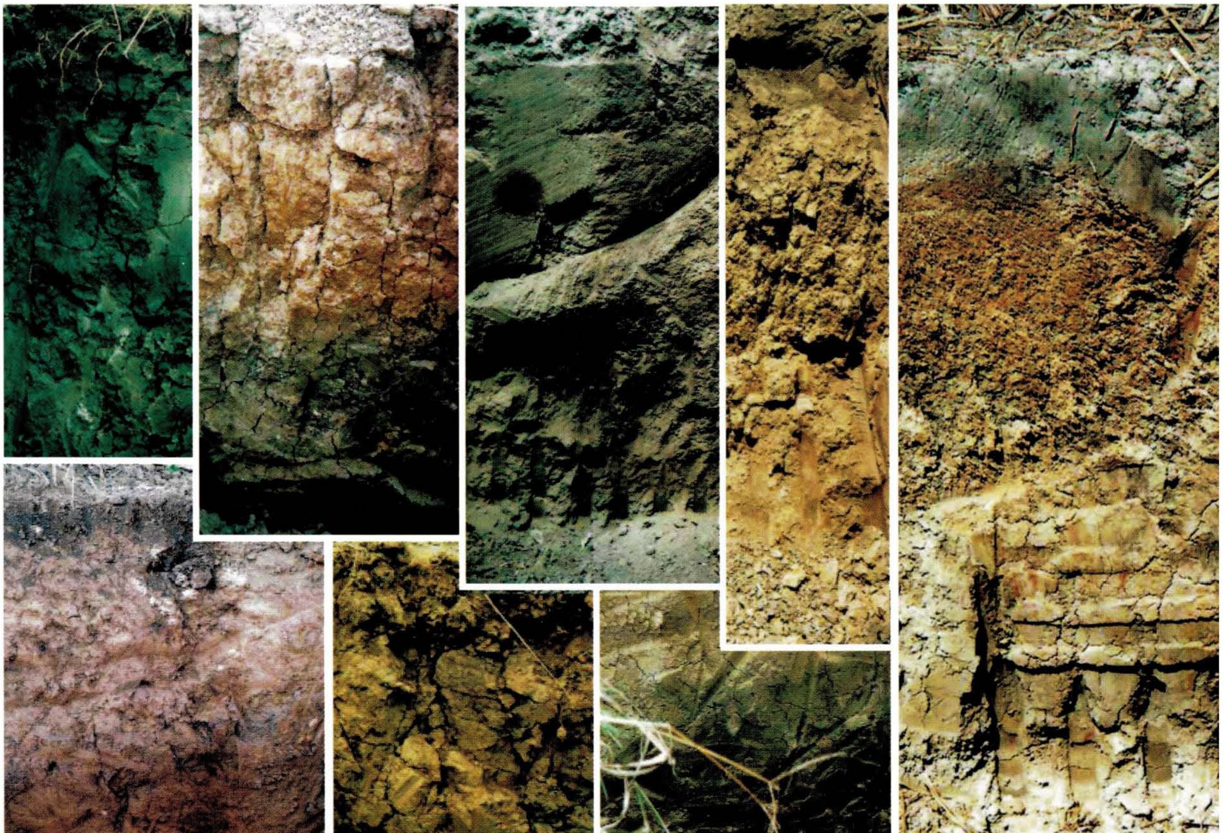
BSES

TECHNICAL PUBLICATION TE04003

SOIL REFERENCE BOOKLET FOR THE PROSERPINE DISTRICT

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

Bernard Schroeder,
Andrew Wood,
Scott Hardy,
Phil Moody
and John Panitz



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

By
Bernard Schroeder[1], Andrew Wood[2], Scott Hardy[3]
Phil Moody[4] and John Panitz[1]

[1]BSES Limited, Bundaberg
[2]CSR Sugar Ltd, Macknade
[3]WRICM Association and Whitsunday Shire Council, Proserpine
[4]Queensland NRMW, Indooroopilly

Substantial funding for this project was received from Envirofund.

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

Disclaimer:

The nutrient management guidelines for different soils in this publication are based on generalised management conditions across each soil type and provide general advice only. They may not apply to the specific conditions on your farm. If you would like to adjust the guidelines to the situation on your farm, we strongly recommend that you take soil and leaf samples from each cane block and seek professional advice. Except as required by law and only to the extent so required, none of the authors, their respective employers / organisations including directors, officers or agents, and publishers makes any representation or warranty, express or implied, as to, or shall in any way be liable (including liability in negligence) directly or indirectly for any loss, damages, costs, expenses or reliance arising out of or in connection with, the accuracy, currency, completeness or balance of (or otherwise), or any errors in or omissions from, any test results, recommendations statements or other information provided to you.

ISBN: 0-949678-15-5

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. 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 scientific and more popular in nature.

Dr Andrew Wood currently holds the position of Productivity Manager, CSR Sugar Ltd in the Herbert River district. Andrew has twenty five 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 various aspects of sugarcane production which were funded by various bodies / organisations (SRDC, CRC Sugar, Envirofund, etc). He is the author or co-author of a large number of scientific papers, books and reports.

Scott Hardy is currently employed as the Coordinator of the Catchment Management Section within the Whitsunday Shire Council. Previously, he has worked as the Coordinator of the Whitsunday Rivers Integrated Catchment Management Association and also as a Land Resource Officer with the Queensland Department of Natural Resources. He has eight years experience in mapping soils and determining land use suitability in the Whitsunday region. Scott has a Degree in Applied Science (Honours) (Coastal Management), a Post Graduate Diploma in Land Resource Studies and a Graduate Certificate in Natural Resources. Scott has been a Certificate Practising Soil Scientist since 1998 under the Australian Soil Science Society accreditation program.

Dr Phil Moody is a Principal Scientist and Group Leader with the Queensland Department of Natural Resources, Mines and Water (NRMW) 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 on a number of scientific papers and reports. He is involved in a number of international projects, particularly in south east Asia.

John Panitz is a Senior Research Assistant at the BSES Limited Southern Experiment Station at 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.

Acknowledgements

We sincerely the following contributors to this publication:

- Ian McBean (Secretary, Proserpine Cooperative Mill, and formerly Manager of CANEGROWERS, Proserpine) for originally proposing that this booklet be produced, for his input in securing funding and his ongoing support for the team.
- John Agnew and Mandy Jeppesen (Extension Officers with Sugar Services Proserpine and BSES Limited) for the useful discussions and input during the initial stages of this project, and particularly for making available the summaries of nutritional data relating to growers' soil samples collected in the district over the past few years.
- Christine Peterson (Whitsunday Rivers ICM Association) for her co-ordinating role and supplying information on irrigation management in the Proserpine region.
- Jason Hillyard (BSES Limited, Bundaberg), Bruce Compton, Siok Ay Yo and Pat Victor (DNR&M, Indooroopilly) for their valuable technical support.
- Bob Stewart who was involved in the production of the Herbert booklet, which serves as the basis for this and future similar publications.
- Natural Heritage Trust (Envirofund), Whitsunday Rivers Integrated Catchment Management Association, CANEGROWERS Proserpine, BSES Limited, CSR Sugar Ltd and the Queensland DNR&M for their financial support.
- Cane growers in the Proserpine district who kindly allowed access to their farms, collection of soil samples and the digging of inspection pits.

The soil specific guidelines in this publication are based on outcomes from various projects that were funded by the Sugar Research and Development Corporation and the Cooperative Research Centre for Sustainable Sugar Production. Their support is gratefully acknowledged.

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 sulphur 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 onto 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: The district yield potential is determined from the best possible yield averaged over all soil types in a district and is defined as the estimated highest average annual district yield (tonnes cane/ha) multiplied by a factor of 1.2. This enables recognition of differences in the ability of districts and regions to produce cane.

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 break 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. That booklet describes the basic principles of soil management and presents nutrient guidelines for Herbert soils. We are now in the position to present a similar booklet aimed at soil-specific nutrient management in the Proserpine district. This is based on a methodology developed within an SRDC-funded project (Improved nutrient management in the Australian sugar industry) and research conducted in the area as part of an Envirofund project (Reducing the off-farm impacts of fertiliser application in Proserpine sugarcane soils).

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 periodic low sugar prices, 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 Proserpine cane growers. Use of these will not only maintain or improve crop yields and soil fertility, but will also provide opportunities for cost reductions whilst enhancing sustainability and delivering positive environmental outcomes.

CHAPTER 1

Introduction to Proserpine soils and their properties

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

Soil formation and distribution

Most sugarcane is grown on the flat to gently undulating alluvial flood plains associated with the tributaries of the Proserpine, O'Connell and Gregory Rivers. The floodplain soils can be grouped according to their position in the landscape. Since the coarsest sediment particles are quickly deposited when rivers are in flood, soils found on active levees close to the main rivers tend to be sandy and well drained. Soils dominated by finer particles occur away from the rivers in back plains and swamps. These heavy textured soils are poorly drained due to their high clay content. Large areas of clay soils are common in the Gregory and Cannon Valley areas. Creek flats associated with smaller creek systems usually have soils that are more similar to levee soils than back plain soils.

Large floodplain areas are found east of the town of Proserpine and south to the O'Connell River. This large flat expanse of land forms the Proserpine – O'Connell river delta and is locally called the Goorganga wetland. Sugarcane is grown on some of the western edges of these wetland areas. The soils that form the wetlands are young and have been influenced by marine processes. Large areas of the Goorganga wetland are underlain by acid sulphate soils. Only small areas of these acid sulphate soils are used for sugarcane production.

Over thousands of years, some rivers have eroded into their beds and have isolated floodplains from flood waters. These relict or old floodplains are called terrace plains. These elevated areas are influenced by the processes of erosion and weathering rather than deposition. In the up-river and Kelsey Creek areas the terraces are ancient and the soils are deeply weathered. Beneath these terraces, sandstone is common and the land is susceptible to gully erosion.

Position in the landscape

Because of the interactive effect of the soil-forming factors, the existence of soils with specific characteristics is predicable in the landscape. Soils differ according to their position in the landscape and due to the interaction between topography, geology, climate and amount of flooding. The coastal hills are composed of acid to intermediate volcanic rocks and the inland range composed of volcanic, sedimentary and intrusive rocks such as granite. The types of soil formed in the hills are directly influenced by the mineral composition of the rock, the prevailing climate and the position in the landscape. In general, soils formed towards the footslopes are deeper than those formed on upper slopes or hill crests due to erosion and deposition. Footslope soils will also be influenced by the mass movement of soil downslope.

The lowlands which incorporate Proserpine, Kelsey Creek, Koolachu and Lethebrook have an interesting geological history. The flat to undulating land between the coastal hills and inland range is the result of a massive geological fault. Some 60 million years ago, the area which incorporates the coastal lowlands was composed of hills. Movements in the earth's crust formed the Hillsborough Fault and the Hillsborough Channel and subsequently caused a deep canyon which has gradually filled with a variety of different sediments.

The older sediments are mostly located in the Koolachu, Tailing Gully, Crystalbrook and Six Mile Creek areas. The older sediments tend to overlie sandstone and produce sodic soils which are usually located above the level of regular flooding. Younger soils that flood more frequently are found closer to creeks and rivers. These tend to be more fertile and more productive for cropping.

Nearly all of the sugarcane in the Proserpine district is grown on alluvial or floodplain soils. The remainder is grown on a range of hillslope soils. The following section discusses the fertility characteristics of these soils, how they react with fertilisers and how they can be managed for sustainable sugarcane production.

Soil field properties

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

Colour

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

Soil Texture

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

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

Structure

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

Soil horizons

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

Chemical Properties

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

Cation Exchange Capacity

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

Organic Matter

Soil organic matter is derived from the breakdown of plant and animal matter. It also has the ability to attract nutrients and has a greater cation exchange capacity than a similar mass of clay. Dark colour and good structure are indicators of high organic matter. Soils in the Proserpine district have organic C contents of up to 2.5%. Organic matter, measured as organic carbon %, improves soil structure and is a source of nitrogen (N), phosphorus (P), sulphur (S) and trace elements. There is no optimum level of organic matter, but it is best to maintain it at the highest possible level. The organic matter content of a soil is determined by the balance between inputs of organic matter forming material and the breakdown (mineralisation) of the existing stabilised soil organic matter (humus). Green harvested sugarcane inputs about 10-15 t/ha in trash and 3 t/ha in roots per year, but 80% 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 Proserpine 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

The Whitsunday Coast soil survey found that 64% of sugarcane is grown on sodic soils. Sodic subsoils restrict rooting depth, reduce soil water availability to roots and may increase susceptibility to surface erosion. Salinity was found to be a minor issue for sugarcane grown in the Whitsunday area. Only 3% of sugarcane land had subsoil salinity levels considered to be moderate to high. Acid sulphate soils were also found to exist in the region with sugarcane grown on about 295ha of these soils. About 80% of the sugarcane in the Whitsunday region is grown on soils with slopes of less than 2%. Soil loss will therefore be a moderate issue for about 20% of sugarcane land.

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.

