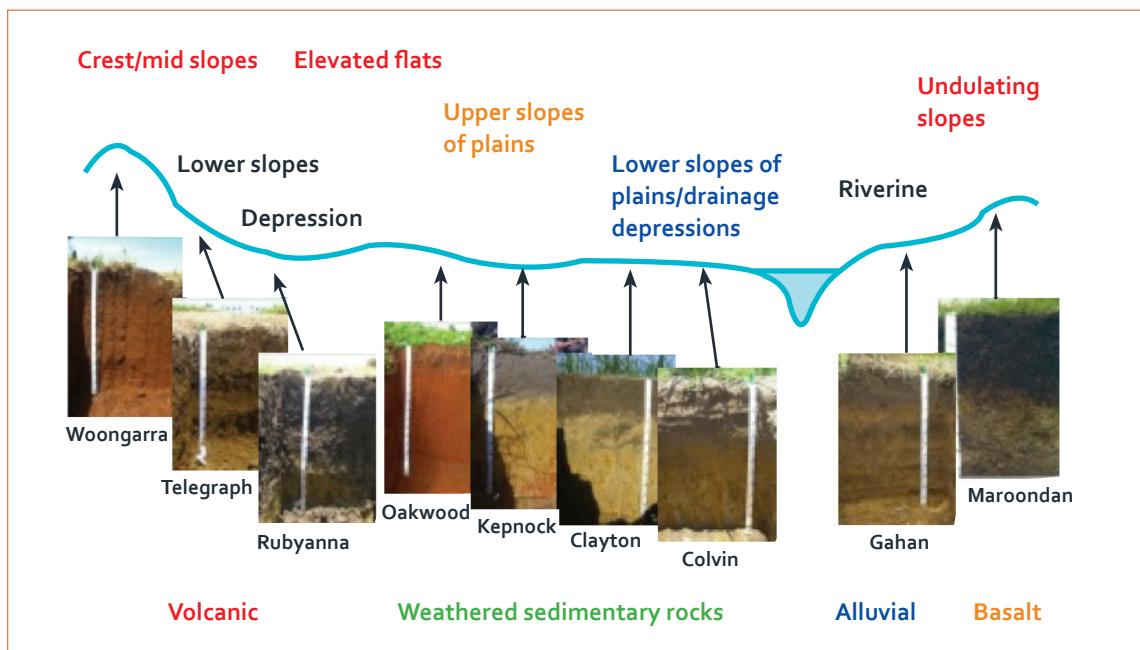


Figure 3.3: Typical Bundaberg landscape between the Hummock and Gin Gin.



## Mapping unit: Alloway

<b>Soil group</b>	Grey sandy loam
<b>Brief description</b>	Sandy topsoil over a yellowish grey clay subsoil
<b>Productivity group</b>	Grey sandy loam
<b>Australian Soil Classification</b>	Redoxic Hydrosol

### Occurrence

Alloway soils occur on gently sloping plains, drainage depressions and lower slopes.

### Formation

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



**Above:** Alloway soil profile.



**Above:** Alloway soil in the Farnsfield 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, Peep and Woco soils which each occupy small sections of the sugarcane growing area.

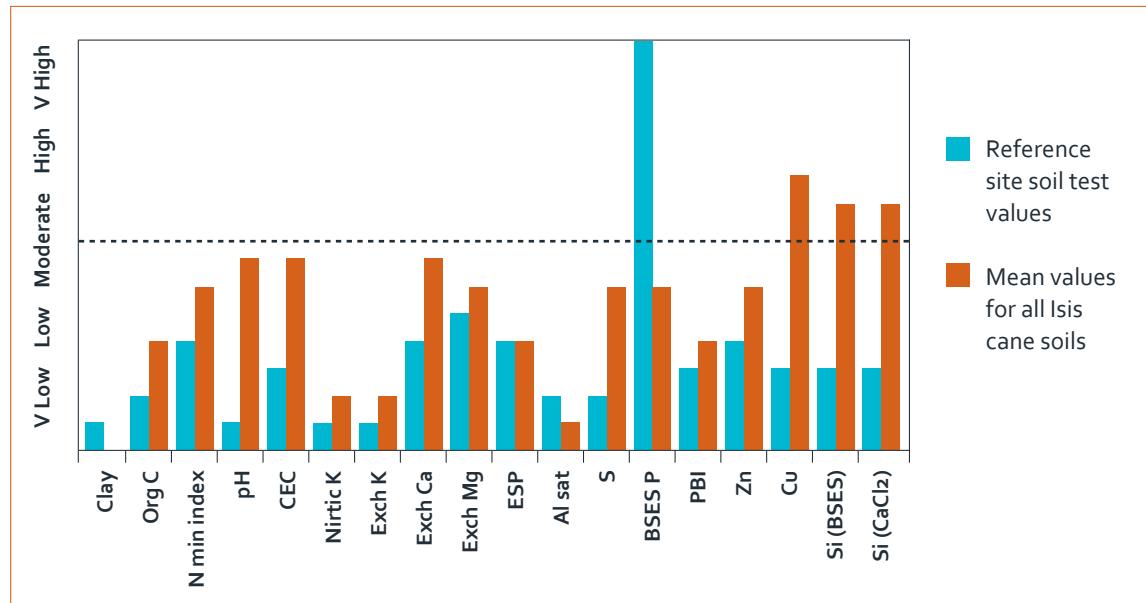
### Physical properties

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

### Chemical properties

Alloway 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. Silicon values are low, which is typical for 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	20	120	10	0	0	0
Replant	0	150	20	120	10	0	0	0
Ratoon	0	150	10	120	10	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

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. Laser grading of these soils is recommended to minimize water ponding. When the landscape is flat, headlands on the lower end of cane blocks should be lowered to allow for drainage from the field.

## 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.

## Mapping unit: Avondale

<b>Soil group</b>	Grey forest soil
<b>Brief description</b>	Sandy topsoil over a mottled nodular grey clay subsoil
<b>Productivity group</b>	Sodic
<b>Australian Soil Classification</b>	Grey Sodosol

### Occurrence

Avondale soils occur on depressions and lower slopes. These soils are often associated with underlying Burrum coal formations.

### Formation

Avondale soils are developed on deeply weathered fine grained sedimentary rocks.



**Above:** Avondale soil profile.



**Above:** Avondale soil in the Webbs Rd area.

### Field appearance

Topsoils are grey loamy sands to sandy loams with bleached A2 horizons. Subsoils are grey sandy clay loams to sandy light clays with red mottles and nodules at depth.

### Similar soils

This soil has similar properties to the Auburn and Kolan soils, which each occupy small sections of the sugarcane growing area.

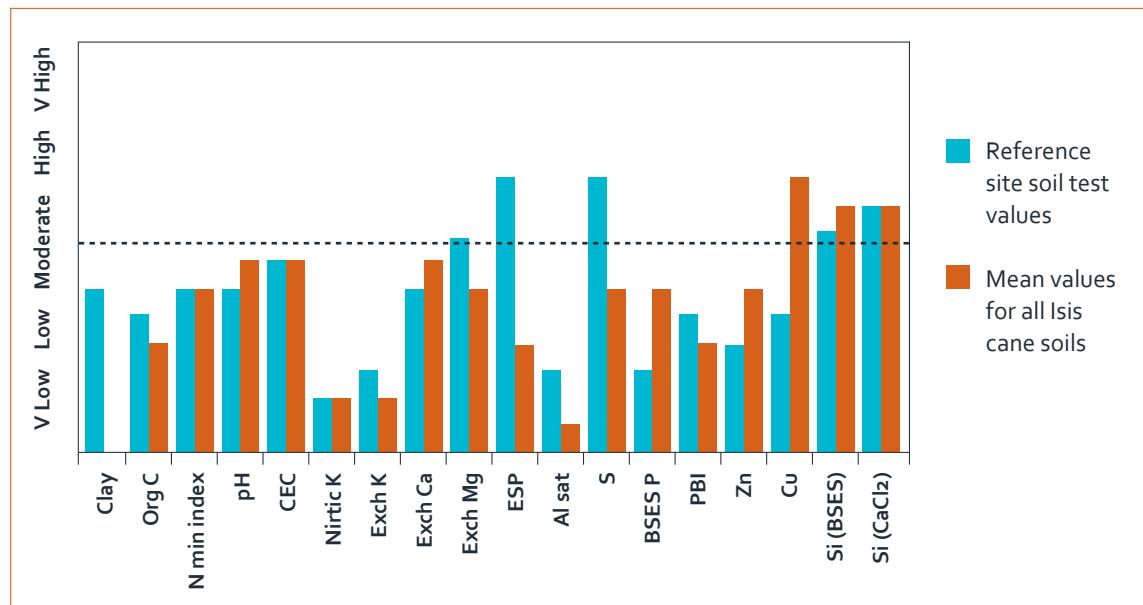
### Physical properties

These soils are often poorly drained, but they have low plant available water capacity due to their sandy nature.

