TECHNICAL PUBLICATION TE07001

SOIL REFERENCE BOOKLET FOR THE JOHNSTONE CATCHMENT

Soil-specific Nutrient Management Guidelines for Sugarcane Production in the Johnstone Catchment

Bernard Schroeder
Andrew Wood
Phil Moody
Bob Stewart
John Panitz
Jason Benn

SOIL-SPECIFIC NUTRIENT MANAGEMENT GUIDELINES FOR SUGARCANE PRODUCTION IN THE JOHNSTONE CATCHMENT

By

Bernard Schroeder[1], Andrew Wood[2], Phil Moody[3], Bob Stewart[4], John Panitz[1] and Jason Benn[5]

[1] BSES Limited, Bundaberg
[2] CSR Sugar Ltd, Macknade
[3] NRW, Indooroopilly
[4] Johnstone River Catchment Management Association Inc
[5] Innisfail Babinda Cane Productivity Services

Substantial funding for this project was received from DAFF (NLP) through FNQ NRM Ltd. This booklet was developed from information collected in an initial project that was partially funded by Envirofund and administered by CANEGROWERS Innisfail.

BSES Limited Technical Publication TE007001

ISBN: 978-0-949678-27-0

CONTENTS

ABOUT THE AUTHORS

Dr Bernard Schroeder is a Principal Scientist with BSES Limited at Bundaberg. He has been involved in R,D&E associated with various aspects of soil fertility and crop nutrition over the past 20 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 developing modified nutrient management guidelines that are soil / district-specific. This work has often been in collaboration with other agricultural scientists, particularly within SRDC and CRC Sugar funded projects. He is the author / co-author of a relatively large number of publications, both technical and more industry focused.

Dr Andrew Wood currently holds the position of Productivity Manager, CSR Sugar Ltd in the Herbert River district. Andrew has more than twenty years experience in the industry. Apart from 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.

Dr Phil Moody is a Principal Scientist and Group Leader with the Queensland Department of Natural Resources and Water at Indooroopilly. He is a well respected soil scientist with special skills and knowledge in soil chemistry. In particular his research initiatives have included substantial work on soil phosphorus and organic carbon. During the last 25 years Phil has been the author or co-author of a number of scientific papers and reports. He is involved in various international projects, particularly in south east Asia.

Bob Stewart operates an agricultural consulting service on the Atherton Tablelands. He currently consults to the wet tropics regional body for natural resource management, FNQ NRM Ltd, as well as offering services for land use assessment and agronomy. He worked in the sugar industry in Ingham and Ayr for many years. He has a background in agricultural science, sustainable agriculture, agricultural engineering and teaching. He worked with Andrew Wood in the early years of the soils mapping exercise in the Herbert Valley. He initiated the National Landcare Program (NLP) project for the development of guidelines for soil-specific nutrient management for the Johnstone sugar industry.

John Panitz is a Senior Extension Agronomist based at the BSES Limited Southern Experiment Station in Bundaberg. He has had over 20 years working experience in an R,D&E environment and, as variety officer, has made a large contribution to the plant breeding program in the Southern Region. More recently he held the position of Extension Officer within the Sugar Services group (combined extension service of BSES Limited and the Bundaberg Cane Pest and Productivity Board). In this role he was primarily responsible for the distribution of approved seed cane in the Bundaberg district. 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. In his current role, John is primarily involved in RD&E relating to nutrient management across regions within the sugar industry.

Jason Benn is manager of the Innisfail Babinda Cane Productivity Services based at South Johnstone Mill.

ACKNOWLEDGEMENTS

We thank the following contributors to this publication:

- Wayne Thomas (Manager of CANEGROWERS, Innisfail) for his ongoing support and input into developing this booklet.
- Mick Ward (Cane Productivity Superintendent, Northern Region, Bundaberg Sugar Ltd) for his support of this and associated projects, and for sharing his knowledge of cane-producing soils in the Innisfail area.
- Sue Berthelsen (Research Scientist, CSIRO, Townsville), Dr Barry Salter (Research Agronomist, BSES Limited, Mackay) and John Reghenzani (Leader Sustainable Agriculture Program, FNQ NRM Ltd, Ingham) for their technical input.
- Mike Goodson (previously Productivity Officer with Innisfail Babinda Cane Productivity Services) for making available the soil analysis data associated with growers samples collected over the recent past.
- Joseph Marano, Ian and Robert Brooks, Felix Garrone, Joe Zappala, Ron Grima, Arthur Cecchi, Jamie Zammit and Bundaberg Sugar Ltd for allowing soil pits to be excavated on their properties.
- Kevin Ghetti and Alan Cross (Farming Supervisors, Bundaberg Sugar Ltd) for their assistance in locating soil reference sites.
- Basil Micale (Chairman: CANEGROWERS, Innisfail), as well as other members of the Innisfail CANEGROWERS Board for their support.
- Alan Hurney (Senior Agronomist, BSES Limited, Tully) and David Calcino (Principal Extension Officer, BSES Limited. Meringa) for their useful input and comments.
- Eve McDonald (BSES Limited, Brisbane) for her advice and assistance in the layout of this booklet.
- Dr Tim Wrigley (Environmental Manager, CANEGROWERS, Brisbane) for his active support of this and other nutrient management projects undertaken by the team.
- FNQ NRM Ltd and CANEGROWERS Innisfail for allowing the group to use their facilities.

The soil-specific guidelines in this publication are based on outcomes from projects that received funding from the Sugar Research and Development Corporation and the Cooperative Research Centre for Sustainable Sugar Production.

Australian Government

Sugar Research and Development Corporation

GLOSSARY OF TECHNICAL TERMS

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

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

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

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

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

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

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

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

Back plain: A low lying area away from rivers where water accumulates and poorly drained, heavy textured soils commonly occur.

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

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

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

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

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

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

Decomposition: The breakdown of a complex substance to something simpler. The process can be caused by weathering, chemical change (increased acidification) or biological action.

Deficiency: A nutrient level below the critical level. In extreme cases a deficiency is reflected by plant symptoms such as leaf colour.

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

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

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

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

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

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

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

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

Humus: Stabilised soil organic matter distinct from decomposing trash.

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

Levee: An elevated area adjacent to rivers and creeks.

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

Median: The middle number in a group of numbers. The median for the list of numbers 4, 5, 8, 20 and 27 is 8. It is different from the mean or average which is the sum of all numbers divided by the number in the list = (4+5+8+20+27)/5 = 12.8. The median is a better predictor of representative soil properties as it is not influenced by extreme values.

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

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 indicating the effects of poor drainage.

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

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

Old land: Land in its second or later crop cycle of sugarcane.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Water holding capacity: The amount of water a soil can hold after drainage and which can be extracted by plants.

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

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

INTRODUCTION

In 2003 a soil reference booklet for the Herbert District entitled *Soil Specific Management Guidelines for Sugarcane Production* was produced for cane growers. This was followed by the publication of a similar booklet for the Proserpine district in 2006. These booklets describe the basic principles of soil management and present nutrient guidelines for soils in each of the districts. We are now in the position to present a similar booklet aimed at soil-specific nutrient management in the Johnstone catchment. This is based on a methodology developed within an SRDC-funded project (Improved nutrient management in the Australian sugar industry) and research conducted in the area as part of an Envirofund project (Development of soil-specific nutrient guidelines for sugarcane in the Johnstone Basin). We are also in the process of using this approach to develop nutrient management guidelines for other districts in the Australian sugar industry.

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

This philosophy is particularly appropriate for the current circumstances in the Australian sugar industry. The escalating costs of fertiliser, the need to reduce production costs and mounting environmental pressures demand responsible soil and nutrient management. The guidelines in this booklet are aimed at providing best-practice soil and nutrient management for cane growers in the Johnstone catchment. 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.

CHAPTER 1

Introduction to Johnstone soils and their properties

The soils described in this report are located in the sugarcane areas that supply cane to Bundaberg Sugar Ltd. The area covered extends from the North Johnstone River to Silkwood in the south, and as such, does not include all the areas supplying cane to Bundaberg Sugar Ltd.

The climate of the area is characterised by hot, wet summers and mild, relatively dry winters. Annual rainfall is high and strongly seasonal, ranging from 3000 to over 4500 mm. Mean monthly temperatures at Innisfail range from a maximum of 30°C in January to a minimum of 15°C in July.

A range of different soil landscapes in the Wet Tropical Coast area have been described by Murtha and Smith (1994). The landscapes of the Johnstone Catchment and the reference soils that occur within them are briefly described below.

Soil landscapes

1. **Beach ridges and swales.** The beach ridges are low sandy ridges oriented roughly parallel to the present coastline, with deep, well-drained sandy soils. The swales between the sandy ridges are occupied by freshwater swamps with black, peaty soils occurring along the margins. **Brosnan** soils are red sandy loams on older beach ridges occupying the area known locally as the Mourilyan sands. **Maria** soils occur to the east and are formed on beach ridge material reworked by river action. **Nind** soils occur in the poorly drained depressions between the sand ridges and are black sandy soils where organic matter has accumulated due to the wet conditions.

2. **Basalt soils.** These are predominantly deep, dark red, strongly structured clay soils. **Pin Gin** soils occur on sloping basalt flows along the North and South Johnstone river valleys and flows from vents such as Pin Gin Hill to the south west of Innisfail. **Eubenangee** soils occur on the gentle slopes along the eastern margins of the major basalt flows. **Mundoo** soils occur on colluvial fans derived from basalt in the eastern areas where the topography is much flatter.

3. **Metamorphic soils.** No reference sites were located within this landscape, as only small areas of metamorphic soils are used for sugarcane production.

4. **Granitic soils.** These soils occur either directly on granite or on colluvial or alluvial fans formed from granitic material. Granitic soils generally have a high proportion of coarse sand and gravel containing quartz grains. **Thorpe** soils occur as yellowish brown sandy loams on mid or lower slopes of colluvial fans.

5. **Alluvial soils.** The appearance and properties of alluvial soils are determined by the type of parent material from which the deposits originate and the nature of the depositional environment. They can be classified into well-drained and poorly drained soils on the basis of subsoil colours and mottling, which reflect the amount of time the lower part of the soil profile is saturated.

   The three main well drained alluvial soils are Liverpool, Tully and Innisfail. **Liverpool** soils occur on low terraces and flood plains along Liverpool Creek and the North and

South Johnstone Rivers. They are subject to frequent flooding. **Tully** soils occur on higher terraces along Liverpool Creek, many of which are above flood levels. **Innisfail** soils occupy similar positions to Tully soils along the North and South Johnstone rivers, but generally have reddish brown subsoils rather than the yellowish brown colours of the Tully soils due to the greater contribution of basaltic materials.

The three main poorly drained alluvial soils are Coom, Bulgun and Ramleh. **Coom** soils are heavy textured soils occurring on mixed alluvium mainly to the east of the Bruce Highway. They flood occasionally and have high water tables for most of the year. **Bulgun** soils usually occur in enclosed depressions and are characterised by darker topsoils but brighter coloured subsoils. **Ramleh** soils are formed on alluvium predominantly derived from metamorphic rocks and have strongly mottled subsoils indicative of saturated conditions for considerable periods of each year.

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 will enable growers to identify soil types more easily. 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, 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. 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

Texture 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. Larger particles include gravel and sand, while the smallest particles are referred to as clay. Silt particles are moderately sized. Soils are classed as sand, loam or clay, or combinations of these, depending on the proportions of the particles. Clay particles have a large surface area and are generally negatively charged. Clay is the most reactive constituent of soil and gives soil the ability to store positively charged nutrients such as potassium, sodium, calcium and magnesium. The fine pores between the clay particles 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 size, shape and level of stability. Their presence in soil affects the way soils behave, the growth of plants and the manner in which soils are managed. For instance, while some structure is essential for soil stability and good water-holding characteristics, large and strong structure can prevent root penetration, impede water 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. For cane producing soils in the Johnstone Catchment, the top 20cm is generally considered mixed topsoil and the 40-60cm depth increment is usually well within the subsoil.

Chemical Properties

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

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

Organic Matter
Soil organic matter is derived from the breakdown of plant and animal matter. It also has the ability to attract nutrients and has a greater cation exchange capacity than a similar mass of clay. Dark colour and good structure are indicators of high organic matter. Soils in the Johnstone district have organic C contents of up to 2.7%. Organic matter, measured as organic carbon %, improves soil structure and is a source of nitrogen (N), phosphorus (P), sulphur (S) and trace elements. There is no optimum level of organic matter, but it is best to maintain it at the highest possible level. The organic matter content of a soil is determined by the balance between inputs of organic matter forming material and the breakdown (mineralisation) of the existing stabilised soil organic matter (humus). Green harvested sugarcane inputs about 10-15 t/ha in trash and 3 t/ha in roots per year, but 80% percent of this is lost by decomposition in the first year. In soils with low clay contents, 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 N mineralisation index provides an estimate of the potential amount of N released from specific soils and 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 the soil. 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, mill ash and bagasse.

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

Low pH reduces the already low CEC of tropical soils and causes the soil CEC to be dominated by the acidic cations H^+ and Al^{3+}. This reduces the storage capacity for nutrients such as Ca, Mg and K and can be critical particularly on sandy soils with low CEC. Soil acidification is a natural process which is made worse by the use of 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 the coastal and marine plains. Acid sulphate soils also exist in this region.

Plant nutrition

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

Nitrogen (N)
CSIRO 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. The rate of mineralisation is 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). More detail is provided on these processes in Figure 1.1. Ammonium-N is subject to volatilisation, a loss often associated with urea applied to the surface of a trash blanket.

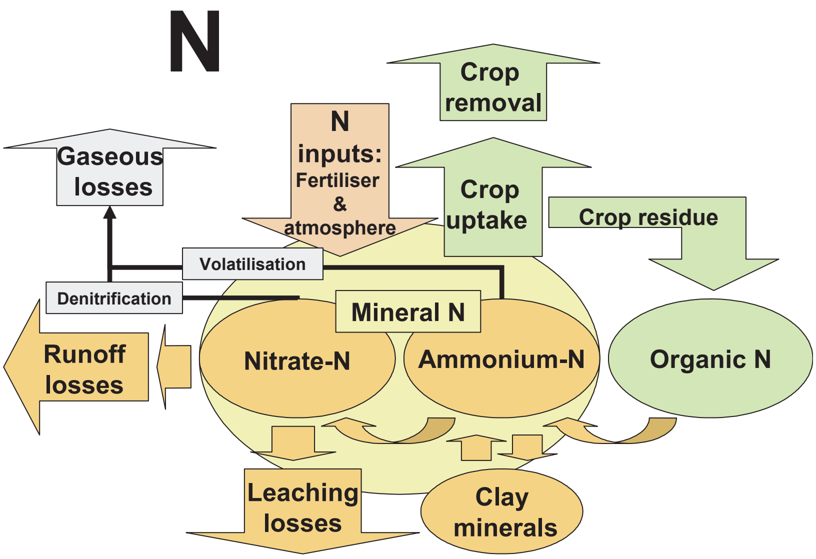


Figure 1.1 Schematic diagram of the nitrogen cycle

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

- Determine soil organic matter mineralisation capacity and apply nitrogen according to the specific requirements of different soils (as shown in Chapter 2).
- Reduce nitrogen losses by leaching, runoff or denitrification by splitting applications of nitrogen, which is the usual practice in plant cane.
- Reduce the potential for denitrification through improved drainage and placement of fertiliser on the cane row where it is less likely to be waterlogged.
- Reduce the potential for ammonia volatilisation when urea is applied to the surface of a trash blanket by delaying application until a cane canopy has developed. Applying the urea below the soil surface removes the possibility of losses by volatilisation but could increase the risk of loss by denitrification if waterlogging occurs.

