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South Pacific Agricultural Chemistry Laboratory Network (SPACNET)

Guide To Interpretation Of Agricultural Sample Analysis Results

SOIL, PLANT, & IRRIGATION WATER

Prepared by B.K. Daly and V. Manu

Landcare Research NZ Limited
June 2003

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SOIL, PLANT, & IRRIGATION WATER

Prepared by Brian K Daly* and Viliami Manu#

* Landcare Research Ltd
Private Bag 11052
Palmerston North
New Zealand

\# Research and Extension Division
Ministry of Agriculture & Forestry
P O Box 14, Nuku'alofa
Kingdom of Tonga

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PREFACE

In 1993, following the production of a new methods of analysis manual at the Fiji Agricultural Chemistry Laboratory (FACL), the manual "Guide to Interpretation of Agricultural Sample Analysis Results: Soil, Plant, Animal Feed, Irrigation Water and Others" (Daly & Wainiqolo, 1993) was produced. This was in response to a demand from Agricultural Extension Officers and others for help in interpreting analytical data from the laboratory. The collection of data was also intended to be an aid to the laboratory analyst in a quality assurance role in deciding if analysis results are within expected ranges. The manual, which brought together information from a number of sources, proved to be very popular and more than 200 were produced for use in Fiji.

At a SPACNET laboratory managers' meeting held at FACL, Koronivia in June 2002, it was decided that an updated version of the manual would be useful in other Pacific Island countries. This document is the result of that update.

It is not expected that this manual will be used directly to make fertiliser recommendations from soil analysis results. Rather it can be used to estimate the soil fertility from which a decision on whether or not fertiliser is needed can be made. Following this at the simplest level where the only information available is the soil fertility assessment, the fertiliser strategy can be worked out by modifying a standard recommendation based on the soil fertility assessment. In contrast where information such as previous yields, fertiliser additions and soil fertility reports are available in the farmer's file held by the extension officer, the strategy can be derived by amending what was added last year after considering such factors as increasing or declining yield and soil fertility. Thus in this way the 'ideal' fertiliser strategy for a particular soil and crop combination can be approached by 'fine-tuning'.

For plant analysis results it is not intended that this manual replace extensive and comprehensive works such as those of Reuter & Robinson (1986 & 1995), but serves as an alternative for the many rural extension officers and others who do not have access to these excellent books. In addition it should serve as a compact summary and collection of data with most relevance to Pacific Island Agriculture.

Brian K. Daly
SPACNET Co-ordinator

INTRODUCTION

The main soil resources of the Pacific countries were formed from either coral soils for the low island atolls (Rarotonga, Tuvalu, Tonga, Kiribati, etc.) or volcanic ash soil of the raised higher islands (Papua New Guinea, Solomon Is, Vanuatu, Fiji, Tonga, Samoa, etc.). Coral soils are usually less fertile with low organic matter giving rise to plant macronutrient deficiencies and high pH resulting in micronutrient deficiencies (Ashgar *et al* 1988). The volcanic soils are relatively more fertile except for weak soil aggregates, due to high clay content, and high phosphorous fixing capabilities due to the presence of short-range order aluminium and iron minerals such as allophane (Trangmar, 1992). Therefore, with intensive cropping and increasing mechanisation of land preparation, soil structure deterioration and macronutrient deficiencies will occur in these volcanic soils (Widdowson, 1977; Manu, 2000).

The trend of the crop production of the South Pacific Island countries during the last three decades has shifted to increased production of cash crops such as coffee, cocoa, copra, kava, vanilla, papaya, squash, sugar cane, oil palm, bananas, ginger, etc. principally for overseas markets. Recently, the export of local root crops such as taro, cassava and yam has also increased significantly. This trend has been accompanied with increased use of imported mineral fertiliser (FADINAP, 1999). A further factor in increased fertiliser use is in the production of subsistence food crops where as a result of decreasing soil fertility or farming of marginal lands the potential of increasing crop yield with mineral fertilisers has become economically viable (Craswell, 1989; Bradbury & Holloway, 1988; O'Sullivan *et al* 1995; Halavatau *et al* 1998).

The potential pollution problems caused by excessive fertiliser use affecting water resources including coastal marine life is a concern. Therefore the need for economical and environmentally sound use of fertiliser is of critical importance to the current and future use of the agricultural resource base of South Pacific countries. The process of soil and plant tissue analysis and subsequently the interpretation of this and other information into sensible fertiliser recommendations for farmers play a key role.

SOIL ANALYSIS & INTERPRETATION

Plant roots normally absorb from the soil, as dissolved ions in soil solution, 13 of the 16 essential nutrients for plant growth (Table 1). Therefore, favorable soil conditions (soil water, pH, temperature, structure, organisms, etc.) must maintain this soil solution in order to allow maximum nutrients to dissolve from the soils for absorption by plant roots.