### Chemical properties

Avondale soils have a low fertility status, sodic by nature 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 and sulphur 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	4	120	30	120	0	0	0	0
Replant	4	140	30	120	0	0	0	0
Ratoon	0	140	15	120	0	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. However caution needs to be exercised where waterlogging occurs regularly. Green cane trash blanketing should not be considered where this occurs regularly. Overhead irrigation should be practised with frequent light irrigations to reduce the incidence of waterlogging. Plant available water capacity is low. When the landscape is flat, headlands on the lower end of cane blocks should be lowered to allow for drainage from the field.

## 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.

## Mapping unit: Burnett

<b>Soil group</b>	Alluvial
<b>Brief description</b>	Brown and black loamy soil on alluvium
<b>Productivity group</b>	Alluvial
<b>Australian Soil Classification</b>	Brown Dermosol

### Occurrence

Burnett soils occur on recent alluvial deposits along the levees and terraces adjacent to the Burnett and Kolan rivers.

### Formation

Burnett soils are formed on young layered alluvium.



**Above:** Burnett soil profile.



**Above:** Burnett soil in the Wallaville area.

### Field appearance

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

### Similar soils

This soil has similar properties to the Gahan and Flagstone.

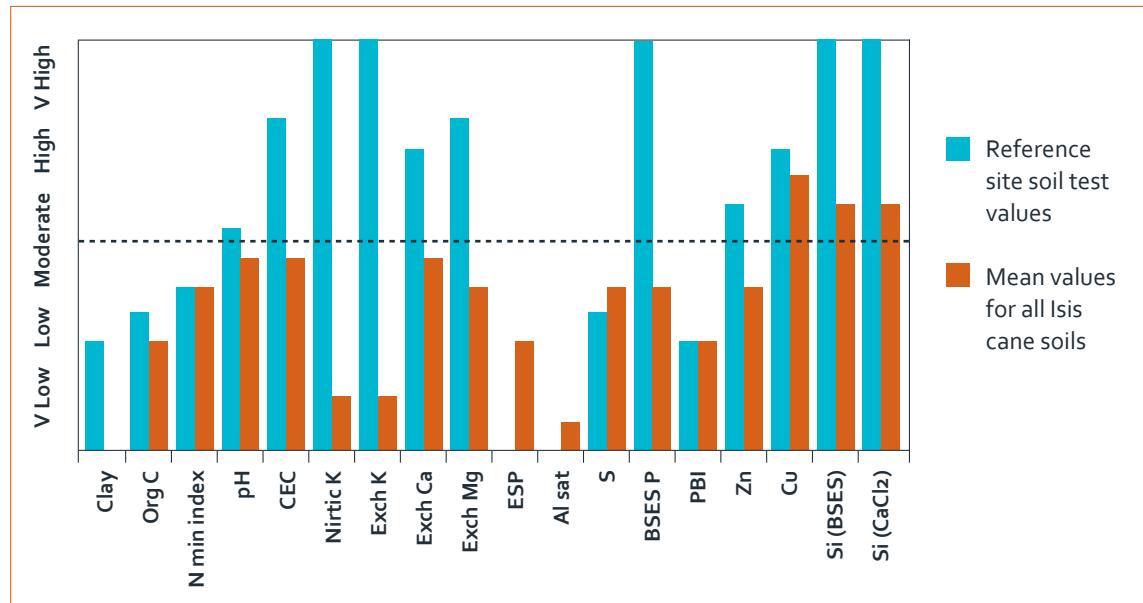
### Physical properties

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 to generalise about their physical properties as sandy layers can alternate with heavier textured material.

### Chemical properties

Burnett 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 topsoil 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. Silicon is usually 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	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	0	10	0	0	0
Ratoon	0	140	0	0	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.

## Mapping unit: Childers

### Soil group

Red volcanic

### Brief description

Red structured clay soil on basalt

### Productivity group

Volcanic

### Australian Soil Classification

Red Ferrosol

### Occurrence

Childers soils occur on the upper and mid slopes in the vicinity of Cordalba, Childers and South Isis, all of which have volcanic origins. They are a major soil in the district and have some of the longest cropping histories.

### Formation

Childers soils are formed *in situ* from weathering basalt. Most Childers soils are found within a few kilometres of the townships of Childers and Cordalba.



**Above:** Childers soil in the Farnsfield Rd area.



**Above:** Childers soil profile.

### Chemical properties

Childers 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 mineralisation potential. The exchange complex is dominated by calcium and magnesium with potassium being moderate to low.

### 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

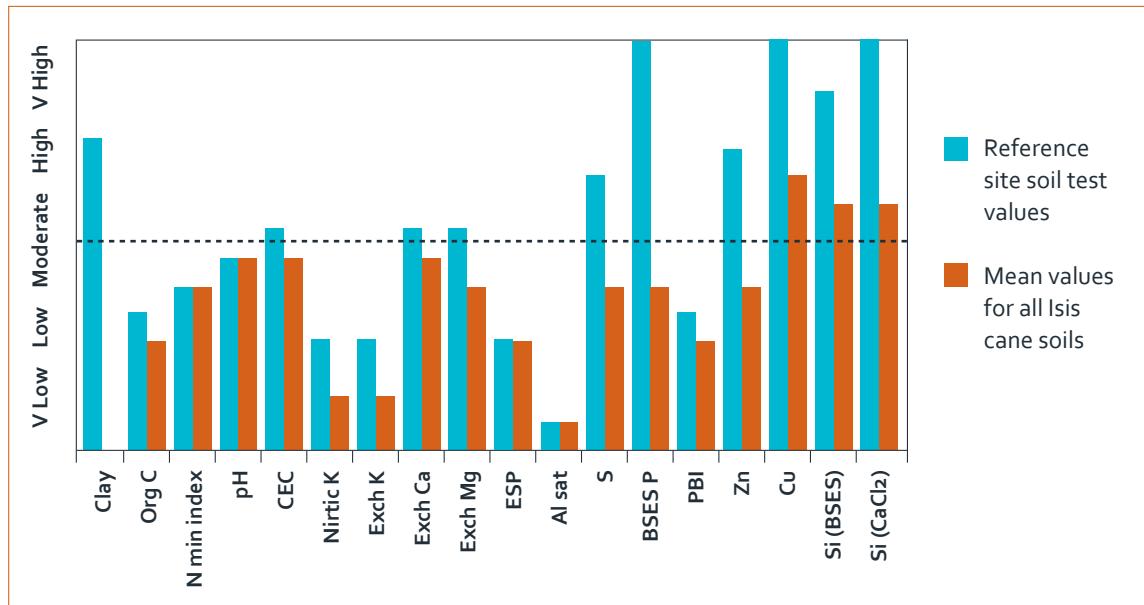
Chin occupies a very small section of the Isis cane supply area, while in Bundaberg, Woongarra soil is a major soil around the Hummock.

### Physical properties

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

Magnesium values are often higher than calcium on some soils that have been irrigated with groundwater containing magnesium. 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	120	0	120	0	0	0	0
Replant	0	140	0	120	0	0	0	0
Ratoon	0	140	0	120	0	0	0	0

### Tillage and water management

When managed well, these soils are relatively easy to till. If tilled when too wet, they are prone to compaction, and will produce large clods. Green cane trash blanketing will assist in moisture retention, as well as reducing the risk of erosion on slopes. 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 can 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.

## Mapping unit: Colvin

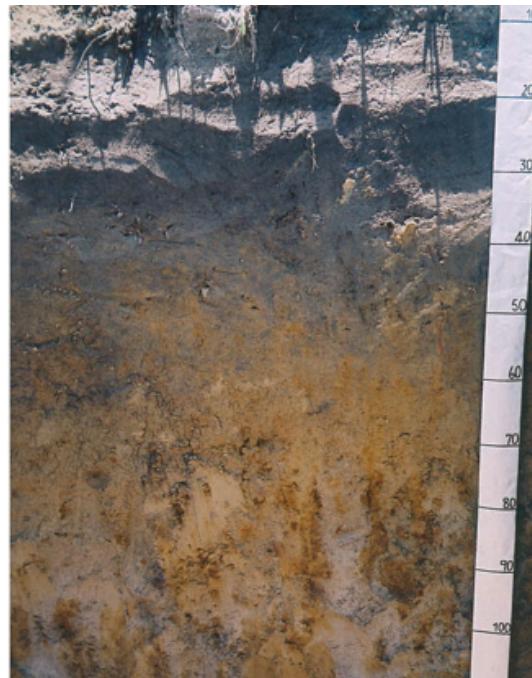
<b>Soil group</b>	Black sand
<b>Brief description</b>	Dark sandy topsoil over a grey mottled sandy subsoil
<b>Productivity group</b>	Coastal
<b>Australian Soil Classification</b>	Semiaquic Podosol

### Occurrence

Colvin soils occur on old beach ridge formations in the marine plains between Fairy mead and Moore Park.