Phosphorus (P)

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

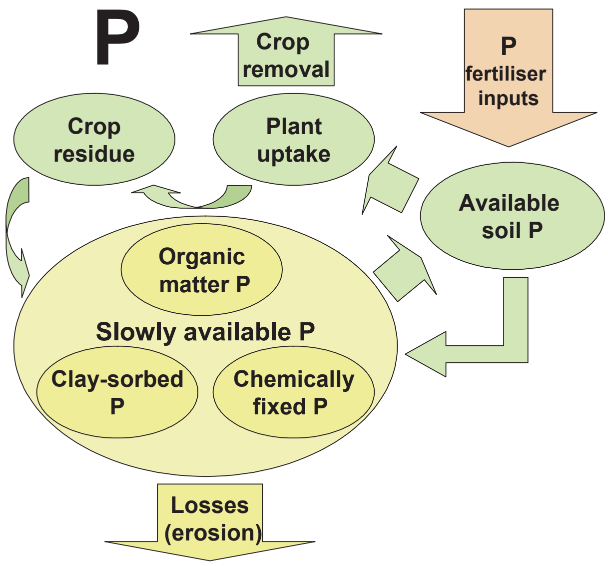


Figure 1.2 Soil phosphorus cycle

Potassium (K)

Sugarcane needs potassium in large quantities mainly for the maintenance of water balance. On average around 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 can represent a major part of the total K in the soil. This breaks down into the slowly available non-exchangeable form of K, which in turn acts 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.

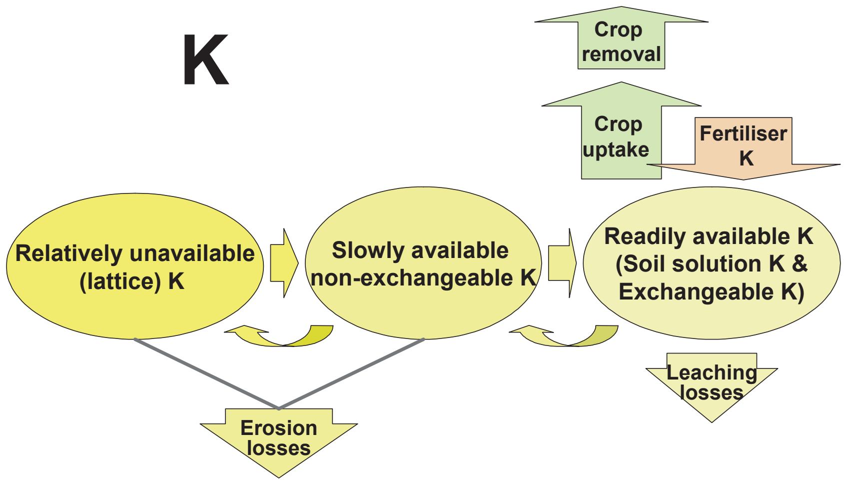


Figure 1.3 Soil potassium cycle

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 around 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 taken up from the soil solution and stored on the CEC. It 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 around 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 what is 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 Johnstone 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 Johnstone soils.

Silicon
Deficiencies of silicon (Si) are possible, particularly on very sandy soils.

CHAPTER 2

Principles for determining nutrient management guidelines

When developing nutrient management guidelines for the different soil types in the Johnstone catchment 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 chances of nutrient loss processes occurring

A wide range of soil physical and chemical properties contained in two databases were used to assist this process. The first comprised data collected for soil reference sits established in the Johnstone catchment (Schroeder *and others*.., 2006) and the second consisted of data from samples taken from cane blocks over the past three to five years. These data were then used to produce the bar graphs for each soil type in Chapter 3. The data presented relates to:

- 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 nitrogen 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 P (index 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
- Silicon (as extracted by dilute sulphuric acid and calcium chloride solution)

Nitrogen (see Wood and others, 2003; Schroeder and others, 2005)
Nitrogen guidelines are 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 yield (tonnes cane /ha) multiplied by a factor of 1.2. The district yield potential for the Wet Tropics is 120 tonnes cane /ha (an estimated highest average annual yield of 100 tonnes cane /ha multiplied by 1.2). The 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 district yield potential than many other districts.

The district yield potential is used to establish the base N application rate according to a 'rule of thumb' previously developed by CSIRO scientists. Accordingly, 1.4 kg N per tonne of cane is needed 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 Johnstone 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 Johnstone catchment calculated over a five 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 will then be 10 kg N/ha greater than those shown in Table 2.1. The N application rates for replant or ratoon cane, in his 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.

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 ratoons
VL	<0.4	160
L	0.4 - 0.8	150
ML	0.8 - 1.2	140
M	1.2 - 1.6	130
MH	1.6 - 2.0	120
H	2.0 - 2.4	110
VH	>2.4	100

After determining the appropriate N application rate in this way, further discounting is required to recognise the contributions of other sources of N. These sources include N from legume fallow crops, harvested legume crops, application of mill by-products and nitrogen remaining in soil after horticultural crops (e.g. bananas and pawpaws).

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 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
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

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
Organic C (%)	<0.4	0.4 - 0.8	0.8 - 1.2	1.2 - 1.6	1.6 - 2.0	2.0 - 2.4	>2.4
Replant cane and ratoon after replant	160	150	140	130	120	110	100
Plant cane after a grass/bare fallow	140	130	120	110	100	90	80
Plant cane after a poor legume crop (e.g. 2 t/ha cowpea green manure: N rate minus **70** kg N/ha)	90	80	70	60	50	40	30
Plant cane after a good legume crop (e.g. 6 t/ha soybean: N rate minus **270** kg N/ha)	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Plant cane after a good legume crop harvested for grain (e.g. 6 t/ha soybean: N rate minus **90** kg N/ha)	70	60	50	40	30	20	10
First ratoon after a good legume crop*	160	150	140	130	120	110	100
Second ratoon after a good soybean/cowpea crop	160	150	140	130	120	110	100

* Data from the Yield Decline Joint Venture and other trials suggest that N applied to the first ratoon sugarcane crop after a legume fallow can possibly be reduced.

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.

- **Mill mud** applied at 100 - 150 wet t/ha: Subtract 80 kg N/ha from plant, 40 kg N/ha from 1st ratoon and 20 kg N/ha from 2nd ratoon.
- **Mill ash** applied at 100 - 150 wet t/ha: No change

Phosphorus

Two techniques are used to decide how much P fertiliser is required. Firstly, a BSES critical level is used to determine the quantity of P fertiliser required. This is then modified by the soil's ability to fix added P (P sorption), which determines how much of the fertiliser P will be available to the crop. The P sorption class of each soil is based on the Phosphorus Buffer Index (PBI), which is measured in the laboratory (Table 2.4). It can also be estimated from the clay % and organic matter content of a particular soil (Table 2.5), although care needs to be exercised in using this in the Johnstone catchment due to the widespread occurrence of deep, dark red basalt soils with high PBI which may not be characterised as having a high PBI using the guidelines in Table 2.5.

Table 2.4 - P sorption classes based on PBI (see Burkitt and others, 2000)

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

Table 2.5 - P sorption classes based on Org C (%) and texture class (see Wood and others, 2003)

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

Currently, some of the older sugarcane areas do not require P fertiliser, due to their long history of P fertilisation. However, investigations are underway to determine whether soils with high PBI (Table 2.4) require some P fertiliser at planting when BSES P is greater than 50 mg/kg. New land, on the other hand, is often deficient in available P and requires P fertiliser in the first crop cycle (Table 2.6). The guidelines in Table 2.6 (see Schroeder and others, 2006) 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 2.6 - **Phosphorus guidelines for old and new land** (see Schroeder and others 2006)

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

As with nitrogen, discounts should be made where mill by-products have been used:

- **Mill mud** applied at 100 - 150 wet t/ha: Apply nil P for at least 2 crop cycles.
- **Mill ash** applied at 100 - 150 wet t/ha: Apply nil P for at least one crop cycle.

Potassium

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

The maximum K rate recommended for the Johnstone catchment 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 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 relatively high K reserves on some soils that slowly but continuously become available. 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 2.7. As for N and P, discounts should be made where mill by-products have been used.

Table 2.7 - Potassium fertiliser guidelines (see Wood and Schroeder, 2004)

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

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

Modifications to suggested K rates are recommended where mill by-products have been used:

- **Mill mud** applied at 100 – 150 wet t/ha: Subtract 40 kg K/ha from first crop.
- **Mill ash** applied at 100 – 150 wet t/ha: Apply nil K for one crop cycle.

Sulphur

As the main natural supply of sulphur in many soils is from the mineralisation of soil organic matter, sulphur fertilising guidelines are based on the nitrogen mineralisation index. Soils are placed in one of three N mineralisation classes and then critical levels for soil sulphate are used to calculate sulphur fertiliser rates (Table 2.8). Discounts should be made where mill by-products have been used.

Table 2.8 - Sulphur fertiliser guidelines (kg S/ha) for plant and ratoon crops

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

Modifications to suggested S rates are recommended where mill by-products have been used:

- **Mill mud** applied at 100 - 150 wet t/ha: Subtract 10 kg S/ha from each of first three crops.
- **Mill ash**: Nil effect

Lime (see Aitken, 2000; Nelson and others, 2000; Wood and others, 2003)
Lime is used to neutralise soil acidity and supply calcium. Soils are constantly being acidified through the use of nitrogen fertilisers, 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 more than urea which acidifies more than calcium ammonium nitrate). Some soil tests include liming estimates to a target pH(water) of 5.5, 6.0 and 6.5. The liming estimate to a soil pH(water) of 5.5 should be used where available, otherwise the guidelines in Table 2.9 can be used. Lime is recommended when soil pH(water) falls below 5.5 (Table 2.9) and when exchangeable Ca is below 1.5 me% (Table 2.10). Discounts are necessary where mill by-products have been used.

Table 2.9 - Lime guidelines for acid soils (when pH(water) <5.5)

CEC (me%)	Suggested lime application (tonnes/ha)
< 1.5	1.25
1.5 - 3.0	2.5
3.1 - 6.0	4
> 6.0	5

Table 2.10 - Ag lime guidelines based on exchangeable Ca (adapted from Calcino and others, 2000)

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

Modifications to suggested lime rates where mill by-products have been used are as follows:

- **Mill mud** applied at 100 – 150 wet t/ha: Subtract 2 t/ha Ag lime.
- **Mill ash** at 100 – 150 wet t/ha: Subtract 2 t/ha Ag lime.

Magnesium

Magnesium guidelines are based on soil critical levels for exchangeable magnesium (Table 2.11). 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, but does not appear to affect plant growth, provided all nutrients are above their critical levels and soil pH is above 5.5.

Table 2.11 - Magnesium guidelines for plant crops (see Calcino, 1994)

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

Sodium

Sodium does not need to be applied to sugarcane, but needs to be reduced when the exchangeable sodium percentage (ESP) is above 5% of the CEC in the topsoil. Where this occurs, it is suggested that subsoil samples be taken to determine ESP in the soil profile and that 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 dependant on exchangeable sodium percentage (ESP). Guidelines are provided in Table 2.12.

Table 2.12 – 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 2.13). The BSES zinc soil test is appropriate for the acidic soils occurring in the Johnstone catchment. The DTPA soil test result should be used if the 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 lime may induce deficiencies, particularly of zinc, when micronutrient levels are marginal.

Table 2.13 - Copper and zinc guidelines (see Calcino and others, 2000)

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

Silicon

Two soil tests are appropriate for assessing silicon deficiencies. These are based on calcium chloride extractable Si and dilute sulphuric acid extractable Si. The latter is sometimes referred to as BSES-Si. Ameliorants are only required if both of the Si test values are low (Table 2.14). Leaf analysis is appropriate for assessing whether crops have been able to take up adequate amounts of Si.

Table 2.14 - Silicon guidelines for plant cane (see Calcino and others, 2000); Berthelsen and others, 1999)

	Sulphuric acid (0.005M)		Calcium chloride (0.01M)	Rating	Suggested application rate
Si (mg/kg)	< 70	and	< 10	Low	Calcium silicate at 4 t/ha; **or** Cement at 3 t/ha **or** Mill ash at 100 – 150 wet t/ha

CHAPTER 3

Description of the Johnstone sugarcane soils and guidelines for their management

This chapter presents information on the location, appearance, properties and management requirements of cane producing soils in the Johnstone catchment. A map showing the cane block layer and the soil associations mapped and described by Murtha (1986) was used in conjunction with expert local knowledge to select 13 soil reference sites, considered representative of the main soils in the area used for sugarcane production. All were located on land currently being used for sugarcane cropping.

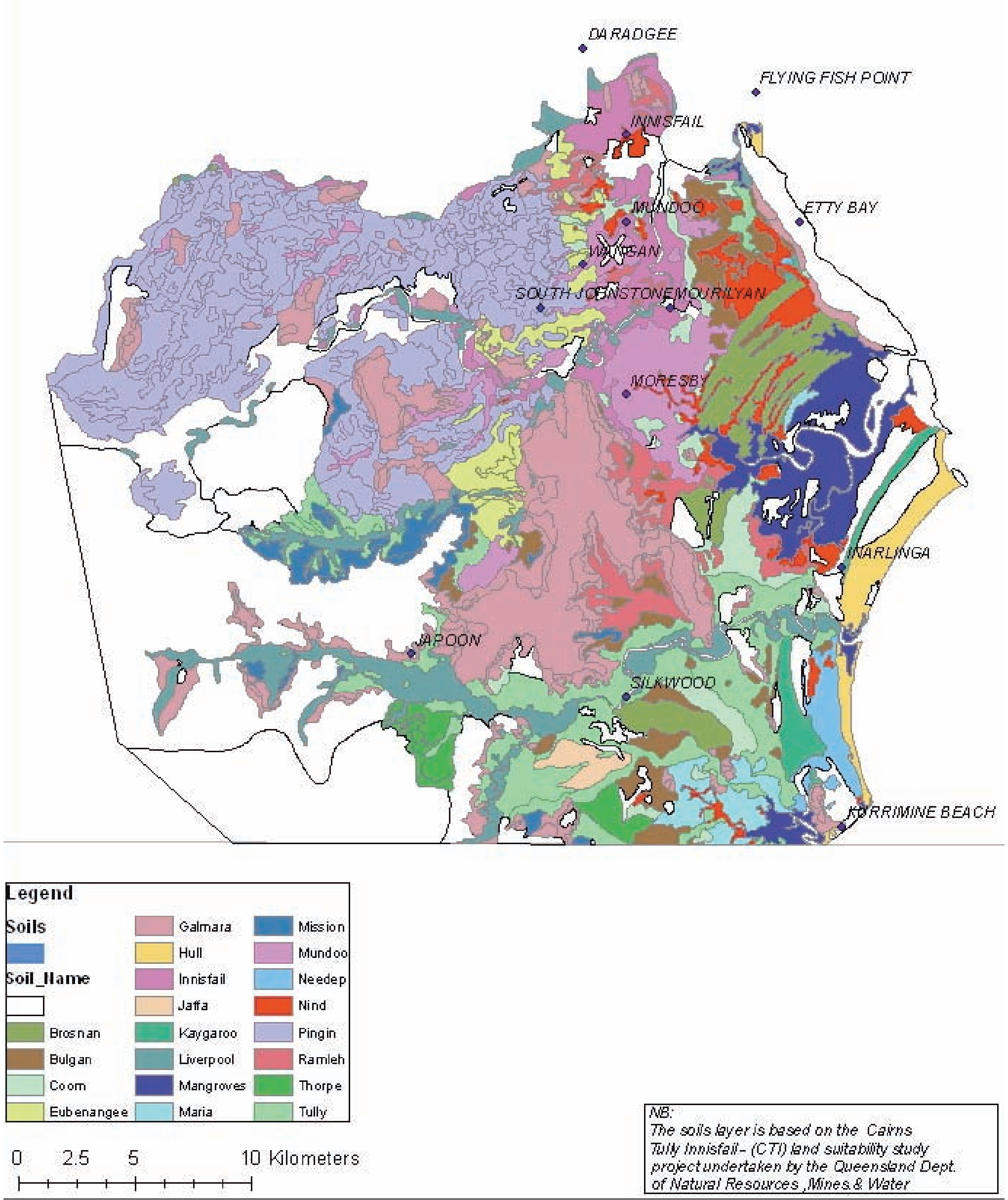


Figure 3.1 - Map of the Johnstone catchment showing soils mapped at a scale of 1:50,000 (see Murtha, 1986).