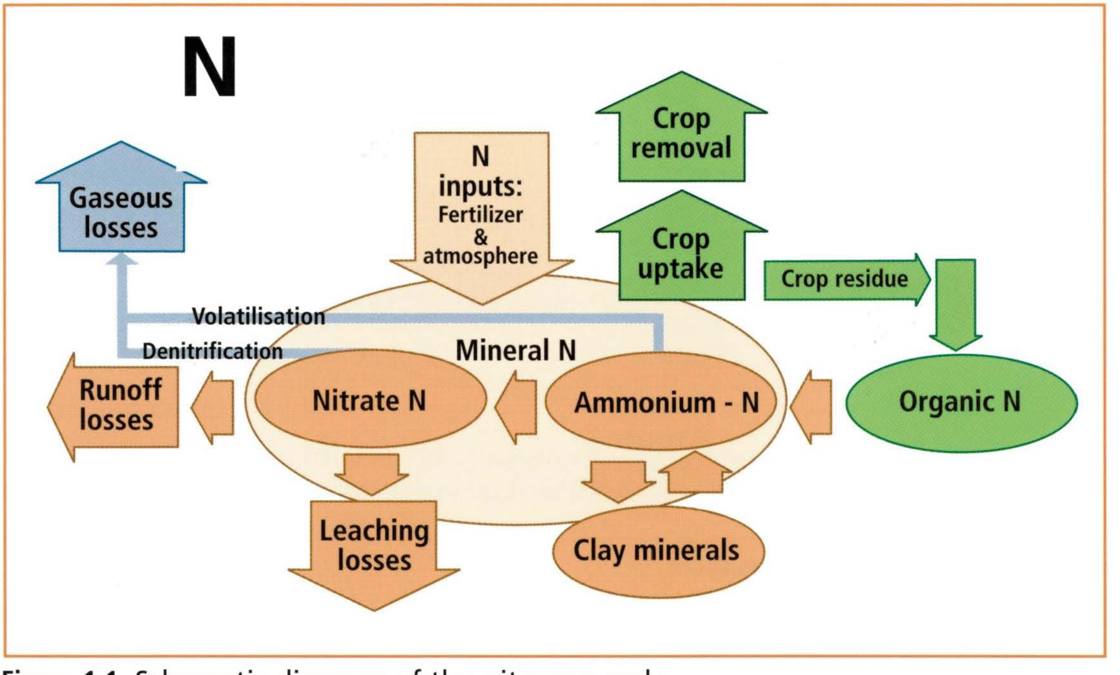


Figure 1.1. Schematic diagram of the nitrogen cycle

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 minimizes 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.

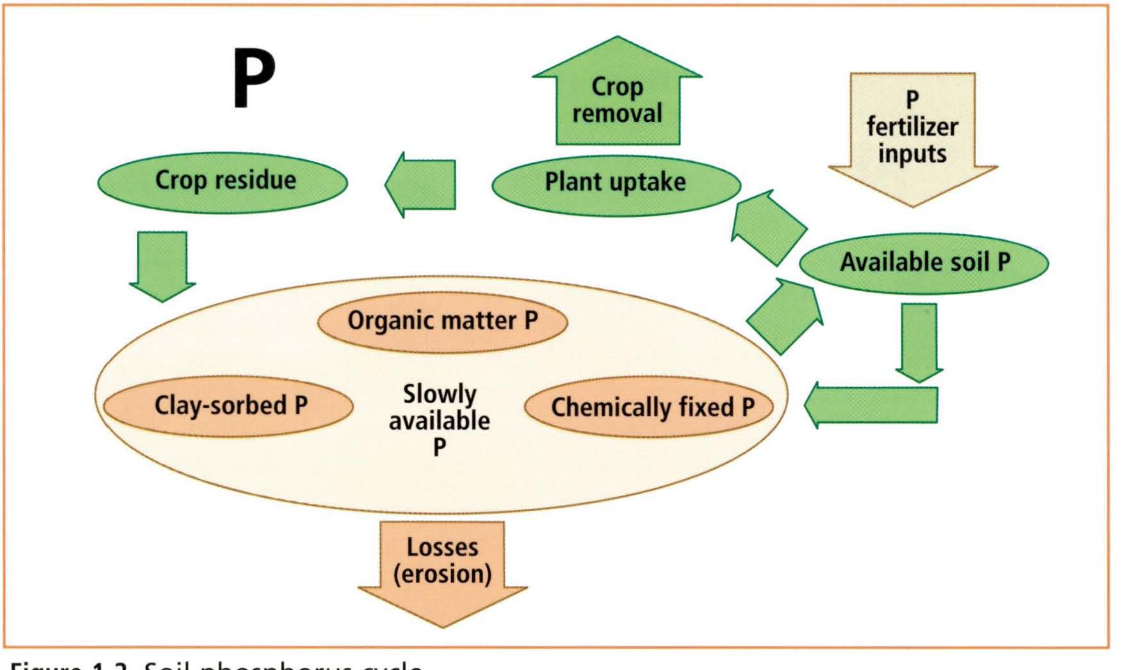


Figure 1.2. Soil phosphorus cycle

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.

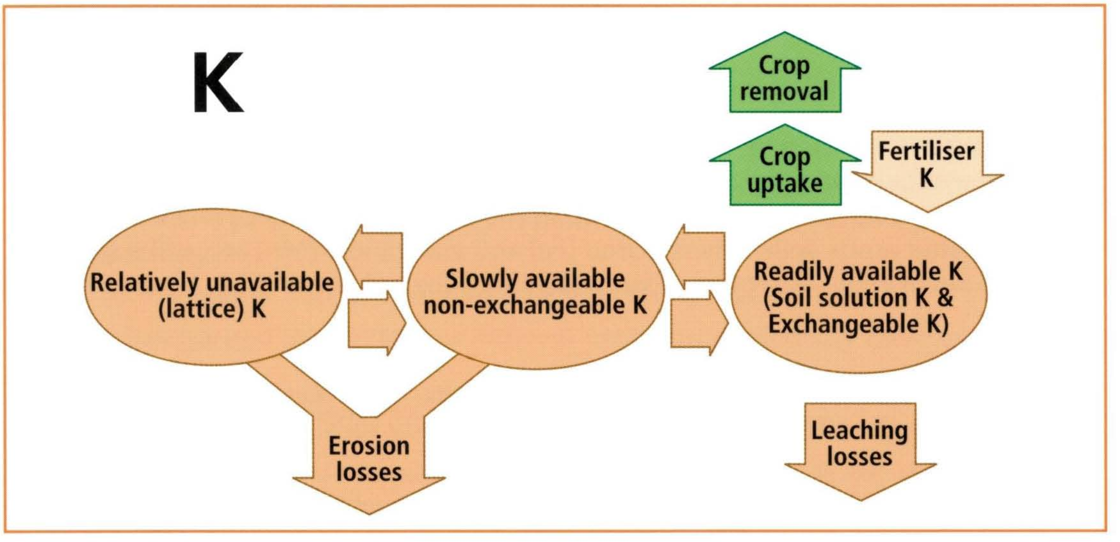


Figure 1.3. Soil potassium cycle

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 Proserpine soils, particularly low organic matter sandy soils, whereas iron (Fe) and manganese (Mn) are well supplied. Little is known about the status of molybdenum (Mo) and boron (B) in Proserpine soils.

Silicon

No deficiencies of silicon (Si) have so far been detected in Proserpine through leaf analysis although soil Si levels can be low in very sandy soils.

CHAPTER 2

Principles for determining nutrient management guidelines

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

1. Crop yield potential
2. Nutrients removed in the harvested crop
3. Nutrients returned to the soil in trash, fallow crops and mill by-products
4. Nutrients released by the mineralisation of soil organic matter
5. Nutrients released by the weathering of soil minerals
6. Nutrients fixed (held tightly) on soil particle surfaces
7. Soil acidity
8. Critical levels of nutrients as determined by soil analysis
9. The balance and interactions of different nutrients, particularly those on the soil CEC
10. 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 representative soil profiles during the various soil surveys of the district and the second consisted of data from samples taken from cane blocks in the period 2002-2004. Medians and ranges of analytical data were used to produce the bar graphs and soil test values 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 and Colwell P (indices of available phosphorus)
- Phosphorus Buffer Index – PBI (a measure of the degree to which added P is held tightly onto soil particle surfaces and is unavailable for plant uptake)
- Sulphur
- Copper and zinc

Nitrogen

Nitrogen guidelines are now based on a combination of **district yield potential** and **soil N mineralisation index**. The district yield potential is determined from the best possible yield averaged over all soil types within a district and is defined as the estimated highest average annual disctrict yeild (tonnes cane/ha) multiplied by a factor of 1.2. This enables us to recognise differences in the ability of districts and regions to produce cane. For example, the Burdekin region with its fertile soils, higher temperatures and access to water, has a higher yield potential than the Proserpine district. These regional yield potentials are used to establish the base N application rate according to an estimate previously developed by CSIRO scientists that 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). The yield potential for the Proserpine district is estimated to be 130 tonnes cane/hectare and therefore the baseline N application rate is set at 170 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.

Table 2.1. N mineralisation index and nitrogen rates

N mineralisation index	Organic Carbon %	Baseline N rate (kg/ha)
VL	<0.4	170
L	0.4 – 0.8	160
ML	0.8 – 1.2	150
M	1.2 – 1.6	140
MH	1.6 – 2.0	130
H	2.0 – 2.4	120
VH	>2.4	110

(< denotes less than; > denotes greater than)

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

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 legume fallow (as supplied by the Sugar Yield Decline Joint venture)

Legume crop	Fallow crop dry mass (t/ha)	N (%)	Total N contribution (kg N/ha)	Total N contribution (kg N/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
Replant cane and ratoon after replant	170	160	150	140	130	120	110
Plant cane after a grass/bare fallow	150	140	130	120	110	100	90
Plant cane after a poor legume crop (e.g. 2 t/ha cowpea green manure: N rate minus **70** kg N/ha)	100	90	80	70	60	50	40
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)	80	70	60	50	40	30	20
First ratoon after a good legume crop*	170	160	150	140	130	120	110
Second ratoon after a good soybean/cowpea crop	170	160	150	140	130	120	110

* Data from the Yield Decline Joint Venture suggests that N applied to the first ratoon sugarcane crop after a good legume crop should follow the normal guidelines and that no reduction be made despite the apparent excess of N being supplied to the plant cane.

Nitrogen application rates for sugarcane should also be modified when 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 (Table 2.4).

Table 2.4. Amount of N to be subtracted from N application rates following the use of mud/ash mixture.

Application rate	To be subtracted from the appropriate N application rate		
	Plant crop	First ratoon	Second ratoon
200 wet t/ha	60 kg N/ha	30 kg N/ha	15 kg N/ha

Phosphorus

Two techniques are used to decide how much P fertiliser is required. Firstly a BSES critical level is used to determine the quantity of P fertiliser required. This is then modified by the soil's ability to fix added P (P sorption), which determines how much of the fertiliser P will be available to the crop. The P sorption class of each soil is based on the Phosphorus Buffer Index (PBI) which is measured in the laboratory (Table 2.6). It can also be estimated from the clay % and organic matter content of a particular soil (Table 2.7). Clay % is not given on most soil tests but can be estimated from a soil texture determination. If that is not available then an estimate of texture can be made from the cation exchange capacity of the soil as shown in Table 2.5).

Table 2.5. Estimate of soil texture class from CEC

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

Table 2.6. P sorption classes based on PBI (See Burkitt and others, 2005)

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

Table 2.7. P sorption classes based on Org C (%) and texture class

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

Many of the older sugarcane areas do not require any P fertiliser due to their long history of P fertilisation. New land, on the other hand, is often deficient in available P and requires P fertiliser in the first crop cycle (Table 2.8).

Table 2.8. Phosphorus guidelines for old and new land (adapted from Calcino and others, 2000

Old land

BSES P in soil test (mg/kg)	P sorption class	Suggested phosphorus application (kg/ha)	
>60	All	Nil P for at least 2 crocycles	
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)

	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.

Mud/ash mixture (applied at 200 wet t/ha)
Apply nil P for at least 2 crop cycles

Potassium

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

The maximum recommended K rate for Proserpine 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 losses by leaching on low CEC sandy soils. It is justified by the relatively high K reserves on most soils which 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. Potassium fertiliser recommendations can then be derived (Table 2.9).

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

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

Replant & Ratoon (kg/ha K)						
Nitric K (me%)	Exchangeable K (me%)					
	< 0.26	0.26 - 0.30	0.31 - 0.35	0.36 - 0.40	0.40 - 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)	

As for N and P, discounts should be made where mill by-products have been used.

Mud/ash mixture (applied at 200 wet t/ha)
Apply nil K on each of first two crops

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 soil sulphate critical levels are used to calculate sulphur fertiliser rates (Table 2.10). Discounts should be made where mill by-products have been used.

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

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

Mud/ash mixture (applied at 200 wet t/ha)
Subtract 15 kg S/ha from each of first two crops

Lime

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

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

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

Mud/ash mixture (applied at 200 wet t/ha)
Subtract 2.5 t/ha Ag Lime from next application

Table 2.12. - Lime guidelines based on exchangeable Ca (adapted from Calcino and others, 2000)

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

Mud/ash mixture (applied at 200 wet t/ha)
Subtract 2.5 t/ha Ag Lime from next application

Magnesium

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

Table 2.13. Magnesium guidelines for plant crops

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 2.14.

Table 2.14. Gypsum requirement for sodic soils

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

Micronutrients

Copper and zinc guidelines are based on previously determined soil critical values (Table 2.15). These micronutrients are most often required on sandy soils. Leaf analysis is the preferred 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 2.15. Copper and zinc guidelines (see Calcino and others, 2000)

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

Silicon

Leaf analysis is the preferred method of diagnosing whether silicon applications are required. However, when soil analyses are used, two tests for silicon are appropriate. These are $CaCl_2$ -extractable Si and dilute H_2SO_4 extractable Si. The latter is sometimes referred to as BSES-Si. Ameliorants are only required if both of the Si tests values are low (Table 2.16).

Table 2.16. Silicon guidelines for plant cane (see Calcino and others, 2000)

	Sulphuric acid (0.005M)		Calcium chloride (0.01M)	Rating	Suggested application rate
Si (mg/kg)	<70	and	<10	Low	Calcium silicate @ 4 t/ha; **or** Cement @ 3t/ha **or** Mill mud/ash @ 200 wet t/ha

CHAPTER 3

Description of Proserpine sugarcane soils and guidelines for their management

This chapter presents information on the location, appearance, properties and management requirements for nine different soil types identified in the cane lands of the Proserpine River District. Two of these soils have been separated into wet and dry categories to reflect local climatic conditions which result in the soils having different properties.

Whitsunday Coast soil survey (see Hardy, 2003)

The soils of the Whitsunday region which includes the Proserpine sugar district were mapped between 1994 and 2001. The mapping was conducted at a scale of 1:50,000 (Figure 3.1). Some of the characteristics used to distinguish the soils include topsoil and subsoil texture, colour, presence of surface cracks, pH, electrical conductivity, parent material and position in the landscape.