Table 1. The essential nutrients, form and uptake pathway for plant growth

Nutrient	Main Form absorb by plants	Main Uptake Pathway
Carbon	CO_2	Gas molecules via leaves
Oxygen	CO_2 H_2O	Gas molecules via leaves Liquid via roots
Hydrogen	H_2O	Liquids via roots
Nitrogen	NO_3^- and NH_4^+	Ions in soil solution via roots

Nutrient	Main Form absorb by plants	Main Uptake Pathway
Phosphorus	$H_2PO_4^-$ and HPO_4^{2-}	Ions in soil solution via roots
Potassium	K^+	Ions in soil solution via roots
Calcium	Ca^{2+}	Ions in soil solution via roots
Sulfur	SO_4^{2-}	Ions in soil solution via roots
Magnesium	Mg^{2+}	Ions in soil solution via roots
Iron	Fe^{2+}, Fe^{3+}	Ions in soil solution via roots
Zinc	Zn^{2+}	Ions in soil solution via roots
Manganese	Mn^{2+}	Ions in soil solution via roots
Copper	Cu^{2+}	Ions in soil solution via roots
Boron	$H_2BO_3^-$	Ions in soil solution via roots
Molybdenum	MoO_4^{2-}	Ions in soil solution via roots
Chlorine	Cl^-	Ions in soil solution via roots

Source: IFA, 1982

The major purpose of the chemical analysis of the soil reported here is to evaluate the available amount of nutrients that plant roots may take up under favorable condition for root growth and root activity (Marschner, 1990). Therefore, the total nutrient content of the soil is rarely used. Also, if the soil condition is unfavorable such as dryness, low pH, cold temperature, poor structure, etc. the roots will not be able to fully extract this available amount.

The plant-available amount of nutrients in soil is determined in laboratories by extracting soils with specific solutions that attempt to simulate the general plant root extractions of nutrients from soils. Two examples are the $NH_4^+CH_3COO^-$ extractant for exchangeable cations and the $NaHCO_3$ extractant for available Olsen-P. These extractants were determined from experiments where the amount of nutrients extracted from the soil has the best correlation with the amount of growth of the plant in the experiment. Therefore, these extractants may be valid only to related soil types and the same indicator plant used in the experiments and care must be taken in extending the interpretation to other soil and plant combinations.

Soil analysis is most useful to annual crops in predicting yields from analysis of the topsoil since the short-term fluctuation of nutrient levels in plant tissue is large as compared to perennial crops (Marschner, 1990).

From these relationships, ranges of soil nutrients are categorised into ratings as low, medium or high according to the crop yield response of the experiments. A rating of "very high" soil nutrient levels may indicate that the amount of nutrients available in the soil is more than enough to supply a good plant growth upon good soil conditions. On the other hand, a rating of "very low" nutrient level indicates that the amount of that nutrient in the soil is too low and the crops may benefits from addition of fertiliser.

Most of the ratings given for soil analyses are from Blakemore *et al* (1987) and were derived to indicate the range of values found in New Zealand soils. Some of the ratings (those for pH, exchangeable Ca and K) have been modified to better describe Fiji soils so that the critical or deficiency level (where known) corresponds with the low - medium boundary. Ratings for modified Truog-available phosphorus, DTPA extractable trace elements, and extractable boron are from other sources and are also given as a guide only as the type of plant grown and other soil properties can have a significant effect on the deficiency level.

PLANT ANALYSIS & INTERPRETATION

In the absence of one of the 13 essential elements supplied by the soil, the plant will be unable to complete vegetative and reproductive growth. The chemical analysis of plant tissue shows only the actual level of nutrients in that particular part of the plant that was sampled and in that particular time of growth (Marschner, 1990). Therefore it is most important to know that there are differences of nutrient levels in different parts of the plant and in combination with different stages of growth, and also may differ with cultivars, species or genus. Generally, C4 plants have a lower content of nitrogen than C3 plants (Marchner, 1990), dicotyledon has higher Ca and B content than monocotyledon, and Leguminosae has higher S content than Gramineae (Reuter & Robinson, 1995). In addition are the different abilities of different nutrients to move from older leaves of plants to young growing leaf buds when the external supply from the soil via roots is insufficient. That is, generally, N, P, K, Mg move easily; S, Zn, Cu, Mo move with intermediate ease; Ca, Mn, Fe and B cannot move (Reuter & Robinson, 1995). This means that the older leaves are most sensitive to deficiency of easily moved nutrients, while on the other extreme, deficiency of Ca and B is best detected on the younger leaves or fruits. However, it is generally agreed that the first matured leaf of a specific stage of growth is the best indicator plant part to be sampled for nutrient levels of plants (Reuter & Robinson, 1995).