CSIRO soil survey

A soil survey of the wet tropical coastal lowlands between the Tully and North Johnstone rivers was conducted by CSIRO Division of Soils during the 1980's. Forty three soil series were recognised and these were characterised in terms of their field morphology and major chemical and physical properties. Soil mapping units were drawn at a scale of 1:50,000 and represent 'Soil Associations' composed of one major soil series associated with one or more minor soil series. The soil survey information is available from a CSIRO publication (Murtha, 1986) and a key to the recognition of soils across the entire wet tropical coast has also been published (Murtha and Smith, 1994).

These two reports focus largely on undisturbed soil profiles and it is important to realise that soils used for sugarcane cropping have been modified to some extent. Surface soil horizons have been mixed throughout the cane area through normal land preparation operations. Deep ripping and mole draining have increased the depth of mixing and large amounts of soil have been moved during land levelling operations. The soil profiles described and illustrated in this handbook are all from cane paddocks and are therefore modified from their natural state.

Soils of the Johnstone catchment

The soils most commonly found in the Johnstone catchment are shown in Table 3.1. Those highlighted in green are the 13 most important sugarcane producing soils as indicated above. The distribution of these soils, in the Johnstone Catchment, is shown in Figure 3.1.

Table 3.1 – Classification of Johnstone sugarcane producing soils

Soil Association	Great Soil Group	Australian Soil Classification
Brosnan	Red earth	Red Kandosol
Bulgun	Gleyed podzolic	Grey Dermosol
Coom	Alluvial	Redoxic Hydrosol
Eubenangee	Krasnozem	Red Ferrosol
Innisfail	Alluvial	Brown Demosol
Liverpool	Alluvial	Orthic Tenosol
Maria	Yellow earth	Yellow Kandosol
Mundoo	Krasnozem	Red Ferrosol
Nind	Acid peat	Fibric Organosol
Pin Gin	Krasnozem	Red Ferrosol
Ramleh	Gleyed podzolic	Brown Dermosol
Thorpe	Yellow earth	Brown Kandosol
Tully	Alluvial	Brown Dermosol
Galmara	Red podzolic	Red Dermosol
Hull	Rudimentary podzol	Podosol
Jaffa	Yellow podzolic	Brown Dermosol
Kaygaroo	Podzol	Podosol
Mission	Red earth	Red Kandosol
Needep	Peaty podzol	Semi-aquic podosol

Location of soils

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

Figure 3.2 - Typical landscape in the Johnstone catchment showing soils derived from basalt and alluvium.

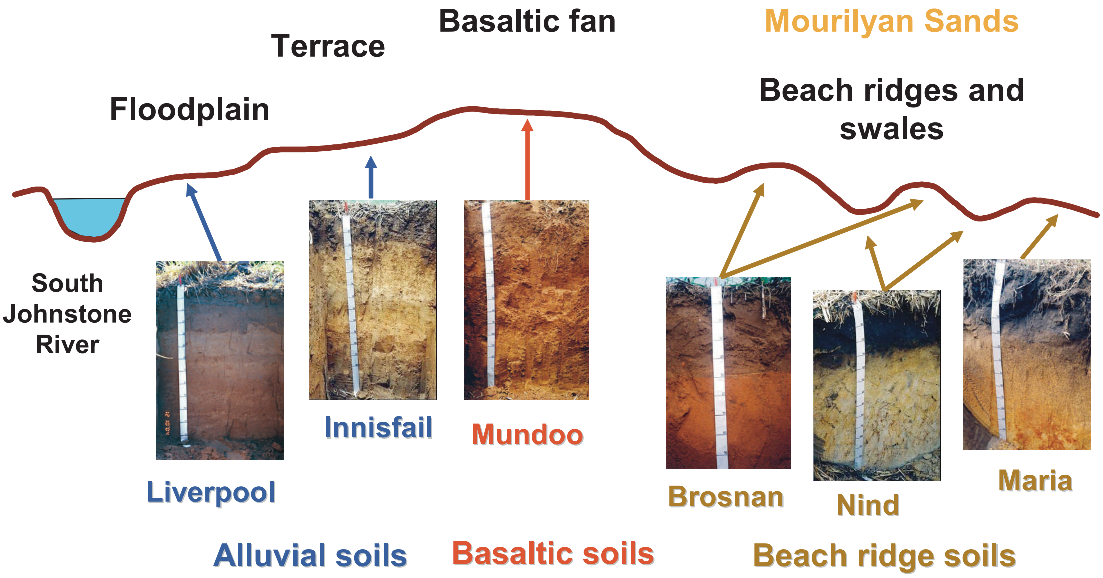


Figure 3.3 - Typical landscape to the east of South Johnstone

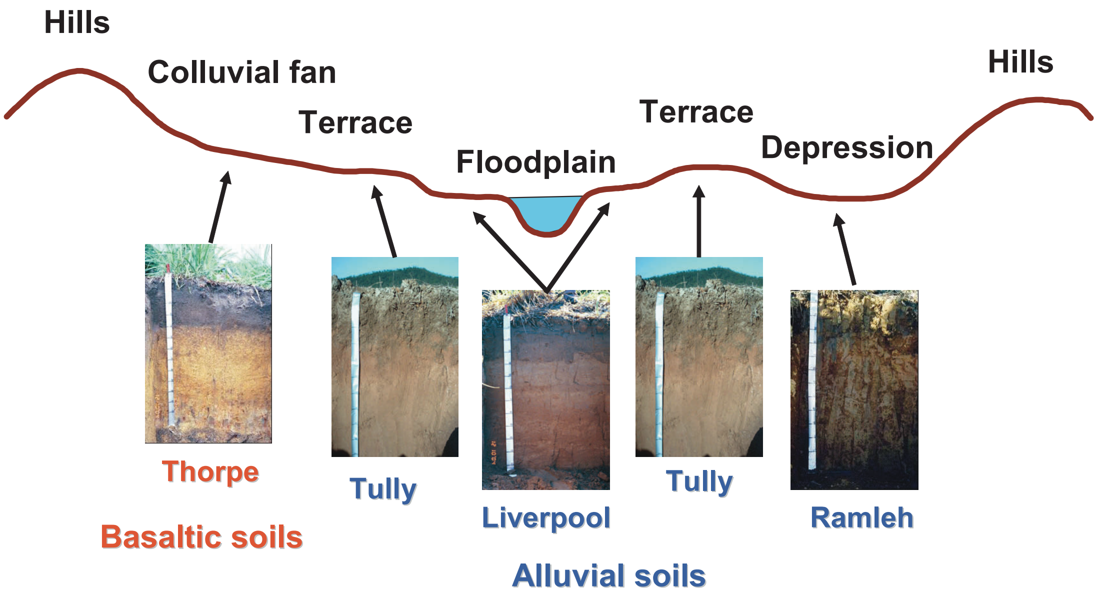


Figure 3.4 - Typical landscape near Japoonvale.

Soil reference sites

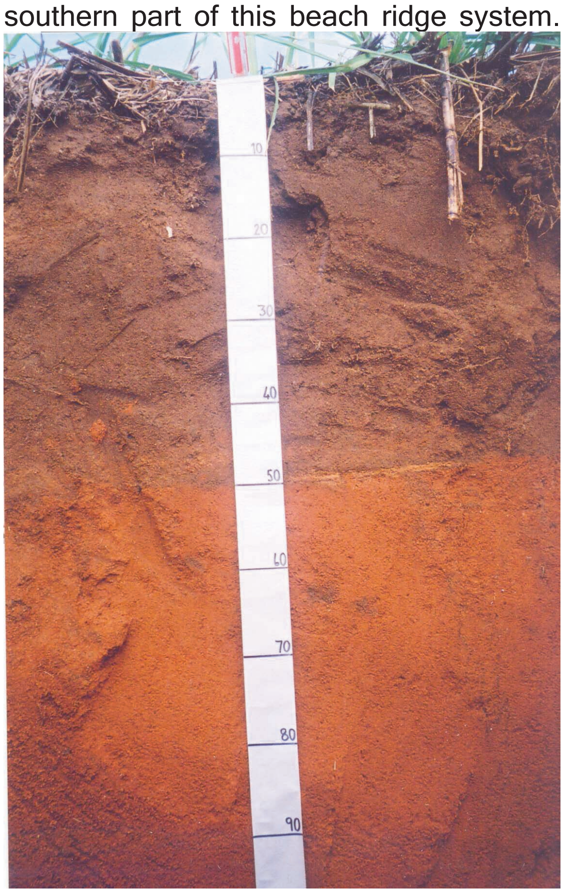
Thirteen soil reference sites representative of the major soil groups are highlighted in Table 3.1. A soil profile was excavated for describing field appearance of the soil at each site. Representative topsoil (0 - 20 cm) and subsoil (40 - 60 cm) samples were taken from the surrounding cane area. These samples were analysed in the laboratory for a range of chemical and physical properties.

In the rest of this chapter information is presented on the occurrence, formation, field appearance and chemical and physical properties of these 13 soils. Bar graphs are used to represent the soil analytical data on a scale from very low to very high for both the reference sites and for median soil test values of samples from growers' fields. It should be noted that median values hide the variability that can occur for some soil test values such as BSES P. Guidelines are given for the management of nutrient applications, tillage, water and environmental risks. Nutrient management guidelines are provided for different crop situations such as fallow plant, replant and ratoons. However specific nutrient guidelines following the use of legume crops and sugar mill by-products are not included and readers need to refer to the information in Chapter 2. The nutrient management guidelines are intended to be used when recent soil and/or leaf tests are not available.

Brosnan (Br) (Red sandy loam)
Great soil group: Red earth
Australian soil classification: Red Kandosol

Occurrence: Brosnan soils occur on beach ridges east and south east of Mourilyan. They occupy about 8% of the sugarcane area in the Johnstone catchment.

Formation:
These relatively young soils have formed on old beach ridges and sand dunes. In particular they form part of the Mourilyan sands which is a large beach ridge system that permanently links the Moresby Range to the mainland. Brosnan soil which are red in colour are the dominant soils in the southern part of this beach ridge system.



Brosnan soil profile

Brosnan soil south east of Mourilyan

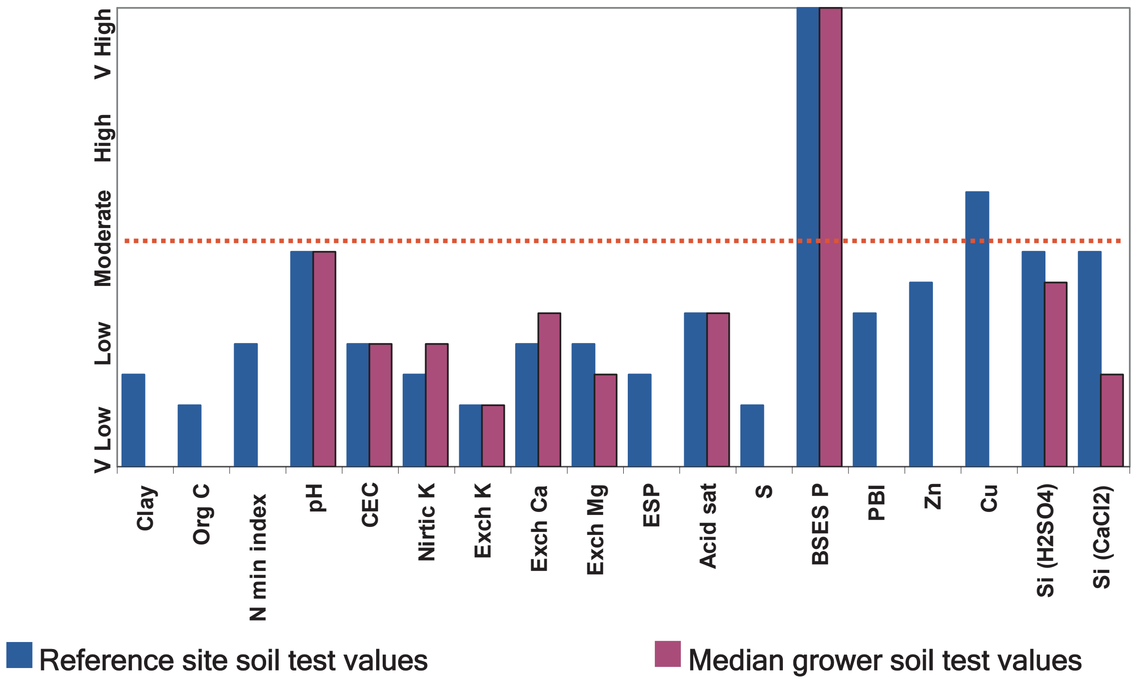
Field Appearance:
Topsoils are dark greyish brown sandy loams with weak fine blocky structure. Subsoils are red sandy clay loams with massive structure.

Similar soils:
Maria (Ma) soil tends to have more yellow subsoils than the Brosnan soils. Nind (Nd) soil which are generally referred to as acid peats are found in close proximity to Brosnan soils. Other soils (podzols) formed on beach ridges are Hull (Hu), Kurrimine (Ku) and Kaygaroo (Ka).

Physical properties:
These sandy soils are permeable, well drained and have low water-holding capacities. They are easy to cultivate within a wide range of moisture contents.

Chemical properties:
These soils have a low nutrient status due to their sandy texture. The organic matter content is low, as is the N mineralisation capacity. Topsoils have low CEC values. Exchangeable potassium and nitric K values are low, as are exchangeable calcium and magnesium. Due to the low organic matter and CEC, these soils tend to acidify easily and soil pH should be monitored. Lime requirement should be determined from soil tests. Although some of these soils tend to have high phosphorus levels, the BSES P values can vary due to different fertiliser application histories. Much of the P in the topsoil is available for plant uptake due to low phosphorus sorption capacities as indicated by low PBI values. Sulphur values are generally low. Silicon is moderate to low and deficiency symptoms have been observed in sugarcane variety Q200 . Micronutrients levels are generally moderate.

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	130	0	100	25	50	0	0
Replant	1	150	0	120	25	50	0	0
Ratoon	0	150	0	120	25	0	0	0

Tillage and water management:
These soils are easily tilled, but tillage operations should be kept to a minimum. There is no need to rotary hoe these soils. Excessive tillage in dry conditions can lead to loss of soil moisture. The soils have low plant available water capacity and are prone to drought. Green cane trash blanketing will aid moisture retention.

Environmental risk management:
As soils are very freely draining, leaching is the main environmental risk. Split applications of fertilisers are appropriate to reduce the potential for nutrients to be lost by leaching. Nutrient retention is limited because of the low CEC of these soils.

Bulgun (Bg) (Dark grey alluvial soils)
Great soil group: Gleyed podzolic
Australian soil classification: Grey Dermosol

Occurrence: Bulgun soils occur in closed depression in isolated pockets across the district on slightly elevated alluvial plains. They occupy about 2% of the sugarcane area in the Johnstone catchment.

Formation:
Bulgun soils are formed on poorly drained alluvium. Their deep dark topsoils are formed by the accumulation of organic matter under wet conditions.