More than 85% of the sugarcane in the Proserpine district is grown on the 24 different soil types listed in Table 3.1. The nine soil types (highlighted in green) account for 60% of the total sugarcane area and are described in detail in this booklet.

Table 3.1. Classification and area of Proserpine Soils

Soil Mapping Unit Name	Area (ha)	Area (%)	Australian Soil classification
Benholme (Bh)	4032	17.3	Grey Vertosol
Calen (Ce)	1978	8.5	Brown Chromosol
Eton (Eo)	1808	7.8	Mesonatric Grey Sodosol
Slater (Sk)	1637	7.0	Subnatric Grey Sodosol
St Helens (St)	1115	4.8	Brown Dermosol
Proserpine (Po)	888	3.8	Stratic Rodosol
Marian (Ma)	784	3.4	Brown Chromosol
Victoria Plains (Vc)	732	3.1	Black Vertosol
Koolachu Ko)	718	3.1	Mesonatric Grey Sodosol
Sandiford (Sa)	650	2.8	Subnatric Grey Sododsol
Sunnyside (Su)	621	2.7	Subnatric Grey Sododsol
Cameron (Cm)	593	2.5	Brown Rodosol
Etowie (Et)	567	2.4	Grey Chromosol
Myrtle (My)	439	1.9	Aquic Vertosol
Dryander (Dy)	372	1.6	Grey Chromosol
Hillsborough (Hs)	337	1.4	Vertosol
Wandarra (Wa)/Wagoora (Wr)	313	1.3	Yellow Dermosol / BrownDermosol
Tailing (Ti)	292	1.3	Mesonatric Grey Sodosol
Foxdale (Fo)	281	1.2	Subnatric Grey Sodosol
Goorganga (Go)	268	1.2	Aquic Vertosol
Dundula (Dn)	248	1.1	Aquic Vertosol
Wollingford (Wo)	236	1.0	Mesonatric Grey Sodosol
Brightly (Bt)	230	1.0	Grey Vertosol

Location of different soils and rainfall zones

Each soil is found in a particular part of the landscape. Three landscape sections covering different parts of the Proserpine landscape are shown in Figures 3.2, 3.3 and 3.4). They illustrate where each soil occurs and its relationship to the river system and different topographic features. The Proserpine district has two distinct rainfall zones. These are referred to as 'wet' and 'dry'. The wet zone lies to the north east and receives more than 1600mm of rainfall per annum. The dry zone receives less than 1600mm of rainfall per annum.

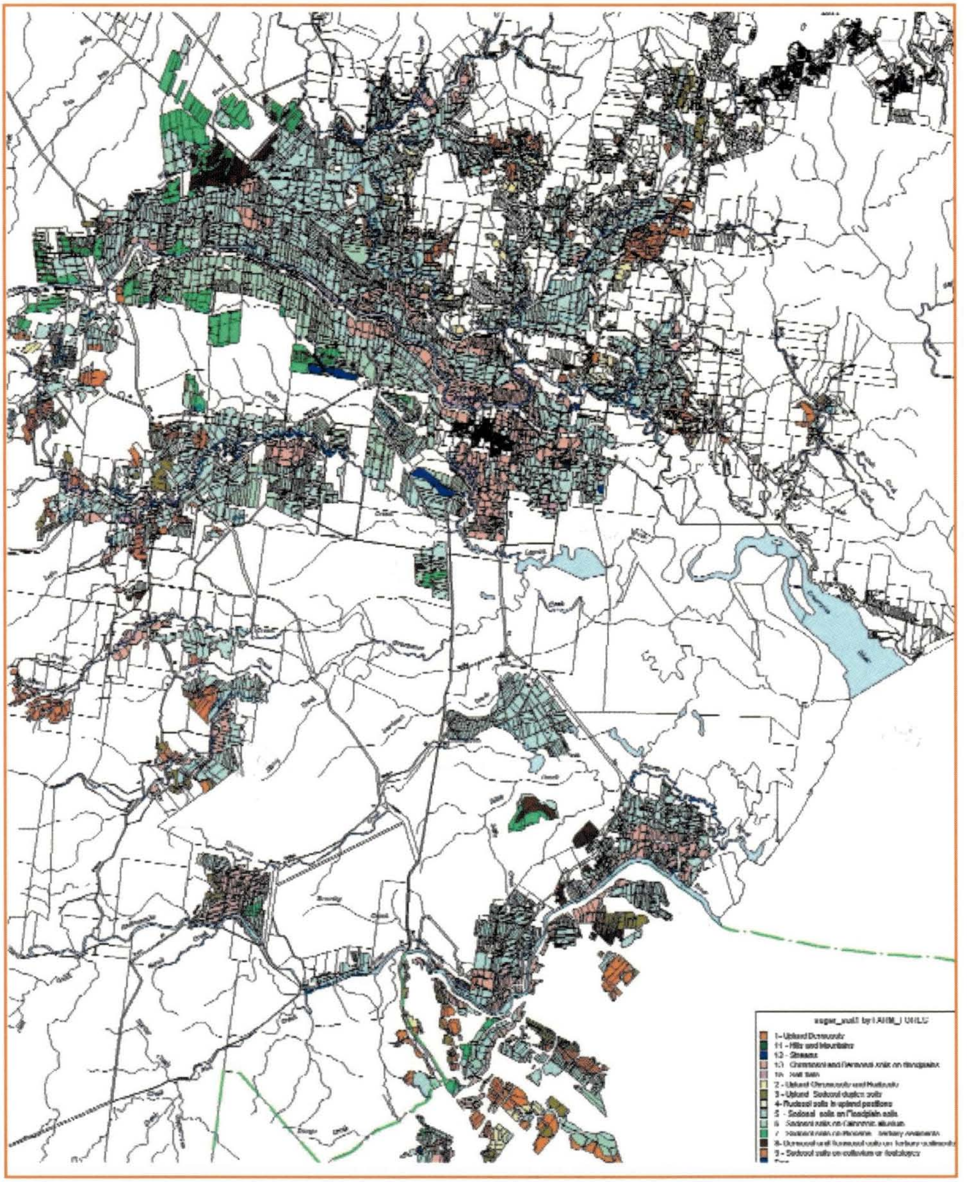


Figure 3.1. Map of the Proserpine district showing soils mapped at a scale of 1:100 000

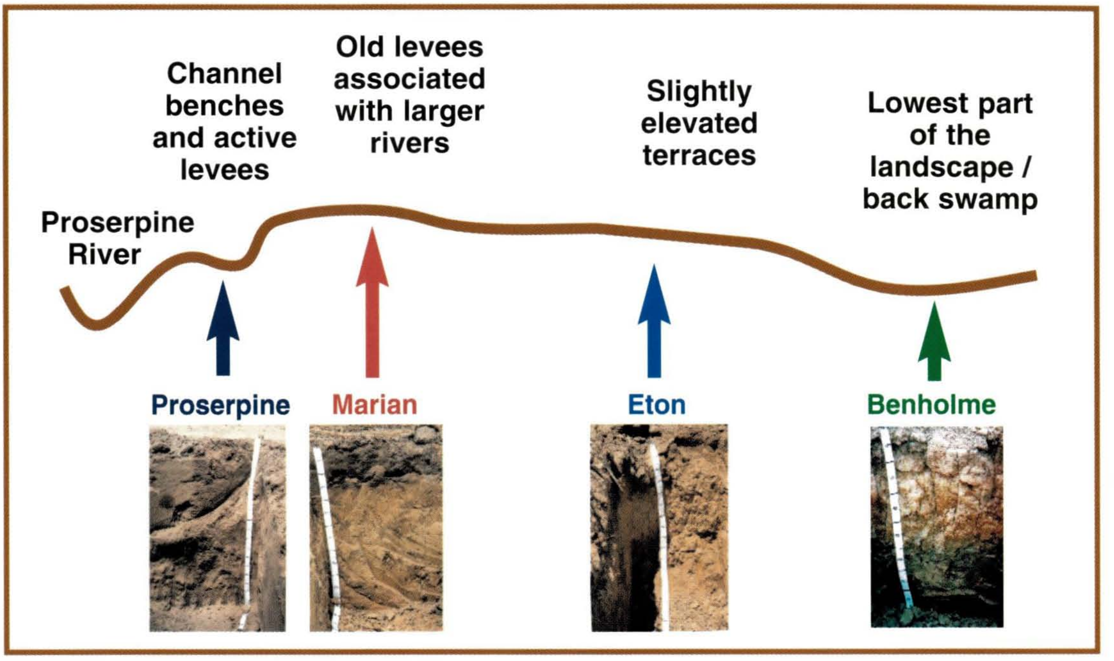


Figure 3.2. Cross-section of the landscape showing soils of the floodplains in the Proserpine district where catchments are dominated by acid volcanic or intrusive rocks.

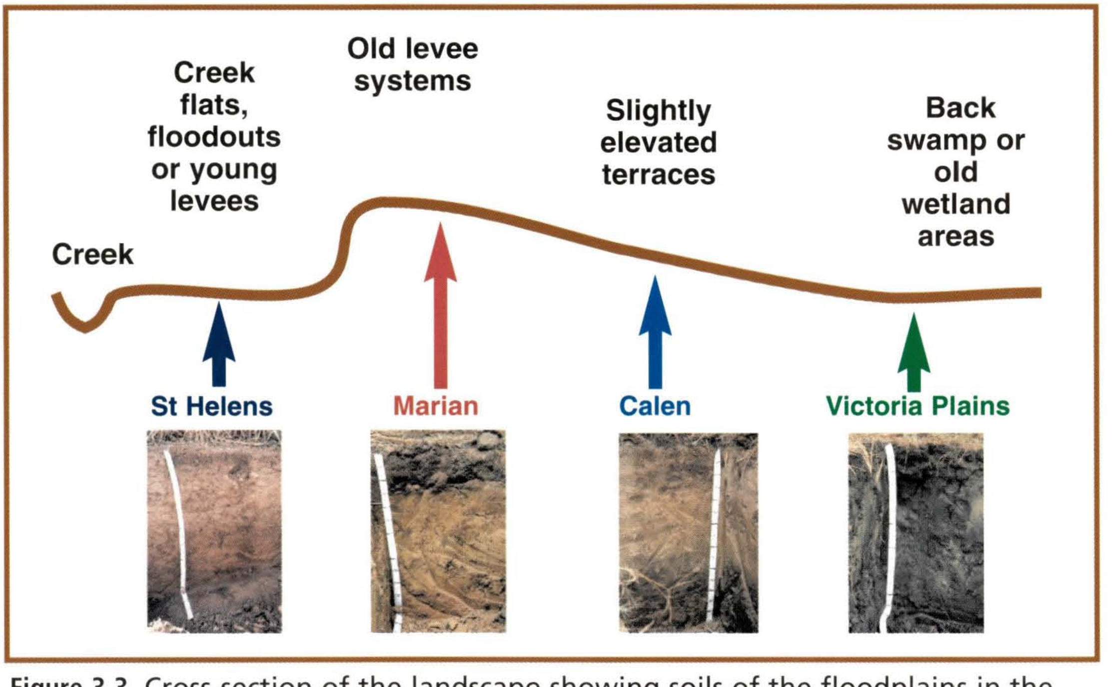


Figure 3.3. Cross-section of the landscape showing soils of the floodplains in the Proserpine district where catchments are dominated by intermediate volcanic or intrusive rocks.

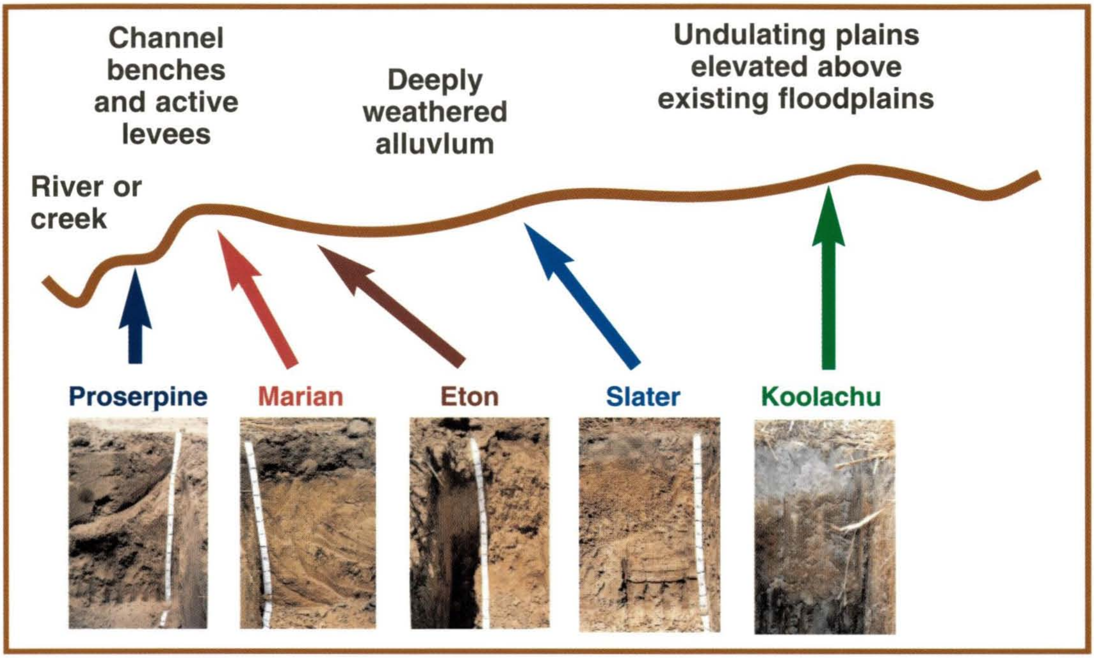


Figure 3.4. Cross-section of the landscape showing soils in the Proserpine district where catchments are dominated by Tertiary sandstones.