### Formation

Colvin soils have formed on deep sandy beach ridges.



**Above:** Colvin soil profile.

### Chemical properties

Colvin soils have a low to moderately low fertility status and are often acidic. The organic carbon content, N mineralisation potential and CEC of the topsoil is 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.



**Above:** 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.

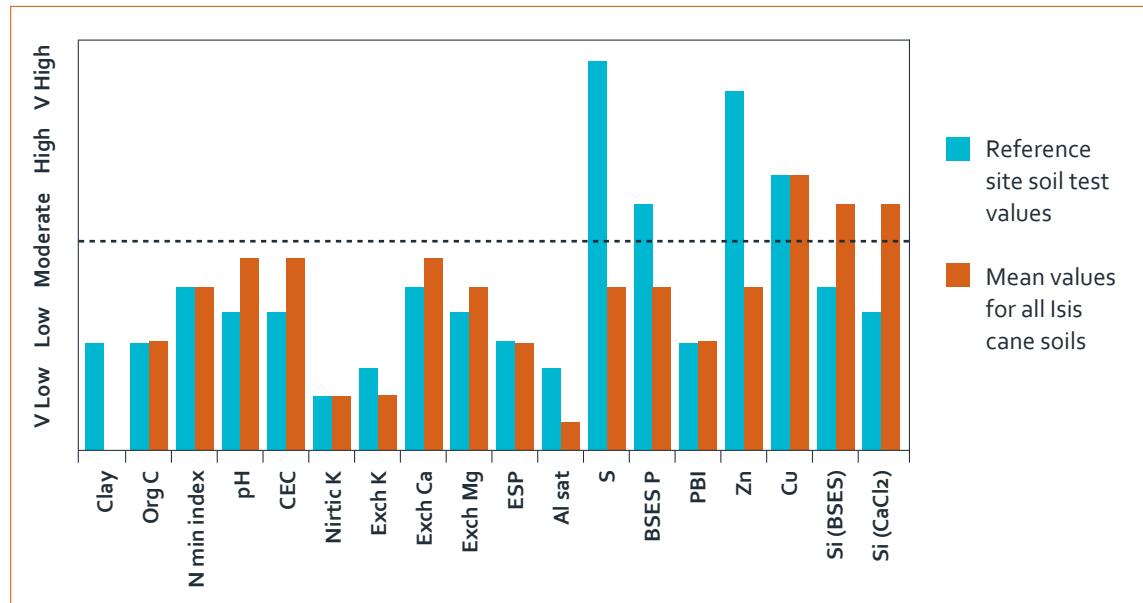
### Similar soils

There are number of soils with similar characteristics. These include Moore Park and Tantitha soils.

### 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.

## 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 excessive rainfall which may lead to 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.

## Mapping unit: Doolbi

### Soil group

Brown volcanic

### Brief description

Brown structured clay soil on basalt

### Productivity group

Volcanic

### Australian Soil Classification

Brown Dermosol

### Occurrence

Doolbi soils occur on the lower slopes of the hillsides around Childers and Cordalba.

### Formation

Doolbi soils are formed *in situ* from weathering basalt. Most Doolbi soils are found in mid to lower slope positions. They have a long history of sugarcane production.



**Above:** Doolbi soil profile.

### Chemical properties

Doolbi soils have a moderately high soil fertility status. The organic matter content and N mineralisation potential are moderate. 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. BSES P values are low to 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.

**Above:** Doolbi soil on mid slopes at South Isis.

### 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.

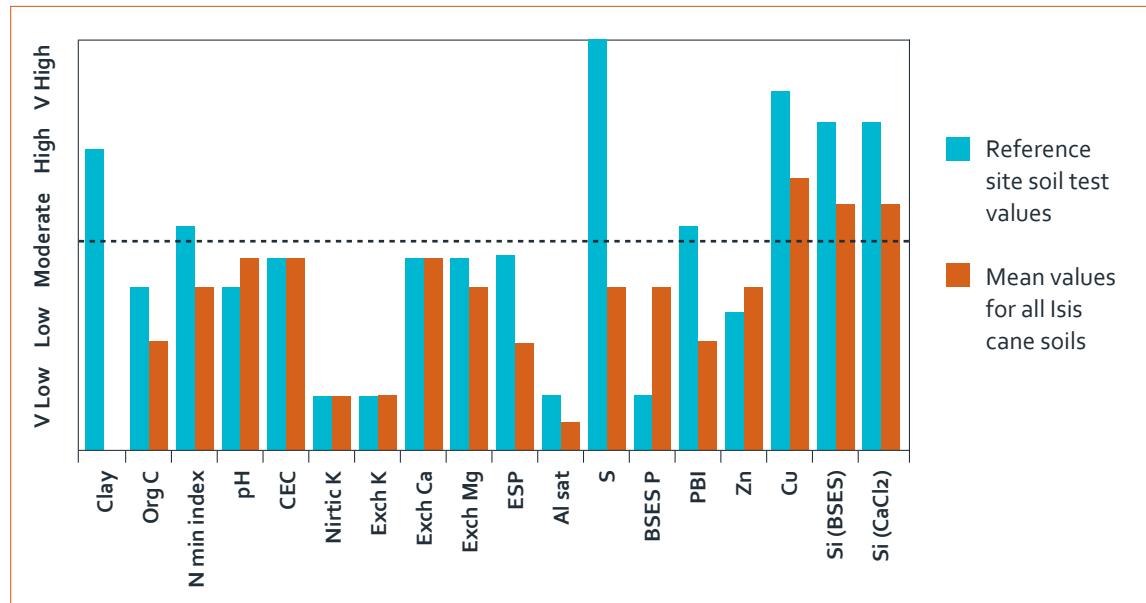
### Similar soils

Ashgrove, Telegraph and Seaview soils, particularly in the Bundaberg 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 1 m. These soils have well-developed structure, but may compact if excessively cultivated when wet.

## 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	120	0	0	0	0
Replant	0	130	30	120	0	0	0	0
Ratoon	0	130	20	120	0	0	0	0

## Tillage and water management

These soils are easily tilled and can 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.

## Mapping unit: Flagstone

<b>Soil group</b>	Alluvial soil
<b>Brief description</b>	Brown and black loamy soil on alluvium
<b>Productivity group</b>	Alluvial
<b>Australian Soil Classification</b>	Brown Dermosol

### Occurrence

Flagstone soils occur on recent alluvial deposits along the levees and terraces adjacent to the Burnett and Kolan rivers.

### Formation

Flagstone soils are formed on young layered alluvium.



**Above:** Flagstone soil profile.

### Chemical properties

Flagstone soils are generally fertile because of the nature of the depositional material. They range from being neutral to slightly acid. The organic carbon content and N mineralisation potential are moderate. The CEC of the topsoil can be high. The K reserves and exchangeable K values are high. 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 and silicon are generally satisfactory.



**Above:** Flagstone soil in the Wallaville area.

### Field appearance

Topsoils are black to brown clay loams. They overlie brown clay to clay loam subsoils. These soils exhibit less distinctive layering than younger alluvial soils.