Bulgun soil profile

Bulgun soil at Silkwood

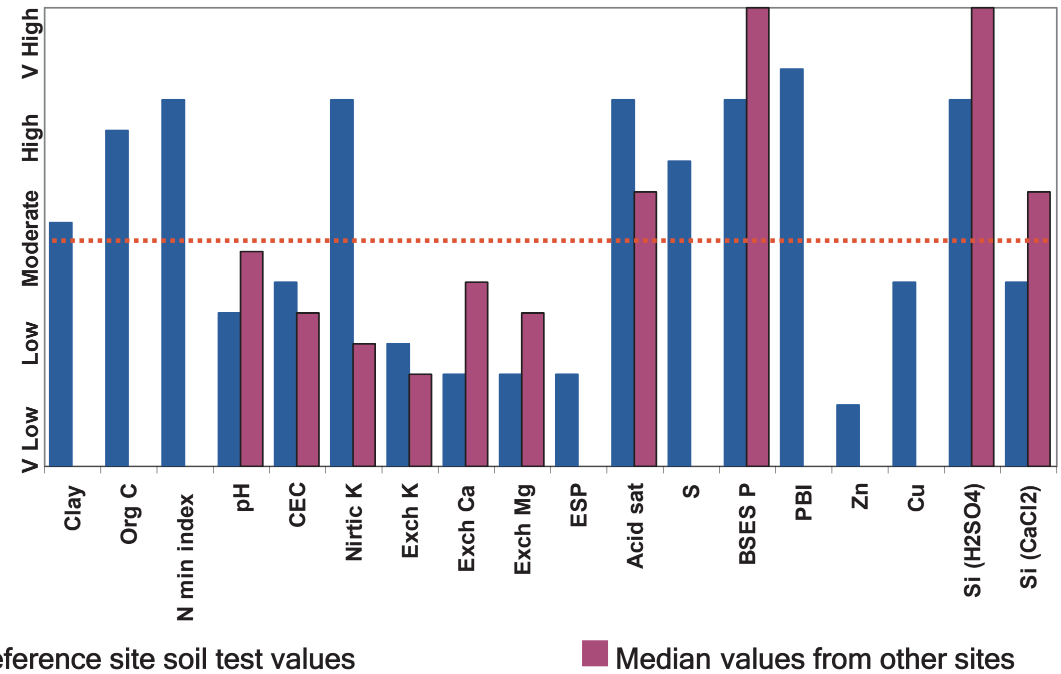
Field Appearance:
Topsoils are dark grey loam to clay loams with strong blocky structure. Subsoils are greyish brown to brownish yellow light/medium clays with strong blocky structure and fine mottles at depth.

Similar soils:
Coom (Co) soils are often found close to Bulgun soils. Other associated poorly drained alluvial soils are Timara (Ti), Hewitt (He), Ramleh (Ra) and Banyan (Ba).

Physical properties:
These soils are poorly drained because of their position in the landscape. They are subject to frequent water-logging and sub-surface lateral water flow.

Chemical properties:
These soils are acidic with high aluminium saturation. However, the acidification rate is low because of their high clay content. Where amelioration is necessary, high rates of lime are required. The organic matter content and N mineralisation potential are high. While the CEC values are low, the anion exchange capacities are high. This means that the exchangeable cations are generally low, but the soils are able to hold onto anions such as sulphate and possibly nitrate. If these soil are limed to pH(water) 5.5, the CEC will increase, enabling the soil to hold more calcium, magnesium and potassium. BSES P values are often high due to past fertiliser histories. PBI values of these soils indicate high P sorbing capacities. Sulphate sulphur values are often high as a consequence of the anion exchange capacities. Silicon values are moderate. Micronutrients should be monitored as low copper and zinc values occur in some cases.

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	90*	0	80	0	75	0	10
Replant	2.5	110*	0	100	0	75	0	10
Ratoon	0	110*	0	100	0	0	0	0

* The nitrogen guidelines assume limited loss by denitrification.

Tillage and water management:

These soils are often wet making conventional tillage operations difficult. Minimum tillage is recommended to conserve soil structure in wet conditions and to maintain soil moisture when dry. If tilled when too wet, these soils are prone to compaction and will produce large clods resulting in poor seedbeds. Alternatively, if over-tilled in dry conditions the risk of erosion caused by flooding is increased. These soils are best suited to strategic tillage systems, which incorporate mound planting (to manage water-logging) and controlled traffic (to manage compaction). Strategic spoon-drainage is suggested in preference to laser-levelling and deep drainage works to manage water-logging.

Environmental risk management:

Loss of nitrogen by denitrification is a risk due to frequent water-logging. Strategies to reduce these losses include mound planting, placement of nitrogen fertiliser into the mound and split fertiliser applications. During high rainfall and flood events there is a potential risk of off-site sediment movement, and erosion control methods should be practiced. These include green cane trash blanketing and grassed waterways and headlands.

Coom (Co) (Greyish brown alluvial soils)
Great soil group: Alluvial
Australian soil classification: Redoxic Hydrosol

Occurrence: Coom soils are found on the alluvial lowlands usually close to swamps. They occupy about 2% of the sugarcane area in the Johnstone catchment.

Formation:
Coom soils are formed on poorly drained alluvium.


Coom soil profile


Coom soil at Cowley

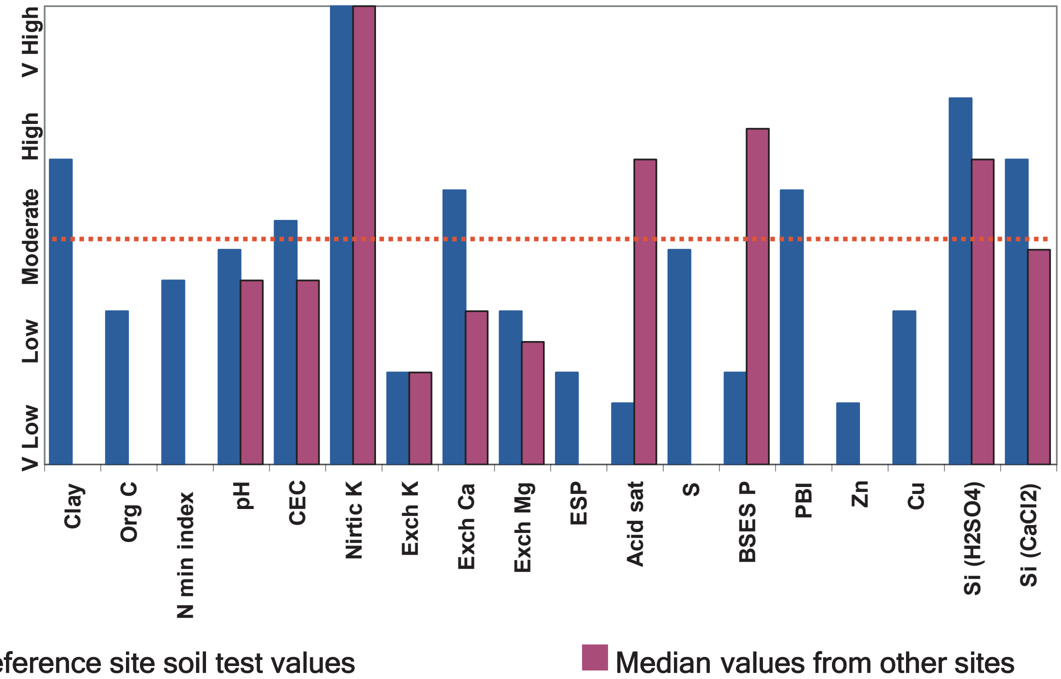
Field Appearance:
Topsoils are dark grey to greyish brown light clay topsoils with blocky structure. Subsoils are mottled light grey and brownish yellow which are seasonally saturated. These subsoils are brightly mottled.

Similar soils:
Bulgun (Bg) soils are often encountered close to Coom soils and have deeper topsoils. Other associated poorly drained alluvial soils are Timara (Ti), Hewitt (He), Ramleh (Ra) and Banyan (Ba).

Physical properties:
These soils are poorly drained and are subject to frequent water-logging because of their position in the landscape. They are hard-setting.

Chemical properties:
These soils are acidic with moderate aluminium saturation. The acidification rate is moderate and pH needs to be checked regularly. The organic matter contents and N mineralisation potentials are moderately low. CEC values are moderate to low. Exchangeable K values are generally low, but high nitric K values indicate some reserves which are available for plant uptake and should be considered when application rates are determined. BSES P values can vary according to past fertiliser histories. PBI values of these soils indicate moderate P sorbing capacities. Sulphur values are moderate. Silicon values are high. Micronutrients should be monitored as copper and zinc values can be low in some soils.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N Kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu Kg/ha	Zn kg/ha
Fallow plant	0	120	30	100	5	0	0	10
Replant	0	140	30	100	5	0	0	10
Ratoon	0	140	15	100	5	0	0	0

Zinc and copper are required at some sites. Refer to Table 2.13 for appropriate application rates.

Tillage and water management:
These soils are often wet making conventional tillage operations difficult. Minimum tillage is recommended to conserve soil structure in wet conditions and to maintain soil moisture when dry. If tilled when too wet, these soils are prone to compaction and will produce large clods resulting in poor seedbeds. Laser-levelling should be considered where appropriate drainage systems are in place. These soils are suited to mound planting and controlled traffic.

Environmental risk management:
Loss of nitrogen by denitrification is a risk due to frequent water-logging. Strategies to reduce these losses include mound planting, placement of nitrogen fertiliser into the mound, split fertiliser applications and stool splitting. During high rainfall and flood events there is a potential risk of off-site sediment and nutrient movement. This risk can be managed by the use of green cane trash blanketing, grassed waterways and headlands and silt traps.

Eubenangee (Eu) (Red clay soils)
Great soil group: Krasnozem
Australian soil classification: Red Ferrosol

Occurrence: Eubenangee soils are found on gently undulating landforms and foot slopes of basaltic hills. They occupy about 2% of the sugarcane area in the Johnstone catchment.

Formation:
Eubenangee are formed *in situ* on basalt and on small alluvial plains at the fringe of the basalts.

Eubenangee soil profile

Eubenangee soil at South Johnstone

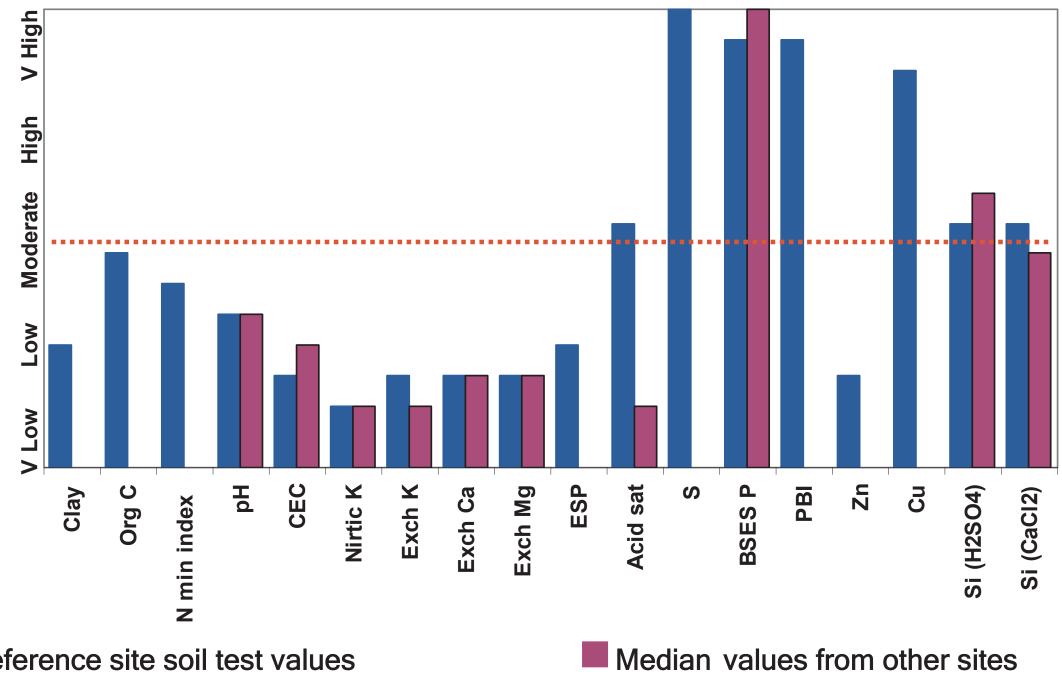
Field Appearance:
Topsoils are dark red clay loam with fine blocky structure. Subsoils are dark red light clay with massive structure. Fine ironstone gravel occurs in the upper profile.

Similar soils:
Pin Gin (Pg), Mundoo (Mu) and Garradunga (Gu) soils are often found on basaltic slopes and alluvial / colluvial fans.

Physical properties:
Eubenangee soils are well drained. Although they have structured topsoils, exposed tilled sites are at risk of erosion because of their position in the landscape. Although these soils have high clay content, their plant available water content is low and profiles are very well drained.

Chemical properties:
These soils are acidic with high aluminium saturation. However, the acidification rate is low because of the high clay content. Lime applications are generally required. The organic matter contents and N mineralisation potentials are moderate. CEC values are very low. High anion exchange capacities indicate that the soils are able to hold onto sulphate sulphur and possibly nitrate. If these soil are limed to pH(water) 5.5, the CEC will increase, enabling the soil to hold more calcium, magnesium and potassium. Exchangeable K and nitric K values are low indicating very limited K reserves and a need for adequate potassium fertiliser applications. PBI values are high, but BSES P can vary according to past fertiliser histories. Sulphur values are very high. Silicon values are moderate. Micronutrients should be monitored.

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	110	0	100	0	75	0	10
Replant	2.5	130	0	120	0	75	0	10
Ratoon	0	130	0	120	0	0	0	0

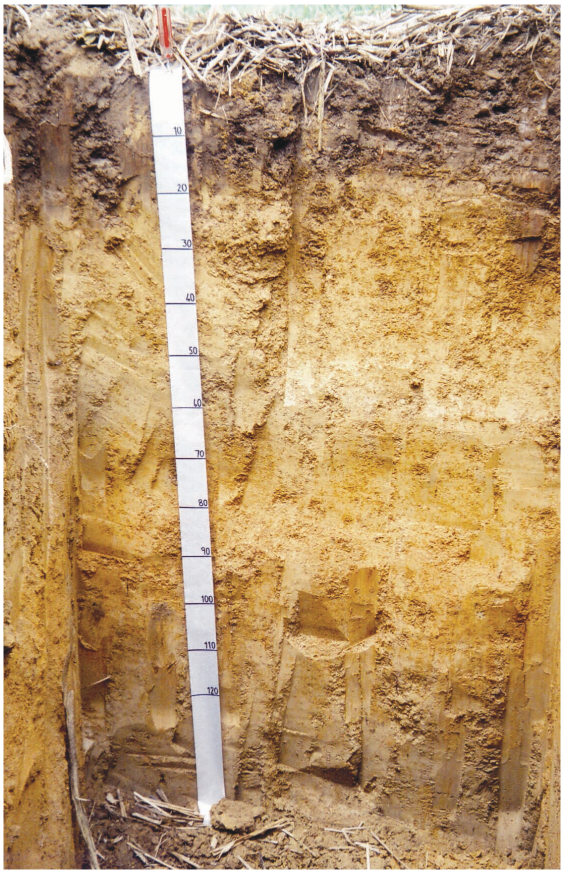
Tillage and water management:
These soils are reasonably easy to till when dry, but will compact and stick to implements when wet. They drain rapidly allowing field access shortly after rain. These soils are suited to zonal tillage, working only the stool space to reduce the risk of erosion. Reduced tillage will also conserve soil structure in wet conditions and maintain soil moisture when dry. Pre-formed mounds should not be made too high otherwise soils will dry out too much in dry periods.

Environmental risk management:
As soils are very freely draining, leaching is an environmental risk. Split applications of fertilisers are appropriate. It is extremely difficult to sub-surface apply fertilisers because the soils physical characteristics often cause it to stick to implements. During high rainfall events there is a potential risk of off-site sediment and nutrient movement. This risk can be managed by the use of green cane trash blanketing, grassed waterways and headlands, and silt traps.

Innisfail (In) (Brown silty clay loam)
Great soil group: Alluvial
Australian soil classification: Brown Dermosol

Occurrence: Innisfail soils are found on stream levees and flood plains. They occupy about 8% of the sugarcane area in the Johnstone catchment.

Formation:
Innisfail soils are formed on well-drained alluvium.