Soil reference sites

Reference sites representative of each of the nine soil types highlighted in Table 3.1 were selected. In the case of the Calen and Benholme soil types, a wet and a dry site were selected to reflect the occurrence of these soils in both rainfall zones. 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 each of these eleven soils. Bar graphs are used to represent the soil analytical data on a scale from very low to very high for both the reference site and selected median soil test values of samples from growers' fields. However, median values hide the variability that occurs, particularly for some soil test values such as BSES P. Soils that have grown sugarcane for many years tend to have much higher BSES P values than more recently cropped areas. Guidelines are also given on 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. 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.

Benholme (Bh) – Dry (Grey cracking clay)

Occurrence: Benholme (dry) soils occur in areas with a rainfall less than 1600 mm. They occupy about 9% of the sugarcane area in the Proserpine district. Large expanses of this clay soil are found in the Kelsey Creek area.

Formation: Benholme soils are formed by floods depositing fine silts and clays. Most Benholme soils are found some distance from the nearest creek or river in the lowest part of the landscape. These soils flood occasionally during the wet season.

Benholme soil in the Kelsey Creek area

Benholme soil profile

Field Appearance: Topsoils are grey light clays which crack when dry. Subsoils are grey to greyish brown with mottles and high clay content.

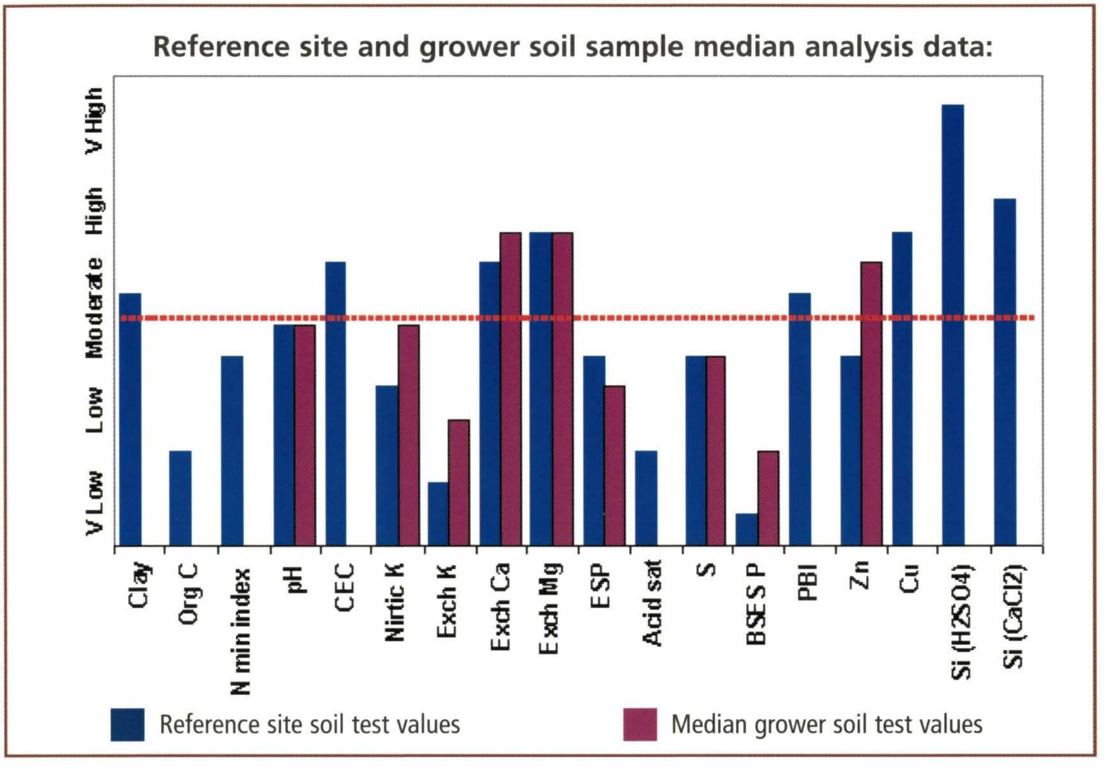
Similar soils: **Dundula (Dn)** and **Brightly (Bt)** which occupy about 1% each of the sugarcane growing area.

Physical properties:

These soils are poorly drained with frequent flooding. Rooting depth is often less than 1m. These soils have moderate structure, are hard-setting and surface cracking is common. Topsoils have a low to moderate tendency to disperse.

Chemical properties:

These soils have a moderate to low nutrient status. The CEC is moderate although the organic matter content is low. Much of the exchange complex is dominated by calcium and magnesium. Potassium reserves are low and exchangeable K is very low. Acidic cations occupy about 15% of the CEC. Most samples indicated low levels of BSES P, with the reference site being particularly low. As the soil has a low P sorbing capacity, little P 'fixation' will occur when phosphorus fertiliser is applied. Sulphur levels are low. Whilst the silicon level in the reference site was high, growers' samples were much lower in silicon.



Nutrient management guidelines:

Crop situation	Lime (t/ha)	N (kg/ha)	P new land (kg/ha)	P old land (kg/ha)	K (kg/ha)	S (kg/ha)	Mg (kg/ha)	Cu (kg/ha)	Zn (kg/ha)
Fallow plant	0	140	60	30	100	15	0	0	0
Replant	0	160	60	30	100	15	0	0	0
Ratoon	0	160	30	20	100	15	0	0	0

Tillage and water management:

It is difficult to obtain a good tilth with these soils and there is a narrow moisture range for effective tillage. The practice of green cane trash blanketing improves soil structure, tilth and soil porosity. Laser levelling is useful for improving surface drainage as these soils occur on very gentle slopes. Readily available water is moderate (65 – 75 mm).

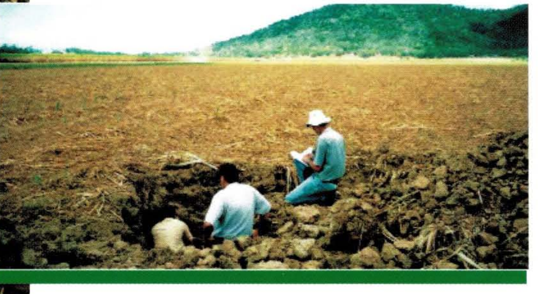
Environmental risk management:

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

Benholme (Bh) – Wet (Grey cracking clay)

Occurrence: Benholme (wet) soils occur in areas with a rainfall greater than 1600 mm. They occupy about 7% of the sugarcane area in the Proserpine district. Large expanses of this clay soil are found in the Cannon Valley and Gregory areas.

Formation: Benholme soils are formed by floods depositing fine silts and clays. Most Benholme soils are found some distance from the nearest creek or river in the lowest part of the landscape. These soils probably flood at least once a year during average wet seasons.



Benholme (wet) soil in the Cannon Valley area

Benholme (wet) soil profile

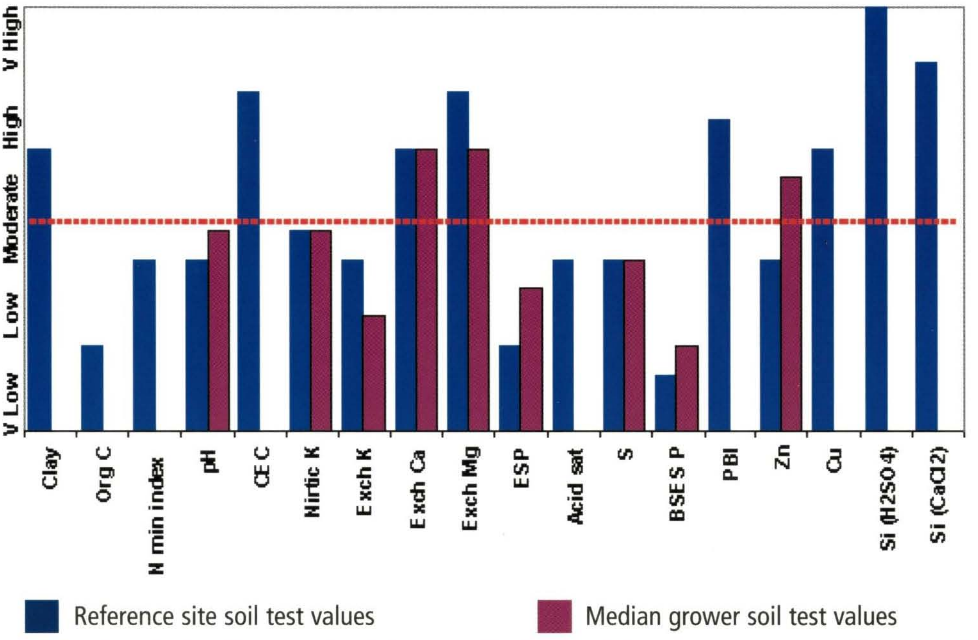
Field Appearance: Topsoils are dark grey light to light-medium clays which crack when dry. Subsoils are grey to greyish brown clays with mottles. Profiles have deeper darker topsoils and generally more clay than the Benholme (dry) soils.

Similar soils: Dundula (Dn) and **Brightly (Bt)** which occupy about 1% each of the sugarcane growing area.

Physical properties:
These soils are poorly drained with seasonally high water tables and frequent flooding. Rooting depth is often less than 1m. These soils are better structured than Benholme (dry) soils, but are still hard-setting and surface cracking is common.

Chemical properties:
These soils have a moderate to low nutrient status. The organic matter content and CEC tend to be higher than Benholme (dry) soils. The exchange complex is dominated by calcium and magnesium. Although most samples indicated low levels of exchangeable potassium, the reserves were moderate. Both are higher than Benholme (dry) soils. Acidic cations occupy a greater percentage of total CEC than Benholme (dry) soils. Most samples indicated low levels of BSES P. As these soils have a moderate P sorbing capacity, greater than replacement amounts of P fertiliser are needed to satisfy crop requirements. Sulphur is moderately well supplied. There is no evidence of micro nutrient or silicon deficiencies.

Reference site and grower soil sample median analysis data:



Nutrient management guidelines:

Crop situation	Lime (t/ha)	N (kg/ha)	P new land (kg/ha)	P old land (kg/ha)	K (kg/ha)	S (kg/ha)	Mg (kg/ha)	Cu (kg/ha)	Zn (kg/ha)
Fallow plant	0	140	60	30	100	15	0	0	0
Replant	0	160	60	30	100	15	0	0	0
Ratoon	0	160	30	20	100	15	0	0	0

Tillage and water management:

It is difficult to obtain a good tilth with these soils and there is a narrow moisture range for effective tillage. The practice of green cane trash blanketing improves soil structure, tilth and soil porosity. Laser levelling is useful for improving surface drainage as these soils occur on very gentle slopes. Irrigation on these soils is not widely practised due to generally adequate rainfall. Readily available water is moderate (65 – 75 mm).

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.

Calen (Ce) – Dry (Grey brown duplex)

Occurrence: Calen (dry) soils occur in areas where the annual rainfall is less than 1600 mm. They occupy about 8% of the sugarcane area in the Proserpine district. Large expanses of these soils are found in the Kelsey Creek, Up River and Bloomsbury areas.

Formation: Calen soils are formed by floods depositing fine silts and clays. Most Calen soils are found some distance from the nearest creek or river and often on slightly elevated terraces. These soils probably flood at least once every 5 to 10 years.

Calen (dry) soil profile

Calen (dry) soil in the Kelsey Creek area

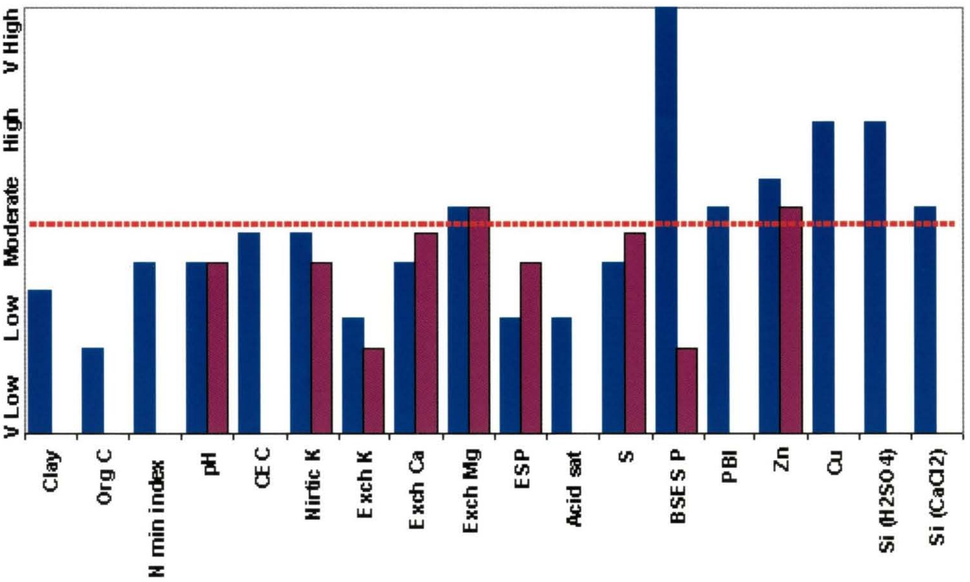
Field Appearance: Topsoils are grey with a sandy clay loam texture and often set hard when dry. Subsoils are greyish brown in colour with a high clay content and have brown and yellow mottles.

Similar soils: **Sunnyside (Su)** and **Sandiford (Sa)** soils which occupy about 3% each of the sugarcane growing area.

Physical properties:
Soils are imperfectly drained with infrequent water-logging. Subsoils are sodic below 600 mm resulting in restricted rooting depth and subsoil permeability. Topsoils are hard-setting and are prone to compaction.

Chemical properties:
These soils have a low to moderately low nutrient status. The CEC and exchangeable cations increase markedly with depth, consistent with an increase in clay content. The organic carbon content and N mineralisation index values are moderately low. Topsoils have a moderate CEC of which about 20% is dominated by acidic cations. Potassium reserves are moderate but most samples indicated very low levels of exchangeable K. Most topsoils have low levels of BSES P and low to moderate P-sorbing capacities. There is no evidence of micro-nutrient or silicon deficiencies. Exchangeable sodium percentage increases markedly with depth.