The interpretation of the chemical analysis of plant tissue is based on known relationships between crop yield and nutrient concentrations in plant tissue. These were usually obtained from screen-house solution or pot experiments or field experiments and the relationships are limited by the crop species and environment of the experiment and may best serve as a guide when applied to the farmer's real world of varying and unpredictable conditions. Mineral nutrient levels are grouped into ranges. If nutrient levels are in the optimum range, then there is a high statistical probability that these nutrients are not limiting to crop growth or yield.

In the traditional agriculture of the Pacific with very little fertiliser application, plant analysis is important in diagnosing mineral disorders limiting plant growth and yield. In annual crops, chemical analysis of plant tissue is best used in diagnosing nutritional status of plants. The chemical analysis of plant tissue of perennial fruits and forest plants reflect accurately the long-term nutritional status due to the relatively smaller seasonal fluctuations of mineral nutrient in plant tissue. Subsequently, soil analysis plays a minor role of providing the overall level of potentially available nutrients (Marschner, 1990)

Critical levels for deficiency and toxicity levels are determined as nutrient levels 5 to 10% below maximum yield from growth experiments under controlled environmental condition (Ulrich & Hills, 1973).

Ratings for coconut are from Weir and Creswell (1995), taro from O'Sullivan *et al* (1995), sweet potato from O'Sullivan *et al* (1997), cassava from Howeler (1995), yam and cocoa from IFA (1980), maize from Cornforth and Sinclair (1984), while all others are derived from Reuter and Robinson (1986 & 1995). Information is given here only for the plants likely to be used in the agriculture of the South Pacific Islands and for one stage of growth. The last reference given above contains data on many more plants and also data on other growth stages for many plants.

WATER ANALYSIS

The ratings given for water analyses are related to the suitability of the water for irrigation and are derived from Richards (1969). The salinity hazard (Electrical Conductivity) rating gives an estimate of the potential of the water to cause plant-damaging accumulation of salts in the soil. The sodium hazard rating uses Sodium Absorption Ratio (SAR) to estimate the potential for the water to increase levels of exchangeable sodium on the exchange complex of the soil. In medium and fine textured soils this can lead to a breakdown of the soil structure and loss of permeability. The total level of salts in the water affects the SAR at which damage to the soil structure would be expected to occur. As the salt level (EC) rises, the SAR at which problems will be experienced is lowered.

SOIL ANALYSIS RESULTS

pH

Rating	pH	Description
very high	> 9.0	extremely alkaline
	8.5 - 9.0	strongly alkaline
	7.9 - 8.4	moderately alkaline
high	7.3 - 7.8	slightly alkaline
	6.7 - 7.2	near neutral
medium	6.1 - 6.6	slightly acid
	5.6 - 6.0	moderately acid
low	4.4 - 5.5	strongly acid
very low	< 4.4	extremely acid

The pH of a soil is, effectively a measure of the acid groups on the exchange complex of clays and organic matter and the extent to which they are neutralised with basic cations, such as calcium and magnesium. Most soils are in the pH range 5.0 - 6.5, with values greater than 7 occurring in soils derived from limestone or coral, and values less than 5 occurring in strongly leached soils under high rainfall or in soils with oxidizable sulfides (such as reclaimed mangrove soils).

pH is an important property of a soil in that it has a significant effect on the availability of many nutrients, with high or low pH causing reduced availability, particularly for micro-nutrients. Also controlled by pH is the occurrence of exchangeable aluminium, which is toxic to most plants and can severely restrict root development. At pH levels above 5.6 free aluminium ions are precipitated as hydroxides, but as the pH falls below 5.6 increasing levels of exchangeable aluminium can occur.

Lime is the most common soil amendment used to correct excess acidity, and it is usual to attempt to raise the pH to near 7. There are dangers in raising the pH to 7 in the soils of the tropics in that nutrient deficiencies can be induced (Kamprath, 1980), particularly for phosphorus and the micronutrients boron, zinc and manganese. A better approach is to aim to neutralize the exchangeable aluminium that is the main problem in most acid soils. In practical terms this only requires raising the pH to above about 5.6.

ELECTRICAL CONDUCTIVITY (EC) (1:5 SOIL:WATER EXTRACT)

Rating	very low	low	medium	high	very high
mS/cm	< 0.15	0.15 - 0.4	0.4 - 0.8	0.8 - 2	> 2

The electrical conductivity that is obtained when a soil sample is suspended in water results from the dissolution of soluble salts and thus is a measure of salinity. Most soils have negligible amounts of soluble salts and give very low EC values. Soluble salts occur in soils due to several causes including the influence of saline groundwater, accumulation of weathering products in arid climates, excess fertiliser additions, or the influence of seawater or seawater affected groundwater (probably the only reason in the humid tropics).