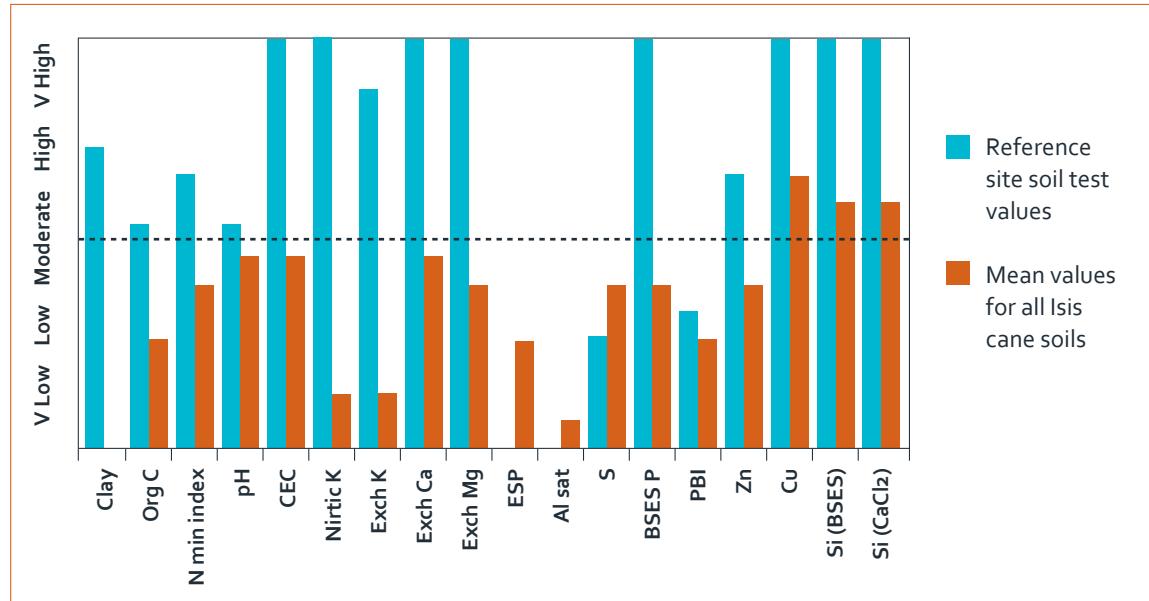
### Similar soils

This soil has similar properties to the Burnett and Gahan.

### Physical properties

These soils are relatively young with some soil structure development. Because of their alluvial nature it is difficult to generalise about their physical properties but subsoils can have higher clay contents.

## 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	0	0	5	0	0	0
Replant	0	120	0	0	5	0	0	0
Ratoon	0	120	0	0	5	0	0	0

## Tillage and water management

These soils can be difficult to manage because of the clay content and their low position in the landscape. These soils have a moderate water-holding capacity. Timing of tillage operations should coincide with appropriate soil moisture content.

## Environmental risk management

Flooding occasionally occurs on lower terraces and drainage depressions. Mid-season harvest is preferable and split applications of nitrogen are recommended to reduce the risk of loss of N by denitrification during wet conditions. Green cane harvest, trash blanketing and grassed headlands are recommended to reduce off-site losses of sediment and nutrients.

## Mapping unit: Gooburrum

**Soil group**

Red sandy loam

**Brief description**

Sandy loam topsoil over a red subsoil

**Productivity group**

Sandy loam

**Australian Soil Classification**

Red Dermosol

### Occurrence

Gooburrum soils occur on crests and plateau areas, and upper and mid slopes of rises.



### Formation

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



**Above:** 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 can have a blocky structure.

### Similar soils

This soil has similar properties to the Farnsfield and Pocket soils which occupy small sections of the sugarcane area.

### Physical properties

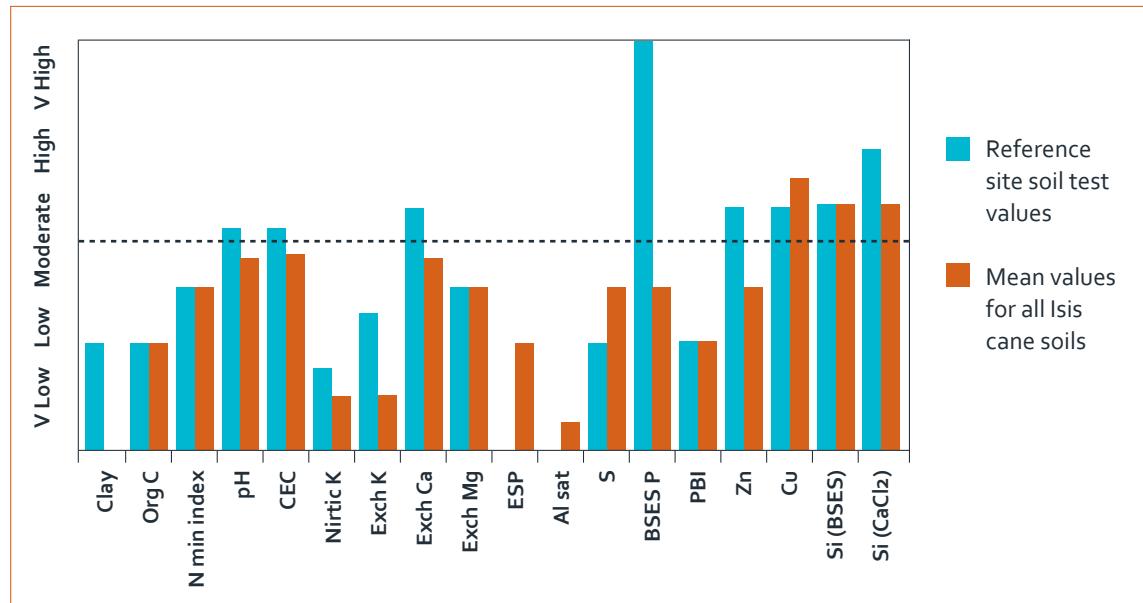
These soils are deep and well-drained. They are prone to erosion on slopes.

**Above:** Gooburrum soil profile.

### Chemical properties

Gooburrum 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	4.0	120	0	80	10	0	0	0
Replant	4.0	140	0	120	10	0	0	0
Ratoon	0	140	0	120	10	0	0	0

## Tillage and water management

As these are permeable soils, 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.

## Mapping unit: Howes

<b>Soil group</b>	Red clay loam
<b>Brief description</b>	Loamy topsoil over a red subsoil
<b>Productivity group</b>	Clay loam
<b>Australian Soil Classification</b>	Red Dermosol

### Occurrence

Howes soils occur on the crests, plateaus and upper slopes of rises and on elevated plains. They are most often found on the plains at South Kolan.

### Formation

Howes soils are developed on deeply weathered fine grained sedimentary rocks from the Elliott formation.



**Above:** Howes soil profile.

### Chemical properties

Howes 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.



**Above:** 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.

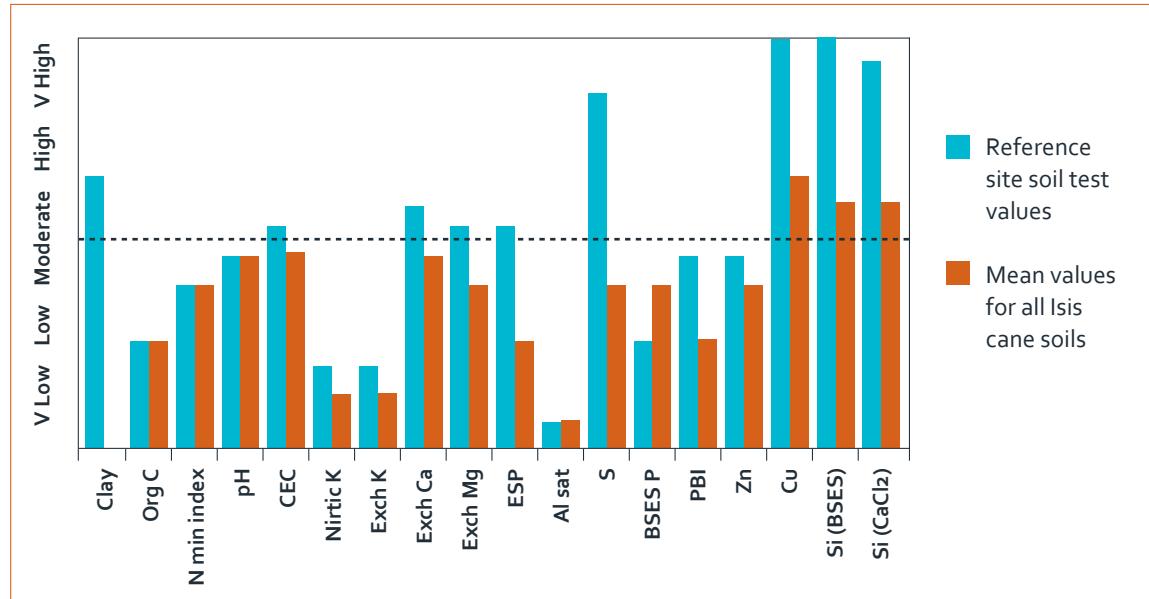
### Similar soils

This soil has similar properties to the Oakwood, Otoo and Watalgan soils.

### Physical properties

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

## 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	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 can be confined to the inter-row by adopting controlled traffic and matching row spacing to machinery. Green cane trash blanketing and the application of organic amendments can improve soil structure, tilth and soil porosity. If managed correctly 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. However if heavy rain or flooding occurs shortly after N application some losses may occur. Loss of nitrate by leaching is possible and fertiliser applications could be split to reduce this risk.