Reference site and grower soil sample median analysis data:



Nutrient management guidelines:

Crop situation	Lime (t/ha)	N (kg/ha)	P new land (kg/ha)	P old land (kg/ha)	K (kg/ha)	S (kg/ha)	Mg (kg/ha)	Cu (kg/ha)	Zn (kg/ha)
Fallow plant	2.5	140	40	20	100	10	0	0	0
Replant	2.5	160	40	20	120	10	0	0	0
Ratoon	0	160	20	10	120	10	0	0	0

Tillage and water management:

It is difficult to obtain a good tilth with these soils and there is a restricted moisture range for effective tillage. Compaction can be reduced by adopting controlled traffic. Green cane trash blanketing greatly improves soil structure, tilth and soil porosity. Laser levelling is useful for improving surface drainage as these soils occur on gentle slopes. Furrow or overhead irrigation is suitable for these soils. Due to the low infiltration rates, U-shaped furrows and slow flow rates per furrow are recommended. Drill length should be adjusted to suit slope and velocity of irrigation water. Readily available water is moderately low (40 – 60 mm). Monitoring the height of the water table and salinity of ground water is suggested.

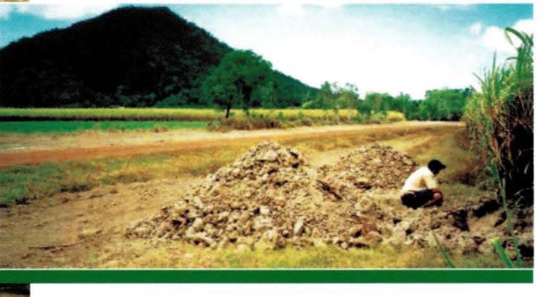
Environmental risk management:

A potential for off-site movement of suspended sediment in irrigation water exists depending on the extent of the slope and drill length. Construction of tail drains and sediment traps could assist in addressing this issue.

Calen (Ce) – Wet (Grey brown duplex)

Occurrence: Calen (wet) soils occur in areas where the annual rainfall is greater than 1600 mm. They occupy about 2% of the sugarcane area in the Proserpine district. Large expanses of these soils are found in the Cannon Valley area.

Formation: Calen soils are formed by floods depositing fine silts and clays. Most Calen soils are found some distance from the nearest creek or river and often occur on slightly elevated terraces. They probably flood at least once every 5 to 10 years.



Calen (wet) soil in the Cannon Valley area

Calen (wet) soil profile

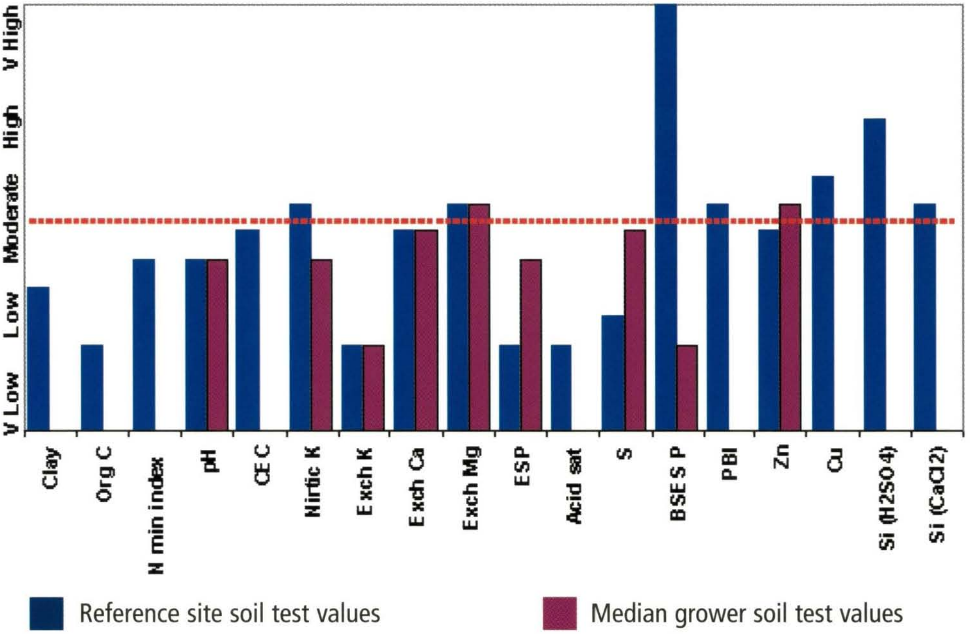
Field Appearance: Topsoils are dark grey sandy clay loams which often set hard when dry. Subsoils are greyish brown in colour with high clay contents and brown and yellow mottles. There are usually abundant iron / manganese concretions in the lower part of the soil profile.

Similar soils: **Sunnyside (Su)** and **Sandiford (Sa)** soils which occupy about 3% each of the sugarcane growing area.

Physical properties:
These soils are imperfectly drained with intermittent water-logging. Subsoils are sodic below 800 mm resulting in restricted rooting depth and permeability. Topsoils are hard-setting and prone to compaction.

Chemical properties:
These soils have a low to moderately low nutrient status. The CEC and exchangeable cations increase gradually with depth consistent with an increase in clay content. Organic carbon and N mineralisation index values are low. Topsoils have a moderate CEC of which about 20% is dominated by acidic cations. Potassium reserves are moderate but nearly all growers' samples have very low levels of exchangeable K. Although the reference site had a high BSES P value, growers' samples were generally low. Topsoils have moderate P-sorbing capacities. There is no evidence of micro-nutrient or silicon deficiencies. Exchangeable sodium percentages increase gradually with depth.

Reference site and grower soil sample median analysis data:



Nutrient management guidelines:

Crop situation	Lime (t/ha)	N (kg/ha)	P new land (kg/ha)	P old land (kg/ha)	K (kg/ha)	S (kg/ha)	Mg (kg/ha)	Cu (kg/ha)	Zn (kg/ha)
Fallow plant	2.5	140	40	20	100	10	0	0	0
Replant	2.5	160	40	20	120	10	0	0	0
Ratoon	0	160	20	10	120	10	0	0	0

Tillage and water management:

It is difficult to obtain a good tilth on these soils and there is a restricted moisture range for effective tillage. Compaction can be reduced by adopting controlled traffic. Green cane trash blanketing, where practised, has greatly improved soil structure, tilth and soil porosity. Laser levelling is useful for improving surface drainage as these soils occur on gentle slopes. Irrigation on these soils is not widely practiced due to adequate rainfall. Readily available water is moderately low (40 – 60 mm).

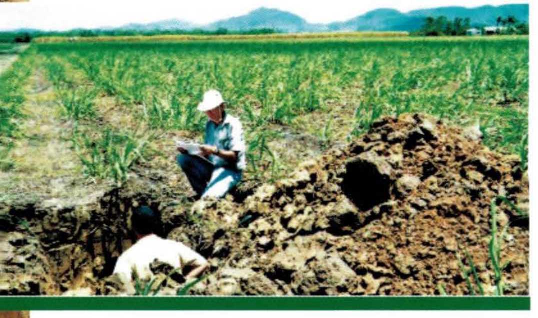
Environmental risk management:

Loss of nitrogen by denitrification is a risk due to intermittent water-logging. Strategies to reduce these losses include mound planting, placement of nitrogen fertiliser in the mound and split fertiliser applications.

Eton (Eo) (Grey duplex)

Occurrence: Eton soils occupy about 8% of the sugarcane area in the Proserpine district. Large expanses of these soils are found in the Up River and Gregory areas.

Formation: Eton soils are formed by floods depositing fine silts and clays. Most Eton soils are found some distance from the nearest creek or river and often occur on slightly elevated terraces. They probably flood at least once every 10 years.



Eton soil in the Gregory area

Eton soil profile

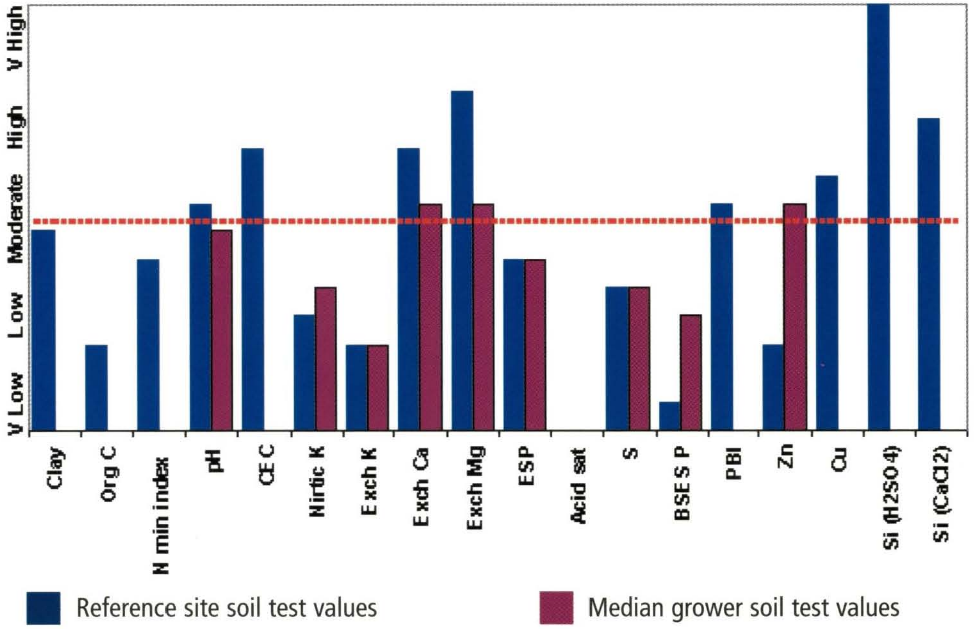
Field Appearance: Topsoils are grey sandy clay loams which often set hard when dry. Subsoils are grey with a high clay content and with brown and yellow mottles.

Similar soils: Sunnyside (Su), Sandiford (Sa) and **Narpi (Nr)** soils which occupy about 3%, 3% and 1% respectively of the sugarcane growing area.

Physical properties:
These soils are imperfectly drained with infrequent flooding. Subsoils are sodic and rooting depth can be less than 1m. Topsoils are hard-setting and prone to compaction.

Chemical properties:
These soils have a low to moderate fertility. The CEC and exchangeable cations increase rapidly with depth consistent with increases in clay content. The organic carbon content and N mineralisation index are low. Topsoils have a relatively high CEC which is dominated by Ca and Mg. Potassium reserves and exchangeable K are low. Topsoils have low P-sorbing capacities, but there is a relatively wide range in BSES P reflecting different fertiliser histories. About 65% of growers' samples are low in P. Sulphur values are moderately low. Exchangeable sodium percentage increases gradually with depth.

Reference site and grower soil sample median analysis data:



Nutrient management guidelines:

Crop situation	Lime (t/ha)	N (kg/ha)	P new land (kg/ha)	P old land (kg/ha)	K (kg/ha)	S (kg/ha)	Mg (kg/ha)	Cu (kg/ha)	Zn (kg/ha)
Fallow plant	0	140	60	20	120	15	0	0	0
Replant	0	160	60	20	120	15	0	0	0
Ratoon	0	160	30	20	120	15	0	0	0

Tillage and water management:

Compaction is an issue in these soils and can be reduced by adopting controlled traffic. Tillage is required to break up topsoil compaction. Green cane trash blanketing, where practised, has improved soil structure, tilth and soil porosity. Laser levelling is useful for improving surface drainage as these soils occur on gentle slopes. They are not generally suitable for furrow irrigation. Water application rates from overhead irrigation may need to be reduced as infiltration rates are generally slow. Readily available water is moderately low (40 – 60 mm).

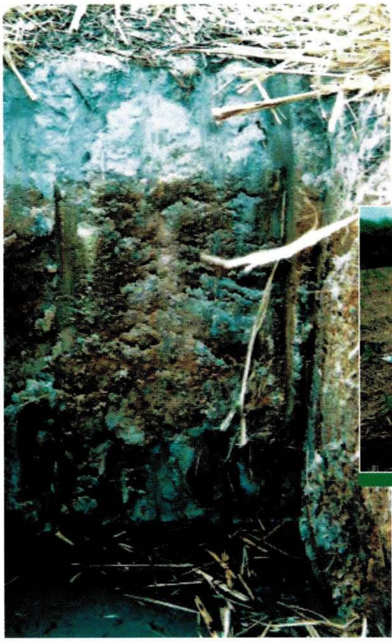
Environmental risk management:

Loss of nitrogen by denitrification is a risk due to flooding and restricted subsoil drainage. Split fertiliser applications are recommended to reduce these losses.

Koolachu (Ko) (Pale grey duplex)

Occurrence: Koolachu soils occupy about 4% of the sugarcane area in the Proserpine district. Large expanses are found in the Up River and Tailing Gully areas.

Formation: Koolachu soils are found on Tertiary sandstones. These areas form undulating plains and are elevated above the existing floodplain and do not readily flood.



Koolachu soil in the Up River area

Koolachu soil profile

Field Appearance: Topsoils are pale grey sandy loams with a pinkish tinge caused by large quartz grains (1 – 5 mm). Subsoils are light grey with bright orange and red mottles and have a light clay texture.

Similar soils: Tenmile (Tm) soils which occupy about 0.5% of the sugarcane growing area.