Innisfail soil profile


Innisfail landscape at Wangan

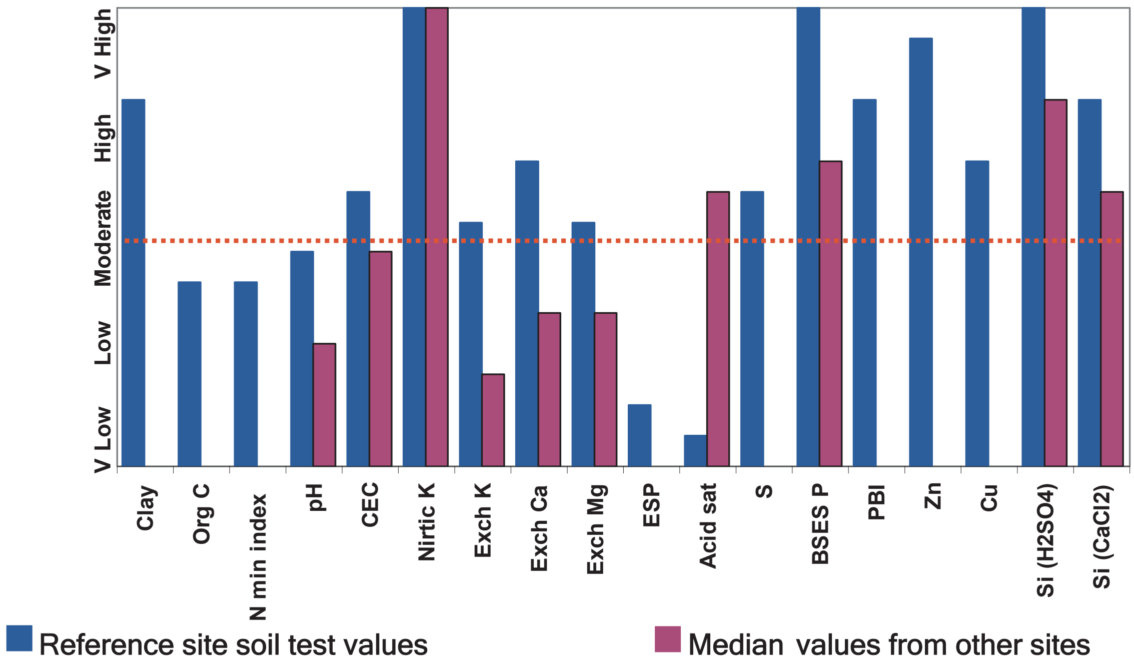
Field Appearance:
Topsoils are brown or reddish brown silty clay loam to light clay with moderate blocky structure. Subsoils are brown silty clay loam to silty clay with moderate to strong blocky structure.

Similar soils:
Liverpool (Li), Tully (Tu) and Midgenoo (Mi) soils are similar well-drained alluvial soils. Innisfail soils are slightly redder in colour due to a greater contribution of basaltic materials.

Physical properties:
These soils are well-drained and have moderate plant available moisture.

Chemical properties:
These soils are fertile and very productive. Whilst being acidic, they have low acidification rates. The organic matter contents and N mineralisation potentials are moderate. CEC values are moderate. Nitric K values are high indicating reserves of non-exchangeable K. Exchangeable K values vary according to previous fertiliser practices. BSES P values also indicate varying P status, but it is generally high. PBI values of these soils are moderate. Sulphur values are moderate. Silicon values are high. Micronutrients are generally well-supplied.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	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	0	0	0	0	0	0
Replant	0	130	0	50	0	0	0	0
Ratoon	0	130	0	50	0	0	0	0

Tillage and water management:
These soils have a high risk of flooding due to their proximity to waterways, but do not remain wet for long periods of time. Compaction is an issue when harvesting in wet conditions. Controlled traffic is recommended to minimise compaction and stool damage. Only light cultivations are needed if operations are conducted in dry conditions.

Environmental risk management:
Loss of nitrogen can occur due to denitrification and surface loss after flood events. Losses may be minimised by early harvesting and early application of nutrients to enable plant uptake prior to inundation. Sub-surface application of nutrients is recommended. Leaching can be an issue but the risk is moderated because of the lower rates of fertilisers applied to these fertile soils. Green cane trash blanketing and grassed waterways and headlands will minimise the risk of runoff losses.

Liverpool (Li) (Greyish brown silty loam)
Great soil group: Alluvial
Australian soil classification: Orthic Tenosol

Occurrence: Liverpool soils are found on lower and younger stream levees and terraces. They occupy about 10% of the sugarcane area in the Johnstone catchment.

Formation:
Liverpool soils are formed on well-drained alluvium.

Liverpool soil profile

Liverpool landscape south of Liverpool Creek

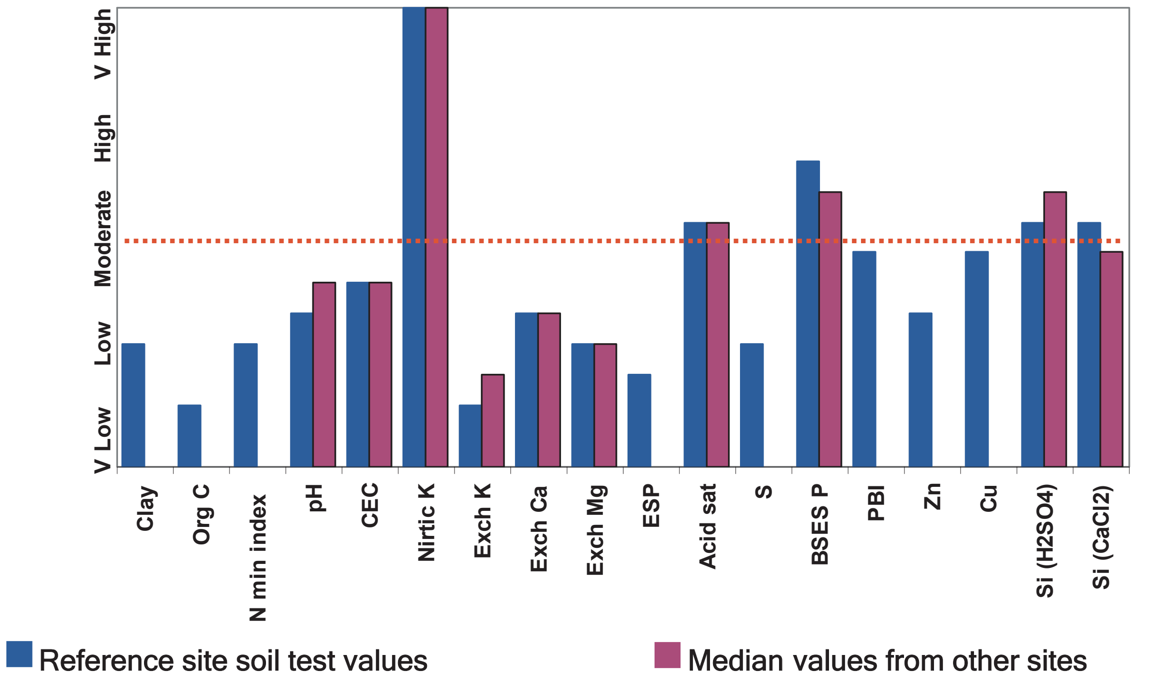
Field Appearance:
Topsoils are dark greyish brown silty loams with friable structure. Subsoils are yellowish brown sandy to silty loams with massive structure.

Similar soils:
Innisfail (In), Tully (Tu) and Midgenoo (Mi) soils are similar well-drained alluvial soils.

Physical properties:
These soils are well-drained and have high moisture availability and substantial effective rooting depths.

Chemical properties:
These soils are fertile but are acidic with moderate aluminium saturation. The risk of acidification is high due to the low CEC and low organic carbon. Lime applications are recommended. The organic matter contents and N mineralisation potentials are low. Nitric K values are high indicating substantial reserves of non-exchangeable K. Exchangeable K values are low to very low. BSES P values are moderate. Although PBI values of these soils can be low, they generally do not pose a risk of phosphate leaching. Sulphur values are moderate. Silicon values are moderate. Micronutrients are moderate although zinc can be low at some sites.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N Kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu Kg/ha	Zn kg/ha
Fallow plant	2.5	130	0	80	15	50	0	0
Replant	2.5	150	0	100	15	50	0	0
Ratoon	0	150	0	100	15	0	0	0

Tillage and water management:
These soils have a high risk of flooding due to their proximity to waterways, but do not remain wet for long periods of time. Compaction is an issue when harvesting in wet conditions. Controlled traffic is recommended to minimise compaction and stool damage. Only light cultivations are needed if operations are conducted in dry conditions.

Environmental risk management:
Loss of nitrogen can occur due to denitrification and surface loss after flood events. Losses may be minimised by early harvesting and early application of nutrients to enable plant uptake prior to inundation. Sub-surface application of nutrients is recommended. Leaching can be an issue but the risk is moderated because of the lower rates of fertilisers applied to these fertile soils. Green cane trash blanketing and grassed waterways and headlands will minimise the risk of runoff losses.

Maria (Yellow/brown sandy loam)
Great soil group: Yellow earth
Australian soil classification: Yellow Kandosol

Occurrence: Maria soils occur on beach ridges where relief is very low and there is little evidence of ridge orientation. They occur in localised areas adjacent to the Moresby River and Maria Creek and occupy about 4% of the sugarcane area in the Johnstone catchment.

Formation:
These relatively young soils have formed on old beach ridges and sand dunes but have been reworked by the action of local rivers and creeks.

Maria soil profile

Maria landscape adjacent to the Moresby River

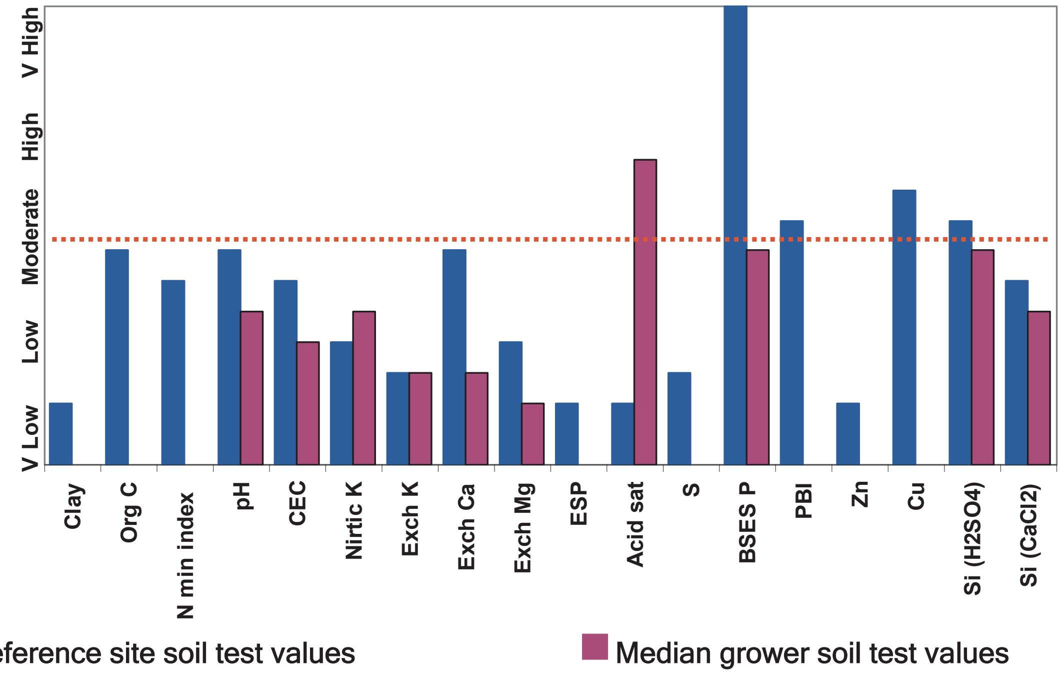
Field Appearance:
Topsoils are black to dark brown sandy loams with massive structure. Subsoils are greyish brown to yellowish brown sandy clay loams with massive structure.

Similar soils:
Brosnan (Br) soils tend to have redder subsoils than Maria soils. Other soils (podzols) formed on beach ridges are Hull (Hu), Kurrimine (Ku) and Kaygaroo (Ka).

Physical properties:
These sandy soils are permeable, well drained and have low water-holding capacities. They are easy to cultivate within a wide range of moisture contents.

Chemical properties:
These soils have a low nutrient status due to their sandy texture. Their organic matter content and N mineralisation capacity are moderate. Topsoils have low CEC values. Exchangeable potassium and nitric K values are low, as are exchangeable calcium and magnesium. Due to the moderate organic matter content, the risk of acidification is not as high as for the Brosnan soils. Lime requirement should be determined from soil tests. Although some of these soils tend to have high phosphorus levels, the BSES P values can vary due to different fertiliser application histories. PBI values are low and therefore do not have management implications for these soils. Sulphur values are very low. Silicon is moderate to low. Micronutrient deficiencies often occur on these soils, particularly zinc.

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	0	100	20	0	0	10
Replant	0	130	0	120	20	0	0	10
Ratoon	0	130	0	120	20	0	0	0

Tillage and water management:
These soils are easily tilled, but tillage operations should be kept to a minimum. There is no need to rotary hoe these soils. Excessive tillage in dry conditions can lead to loss of soil moisture. The soils have low plant available water capacity and are prone to drought. Green cane trash blanketing will aid moisture retention.

Environmental risk management:
As soils are very freely draining, leaching is the main environmental risk. Split applications of fertilisers are appropriate to reduce the potential for nutrients to be lost by leaching as these soils have limited nutrient retention due to low CEC.

Mundoo (Mu) (Red clay soils)
Great soil group: Krasnozem
Australian soil classification: Red Ferrosol

Occurrence: Mundoo soils are found on gently undulating alluvial fans between the basalt country and the Mourilyan sands. They occupy about 8% of the sugarcane area in the Johnstone catchment.

Formation:
Mundoo soils are formed from redistributed basaltic material on undulating alluvial fans.


Mundoo soil profile


Mundoo landscape near Innisfail aerodrome

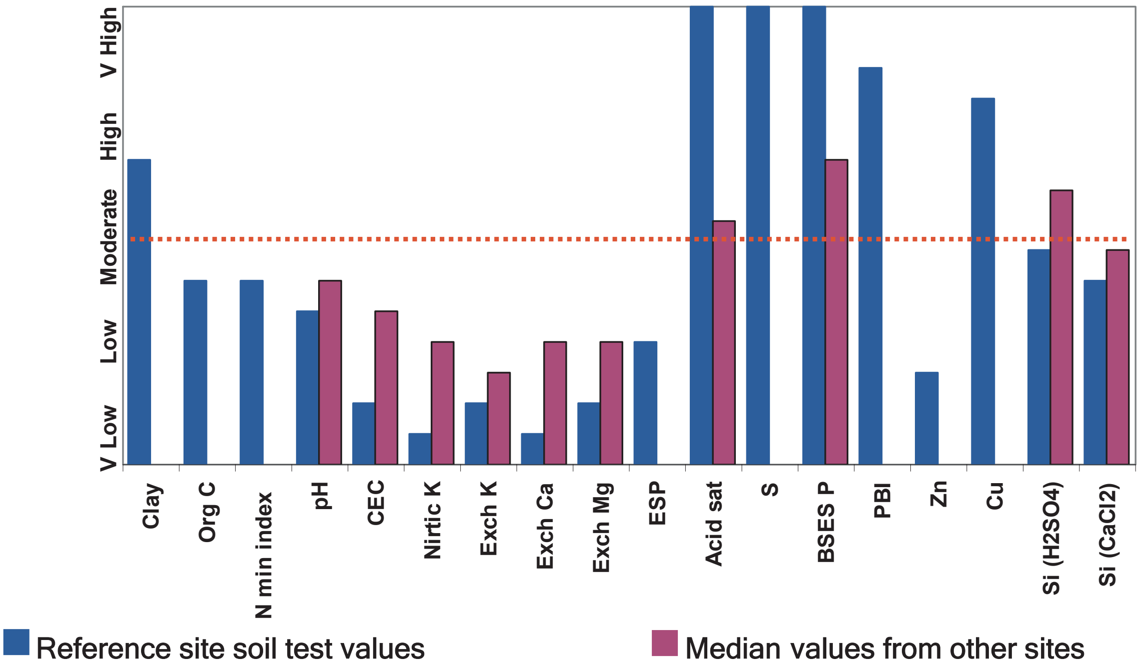
Field Appearance:
Topsoils are dark reddish brown clay loams with weak structure. Subsoils are red to yellowish red light to medium clays with blocky structure.