## Mapping unit: Kepnock

<b>Soil group</b>	Yellow clay loam
<b>Brief description</b>	Loamy topsoil over a mottled yellow subsoil
<b>Productivity group</b>	Clay loam
<b>Australian Soil Classification</b>	Yellow Dermosol
<b>Occurrence</b>	
Kepnock soils occur on the mid to lower slopes of rises and plains. They are one of the major soils in the district.	
<b>Formation</b>	
Kepnock soils are developed on deeply weathered fine grained sedimentary rocks.	
	
	

**Above:** 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, Calavos and Cedars soils each of which occupy small sections of the sugarcane growing area.

### Physical properties

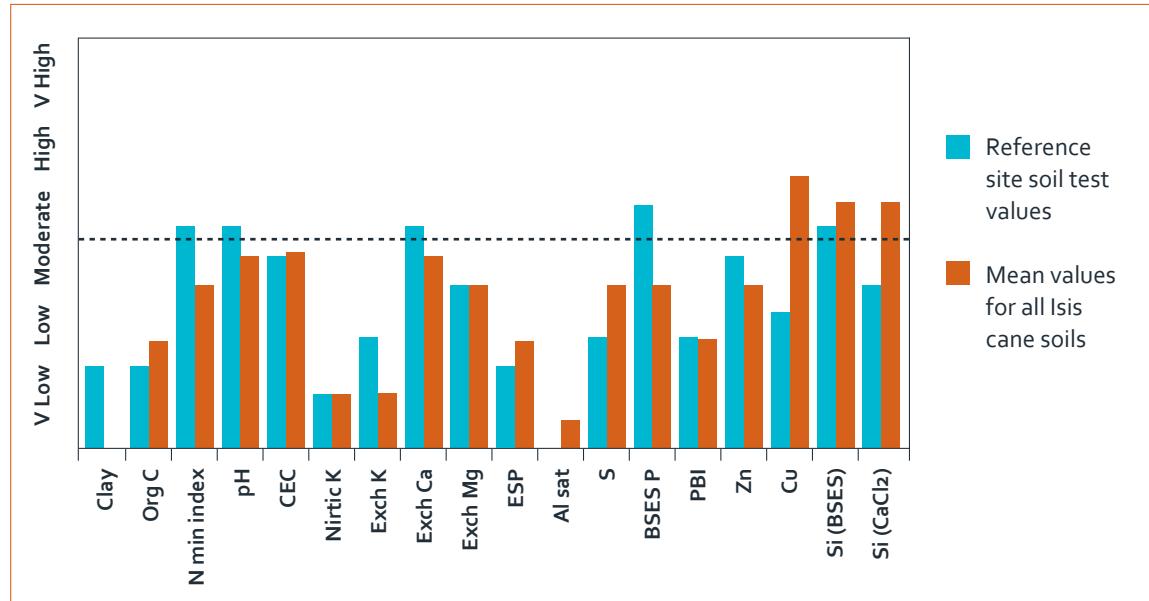
These soils are moderately permeable and moderately well-drained. They are prone to hardsetting and can be subject to erosion depending on the slope.

**Above:** Kepnock soil profile.

### Chemical properties

Kepnock 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 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	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, which is usually 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.

## Mapping unit: Kolan

### Soil group

Grey forest soil

### Brief description

Sandy to loamy topsoil with sodic clay subsoil

### Productivity group

Sodic

### Australian Soil Classification

Grey Kurosol

### Occurrence

Kolan soils occur on crests and hill slopes adjacent to the Kolan and Burnett Rivers.

### Formation

Kolan soils occur on moderately weathered sedimentary rocks.



**Above:** Kolan soil profile.

### Chemical properties

Kolan soils have a moderate to good fertility status and range from neutral to acid at the surface, but are usually acidic in the subsoil. The organic carbon content, N mineralisation potential and CEC of the topsoils are low to moderate. K reserves and exchangeable K values are moderate. These soils are sodic with sodicity increasing to depth. Topsoils have low P-sorbing capacities. BSES P varies according to fertiliser histories. The BSES P value for the reference site was low. Sulphur and micronutrient values are generally satisfactory.



**Above:** 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.

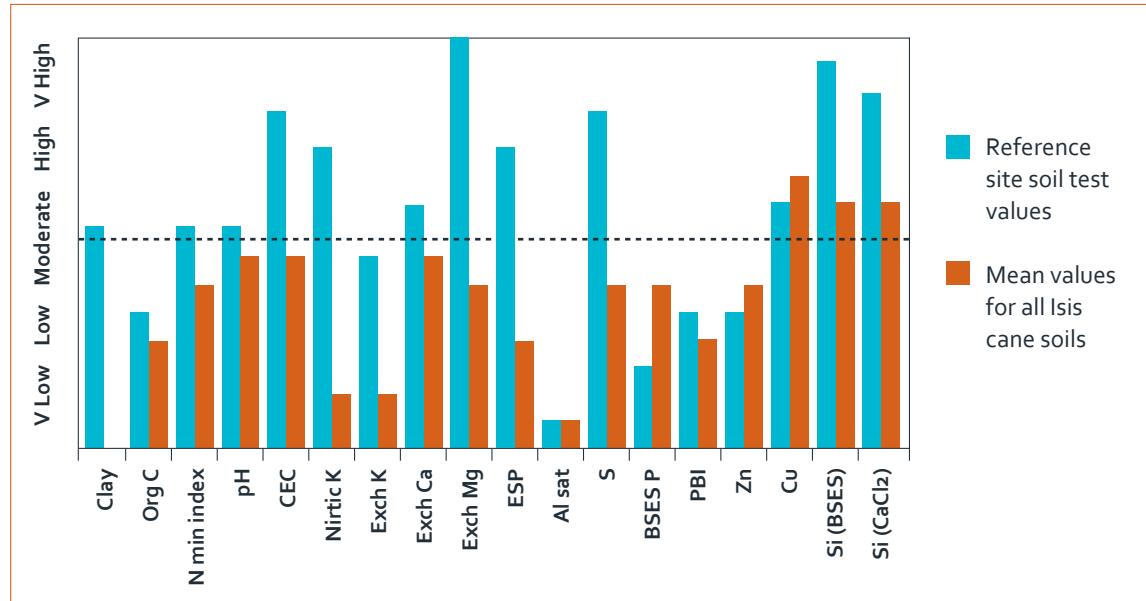
### Similar soils

This soil has similar properties to the Auburn and Givelda 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.

## 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 rationalised. 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 can be limited by adopting controlled traffic and matching row spacing to machinery. 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 grading 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 to blocks for the second fertiliser application may be difficult in wet years.

## Mapping unit: Mahogany

### Soil group

Dark sand

### Brief description

Dark sandy topsoil over a sandy subsoil

### Productivity group

Sand

### Australian Soil Classification

Redoxic Hydrosol

### Occurrence

Mahogany soils occur in depressions and on gentle lower slopes.

### Formation

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



**Above:** Mahogany soil profile.

### Chemical properties

Mahogany 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.



**Above:** Mahogany soil in the Three Chain Rd area.

### Field appearance

Topsoils are dark grey to black sands to sandy loams. They overlie a bleached A 2 horizon. Subsoils are grey mottled sandy clay loams to sandy clays with massive structure.

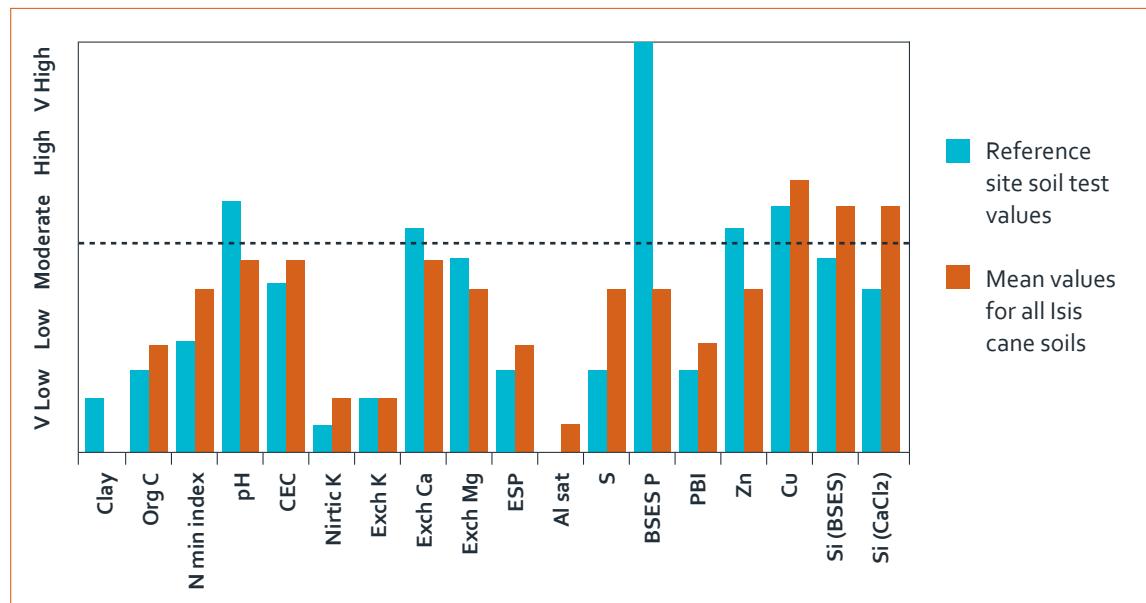
### Similar soils

This soil has similar properties to the Rothchild and Kinkuna. 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.