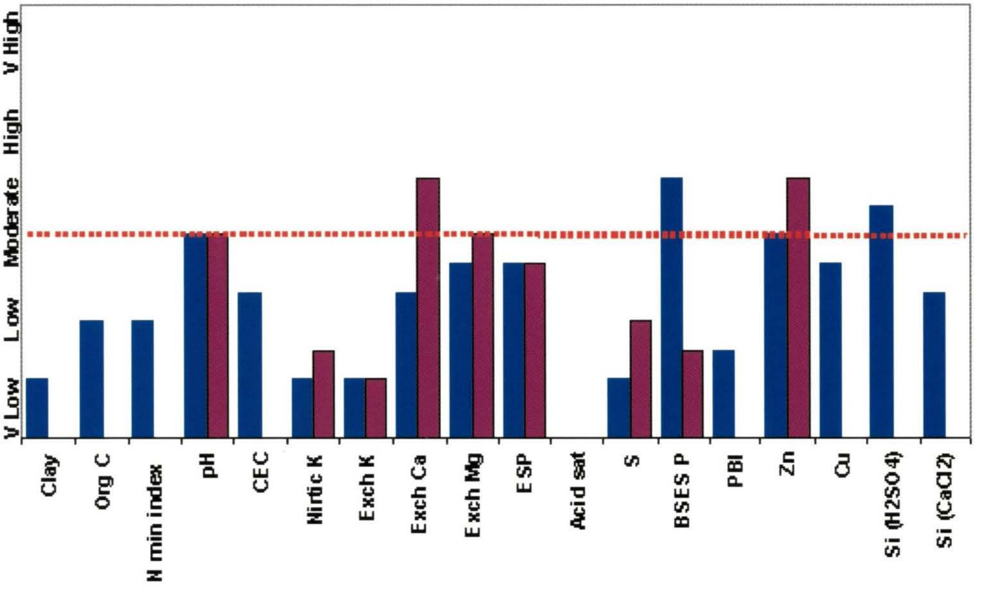
Physical properties:

These soils are hard setting and are massive or poorly structured. Due to their sodic properties these soils are dispersive and rooting depth is restricted to 0.3 – 0.6m.

Chemical properties:

These soils have a low fertility status. Topsoil CEC values are low but increase with depth. The organic carbon content, N mineralisation index, potassium reserves, exchangeable K and sulphur are all low. Topsoils have very low P-sorbing capacities. BSES P values are variable and reflect different P application histories, although about 75% of growers' samples are low. The exchangeable sodium percentage values indicate moderate sodicity which increases with depth. There is no evidence of widespread micro-nutrient deficiencies.

Reference site and grower soil sample median analysis data:



Nutrient management guidelines:

Crop situation	Lime (t/ha)	N (kg/ha)	P new land (kg/ha)	P old land (kg/ha)	K (kg/ha)	S (kg/ha)	Mg (kg/ha)	Cu (kg/ha)	Zn (kg/ha)
Fallow plant	0	130	40	30	100	10	0	0	0
Replant	0	150	40	30	120	10	0	0	0
Ratoon	0	150	20	10	120	10	0	0	0

Tillage and water management:

Minimum tillage is recommended on these hard setting sodic soils. They are prone to compaction but this can be alleviated with controlled traffic. Green cane trash blanketing will improve soil structure, tilth and soil porosity and will reduce erosion risk. Laser levelling is useful for improving surface drainage as these soils occur in gently sloping areas. They have low infiltration rates and are not suited to furrow irrigation. Overhead spray irrigation is recommended. Readily available water is moderate (45 – 75 mm).

Environmental risk management:

These soils, which occur on 1 to 3% slopes, are prone to erosion. Loss of nitrogen by denitrification is possible as these soils have restricted drainage and low infiltration rates. Risk of runoff from excess irrigation is likely. As the P-sorbing capacity is very low, leaching of phosphorus is possible when BSES P is very high.

Marian (Ma) (Brown duplex)

Occurrence: Marian soils occupy about 3% of the sugarcane area in the Proserpine district. This soil is found in the Up River and O'Connell River areas.

Formation: Marian soils occur on old levee systems associated with larger rivers. These relict levees experience major flood events every 20 to 50 years. They are formed from fine sands and silts deposited during these events.

Marian soil profile

Marian soil in the O'Connell River area

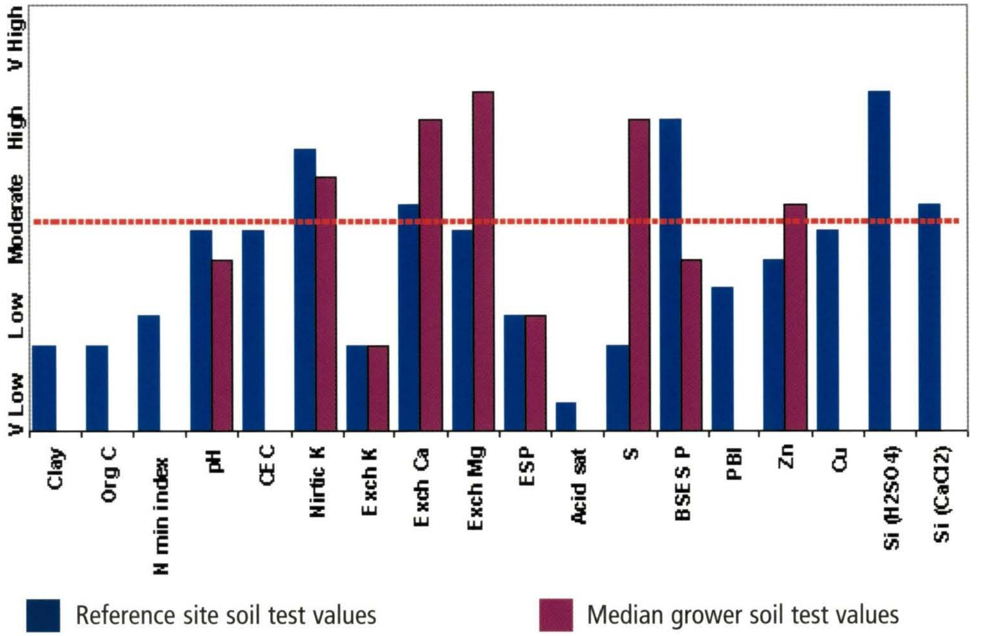
Field Appearance: Topsoils are greyish brown sandy clay loams and often set hard when dry. Subsoils are greyish brown with moderately high clay content. Brown and yellow mottles commonly occur.

Similar soils: Mirani (Mi) and **Conway (Co)** soils which both occupy about 1% of the sugarcane growing area.

Physical properties:
These soils are moderately well-drained. Rooting depth can be up to 1m. Topsoils are hard-setting and prone to compaction.

Chemical properties:
These soils are moderately fertile. Topsoil CEC values are moderate and increase with depth. This is consistent with increasing clay content. The organic carbon and N mineralisation index values are low. Although exchangeable K values are generally low, reserves of potassium are quite high. Topsoils have low P-sorbing capacities. A relatively wide range in BSES P reflects different fertiliser histories with around 45% of growers samples being low in BSES P. Sulphur values at the reference site are low, but are higher where growers have applied S routinely. There is no evidence of micronutrient deficiencies.

Reference site and grower soil sample median analysis data:



Nutrient management guidelines:

Crop situation	Lime (t/ha)	N (kg/ha)	P new land (kg/ha)	P old land (kg/ha)	K (kg/ha)	S (kg/ha)	Mg (kg/ha)	Cu (kg/ha)	Zn (kg/ha)
Fallow plant	2.5	140	40	20	80	0	0	0	0
Replant	2.5	160	40	20	100	0	0	0	0
Ratoon	0	160	20	0	100	0	0	0	0

Tillage and water management:

These soils are prone to hard setting and compaction but this can be alleviated with controlled traffic. The practice of green cane trash blanketing has improved soil structure, tilth and soil porosity. These soils have average to good drainage but laser levelling may be useful for improving surface drainage in some situations where the topography is flat. If flood irrigated, U-shaped furrows are most suitable with medium flow rates. Readily available water in the profile is moderately low (40 – 65 mm).

Environmental risk management:

Loss of nitrogen by denitrification is not usually a factor except when heavy rain or flooding occurs shortly after N application.

Proserpine (Po) (Sandy alluvial)

Occurrence: Proserpine soils occupy about 4% of the sugarcane area in the Proserpine district. They are found in small areas adjacent to the Proserpine and O'Connell Rivers.

Formation: Proserpine soils occur on channel benches and active levee systems associated with larger rivers. These young levee soils experience flooding frequently on the O'Connell River, but rarely on the Proserpine River as the flow is stabilised by the Peter Faust Dam. These soils were formed by the accumulation of fine and coarse sands from flood events.

Proserpine soil adjacent to the Proserpine River

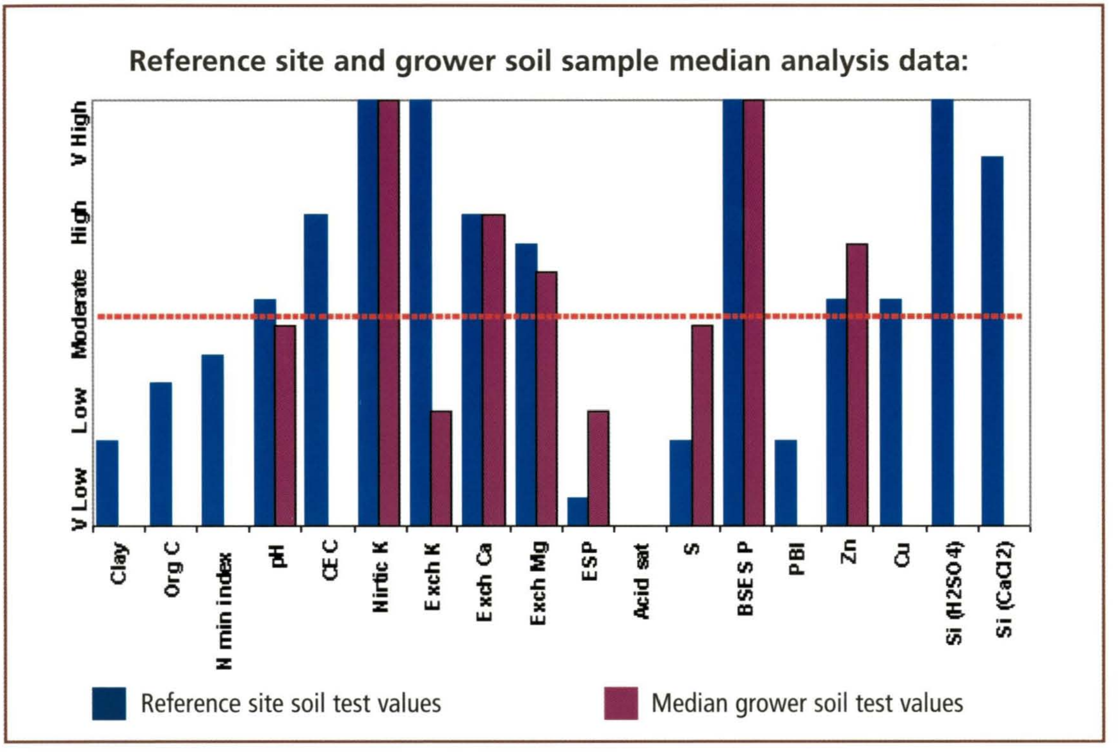
Proserpine soil profile

Field Appearance: Topsoils are greyish brown sandy loams which commonly form a surface crust when dry. Subsoils are greyish brown with a low clay content. The structure of the top and subsoil is very weak. Profiles are very well drained.

Similar soils: **Cameron (Cm)** soil which occupies about 3% of the sugarcane growing area.

Physical properties:
Although these soils are sometimes hard setting, these are easy to work. Drainage is good and rooting depth of >1 m is common.

Chemical properties:
These soils have a relatively high fertility status and are weakly acid. The CEC of both the top and subsoil are high and exchangeable cations remain constant with depth. The organic carbon and N mineralisation index are moderately low. Potassium reserves are very high, but exchangeable K values are variable due to past fertilisation practices. About 70% of growers' samples are low in exchangeable K. Topsoils have very low P-sorbing capacities and BSES P is generally high. Sulphur in the reference soil is low but the S status of the growers' samples varies markedly. There is no evidence of micro-nutrient deficiencies.



Nutrient management guidelines:

Crop situation	Lime (t/ha)	N (kg/ha)	P new land (kg/ha)	P old land (kg/ha)	K (kg/ha)	S (kg/ha)	Mg (kg/ha)	Cu (kg/ha)	Zn (kg/ha)
Fallow plant	0	130	40	0	80	5	0	0	0
Replant	0	150	40	0	100	5	0	0	0
Ratoon	0	150	20	0	100	5	0	0	0

Tillage and water management:

These soils are easily tilled. They have good drainage but are prone to flooding. They are suited to overhead irrigation. However if furrow irrigation is used, V-shaped furrows and high flow rates are recommended to suit the rapid infiltration rate. Readily available water is 70 – 80 mm.

Environmental risk management:

As frequent flooding and saturation of the soil profile occurs, loss of nitrogen by denitrification is possible and split applications of N are suggested. Leaching losses in sandy profiles will also be reduced with split applications. Phosphorus loss by leaching is a risk as soils have a very low P-sorbing capacity. This is of particular concern when BSES P values are high, which is common on these soils.

St Helens (St) (Loamy alluvial)

Occurrence: St Helens soils occupy about 5% of the sugarcane area in the Proserpine district. This soil is found in pockets adjacent to moderately sized creeks or small rivers mainly in the Kelsey Creek and Gregory River areas.

Formation: St Helens soils occur on creek flats, flood plains or young levees adjacent to creeks. These soils are formed on fine sands and silts deposited during floods.