Excess salt in a soil can cause loss of soil structure in fine textured soils and inhibits or prevents plant growth, except for a few salt resistant species such as halophytic grasses and shrubs, and mangroves. Damage to sensitive plants, particularly when germinating, will occur when the conductivity is above about 0.4 mS/cm, although damage may occur to plants in sandy soils at lower levels.

Saline soils are defined as those soils that contain sufficient salt to impair the growth of crop plants. The most commonly used criteria for identifying saline soils is EC > 4 mS/cm in a saturation extract. This is equivalent to about 0.8 mS/cm in the 1:5 extraction method results are given for here.

The approximate percentage of total soluble salts can be estimated by multiplying the EC (mS/cm) by 0.35 and the approximate milliequivalent / 100 g soluble salts by multiplying by 5.

AVAILABLE PHOSPHORUS

Rating	Olsen-P (mg/kg)	Mod. Truog-P * (mg/kg)	Bray-2 P (mg/kg)
very high	> 50		
high	30 - 50	> 60	> 40
medium	20 - 30	20 - 60	20 - 40
low	10 - 20	10 - 20	10 - 20
very low	< 10	< 10	< 10

* Ratings for modified Truog phosphorus from FSC, Lautoka (J Gawander, pers comm).

Only a small proportion of the total phosphorus in soils is immediately available to plants. The major part of the phosphorus is present in potentially available or permanently unavailable forms, with the permanently unavailable pool being the largest in the strongly weathered soils of the tropics. The potentially available forms include organic phosphorus, primary phosphate minerals (which may have been added as phosphate rock), and other un-dissolved fertiliser. Permanently unavailable forms include phosphorus complexed or occluded with secondary iron oxide minerals that are present in large amounts in the oxisol soils found in the drier regions of the tropics. Phosphorus is also complexed and rendered unavailable by some alumino-silicate clays such as the clay mineral allophane that is found in young soils from volcanic ash in wetter climates.

Dabin (1980) gave the range of different forms of phosphorus in weathered tropical soils as follows:

- Active forms (available and inorganic potentially available) — 10-20% of total
- Organic forms — 10-30% of total
- Occluded and residual forms — 50-80% of total

The reactions that fix or occlude phosphorus can occur rapidly enough to make phosphorus added as fertiliser unavailable. Therefore extra phosphate additions and differing ways of applying the fertiliser (side-banding and split dressings) are needed for the oxisol and allophanic soils. The fixation of added phosphorus is also pH dependant, with acid soils having the largest fixation and hence the lowest availability of added phosphorus.

The differing phosphorus extractant methods used attempt to estimate the plant-available fraction. Olsen-P has been shown to give good correlations with plant uptake in many countries and is one of the most widely used methods. Bray-2 available P has been found to give better correlations with tree growth on acid soils in New Zealand, while the modified Truog method is used by FSC for sugar cane soils.

For most crops the adequacy level for phosphorus supply is represented by the medium range in the above table. Soils with high levels of available phosphorus are very unlikely to show plant growth responses to added phosphorus, while soils with low levels are likely to give responses.

ORGANIC MATTER (CARBON AND NITROGEN)

Rating	**Carbon** (%)	**Nitrogen** (%)
very high	> 20	> 1.0
high	10 - 20	0.6 - 1.0
medium	4 - 10	0.3 - 0.6
low	2 - 4	0.1 - 0.3
very low	< 2	< 0.1

Organic matter is important in soils as it maintains soil structure and water holding capacity. Also mineralisation of organic matter is an important source of nutrients, particularly in tropical soils under conditions of low-input agriculture where it is the major source of plant nutrients. For this low input style of agriculture to be sustainable the level of organic matter must be maintained. The quantity of organic matter present and its state of decomposition depends on a balance between the addition of raw organic matter, as plant or animal tissue, and its breakdown or mineralisation by organisms. Generally when land use is changed from a continuous vegetation cover to cropping, organic matter will decrease until a new, lower equilibrium is reached. If organic additions are increased by a change in land use or by mulching, organic matter will increase to a higher equilibrium level.

The ratings for carbon and nitrogen give an indication of the total organic matter in soil, while the ratio between the two indicates the state of decomposition. Well decomposed, relatively stable organic matter has a C/N ratio of about 10 - 12, while recently added organic matter or organic matter in peats, where decomposition is retarded by water-logging, has C/N ratios of 20 or more.

Total organic matter can be estimated from carbon figures by multiplying by 1.72. Except for soils with very low carbon contents, this value usually correlates well with an alternative organic matter estimate that is from the weight loss obtained after igniting the soil at 500°C (loss on ignition).