Similar soils:
Pin Gin (Pg), Eubenangee (Eu) and Garradunga (Gu) soils are other soils found on basaltic slopes.

Physical properties:
Mundoo soils are well drained and have deep profiles. Exposed tilled sites are at risk of erosion because of their weak structure and position in the landscape. Although these soils have a high clay content, their plant available water content is low. Readily available water is moderated by the extensive rooting depth.

Chemical properties:
These soils are strongly acidic with very high aluminium saturation, but the acidification rate is low because of the high clay content. Lime applications are recommended. The organic matter content and N mineralisation potential are moderately low. CEC values are extremely low. High anion exchange capacities indicate that the soils are able to hold onto sulphate sulphur and possibly nitrate. If these soils are limed to pH(water) 5.5, the CEC will increase, enabling the soil to hold more calcium, magnesium and potassium. Exchangeable K and nitric K values are low indicating very limited K reserves and a need for adequate potassium fertiliser applications. PBI values are high. BSES P values tend to be high due to past fertiliser applications. Sulphur values are very high. Silicon values are low to moderate. Micronutrients should be monitored and, in particular, zinc levels are often low.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N Kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu Kg/ha	Zn Kg/ha
Fallow plant	3	110	0	100	0	75	0	10
Replant	3	130	0	120	0	75	0	10
Ratoon	0	130	0	120	0	0	0	0

Tillage and water management:
These soils are relatively easy to till when dry, but will compact and stick to implements when wet. They drain rapidly allowing field access shortly after rain. These soils are suited to zonal tillage, working only the stool space to reduce the risk of erosion. Reduced tillage will also conserve soil structure in wet conditions and maintain soil moisture when dry. Pre-formed mounds should not be made too high otherwise soil will dry out quickly in dry periods.

Environmental risk management:
As soils are very freely draining, leaching is an environmental risk. Split applications of fertilisers are appropriate. During high rainfall events there is a potential risk of off-site sediment and nutrient movement. This risk can be managed by the use of green cane trash blanketing and grassed waterways and headlands.

Nind (Nd) (Dark peat soil)
Great soil group: Acid peat
Australian soil classification: Fibric Organosol

Occurrence: Nind soils are found surrounding freshwater swampy areas and between the beach ridges east of Mourilyan. They occupy 1-2% of the sugarcane area in the Johnstone catchment.

Formation:

Nind soils are highly organic in the upper part of the profile. They are permanently flooded unless artificially drained. The underlying material ranges from coarse sand to very finely textured alluvium.

Nind soil profile

Nind landscape on the New Harbour Line Rd

Field Appearance:

Topsoils are very dark coloured deep fibrous peat soils. Subsoils range from coarse sand to fine textured alluvium.

Similar soils:

Bulguru (Bu) soils are also found in swampy areas, but closer to the mangroves than the Nind soils.

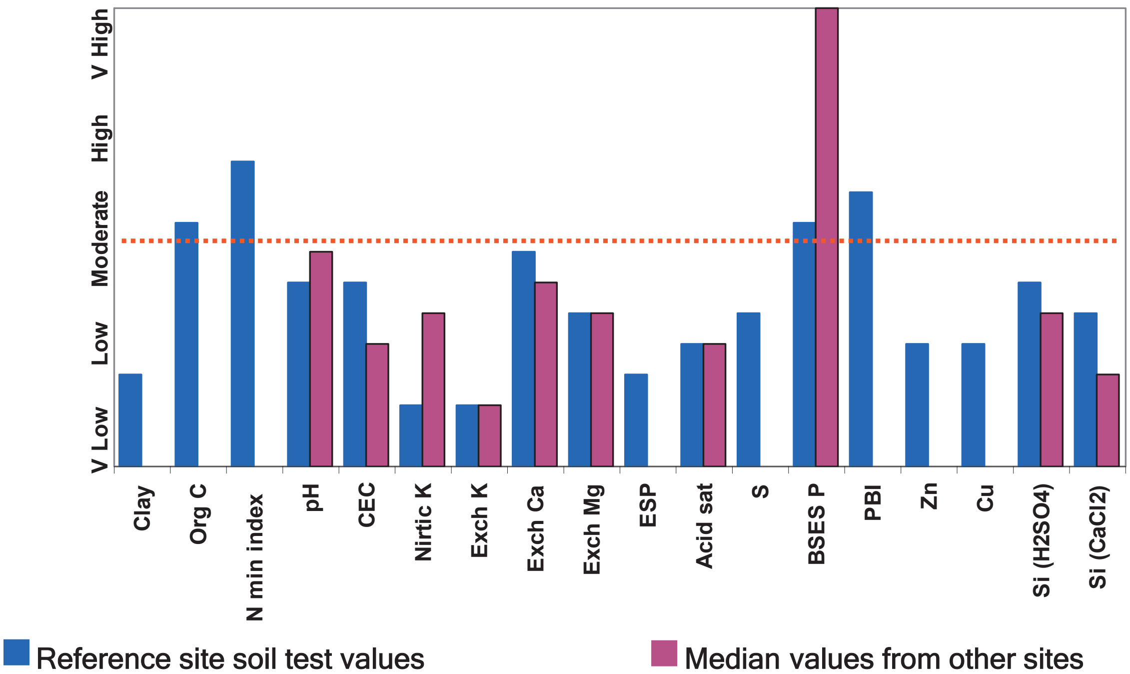
Physical properties:

These soils are poorly drained and have high water tables. When drained the soil profile shrinks appreciably because of oxidation of organic matter. When drained and dry, these soils can burn.

Chemical properties:

These soils are moderately acidic, with low aluminium saturation. The acidification rate is low due to high organic matter content. The organic matter content of the reference site is moderate, but these soils can have organic carbon values of at least 5%. N mineralisation potentials should therefore be very high. CEC values are low. Exchangeable K and nitric K values are low. Calcium and magnesium values are moderate. BSES P values are moderate. PBI values are of these soils indicate low P sorbing capacities. Sulphate sulphur values are low. Silicon values are low and micronutrients are also low and should be monitored.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

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

* The nitrogen guidelines assume limited loss by leaching and denitrification

Silicon, zinc and copper may be required at some sites. Refer Tables 2.13 and 2.14 for appropriate rates.

Tillage and water management:

These soils are often wet making access difficult. Without drainage, these soils cannot be cropped. Only light cultivation is required. These soils are suited to mound planting and controlled traffic.

Environmental risk management:

Loss of nitrogen by leaching and denitrification is a risk due to high rainfall and frequent water-logging. Strategies to reduce these losses include split fertiliser applications, mound planting, placement of nitrogen fertiliser into the mound and stool splitting. Burning cane crops prior to harvest could ignite these high organic matter soils. This risk can be managed by the use of green cane trash blanketing. These soils are potentially acid sulphate at depth. Deep drains should not be constructed without adequate testing.

Pin Gin (Pg) (Red clay soils)
Great soil group: Krasnozem
Australian soil classification: Red Ferrosol

Occurrence: Pin Gin soils are found on undulating low basaltic hilly landscapes and occupy the greater part of the basaltic uplands. They occupy about 20% of the sugarcane area in the Johnstone catchment.

Formation:
Pin Gin soils are formed *in situ* on older basalt flows and younger flows from vents such as Pin Gin hill.

Pin Gin soil profile

Pin Gin landscape at Coorumba on the Palmerston Highway

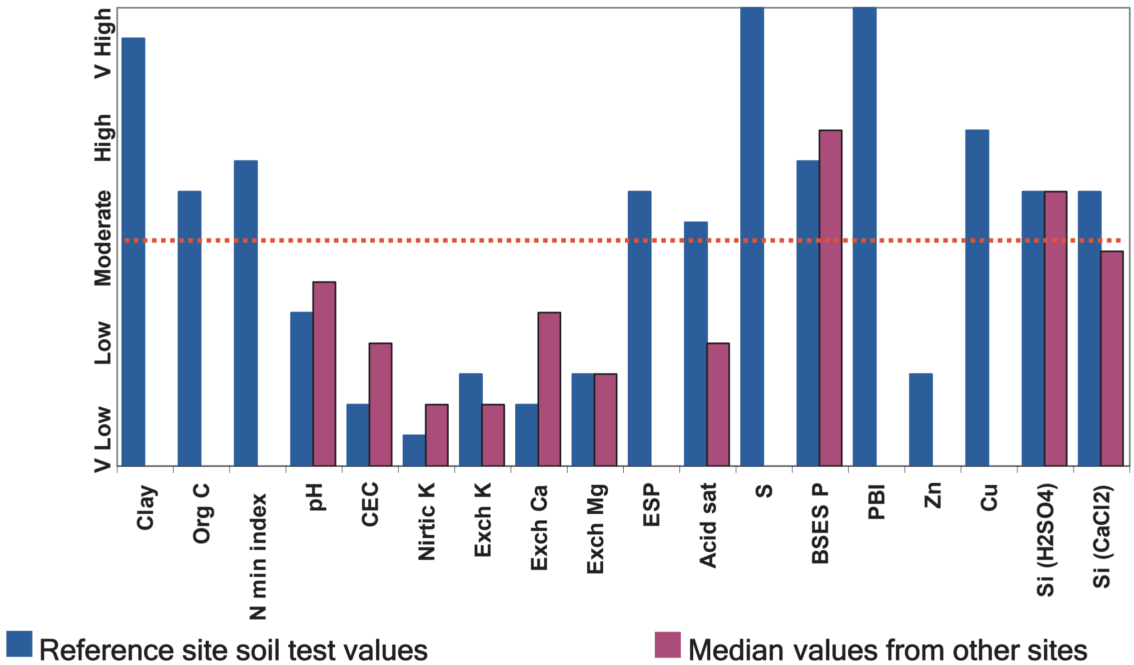
Field Appearance:
Topsoils are dark reddish brown well-structured clay loams. Subsoils are dark red clay loams with massive to weak fine blocky structure. Texture changes to a light clay with depth.

Similar soils:
Eubenangee (Eu), Mundoo (Mu) and Garradunga (Gu) soils are also found on basaltic slopes and alluvial / colluvial fans.

Physical properties:
Pin Gin soils are well drained. Although they have structured topsoils, exposed tilled sites are at risk of erosion because of their position on steep slopes. Although these soils have high clay content, their plant available water content is low.

Chemical properties:
These soils are strongly acidic with moderate aluminium saturation. The acidification rate is low because of the high clay content. Lime applications are recommended. The organic matter contents and N mineralisation potentials are moderately high. Cultivation of these soils has caused a substantial decrease in organic matter content and CEC values. High anion exchange capacities indicate that the soils are able to hold onto sulphate sulphur and possibly nitrate. If these soil are limed to pH(water) 5.5, the CEC will increase, enabling the soil to hold more calcium, magnesium and potassium. Exchangeable K and nitric K values are low indicating very limited K reserves and a need for adequate K fertiliser applications. PBI values are very high, but BSES P can vary according to past fertiliser histories. It is possible that P fertiliser is required at higher levels of BSES P than for other soils due to their high retention of P. Sulphur values are very high. Silicon values are moderate. As zinc levels are often low, micronutrients should be monitored.

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	100*	0	100	0	75	0	10
Replant	2.5	120*	0	120	0	75	0	10
Ratoon	0	120*	0	120	0	0	0	0

* Higher N application rates will be required on sites with lower organic matter which has resulted from erosion.

Tillage and water management:

These soils are relatively easy to till when dry, but will compact and will stick to implements when wet. However, they drain rapidly allowing field access shortly after rain. These soils are suited to zonal tillage, working only the stool space to reduce the risk of erosion. Reduced tillage will also conserve soil structure in wet conditions and maintain soil moisture when dry. Pre-formed mounds should not be made too high otherwise soils will dry out quickly during dry periods.

Environmental risk management:

As soils are very freely draining, leaching is an environmental risk. Split applications of fertilisers are appropriate. It is extremely difficult to sub-surface apply fertilisers because the soils physical characteristics often cause it to stick to implements. During high rainfall events there is a potential risk of off-site sediment and nutrient movement. This risk can be managed by the use of green cane trash blanketing, grassed waterways and headlands and silt traps.

Ramleh (Ra) (Brown silty alluvial soils)
Great soil group: Gleyed podzolic
Australian soil classification: Brown Dermosol

Occurrence: Ramleh soils are found in the upper reaches of Cowley and Moresby Creek. They occupy about 4% of the sugarcane area in the Johnstone catchment.

Formation:
Ramleh soils are formed on poorly drained alluvium derived mainly from metamorphic rocks.


Ramleh soil profile


Ramleh landscape at Warrubullen

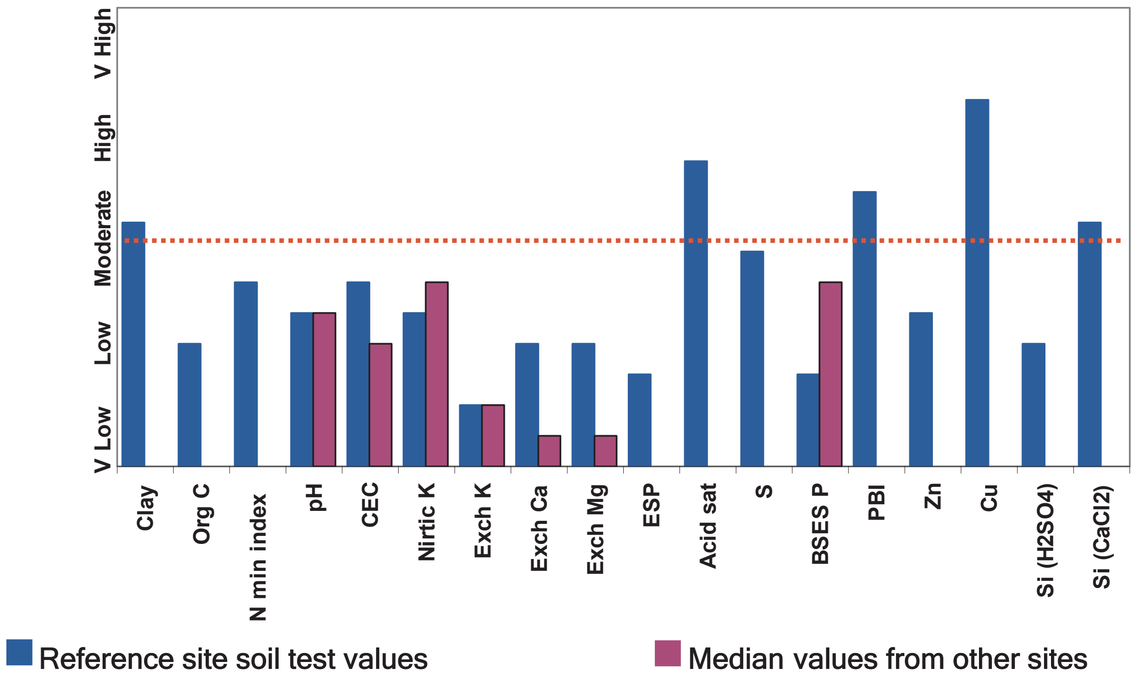
Field Appearance:
Topsoils are brown silty clay loams with fine blocky structure. Subsoils are gleyed grey to olive strongly mottled silty to medium clays.

Similar soils:
Bulgun (Bg) and Coom (Co) soils occur in similar positions.

Physical properties:
These soils are poorly drained and are subject to frequent water-logging because of their position in the landscape. They are hard-setting.

Chemical properties:
These soils are naturally acidic, with high aluminium saturation. The acidification rate is moderate and pH needs to be checked regularly. Lime applications are therefore recommended. The organic matter contents and N mineralisation potentials are low. CEC values are low, as are exchangeable potassium, calcium and magnesium. Nitric K values are also low indicating limited reserves of non-exchangeable K and a need for adequate K fertiliser applications. BSES P and PBI values are low. Sulphur values are moderate. Silicon values are low to moderate. Micronutrients should be monitored as zinc levels in particular can be low.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N Kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu Kg/ha	Zn kg/ha
Fallow plant	2.5	120	30	100	5	0	0	0
Replant	2.5	140	30	120	5	0	0	0
Ratoon	0	140	15	120	5	0	0	0

Tillage and water management:
These soils are often wet making conventional tillage operations difficult. Minimum tillage is recommended to conserve soil structure in wet conditions and to maintain soil moisture when dry. If tilled when too wet, these soils are prone to compaction and will produce large clods resulting in poor seedbeds. Laser-levelling should be considered where appropriate drainage systems are in place. These soils are suited to mound planting and controlled traffic.