St Helens soil profile

St Helens soil in the Kelsey Creek area

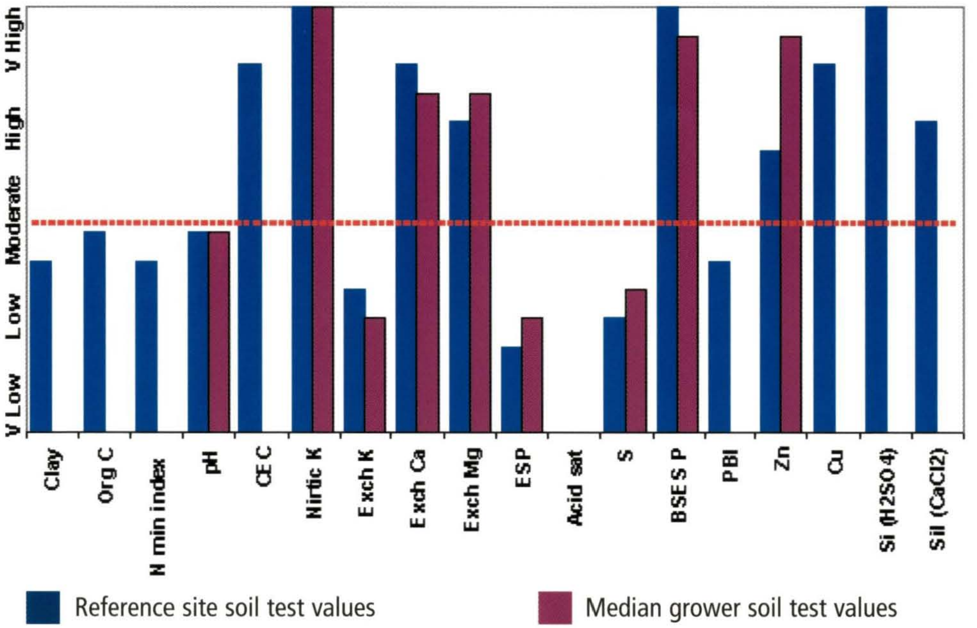
Field Appearance: Topsoils are greyish brown sandy clay loams which often set hard when dry. Subsoils are dark brown with moderate clay contents.

Similar soils: **Cameron (Cm)** soils which occupy 3% of the sugarcane growing area.

Physical properties:
They are usually hard setting and prone to compaction. Drainage is moderate to good and rooting depth of >1 m is common.

Chemical properties:
These soils have a moderately high fertility and are weakly acid. Topsoil CEC values are generally high and exchangeable cation concentrations are constant with depth. This reflects the similar clay content of the top and subsoils. The organic carbon content and N mineralisation index values are both moderately high. Potassium reserves are high but exchangeable K values are variable with about 75% of growers' samples being greater than 0.2 me% K. Topsoils have low P-sorbing capacities and 70% of growers' samples contain high levels of BSES P. Sulphur values are moderately low and micro-nutrients are well-supplied.

Reference site and grower soil sample median analysis data:



Nutrient management guidelines:

Crop situation	Lime (t/ha)	N (kg/ha)	P new land (kg/ha)	P old land (kg/ha)	K (kg/ha)	S (kg/ha)	Mg (kg/ha)	Cu (kg/ha)	Zn (kg/ha)
Fallow plant	0	120	60	0	80	10	0	0	0
Replant	0	140	60	0	100	10	0	0	0
Ratoon	0	140	30	0	100	10	0	0	0

Tillage and water management:

As these soils are prone to hard setting and compaction, green cane trash blanketing when practised, may improve soil structure, tilth and soil porosity. These soils are well drained but are prone to flooding. They are suited to furrow or overhead irrigation. Medium to high flow rates are appropriate in relation to furrow irrigation. Readily available water is moderately high (75 – 85 mm).

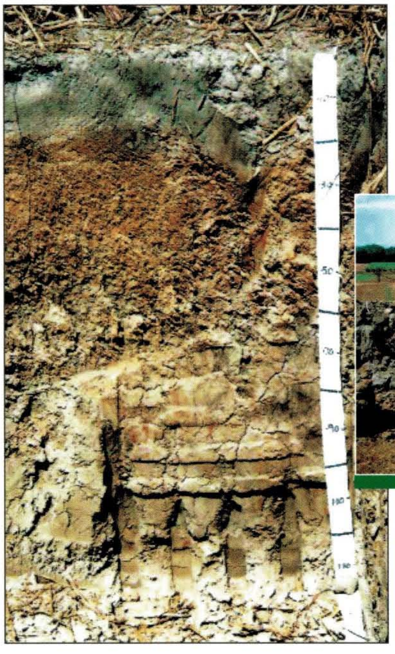
Environmental risk management:

Maintenance of soil cover is desirable as there is a risk of erosion with these soils. As frequent flooding occurs, loss of nitrogen by denitrification is possible and split applications of N are suggested.

Slater (Sk) (Grey duplex)

Occurrence: Slater soils occupy about 7% of the sugarcane area in the Proserpine district. This soil is found in the Up Rriver, Crystalbrook and Kelsey Creek areas.

Formation: Slater soils occur on old deeply weathered alluvium. Sandstone is usually found at depths below 1.5 m. Slater soils occur on very old floodplains which usually do not flood.



Slater soil profile

Slater soil in the Kelsey Creek area

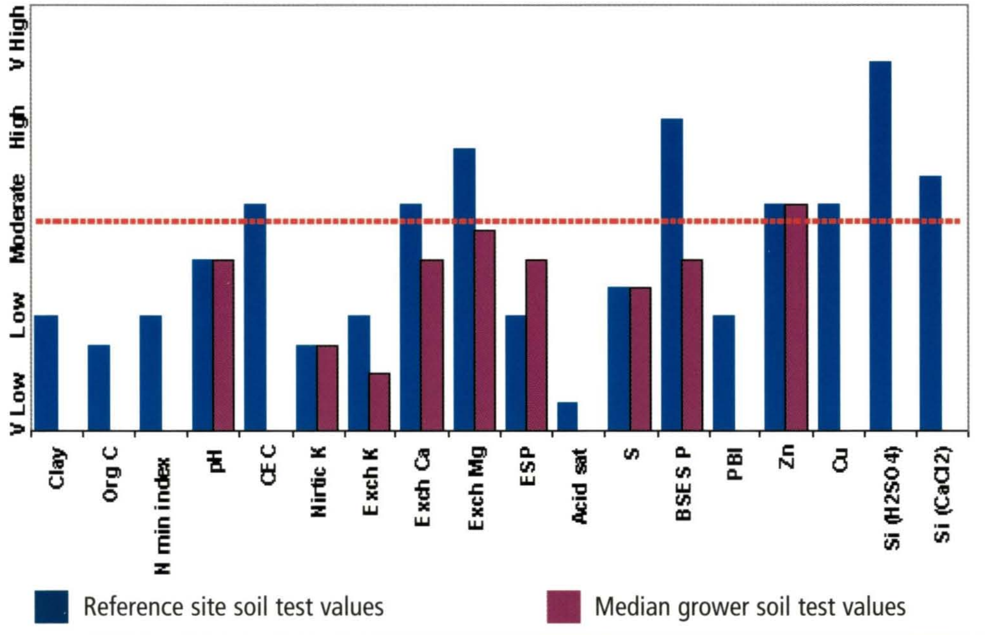
Field Appearance: Topsoils are pale grey sandy loams with poor structure. Subsoils are light grey with bright orange and red mottles, and light to medium clay texture.

Similar soils: Tailing (Ti) soils which occupy about 1% of the sugarcane growing area.

Physical properties:
They are hard setting with massive or poor structure. They are dispersive due to their sodic properties. Rooting depth is restricted to about 0.5 m. These soils are prone to erosion.

Chemical properties:
These soils have a low to moderate fertility. Their CEC and exchangeable cations increase with depth which is consistent with the increased clay content. Organic carbon and N mineralisation index are low. Potassium reserves and exchangeable K are low with 85% of growers' samples having less than 0.2 me% K. Topsoils have low P-sorbing capacities and BSES P values in the growers' samples reflect varying inputs of P fertiliser. Sulphur values are moderately low. The exchangeable sodium percentage values for the growers' samples indicate moderate sodicity which increases with depth.

Reference site and grower soil sample median analysis data:



Nutrient management guidelines:

Crop situation	Lime (t/ha)	N (kg/ha)	P new land (kg/ha)	P old land (kg/ha)	K (kg/ha)	S (kg/ha)	Mg (kg/ha)	Cu (kg/ha)	Zn (kg/ha)
Fallow plant	0	140	40	20	100	15	0	0	0
Replant	0	160	40	20	120	15	0	0	0
Ratoon	0	160	20	10	120	15	0	0	0

Tillage and water management:

Minimum tillage and controlled traffic are appropriate for these hard setting sodic soils which are also prone to compaction. Green cane trash blanketing will improve structure, tilth and soil porosity. Laser leveling is useful for improving surface drainage. These soils are imperfectly drained and generally not suited to furrow irrigation due to low infiltration rates. Overhead spray irrigation is recommended. Readily available water is low (30 – 45 mm).

Environmental risk management:

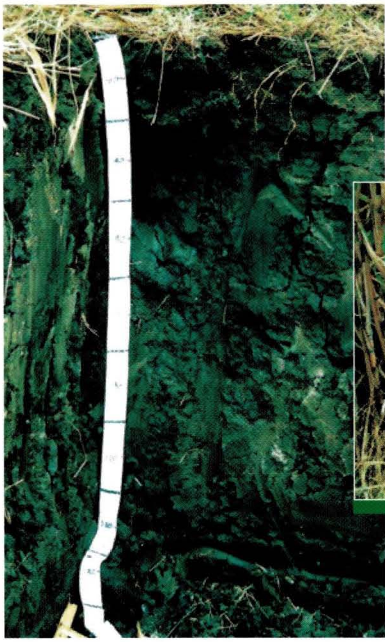
These soils are prone to erosion. Loss of nitrogen by denitrification is possible as the soils are imperfectly drained and have low infiltration rates. Strategies to reduce these losses include mound planting, placement of nitrogen fertiliser in the mound and split fertiliser applications.

Victoria Plains (Vc) (Black cracking clay)

Occurrence: Victoria Plains soils occupy about 3.5% of the sugarcane area in the Proserpine district. Large expanses are found in the Cannon Valley and Gregory areas.

Formation: Victoria Plains soils are formed by floods depositing fine silts and clays. Most of these soils are found some distance from the nearest creek or river and were probably once wetland areas. These soils flood at least once during most wet seasons.

Victoria Plains soil in the Cannon Valley area



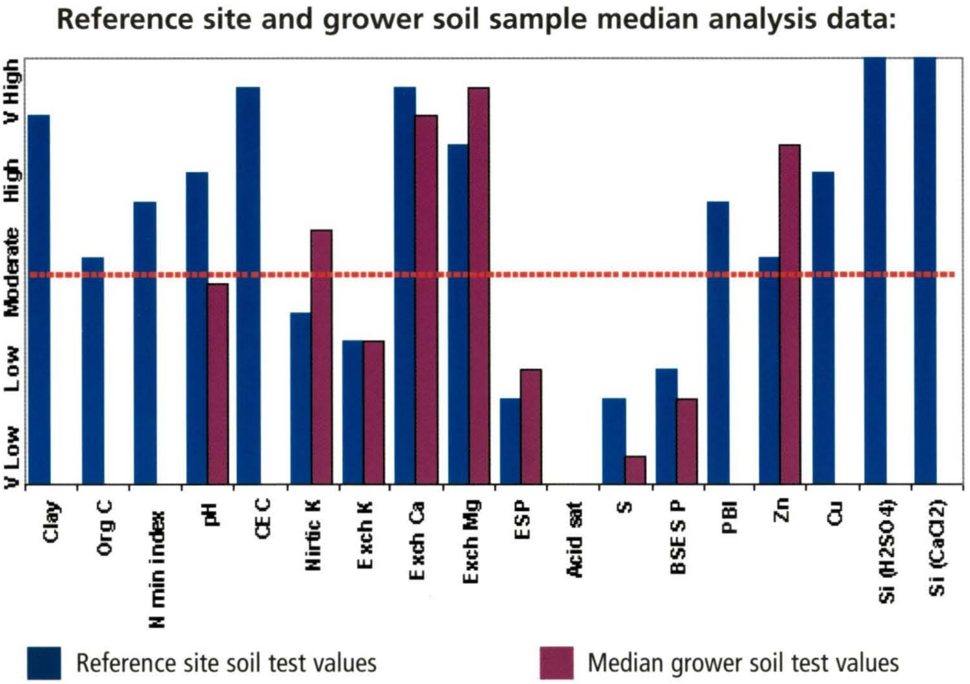
Victoria Plains soil profile

Field Appearance: Topsoils are black, cracking and self-mulching clays. Surface cracks can be as wide as 3 – 5 cm during the dry season. Subsoils are black to dark grey with high clay contents. Lime nodules often occur at depth.

Similar soils: Brightley (Bt) soil which occupies about 1% of the sugarcane growing area.

Physical properties:
These soils have a high clay content. The clays expand when wet causing the surface soil to move. In the dry season the clays shrink causing wide cracks to form. These soils have an excellent surface structure and are not hardsetting. Rooting depth is less than 1 m.

Chemical properties:
These soils have a high fertility status although BSES P and S are often low. In view of the high P sorption capacity of these soils, there is a need to apply P fertilisers in excess of crop removal rates. The CEC is high and exchangeable cations such as Ca and Mg increase with depth consistent with an increase in clay content. Organic carbon and N mineralisation index are moderately high. Exchangeable and non-exchangeable K reserves are moderate. Silicon is very high and micro nutrients are generally well supplied.



Nutrient management guidelines:

Crop situation	Lime (t/ha)	N (kg/ha)	P new land (kg/ha)	P old land (kg/ha)	K (kg/ha)	S (kg/ha)	Mg (kg/ha)	Cu (kg/ha)	Zn (kg/ha)
Fallow plant	0	110	80	40	100	15	0	0	0
Replant	0	110	80	40	100	15	0	0	0
Ratoon	0	130	40	30	100	15	0	0	0

Tillage and water management:

A small window of opportunity exists to till these soils successfully as they become unworkable when too wet or too dry. These soils are also poorly drained and are frequently flooded. Rooting depth can be less than 1 m due to the heavy clay texture and shallow water table. They are suitable for both overhead and furrow irrigation, but infiltration rates are low except when soils are dry. Readily available water is relatively high (60 – 85 mm).

Environmental risk management:

Loss of nitrogen by denitrification is a major risk due to frequent waterlogging. Strategies to reduce these losses include mound planting, placement of N fertiliser into the mound and split fertiliser applications.

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.

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.