## 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.

## Mapping unit: Maroondan

<b>Soil group</b>	Black clay
<b>Brief description</b>	Black cracking clay on basalt
<b>Productivity group</b>	Clay
<b>Australian Soil Classification</b>	Black Vertosol

### Occurrence

Maroondan soils occur on crests, slopes and low lying flats east of Gin Gin.

### Formation

Maroondan soils are developed on Tertiary volcanic rocks, including Gin Gin Basalt.



**Above:** Maroondan soil profile.



**Above:** Maroondan soil in the Gin Gin area.

### Field appearance

Topsoils are heavy black clays which exhibit self-mulching properties. They overlie black medium to heavy clay subsoils. Stones, boulders and “rotten rock” may occur in the surface layers of these soils.

### Similar soils

Small pockets of Windermere soils are found in the district.

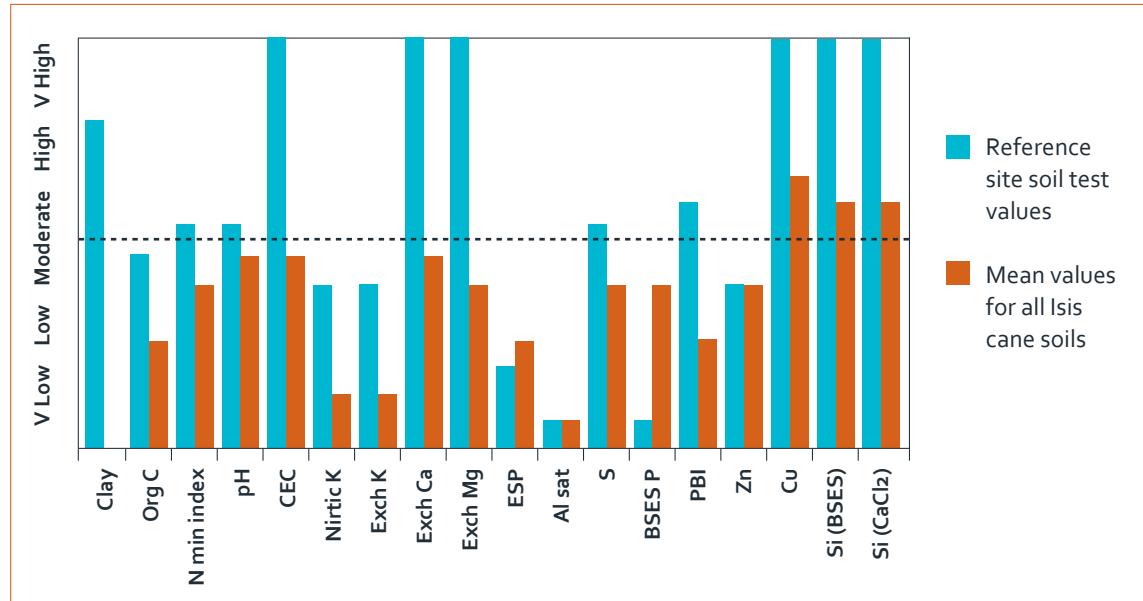
### Physical properties

These soils are recognised for their ability to form cracks, both on the surface and to depth. Water intake occurs initially easily via the cracks, but is slowed as the soil swells. They are prone to compaction when wet. These soils are strongly adhesive. They are also prone to erosion.

### Chemical properties

Maroondan soils have a relatively high nutrient status. Organic carbon content and N mineralisation potential are moderate. CEC in the top and subsoil is 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-nutrient values, especially Zn, can 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 successful 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.

## Mapping unit: Quart

**Soil group**

Grey sand

**Brief description**

Grey sandy topsoil over a grey sandy subsoil

**Productivity group**

Sand

**Australian Soil Classification**

Yellow Kandosol

### Occurrence

Quart soils mostly occur on very gently sloping areas north of the Elliott River.



### Formation

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



**Above:** Quart soil profile.

### Chemical properties

Quart 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.

**Above:** Quart soil north of the Elliott River.

### Field appearance

Topsoils are grey loamy sands to sandy loams over bleached A 2 horizons. They overlie pale yellow to grey sandy loam to sandy clay loams. Soils have little structure.

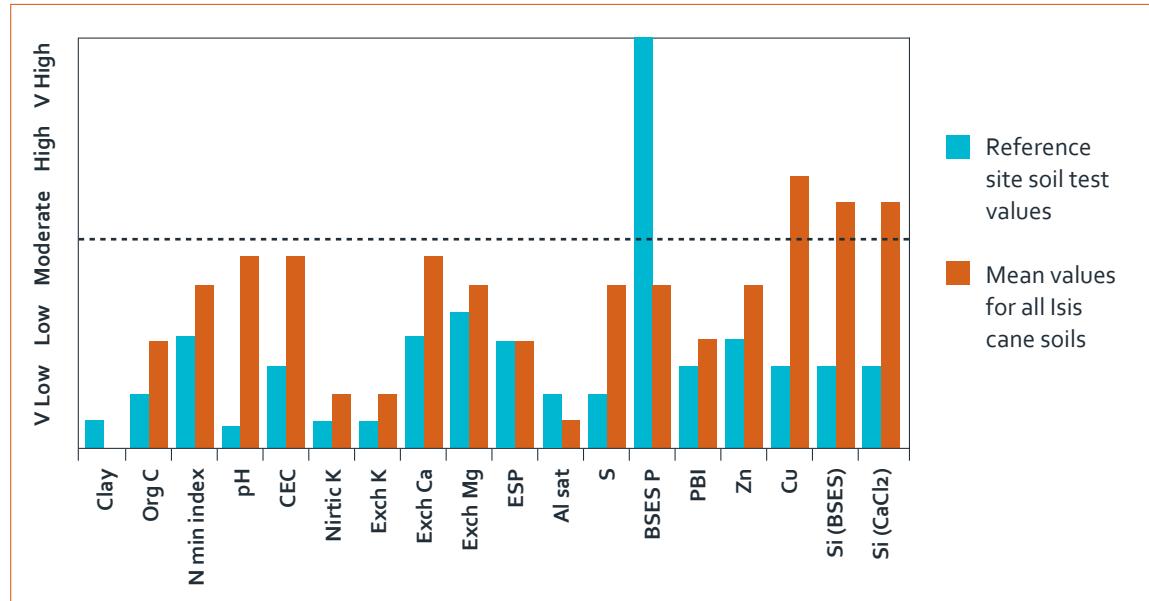
### Similar soils

This soil has similar properties to Wallum and Winfield soils. Theodolite soils are more poorly drained.

### Physical properties

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

## 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.

## Mapping unit: Walla

<b>Soil group</b>	Grey clay
<b>Brief description</b>	Grey cracking clay
<b>Productivity group</b>	Clay
<b>Australian Soil Classification</b>	Grey Vertosol

### Occurrence

Walla is a minor soil in the district. These soils 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.



**Above:** Walla soil in the Wallaville area.

### Field appearance

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

### Similar soils

Small sections of Bucca and Hinkler 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.