Environmental risk management:
Loss of nitrogen by denitrification is a risk due to frequent water-logging. Strategies to reduce these losses include mound planting, placement of nitrogen fertiliser into the mound, split fertiliser applications and stool splitting. During high rainfall and flood events there is a potential risk of off-site sediment and nutrient movement. This risk can be managed by the use of green cane trash blanketing, grassed waterways and headlands, and silt traps.

Thorpe (Th) (Dark grey sandy loam)
Great soil group: Yellow earth
Australian soil classification: Brown Kandosol

Occurrence: Thorpe soils occur on mid to lower colluvial fans associated with the granitic hills in the south western part of the catchment. They occupy about 2% of the sugarcane area in the Johnstone catchment.

Formation:
These soils have formed on granite or colluvial fans composed of gravelly granitic material.

Thorpe soil profile

Thorpe landscape at Japoonvale

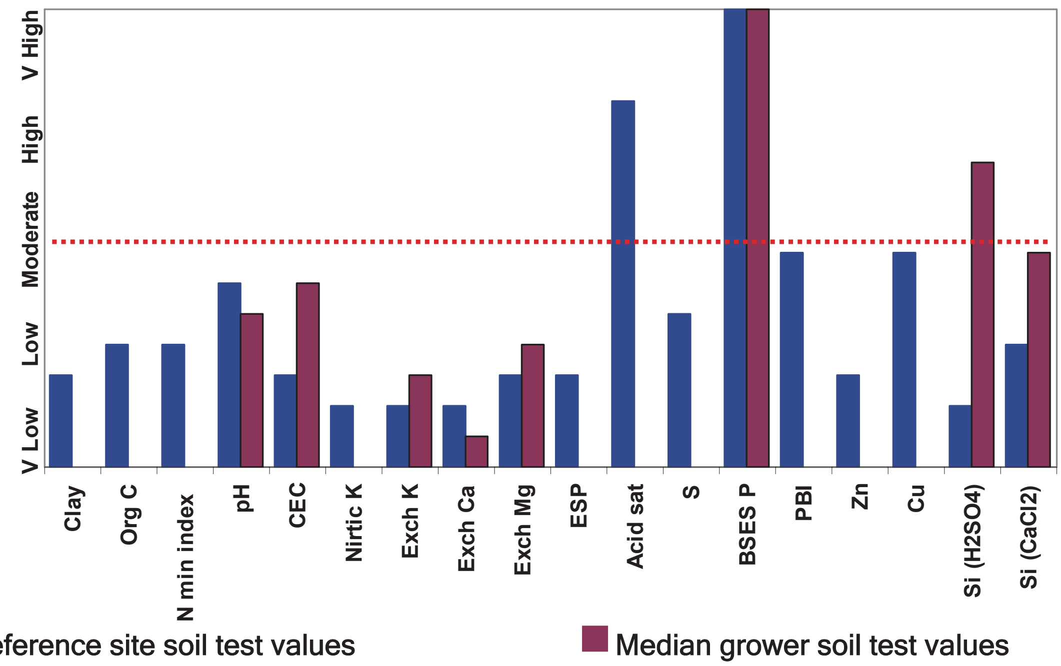
Field Appearance:
Topsoils are dark grey sandy loams. Subsoils are yellowish brown sandy clay loams with massive structure overlying mottled light grey and pale brown coarse sands.

Similar soils:
Tyson (Ty), Lugger (Lu) and Utchee (Ut) are similar soils derived from granite.

Physical properties:
These sandy soils are permeable, reasonably well drained and have low water-holding capacities. They are easy to cultivate, but are abrasive due to the coarse sand and gravel.

Chemical properties:
These soils have low fertility, are strongly acidic and have high aluminium saturation. Lime applications are recommended. The organic matter content and N mineralisation capacity are low. Topsoils have low CEC values. Exchangeable potassium and nitric K values are low indicating low K reserves and the need for adequate K fertiliser applications. Exchangeable calcium and magnesium are also low. The risk of acidification is moderate. BSES P values are high. PBI values are low, but can be higher at the margins of the soil type. Sulphur values are very low. Silicon is low. Micronutrients deficiencies occur on these soils, particularly zinc.

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	0	100	10	75	0	10
Replant	2.5	140	0	120	10	75	0	10
Ratoon	0	140	0	120	10	0	0	0

Silicon may be required at some sites. Refer to Table 2.14 for appropriate rates.

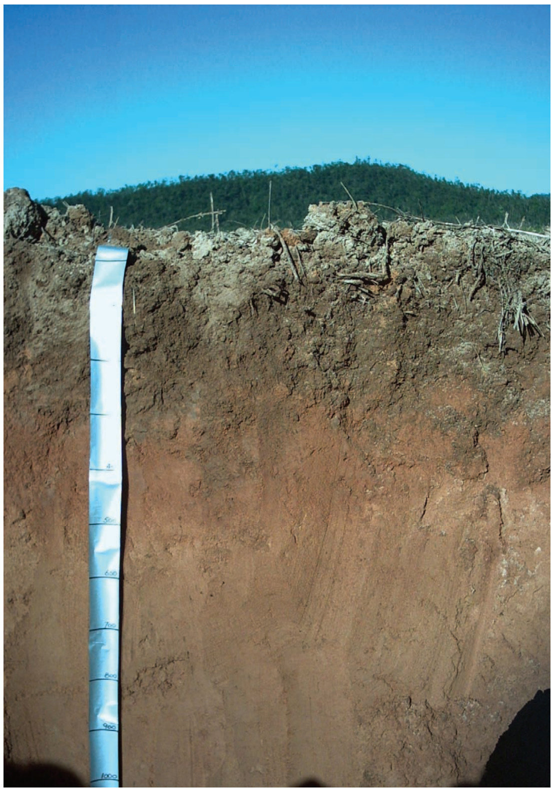
Tillage and water management:
These soils are easily tilled. However, tillage operations should be kept to a minimum as there is a risk of plough-pan formation in sub-surface layers. Excessive tillage in dry conditions can lead to loss of soil moisture. The soils have low plant available water capacity and are prone to drought. Green cane trash blanketing will aid moisture retention.

Environmental risk management:
As soils are very freely draining, leaching is a risk. Runoff is also a significant risk during high rainfall events. Split applications and sub-surface placement of fertilisers are appropriate to minimise nutrient losses. Green cane trash blanketing, minimum tillage, use of spoon drains, and grassed waterways and headlands will help reduce the risk of erosion.

Tully (Tu) (Dark grey brown silty loam)
Great soil group: Alluvial
Australian soil classification: Brown Kandosol

Occurrence: Tully soils are found on stream levees, flood plains and higher terraces. They occupy about 15% of the sugarcane area in the Johnstone catchment, and are considered desirable for cropping because of a combination of good fertility, physical properties and position in the landscape.

Formation:
Tully soils are formed on well-drained alluvium.


Tully soil profile


Tully landscape south of the Liverpool Creek

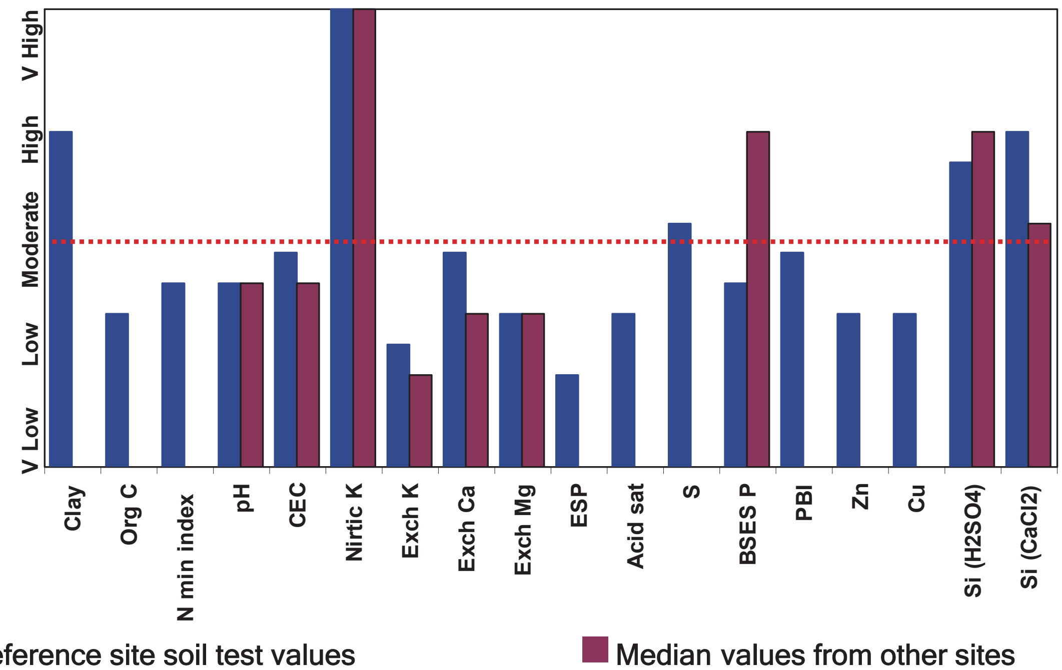
Field Appearance:
Topsoils are shallow, dark greyish brown silty loams to silty clay loams. Subsoils are yellowish brown silty clay loams to light clays with a moderate fine blocky structure grading into grey mottled material below a depth of about 70 cm.

Similar soils:
Liverpool (Li), Innisfail (In) and Midgenoo (Mi) soils are similar well-drained alluvial soils.

Physical properties:
These soils are well-drained, but due to their position in the catchment, can have high water tables. They have high plant available moisture.

Chemical properties:
These soils are acidic, but have low acidification rates. The organic matter contents and N mineralisation potentials are moderately low. CEC values are moderate. Nitric K values are high indicating reserves of non-exchangeable K. However, exchangeable K values are low. BSES P and PBI values are moderate. Sulphur values are moderate. Silicon values are high. Micronutrient levels need to be monitored.

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	20	100	5	0	0	0
Replant	4	140	20	100	5	0	0	0
Ratoon	0	140	15	100	5	0	0	0

Tillage and water management:
Good tilth can be achieved with light cultivations provided these soils are not worked when wet. Minimal or zonal tillage is appropriate. Controlled traffic is recommended to minimise compaction and stool damage.

Environmental risk management:
Loss of nitrogen can occur due to denitrification after flood events and extended wet periods. Split fertiliser applications and sub-surface placement is appropriate to minimise nutrient losses. Green cane trash blanketing will be beneficial for improving soil health and minimising runoff losses.

CHAPTER 4

Nutrient requirements for specific blocks of sugarcane

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

Soil testing

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

Step 1. Sample collection
Collect soil samples according to the guidelines provided in Appendix 2.

Step 2. Sample analysis
Submit samples to a reputable laboratory for analysis.

Step 3. Interpretation of results and calculating nutrient inputs
Ensure sound interpretation of the results and appropriate fertiliser recommendations by having an understanding of the basic process and getting advice from capable advisers and extension officers.

Step 4. Fertiliser applications
Apply fertilisers at the appropriate rates and keep records of nutrient inputs.

Interpretation of soil test values

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

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

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

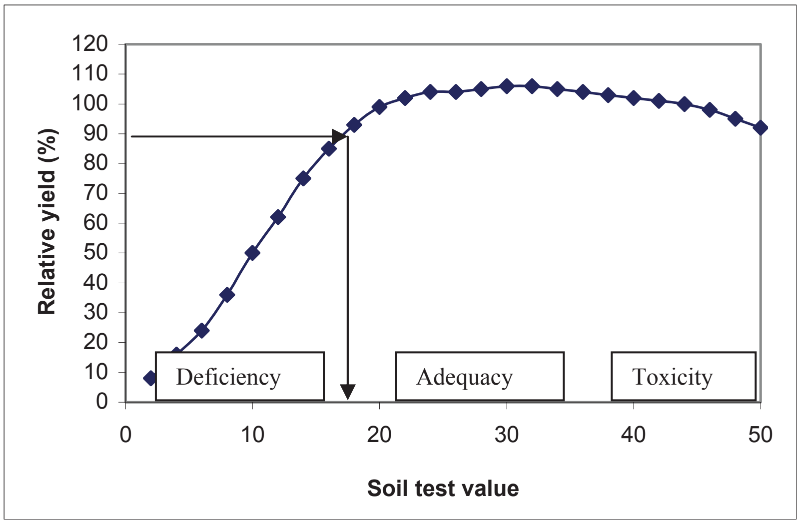


Figure 4.1 An example of a nutrient response curve for sugarcane.

Soil test report		
Trading Name: Bloggs & Bloggs	Field Name: Block 1	
Location: Johnstone Catchment	Section of Field: A	
Contact Name: Joe Bloggs	GPS Latitude:	GPS Longitude:
Work Phone:	Sample type:	Depth: 0-20 cm
Adviser:	Lab Report Number:	Sampling Date:
Phone:	Crop: Sugarcane	
	Stage: Plough-out/Replant	Target Yield: 120 tonnes/ha

		Low	<Optimum	Satisfactory	>Opt/ Norm	High	Excess/ Toxic
pH (1:5 water)	4.9						
Electr. Conduct dS/m	0.03						
Organic C (%)	0.73						
Sulphate S (MCP) mg/kg	6						
P (BSES) mg/kg	22						
K (Nitric) me%	0.18						
K (Amm. Acetate) me%	0.11						
Ca (Amm. Acetate) me%	0.60						
Mg(Amm.Acetate) me%	0.21						
Aluminium (KCl) me%	0.80						
Na (Amm. Acetate) me%	0.04						
Copper (DTPA) mg/kg	0.45						
Zinc (DTPA) mg/kg	0.2						
Zinc (HCl) mg/kg	0.4						
Mn (DTPA) mg/kg	15						
Silicon ($CaCl_2$) mg/kg	4						
Silicon (BSES) mg/kg	36						
ECEC me%	1.76						
Aluminium saturation %	45						
Sodium % of cations (ESP)	2.3						
Phos. Buffer Index (PBI)	38						
Colour (Munsell)	Grey Brown						
Texture	Sandy Loam						

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

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

Nitrogen

N requirement is **150 kg N/ha** because the N mineralisation index is LOW due to an Org C (%) value of 0.73%. This requirement is appropriate for replant cane and ratoon cane after replant, but is modified according to the effect of fallow management or the use of ameliorants such as mill mud and/or mill ash. If, for example, the plant cane followed a grass/bare/poor legume fallow, the plant crop N requirement reduces to **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 the 'soil texturing' method described in Appendix 1.

Potassium

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

Sulphur

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

Magnesium

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

Copper and zinc

Although leaf analysis is the preferred means of determining micronutrient requirements, the soil tests indicate that zinc is required (**10 kg Zn/ha**) because both the DTPA and BSES (HCl) zinc values are less than the critical values shown in Table 2.13.

Silicon

Silicon is required because both soil tests (BSES and $CaCl_2$) are below the respective critical values shown in Table 2.14. Si can be applied as calcium silicate (4 t/ha) **or** cement (3 t/ha) **or** mill mud/ash (150 wet t/ha).

Lime

Lime requirement is 2.5 t/ha because the soil pH(water) value is below 5.5 and the cation exchange capacity is 1.76 me%.

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

Crop	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Zn (kg/ha)	Si (as mill mud/ash (t/ha)	Lime prior to planting (t/ha)
Replant cane	150	20	100	15	10	150	2.5
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 decreases as the season progresses.