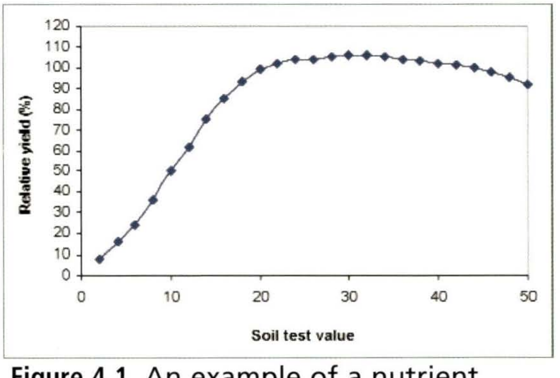


Figure 4.1. An example of a nutrient response curve for sugarcane.

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 district yield potential and the N mineralisation index, which depends on the organic carbon content (%) of the soil. Actual soil test values are interpreted by using the information provided in Chapter 2.

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

Loss of nitrogen by denitrification is a risk due to frequent waterlogging. Strategies to reduce these losses include mound planting, placement of N fertiliser into the mound and split fertiliser applications.

	Soil test report	
Trading Name: Bloggs & Bloggs	**Field Name:** Block 1	
Location: Proserpine	**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:** 130 tonnes/ha

		Low	<Optimum	Satisfactory	>Opt/ Norm	High	Excess/ Toxic
pH (1:5 water)	5.1	■					
Electrical Conductivity dS/m	0.02			■			
Organic C (%)	0.7	■					
Sulphate sulphur (MCP) mg/kg	12		■				
Phosphorus (BSES) mg/kg	25		■				
Potassium (Nitric) me%	1.52					■	
Potassium (Amm. Acetate) me%	0.14	■					
Calcium (Amm. Acetate) me%	1.11		■				
Magnesium (Amm.Acetate) me%	0.52				■		
Aluminium (KCl) me%	1.68					■	
Sodium (Amm. Acetate) me%	0.07	■					
Copper (DTPA) mg/kg	0.6			■			
Zinc (DTPA) mg/kg	0.4			■			
Zinc (HCl) mg/kg	0.7			■			
Manganese (DTPA) mg/kg	105					■	
Iron (DTPA) mg/kg	54				■		
Silicon (BSES) mg/kg	120				■		
Cation Exch Capacity me%	3.52		■				
Aluminium saturation %	47.9					■	
Sodium % of cations (ESP)	1.86	■					
Colour (Munsell)	Grey Brown						
Texture	Sandy Clay Loam						

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

Appropriate fertiliser inputs for this soil test report are calculated using the guidelines in Chapter 2, as demonstrated below:

Nitrogen

N requirement is **160 kg N/ha** because the N mineralisation index is LOW due to an Org C (%) value of 0.7%. 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 **140 kg N/ha.**

Phosphorus

P requirement for plant cane is **20 kg P/ha** because the block has been previously cropped to sugarcane (OLD LAND), the BSES P value is 25 mg/kg and the P sorption class is MODERATE (due to a texture described as sandy clay loam ie. a moderate clay content (24 – 36% clay) and an organic C (%) value of 0.7%). Maintenance dressings of P at a rate of **20 kg P/ha** are also required in subsequent ratoon crops in this case. As clay content is not normally reported in soil tests it is reasonable to use an approximate clay content determined from the ECEC (Table 2.4) or using the 'soil texturing' method described in Appendix 1.

Potassium

K requirement is **100 kg K/ha** because the Nitric K value is greater than 0.7 me%, the texture is described as sandy clay loam (loam) and an exchangeable K value of 0.14 me%. **100 kg K/ha** is needed for each ratoon crop.

Sulphur

S requirement is **10 kg S/ha** for the plant and all ratoon crops because the soil sulphur value is 12 mg/kg and the N mineralisation index is known to be LOW (as described above).

Magnesium

No Mg is required because the Mg soil test value is 0.52 me% which indicates relatively high reserves.

Copper and zinc

Although leaf analysis is the preferred means of determining micronutrient requirements, the soil tests indicate that neither copper nor zinc are required as the soil tests are above the critical values.

Silicon

No silicon is required as the soil test value (120 mg/kg) is above the value (70 mg/kg) below which a response is likely.

Lime

Lime requirement is 2.5 t/ha because the soil pH(water) value is below 5.5 and the cation exchange capacity is 3.52 me% (which is a medium CEC).

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)	Lime (t/ha) (prior to planting)
Replant cane	160	20	100	10	2.5
Ratoon crops	160	0	100	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		3 mg/kg
Zn		13 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

BSES Sugarcane for the future

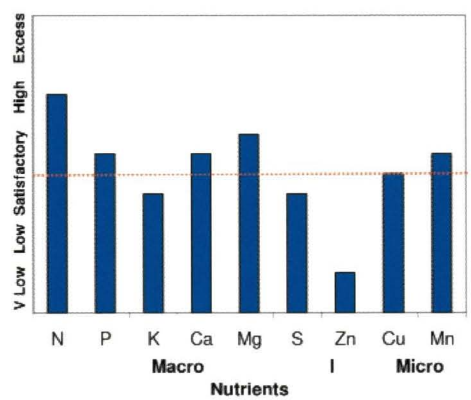
	Bloggs, J	
Address	**Kelsey Creek**	
	Proserpine	**4800**
Telephone		
Sample No:	**5001**	
Block	**E6**	
Sampling date	**16-Jan-04** Age	**6** months
Crop	**1R**	
Variety	**Q138**	
Mill	Proserpine	

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** %

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.

Leaf nutrient status



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

Figure 4.3. Example of 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.

Integrated nutrient management

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

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

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

CHAPTER 5

Concluding remarks

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

Our new philosophy focuses on the management of different soils to enhance their ability to store and supply a wide range of nutrients to the crop. It emphasises the importance of 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:

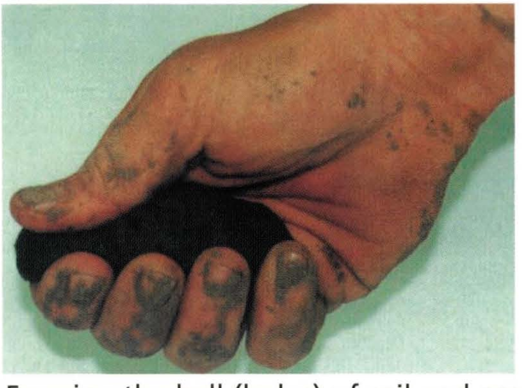
- Lime is recommended for the amelioration of soil acidity even though many soils are well supplied with calcium.
- Our nutrient management guidelines take into account the release of N, P and S in the soil through the mineralisation of soil organic matter. Our N guidelines in particular are slightly lower than current recommendations. This is particularly important given current concerns regarding elevated levels of nitrate in the waters of the Great Barrier Reef lagoon.
- We recognise that soils differ in their capacity to sorb added P fertiliser and render it less available to sugarcane crops. We therefore interpret the standard BSES P test somewhat differently for different soils.
- Our K guidelines are broadly similar to existing 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 Proserpine 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 Sugar Services Proserpine and the BSES soil and leaf analysis 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

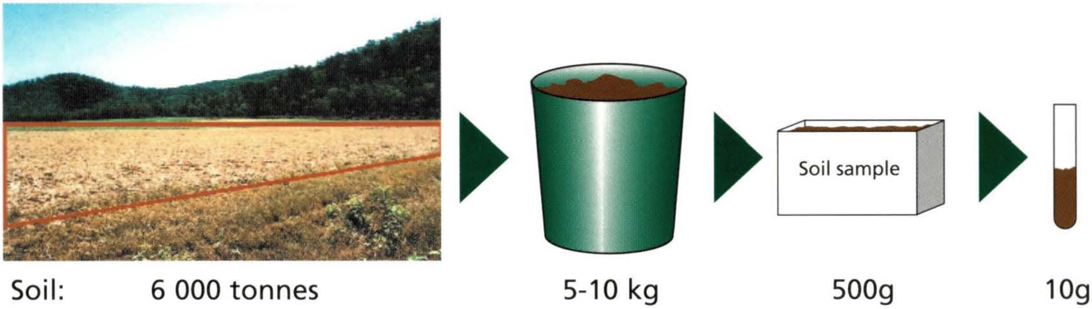
Simplified guide to determining soil texture.

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 and greasy feel, with coherence, but no obvious sandiness or silkiness.	25	**Loam**	10 - 24
Smooth, silky feel, with distinct coherence	25	**Silt loam**	10 - 24
Sandy feel but with distinct coherence	25-40	**Sandy clay loam**	20 - 30
Smooth feel with strong coherence and no obvious sand grains	40-50	**Clay loam**	25 - 40
Smooth, silky feel with distinct coherence	40-50	**Silty clay loam**	25 - 40
Easily moulded with sandy feel	50-75	**Sandy clay**	25 - 50
Easily moulded with smooth and silky feel	50-75	**Light clay / silty clay**	35 - 45
Easily moulded (like plasticine), smooth feel, but with resistance to shearing.	>75	**Medium / heavy clay**	> 45

Appendix 2

How to take a soil sample

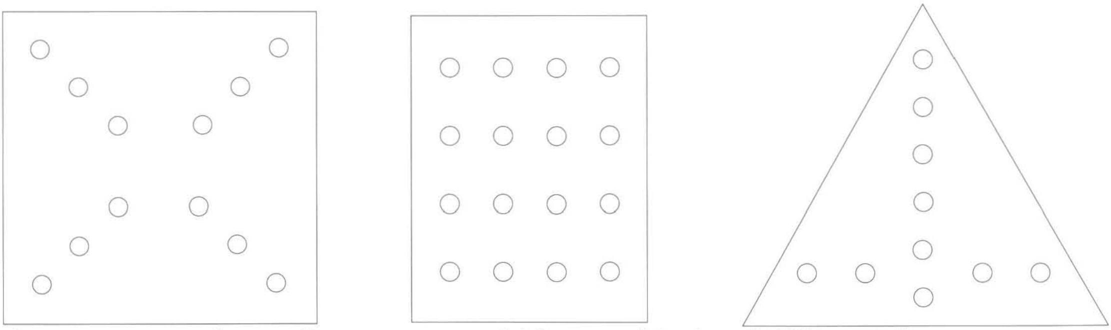
Soil tests in the laboratory are carried out on a 10 g sample which is taken from about 500 g of soil submitted to the laboratory. Usually this 500 g sample is a sub-sample of about 10 kg of soil which ideally should be sampled from a block of cane (average 2 hectare area) which contains about 6 000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



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

Soil sampling procedure

- Determine the area that is to be sampled. Ensure that the area (or block) being sampled does not exceed 2 or 3 hectares and that it is relatively uniform in soil type. In large blocks consider taking multiple samples and if a block consists of more than one distinct soil type, sample each separately. Avoid 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.

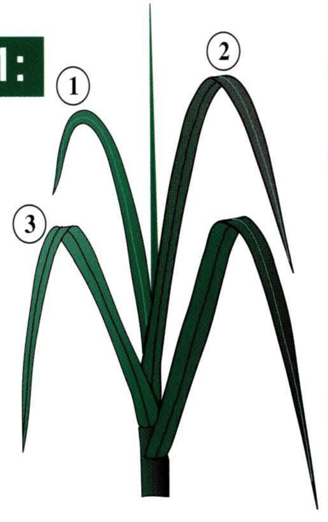
- Whilst there is some debate as to where soil samples should be taken in relation to the cane row or inter-row, we suggest that all samples be taken from the shoulder of the cane row, approximately mid way between the centre of the cane row and the centre of the inter-row. By following this rule you 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 Sugar Services Proserpine.
- 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

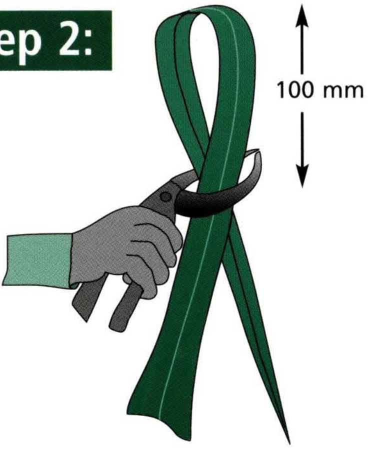
How to take a leaf sample

Step 1:

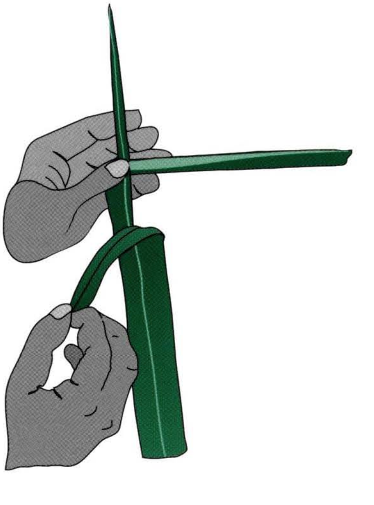


- Select leaves from stalks of average height.
- Sample the third leaf from the top of the stalk (as shown on the diagram). Counting from the top of the plant, the first leaf is the one that is more than half-unrolled. The third leaf usually corresponds to the top visible dewlap.
- Collect 30 - 40 leaves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

Step 2:



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



- Strip out & discard the midrib from each 200-300mm section.

Step 3:

- Bundle the leaf strips together and attach a completed BSES Leaf Analysis label (as shown opposite).

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

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 your local Extension Officer, Sugar Services Proserpine or BSES Bundaberg (4132 5200).

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.

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.) (2000). Manual of Canegrowing, BSES, Brisbane pp153-193.

Hardy, S (2003). Soils and land suitability of the Whitsunday Coast area. Whitsunday Shire Council, Proserpine.

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

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

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

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

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., Schroeder, B.L., (2004). Potassium; A critical role in sugarcane production particularly in drought conditions. Proc. Aust. Soc. Sugar Cane Technol., 21: CD-ROM.

Wood, A.W., Schroeder, B.L. and Stewart, R.L. (2003). The development of site specific nutrient management guidelines for sustainable sugarcane production. 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. Soil reference booklet for the Herbert district.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.

BSES

Sugarcane for the future