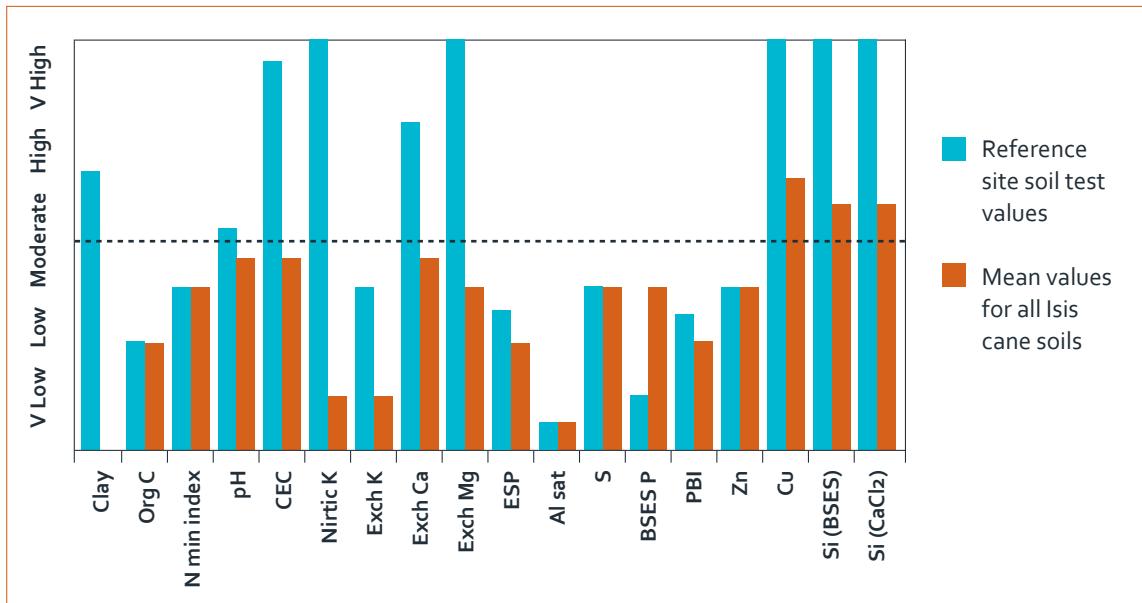
**Above:** Walla soil profile.

### Chemical properties

Walla 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	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	80	10	0	0	0
Replant	0	140	30	100	10	0	0	0
Ratoon	0	140	15	100	10	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 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.

## Mapping unit: Woolmer

<b>Soil group</b>	Yellow sandy loam
<b>Brief description</b>	Sandy topsoil over a yellow subsoil
<b>Productivity group</b>	Sandy loam
<b>Australian Soil Classification</b>	Yellow Dermosol

### Occurrence

Woolmer soils occur on mid slopes in the Childers and Farnsfield areas.

### Formation

Woolmer have formed on deeply weathered coarse grained sedimentary rocks.



**Above:** Woolmer soil profile.

### Chemical properties

Woolmer 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.



**Above:** Woolmer soil in the Tarda Rd area.

### Field appearance

Topsoils are grey loamy sands to sandy loams over bleached A2 horizons. The subsoils are massive yellow to brown sandy clays to medium clays, with red mottles.

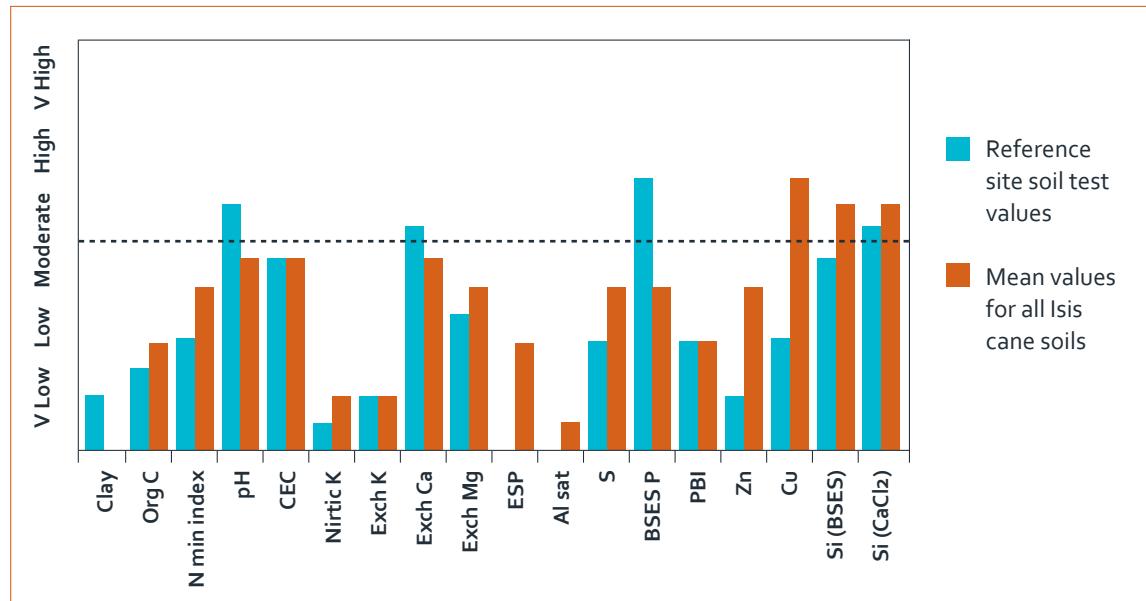
### Similar soils

This soil has similar properties to the Isis, Meadowvale and Littabella 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 1 m.

## 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	0	100	15	75	10	10
Replant	0	150	0	120	15	75	10	10
Ratoon	0	150	0	120	15	75	0	0

## Tillage and water management

If irrigation is practiced, frequent light applications of water using overhead irrigation 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.

# 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 the SIX EASY STEPS 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.

#### 1. Sample collection

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

#### 2. Sample analysis

Submit samples to a reputable / accredited laboratory for analysis.

#### 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 accredited advisor/s.

#### 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.

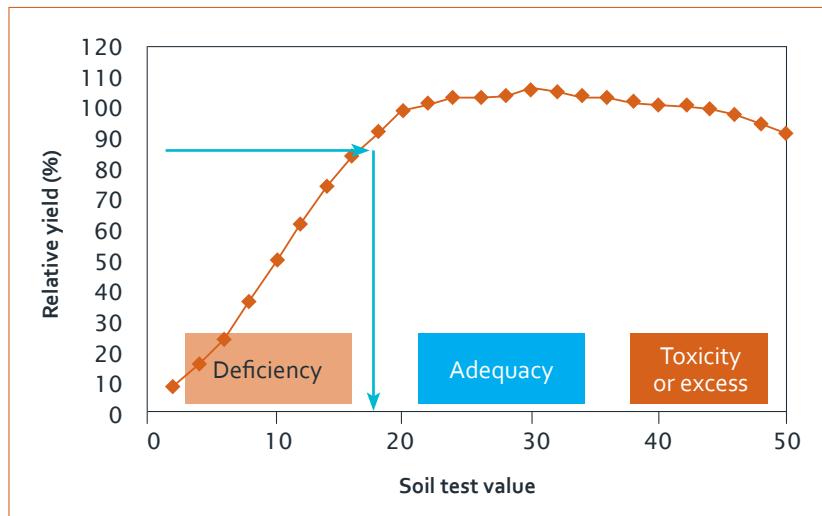


Figure 4.2: Example of a soil test report from a commercial laboratory.

Soil test report							
Trading Name: Bloggs & Bloggs		Paddock Name: Farm 4660			Sample Name: Block 12		
Location: Isis		GPS Latitude:			GPS Longitude:		
Contact Name: Joe Bloggs		Phone:			Adviser:		
Sample Number: 543216		Sample type: Soil			Depth: 0-20 cm		
Sampling Date: 12 January		Crop: Sugarcane			Stage: Fallow		
	Value	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%	0.35						
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 <sub>2</sub> ) mg/kg	24						
Silicon (BSES) mg/kg	86						
ECEC me%	1.76						
Aluminium saturation %	45						
Sodium % of cations (ESP)	2.3						
Phos. Buffer Index (PBI)	38						
Colour (Munsell)	Grey brown						
Texture	Loamy sand						

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 2.7**) 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

There is no Mg requirement for plant or ratoon crops because the exchangeable Mg value is 0.35 meq/100g, which is above the critical value, as shown in **Table 2.13**.

### 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 HCl zinc values are less than the critical values shown in **Table 2.15**.

### Silicon

Application of a silica product is not required as *both* soil tests (BSES and CaCl<sub>2</sub>) are above the respective critical values shown in **Table 2.16**.

### 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 meq/100g (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 following a bare fallow and three successive ratoons) is as follows:

Crop	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Zn kg/ha	Lime prior to planting (t/ha)
Plant cane	130	20	100	15	10	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.