Table 4.1 - Third leaf nutrient critical values for sugarcane

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

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

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

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

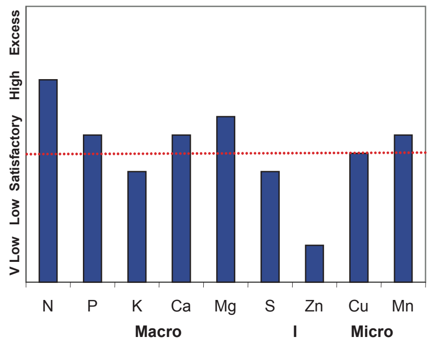
BSES Leaf Analysis Service, Ashfield Road / Private Bag 4, Bundaberg DC 4670

	Bloggs, J		
Address	**Innisfail**		
	Innisfail	**4800**	
Telephone			
Sample No:	**5001**		
Block	**E6**		
Sampling date	**16-Jan-04**	Age	**6** months
Crop	**1R**		
Variety	**Q138**		
Mill	South Johnstone		

Leaf nutrient status

Sugarcane for the future

Leaf data	**Actual:**	**Critical:**
Nitrogen (N)	**2.21** %	1.8 % *
Phosphorus (P)	**0.20** %	0.18 %
Potassium (K)	**0.92** %	1.1 %
Calcium (Ca)	**0.24** %	0.2 %
Magnesium (Mg)	**0.18** %	0.08 %
Sulfur (S)	**0.12** %	0.13 %
Zinc (Zn)	**8** mg/kg	13 mg/kg
Copper (Cu)	**3** mg/kg	3 mg/kg
Manganese (Mn)	**25** mg/kg	15 mg/kg
Iron (Fe)	**57** mg/kg	
Silicon (Si)	**0.88** %	0.7 %



Remarks:

One or more of the macro nutrients are below satisfactory levels

One or more of the micro nutrients are below satisfactory levels
- foliar application should be considered if the cane is less than 5 months old

Nutrients applied

N	**170** kg/ha
P	**20** kg/ha
K	**60** kg/ha

* Leaf N critical value depends on the date and age of cane at sampling.

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 increased colour and amino N levels in cane juice are indicative of high N application rates. Unfortunately the absence of critical values for N and other nutrients have not enabled this technique to be used for developing routine fertiliser recommendations.

Nutrient management using the ‘Six Easy Steps’

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 ‘Six Easy Steps’ approach consists of:

1. Knowing which soils occur in each block of your farm. Soil maps are available for most farms.
2. Understanding the properties of each soil and the nutrient processes and loss pathways likely top occur in each soil.
3. Regular soil testing (blocks should be sampled before every crop cycle).
4. Adopting soil-specific nutrient management guidelines to determine fertiliser plans for each block on the farm.
5. Using leaf analysis as a check on the adequacy of fertiliser recommendations (enabling modifications to the fertiliser plans).
6. Maintaining a good record keeping system which enables informed decisions to be made based on block histories and longer-term nutrient management strategies.

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

CHAPTER 5

Concluding remarks

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

Our new philosophy focuses on the management of different soils to enhance their ability to store and supply a wide range of nutrients to the crop. It emphasises the importance of building up high 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 some 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 traditional application rates. This is particularly important given 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 past recommendations but take into account differences in soil texture. They are higher than current K usage and recognise the low exchangeable K levels in nearly all Johnstone 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 which we hope will encourage growers to make much greater use of these tools through local extension staff from BSES and the Innisfail Babinda Cane Productivity Services Sugar Services.

APPENDIX 1

How to determine soil texture

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

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

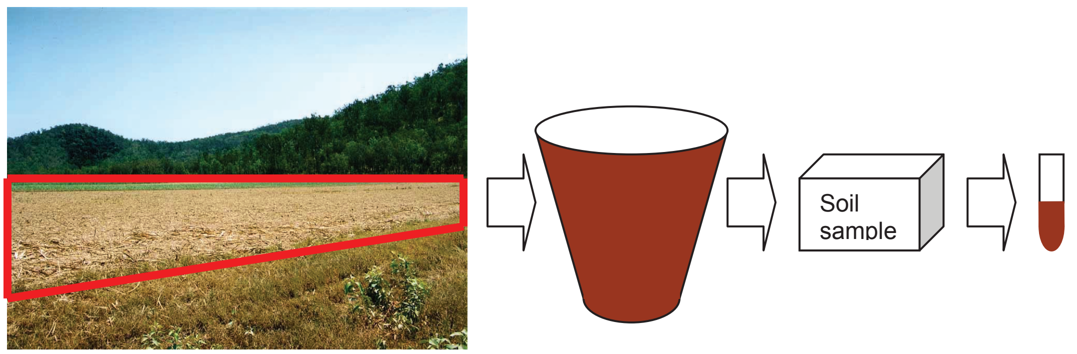
Simplified guide to determining soil texture.

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

APPENDIX 2

How to take a soil sample

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

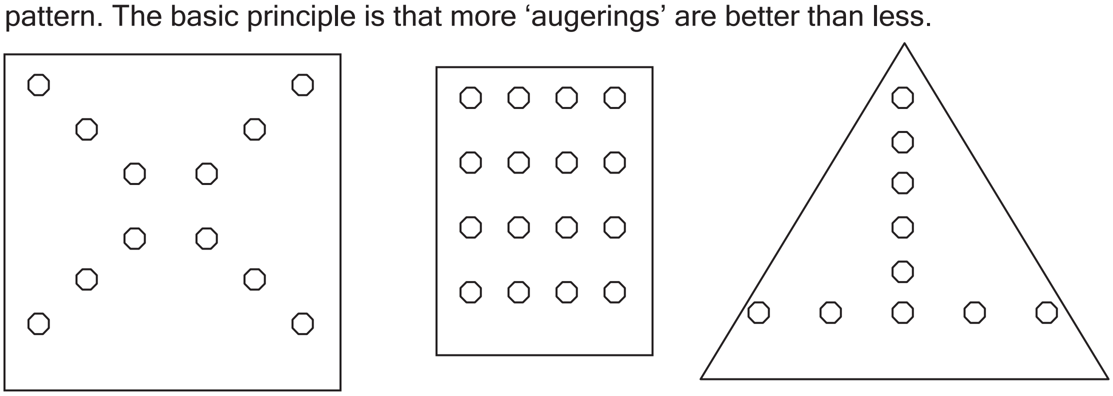


Soil: 6 000 tonnes 5-10 kg 500g 10g

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

Soil sampling procedure

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



Some suggested sampling patterns within cane blocks of different shapes.

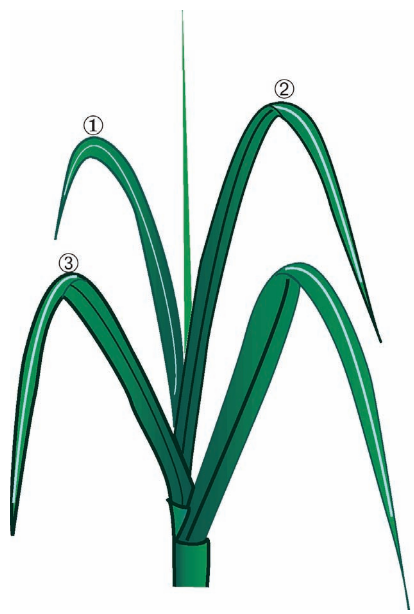
- Whilst there is some debate as to where soil samples should be taken in relation to the cane row or inter-row, we suggest that all samples be taken from the shoulder of the cane row, approximately mid way between the centre of the cane row and the centre of the inter-row. By following this rule you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

APPENDIX 3

How to take a leaf sample

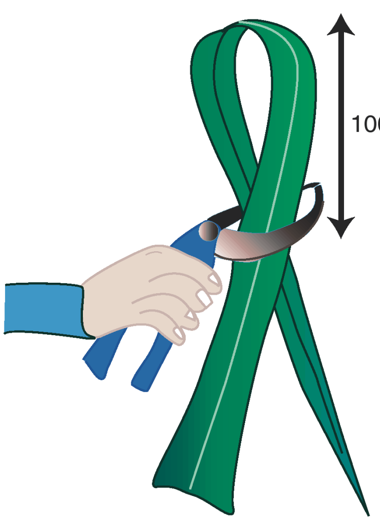
Step 1

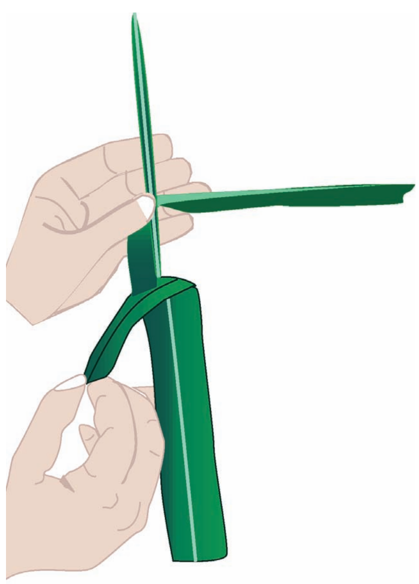


- Select leaves from stalks of average height.
- Sample the third leaf from the top of the stalk (as shown on the diagram). Counting from the top of the plant, the first leaf is the one that is more than half-unrolled. The third leaf usually corresponds to the top visible dewlap.
- Collect 30 - 40 leaves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

Step 2

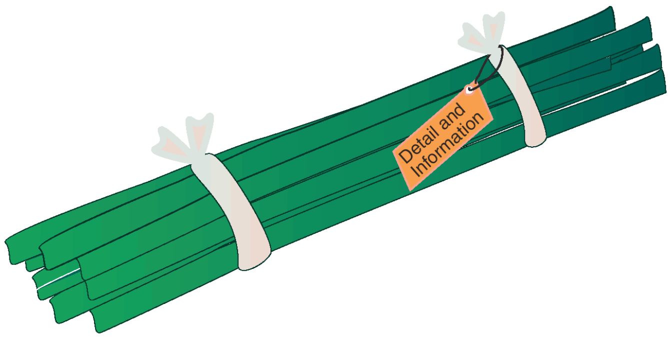
- Fold the leaves in half (top to base) and cut a 100-200 mm length from these folded leaves (giving a total 200-300 mm section of each leaf). Retain these middle 200-300 mm sections of the leaf blades and discard the remaining top and bottom sections.
- Strip out & discard the midrib from each 200-300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





Step 3

- Bundle the leaf strips together and attach a completed BSES leaf sample label.



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

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

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

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

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

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

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.

Aitken, R.L. (2000). Control of acidity and soil acidification. In Bruce, R.C. (ed.). Sustainable nutrient management in sugarcane production: Short Course. CRC for Sustainable Sugar Production, Townsville, pp. 59-62.

Bell, M.J., Halpin, N.V., Garside, A.L., Stirling, G.R., Moody, P.W. and Robotham, B.G. (2003). Evaluating combinations of fallow management, controlled traffic and tillage options in prototype sugarcane farming systems at Bundaberg. Proc. Aust. Soc. Sugar Cane Technol., 25: (CD-ROM).

Berthelsen, S. Noble, A.D. and Garside, A.L. (1999). Silicon research down under: past present and future. Silicon in Agriculture Conference Proceedings, Fort Lauderdale, Florida. Elsevier Science B.V., Amsterdam Publishing Division, The Netherlands.

Bramley, R.G.V. and Wood, A.W. (2000). Risk assessment of phosphorus (P) loss and guidelines for P use in lower Herbert soils. Final Report, SRDC, Project CLW010.

Bruce, R.C. (ed.) (2000). Sustainable Nutrient Management in Sugarcane Production Shortcourse. CRC for Sustainable Sugar Production, Townsville.

Bruce, R.C. (ed.) (2002). Managing Soils, Nutrients and the Environment for Sustainable Sugar Production. CRC for Sustainable Sugar Production, Townsville.

Burkitt, L.L., Moody, P.W., Gourley, C.J.P and Hannah, M.C. (2000). A simple phosphorus buffering index for Australian soils. Australian Journal of Soils Research 40, 497 – 513.

Calcino, D.V. (1994). Australian Sugarcane Nutritional Manual. BSES/SRDC, Indooroopilly.

Calcino, D.V., Kingston, G. and Haysom, M.B.C. (2000). Nutrition of the plant. In: Hogarth, D.M. and Allsopp, P.G. (eds.). Manual of Cane Growing. Bureau of Sugar Experiment Stations, Indooroopilly, pp 153-193.,

Garside, A.L. and Bell., M.J. (2001). Fallow legumes in the Australian sugar industry: Review of recent research findings and implications for the sugarcane production system. Proc. Aust. Soc. Sugar Cane Technol., 23: 230-235.

Hogarth, D.M. and Allsopp, P.G. (eds.) (2000). Manual of Canegrowing. Bureau of Sugar Experiment Stations, Indooroopilly.

Murtha, G.G. (1986). Soils of the Tully – Innisfail Area, North Queensland. Division of Soils Report 82, CSIRO, Australia.

Murtha, G.G. and Smith, C.D. (1994). Key to Soils and Land Sustability of the wet Tropical Coast, Cardwell – Cape Tribulation. CSIRO, Australia.

Nelson, P.N (2000). Field Guide for Diagnosis of Sodic Soils in the Australian Sugar Industry. CRC for Sustainable Sugar Production Technical Publication, Townsville.

Nelson, P.N., Noble, A.D., Bramley, R.G.V. and Schroeder, B.L. (2000). Why do soils behave as they do? .). Sustainable nutrient management in sugarcane production: Short Course. CRC for Sustainable Sugar Production, Townsville, pp. 27-42.

Peverill, K.I., Sparrow, L.A. and Reuter, D.J. (1999). Soil Analysis: An Interpretation Manual. CSIRO Publishing, Collingwood.

Schroeder, B.L., Moody, P.W. and Wood, A.W. (2003). Improved nutrient management in the Australian sugar industry. Final Report, SRDC, Project BSS232.

Schroeder, B.L. and Wood, A.W. (2001). Assessment of the nitrogen mineralising potential of soils in two different landscapes in the Australian sugar industry – implications for N fertiliser management. Proc. Aust. Soc. Sugar Cane Technol., 23: 281-288.

Schroeder, B.L., Wood, A.W., Hardy, S., Moody, P.W. and Panitz, J.P. (2006). Soil-Specific Nutrient Management Guidelines for Sugarcane Production in the Proserpine District. Technical Publication TE04003, BSES Limited, Indooroopilly.

Schroeder, B.L., Wood, A.W., Moody, P.W., Bell, M.J. and Garside, A.L. (2005). Nitrogen fertiliser guidelines in perspective. Proc. Aust. Soc. Sugar Cane Technol., 27: 291-304.

Schroeder, B.L., Wood, A.W., Moody, P.W., Panitz, J.H., Agnew, J.R., Sluggett, R.J. and Salter, B. (2006). Delivering nutrient management guidelines to growers in the central region of the Australian sugar industry. Proc. Aust. Soc. Sugar Cane Technol., 28: 142-154.

Schroeder, B.L., Wood, A.W., Moody, P.W., Stewart, R.L., Panitz, J.H., Berthelsen, S. and Ward, M. (2006). Soil Reference Sites and Nutrient Management Guidelines for Sugarcane in the Johnstone District. Envirofund Report.

White, R.E. (1997). Principles and Practices of Soil Science. 3rd Edition. Blackwell Science Ltd, Oxford.

Wood, A.W. (2002). Inventory of Herbert soils for Sustainable Sugarcane Production, Final Report, Natural Heritage Trust, Project 972077.

Wood, A.W., Noble, A.D. and Bramley, R.G.V. (2002). Improving the environment for sugarcane growth through the amelioration of soil acidity. Final Report, SRDC, Project CSR024.

Wood, A.W. and Schroeder, B.L. (2004). Potassium: A critical role in sugarcane production, particularly in drought conditions. Proc. Aust. Soc. Sugar Cane Technol., 26: CD-ROM.

Wood, A.W., Schroeder, B.L. and Stewart, R.L. (2003). Soil Specific Management Guidelines for Sugarcane Production. CRC for Sustainable Sugar Production Technical Publication, Townsville.

Wood, A.W., Schroeder, B.L., Stewart, R.L. and Roth, C.H. (2003). A reference booklet for cane growers on the nutrition and fertilising of sugarcane for different soil types. Final Report, SRDC, Project CSR026.