Unfortunately, total nitrogen gives no indication of the availability of nitrogen to plants, with the exception that soils with very low total nitrogen will have low available nitrogen. Although there are some methods available for estimating available nitrogen, they have not been well calibrated with plant up-take for a variety of soils and plants. It is preferable therefore to use foliar analysis to check for adequacy of nitrogen nutrition.

CATION EXCHANGE PROPERTIES

Rating	Cation Exchange Capacity	Total Exch. Bases	Base Saturation	Ca	Exchangeable Mg	K	Na
	---me/100g---		%	---------me/100g-------			
very high	> 40	> 30	80 - 100	> 20	> 7	> 1.2	> 2
high	25 - 40	15 - 30	60 - 80	10 - 20	3 - 7	0.6 - 1.2	0.7 - 2
medium	15 - 25	4 - 15	30 - 60	2 - 10	1 - 3	0.3 - 0.6	0.3 - 0.7
low	10 - 15	2 - 4	20 - 30	1 - 2	0.5 - 1	0.1 - 0.3	0.1 - 0.3
very low	< 10	< 2	< 20	< 1	< 0.5	< 0.1	< 0.1

Cation exchange is the soil property related to the negative charges on the surfaces of clay and organic particles. These charges are balanced by positively charged cations (commonly Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} and Al^{3+}). As the cations are held on the exchange complex and are not dissolved in the soil solution they are resistant to leaching, but are exchangeable with other cations from the soil solution, fertilisers, or plant roots.

Cation Exchange Capacity (CEC) is a measure of the total number of sites available for cation exchange. The CEC of a soil consists of a fixed component of negative charge and a component that increases with increasing pH (variable charge). The measurement quoted here is made at pH 7 that enables comparisons to be made between soils that have different field pH. If required, the CEC at field pH or 'effective' CEC can be calculated by adding the total exchangeable bases to the exchangeable acidity (exchangeable aluminium).

The expression "Total Exchangeable Bases" is the sum of the main exchangeable cations that have basic oxides (Ca, Mg, K and Na), and excludes the other main cation - aluminium. Expressed as a percentage of CEC it becomes base saturation (%BS), which indicates the proportion of the CEC that is occupied by basic cations. This value is a useful indicator of the state of leaching, with a low or very low %BS representing strong leaching.

Exchangeable Ca is usually the most abundant of the exchangeable bases, and so largely controls the base saturation and pH. Deficiency of Ca as a nutrient is rare and probably occurs only in the very low range (< 1.0). Generally Ca is added as lime to correct pH problems before Ca deficiency becomes a problem.

Critical soil levels for plant growth for exchangeable Mg and K vary considerably with crop type. The Mg critical level is about 0.3 - 0.5 me/100 g, while for K critical levels vary from about 0.5 me/100 g for vegetables and other high K-demand crops, to 0.2 - 0.3 me/100 g for other crops.

Exchangeable Na levels are useful for indicating possible salt effects on soil in coastal or saline areas. If the percentage of exchangeable Na on the CEC exceeds 12-15% dispersion of clay can occur with consequent breakdown of soil structure.

EXCHANGEABLE ACIDITY, SULFATE-PHOSPHATE EXTRACTABLE

Rating	**Exchangeable (KCl extr.) Acidity** me/100g	**Sulfate-phosphate extractable** mg/kg
very high	> 5	> 150
high	2 - 5	50 - 150
medium	0.5 - 2	15 - 50
low	0.1 - 0.5	5 - 15
very low	< 0.1	< 5

Exchangeable Acidity

Exchangeable acidity measures the acidity that can be released from the exchange complex of soil with an excess of a neutral salt (1 M KCl). This acidity is predominantly, if not completely, in the form of exchangeable aluminium (Al^{3+}). The Al^{3+} occupies the portion of the permanent charge CEC not occupied by exchangeable bases. Significant quantities of exchange acidity only occur in soils when the pH is less than 5.6.

Exchangeable Al is toxic to plants, and in most acid soils it is not the low pH that restricts plant growth, but the high levels of Al^{3+}. Levels of exchangeable acidity above about 1 me/100 g in clay soils and lower levels in sandy soils may restrict plant growth mainly by limiting root development. This can be alleviated by adding lime to the soil to raise the pH above 5.6, thus precipitating as hydroxides the exchangeable aluminium that cause the problem.

Extractable Sulfate

A level of extractable sulfate of 10-15 mg/kg is usually regarded as the critical level for adequate supply of sulfur. However plant growth responses to fertiliser sulfur are rare in maritime countries, sometimes even when low levels of extractable sulfur are measured, because of the continuing input of sulfate from salt picked up from sea-spray and transported by wind. Inherent soil sulfur deficiencies are also often undetected as large quantities of phosphate as superphosphate are used in many agricultural systems and superphosphate contains 10 - 12% S as well as containing 9 - 10% phosphorus.