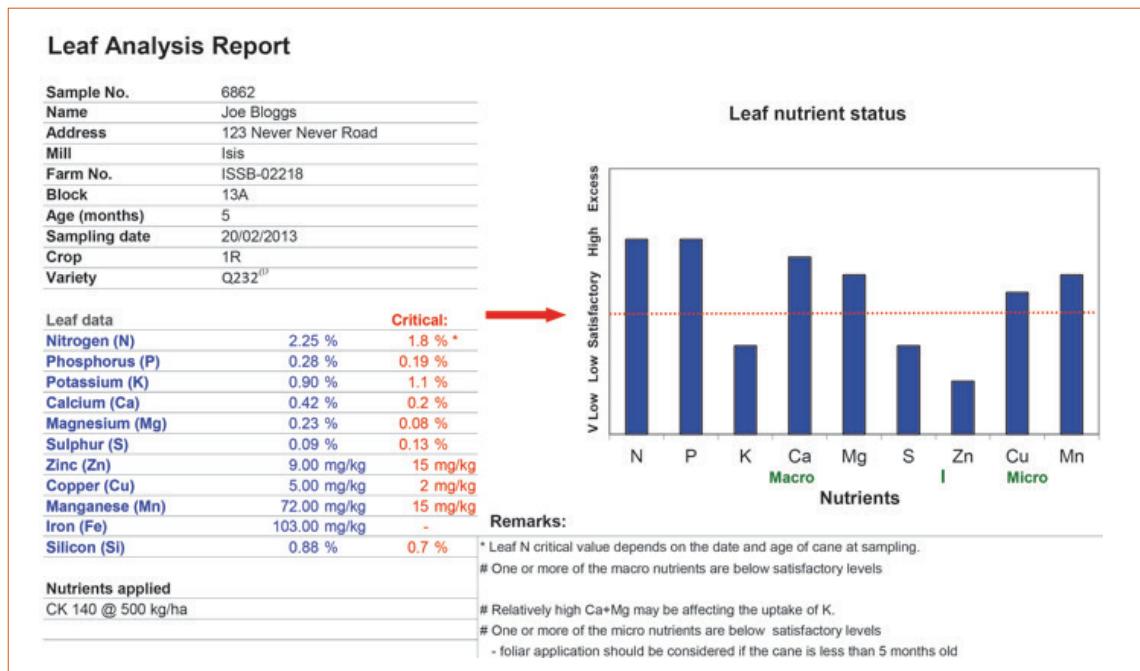
Nutrient	Month of sampling	Third leaf critical nutrient value
N	Nov – mid Jan	1.9 %
	Mid Jan – Feb	1.8 %
	Mar – May	1.7 %
P		0.19 %
K		1.1 %
Ca		0.2 %
Mg		0.08 %
S	Nov – May	0.13 %
Cu		2 mg/kg
Zn		15 mg/kg
Mn		15 mg/kg
Si		0.55 %

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.

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.

## SIX EASY STEPS nutrient management package

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 management package is the SIX EASY STEPS which comprise:

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 to occur in each soil.
3. Regular soil testing (blocks should be sampled before every crop cycle).
4. Developing a nutrient management plan for each block using the current guidelines.
5. Checking on the adequacy of nutrient inputs using leaf analysis or on-farm replicated strip trials.
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 Isis 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.

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 Isis / 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.



**Left:** Forming the ball (bolus) of soil and pressing it into a ribbon.

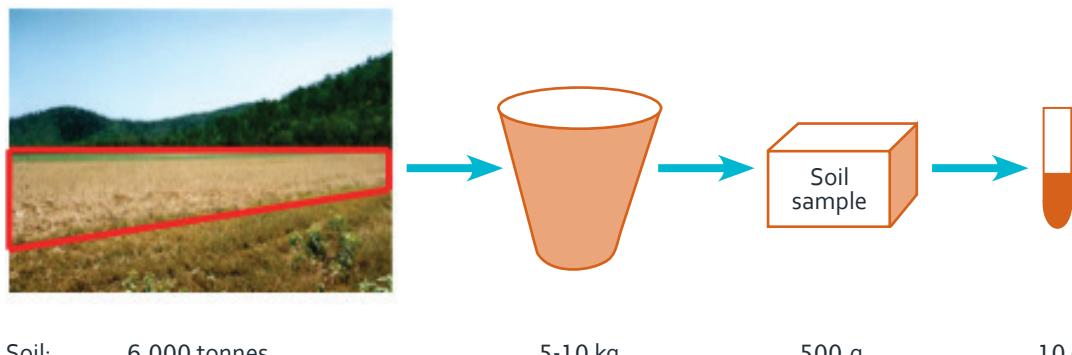
**Below:** Simplified guide to determining soil texture.

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 or 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

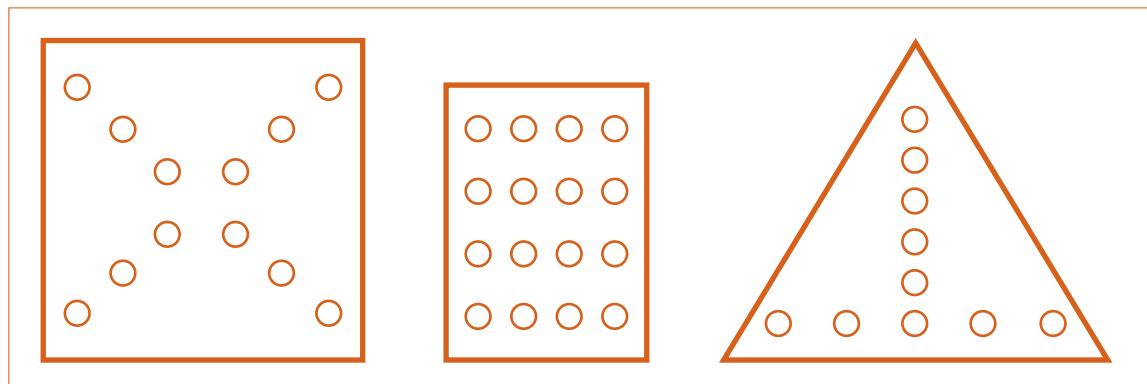
Soil tests in the laboratory are carried out on a 10 g sample which is taken from about 500 g of soil submitted to the laboratory. Usually this 500 g sample is a sub-sample of about 10 kg of soil which ideally should be sampled from a block of cane (average 2 hectare area) which contains about 6 000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



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 type 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.



**Above:** Some suggested sampling patterns within cane blocks of different shapes.

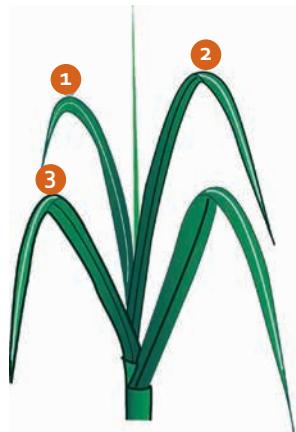
- Whilst there is some debate as to where soil samples should be taken in relation to the cane row or inter-row, we suggest that all samples be taken from the shoulder of the cane row, approximately mid-way between the centre of the cane row and the centre of the inter-row. By following this rule you 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 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 (500 g-1 kg) should be sub-sampled for analysis. Ideally this should occur after air-drying and initial sieving. However, such facilities are not always available.
- 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

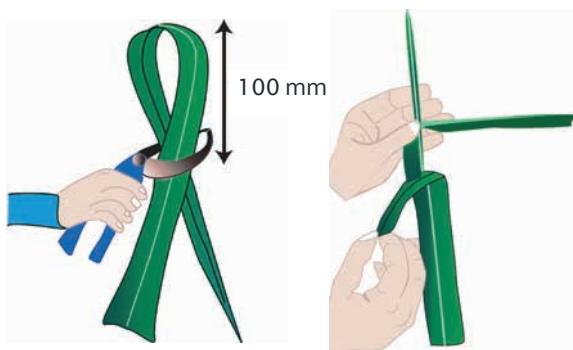
## How to take a leaf sample

### Step 1



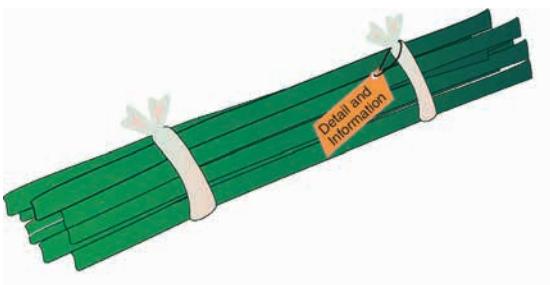
- Select leaves from stalks of average height.
- Sample the third leaf from the top of the stalk (as shown on the diagram). Counting from the top of the plant, the first leaf is the one that is more than half-unrolled. The third leaf usually corresponds to the top visible dewlap.
- Collect 30-40 leaves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

### Step 2



- Fold the leaves in half (top to base) and cut a 100-150 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 label with sample details.
- Place the sample in a cool environment (polystyrene cooler) until it can be dried in an oven (at about 60°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 a reputable laboratory for analysis.

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.
- At least 6 weeks has passed since fertiliser applications.

It is important that leaves are sampled correctly and that all the details requested by the testing laboratory are supplied as accurately as possible. This will enable meaningful interpretation of the analysis results.

# 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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