DTPA EXTRACTABLE Fe, Mn, Cu and Zn

Rating	Iron	Manganese	Copper mg/kg	Zinc
Deficient	< 2.5			< 0.8
Low	2.5-4.5	< 1.0	< 0.2	0.8-1.2
Adequate	> 4.5	> 1.0	> 0.2	> 1.2

Values are from Lindsay and Norvell (1978) and were derived on Mollisols in the USA. Calibrations have not been done on tropical soils in the Pacific so these figures should be used with caution and, where possible, foliage analyses carried out to check possible trace element deficiencies.

EXTRACTABLE BORON

Plants vary considerably in their deficiency and toxicity levels of boron in soils however the following levels have been suggested by Reisenauer et al (1973) as a guide.

Rating	Boron mg/kg
Soils may not supply sufficient B to support normal growth.	< 1
Soils usually allow normal growth of plants.	1-5
Soils may supply toxic quantities of B.	> 5

PLANT ANALYSES RESULTS

Definitions used in tables:

Deficient: Likely to result in significant reduction in yield and quality

Low: Likely to result in minor yield loss or reduction in quality

Optimum: Not requiring any addition of fertiliser

High: Likely to result in significant reduction in yield and quality due to toxicity

SPECIES:
BANANA *(Musa Spp.)*

Plant Part: Strips 15-20 cm wide from each side of midrib of 3rd youngest leaf.
Stage of Growth: Periods of active growth from medium-sized suckers with broad leaves.
Other conditions:

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %	< 2.6	2.6 – 2.7	2.8 - 4.0	
Phosphorus	P %	< 0.13	0.13 – 0.19	0.2 - 0.25	> 0.25
Potassium	K %	< 2.5	2.5 – 3.0	3.1 - 4.0	> 4.0
Sulphur	S %	< 0.1	0.1 – 0.2	0.23 - 0.27	> 0.27
Calcium	Ca %	< 0.5	0.5 – 0.7	0.8 - 1.2	> 1.25
Magnesium	Mg %	< 0.2	0.20 – 0.29	0.3 - 0.46	> 0.46
Chlorine	Cl mg/kg		0.6	0.8 – 0.9	
Iron	Fe mg/kg		80	70 - 200	
Manganese	Mn mg/kg	<10	25	100-2200	4000 - 6000
Zinc	Zn mg/kg	< 14	14 - 20	21 - 35	> 35
Copper	Cu mg/kg	< 3	3 - 6	7 - 20	
Boron	B mg/kg	< 10	10 - 19	20 - 80	81 – 300

SPECIES:
CASSAVA (*Manihot Esculenta*)

Plant Part: Youngest mature leaf blade.
Stage of Growth: 3 – 4 months after planting.
Other Conditions:

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %	< 4.8	4.8 – 5.1	5.1 – 5.8	>5.8
Phosphorus	P %	< 0.36	0.36 – 0.38	0.38 - 0.50	>0.50
Potassium	K %	< 1.26	1.26 – 1.42	1.42 – 1.88	1.88 – 2.40
Sulphur	S %	< 0.27	0.27 – 0.30	0.3 - 0.36	>0.36
Calcium	Ca %	< 0.41	0.41 – 0.50	0.50 – 0.72	0.72 – 0.88
Magnesium	Mg %	< 0.22	0.22 – 0.24	0.24 – 0.29	>0.29
Iron	Fe mg/kg	< 110	110 - 120	120 - 140	140 - 200
Manganese	Mn mg/kg	< 40	40 - 50	50 - 150	150 - 250
Zinc	Zn mg/kg	< 32	32 - 35	35 - 57	57 - 120
Copper	Cu mg/kg	<4.8	4.8 – 6.0	6 - 10	10 - 15
Boron	B mg/kg	< 15	15 - 18	18 - 28	28 - 64

SPECIES:
CHICKPEA (*Cicer Arietinum*)

Plant Part: All above-ground plant parts.
Stage of Growth: Vegetative.
Other conditions:

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %			> 2.3	
Phosphorus	P %			> 0.24	
Potassium	K %				
Sulphur	S %			> 0.15	
Calcium	Ca %				
Magnesium	Mg %				
Iron	Fe mg/kg				
Manganese	Mn mg/kg				> 120
Zinc	Zn mg/kg			12 - 500	
Copper	Cu mg/kg			4 - 35	
Boron	B mg/kg			> 40	

SPECIES:
CITRUS *(Citrus Spp.)*

Plant Part: Healthy mature leaves from the middle of non-fruiting spring extension growth. Take leaves at shoulder height.
Stage of Growth: When leaves are 5 - 7 months old.
Other Conditions:

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %	< 2.2	2.2 – 2.3	2.4 - 2.6	2.7 - 30
Phosphorus	P %	< 0.09	0.09 – 0.11	0.12 - 0.16	0.17 - 0.25
Potassium	K %	< 0.4	0.4 – 0.69	0.7 - 1.5	1.6 - 2.3
Sulphur	S %	< 0.14	0.14 – 0.20	0.21 - 0.40	0.41 - 5.0
Calcium	Ca %	< 1.6	1.6 – 2.9	3.0 - 6.0	6.1 – 7.0
Magnesium	Mg %	< 0.16	0.16 – 0.25	0.26 - 0.60	0.7 - 1.2
Iron	Fe mg/kg	< 36	36 - 60	61 - 120	121 - 200
Manganese	Mn mg/kg	< 16	16 - 24	25 - 80	81 - 300
Zinc	Zn mg/kg	< 16	16 - 24	25 - 80	81 - 300
Copper	Cu mg/kg	< 3	3 - 5	6 - 10	11 - 15
Boron	B mg/kg	< 21	21 - 30	31 - 100	101 - 260

SPECIES:
COCOA *(Cacao Theobroma)*

Plant Part: 3rd and 4th matured leaves
Stage of Growth:
Other conditions:

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %	<1.80	1.80 – 2.00	2.35 – 2.50	
Phosphorus	P %	<0.08	0.10 – 0.13	>0.18	
Potassium	K %	<1.00	1.0 – 1.2	>1.2	
Sulphur	S %				
Calcium	Ca %	<0.30	0.30 – 0.40	>0.40	
Magnesium	Mg %	<0.20	0.20 – 0.45	>0.45	
Iron	Fe mg/kg	50		65 – 170	
Manganese	Mn mg/kg		20	50 – 400	
Zinc	Zn mg/kg	16	20	80 – 170	
Copper	Cu mg/kg	4	8	8 – 12	
Boron	B mg/kg	10		25 - 70	
Molybdenum	Mo mg/kg	0.5		1.0 – 2.5	

SPECIES:
COCONUT (*Cocos Nucifera*)

Plant Part: Leaf 14 in mature plants or 4 or 9 in young plants.
Stage of Growth: August (preferably).
Other conditions: Composite of 25 - 30 palms.

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %			1.8 - 2.0	
Phosphorus	P %			0.11 – 0.13	
Potassium	K %			1.2 – 1.5	
Sulphur	S %			0.13	
Calcium	Ca %	<0.1		0.3 - 0.54	>0.55
Magnesium	Mg %	<0.17	0.17 – 0.24	0.25 – 0.30	
Iron	Fe mg/kg			50	
Manganese	Mn mg/kg			30	
Zinc	Zn mg/kg			-	
Copper	Cu mg/kg			5 - 7	
Boron	B mg/kg			5 - 10	

SPECIES:
COFFEE (*Coffee Arabica*)

Plant Part: 3rd or 4th pair of leaves from the tip of actively growing and bearing branches.
Stage of Growth: Feb – April after harvest or Sep – Oct before vegetative growth.
Other conditions: Take 4 pairs of leaves from at least 15 trees, midway between ground level and the topmost branches. Keep samples cool and wash with dil. acetic acid with a wetting agent (0.25 ml in 5 L) for 10 mins; drain and rinse in distilled water

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %	<2.2	2.2 – 2.4	2.5 – 3.0	>3.0
Phosphorus	P %	<0.1	0.1 – 0.14	0.15 – 0.20	>0.20
Potassium	K %	<0.15	1.5 – 2.0	2.1 – 2.6	>2.6
Sulphur	S %			0.02 – 0.10	
Calcium	Ca %	<0.4	0.4 – 0.7	0.75 – 1.5	>1.5
Magnesium	Mg %	<0.1	0.1 – 0.24	0.25 – 0.40	>0.4
Iron	Fe mg/kg	<40	40 - 69	70 - 200	>200
Manganese	Mn mg/kg	<25	25 - 49	50 - 100	101 - 700
Zinc	Zn mg/kg	<10	10 - 14	15 - 30	>30
Copper	Cu mg/kg	<10	10 - 15	16 - 20	>20
Boron	B mg/kg	<25	25 - 39	40 - 100	101 - 200

SPECIES:
GINGER (*Zingiber Officinale*)

Plant Part: 3rd leaf blade below apex for N; upper leaf blade for other nutrients.
Stage of Growth: 6 months for N; 2 - 3 months for other nutrients.
Other Conditions:

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %			> 3.3	> 4.6
Phosphorus	P %	0.13 - 0.14		0.24 - 0.33	> 0.69
Potassium	K %	0.9 - 1.1		3.9 - 5.7	
Sulphur	S %	0.09 - 0.11		0.35 - 0.4	
Calcium	Ca %	0.05 - 0.07		1.1 - 1.3	
Magnesium	Mg %	0.08 - 0.09		0.5 - 0.8	
Iron	Fe mg/kg	13 - 36		110 - 160	
Manganese	Mn mg/kg	20 - 22		125 - 250	
Zinc	Zn mg/kg	15 - 20		30 - 43	
Copper	Cu mg/kg	2 - 4		8 - 10	
Boron	B mg/kg	14 - 20		80 - 112	> 275

SPECIES:
MAIZE (*Zea Mays*)

Plant Part: Ear leaf.
Stage of Growth: Early silking.
Other Conditions:

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %	< 2.00	2.00 - 2.24	2.25 - 3.30	> 3.30
Phosphorus	P %	< 0.15	0.15 - 0.17	0.18 - 0.32	> 0.32
Potassium	K %	< 1.25	1.25 - 1.70	1.71 - 2.25	> 2.25
Sulphur	S %	< 0.10	0.10 - 0.12	0.13 - 0.25	> 0.25
Calcium	Ca %	< 0.10	0.10 - 0.20	0.21 - 0.50	> 0.50
Magnesium	Mg %	< 0.10	0.10 - 0.12	0.13 - 0.24	> 0.24
Iron	Fe mg/kg	< 10	10 - 20	21 - 251	> 251
Manganese	Mn mg/kg	< 15	15 - 19	20 - 150	> 150
Zinc	Zn mg/kg	< 10	10 - 20	21 - 70	> 70
Copper	Cu mg/kg	< 2	2 - 5	6 - 20	> 20
Boron	B mg/kg	< 2	2 - 5	6 - 20	> 20

SPECIES:
MANGO (*Mangifera Indica*)

Plant Part: Youngest Mature Leaf from the non-bearing branches.
Stage of Growth: Just prior to flowering in August to September period.
Other Conditions 50 leaves; a dilute acetic acid wash and distilled water rinse is suggested.

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %		0.9	1.0 - 1.5	
Phosphorus	P %		0.12	0.13 - 0.18	
Potassium	K %	<0.25	0.25– 0.29	0.3 – 1.2	
Sulphur	S %			0.06 – 0.22	
Calcium	Ca %			2.0 – 3.5 or 3.0 – 5.0	>5.0
Magnesium	Mg %			0.2 - 0.4	>0.8
Iron	Fe mg/kg			70 - 200	
Manganese	Mn mg/kg			60 - 200	
Zinc	Zn mg/kg	<15	15 - 19	20 - 100	>250
Copper	Cu mg/kg			10 - 20	>600
Boron	B mg/kg			30 - 100	

SPECIES:
OIL PALM (*Elaeis Guineensis)*

Plant Part: Leaf 17 for mature plant or Leaf 3 for young plants, sampling about 6 leaflets halfway. he central 15-cm length of each sub-sampled.
Stage of Growth:
Other conditions: 20 trees should be sampled to represent up to about 25 ha.

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %			2.7 – 2.8 or 2.8 – 3.0	
Phosphorus	P %			0.18 – 0.19 or 0.19 – 0.21	
Potassium	K %			0.13 or 0.15 – 0.18	
Sulphur	S %				
Calcium	Ca %			< or = 0.6 or 0.3 – 0.5	
Magnesium	Mg %			0.3 – 0.35	
Molybdenum	Mo mg/kg			0.5 – 1.0	
Manganese	Mn mg/kg			150 - 200	
Zinc	Zn mg/kg			15 - 20	
Copper	Cu mg/kg			5 - 8	
Boron	B mg/kg			10 - 20	

SPECIES:
PAWPAW (*Carica Papaya*)

Plant Part: Petiole of the youngest fully expanded leaf subtending the most recently opened flower.
Stage of Growth: Spring.
Other Conditions:

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %		0.8 – 1.0	1.3 - 2.5	>2.5
Phosphorus	P %		<0.2	0.2 - 0.4	>0.4
Potassium	K %		2.8	3.0 - 6.0	>6.0
Sulphur	S %			0.3 - 0.8	
Calcium	Ca %		<1.0	1.0 – 2.5	>3.0
Magnesium	Mg %			0.5 - 1.5	
Iron	Fe mg/kg			20 - 80	
Manganese	Mn mg/kg		10 - 19	25 - 150	
Zinc	Zn mg/kg			10 - 30	
Copper	Cu mg/kg		<4	4 - 10	
Boron	B mg/kg	<16	16 - 18	20 - 50	>50

SPECIES:
PEANUTS (*Arachis Hypogaea*)

Plant Part: Youngest mature leaf blade.
Stage of Growth: Pre-flowering or flowering.
Other conditions:

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %			3.5 - 4.5	
Phosphorus	P %	< 0.2		0.25 - 0.5	
Potassium	K %			2.0 - 3.0	
Sulphur	S %			0.2 - 0.3	
Calcium	Ca %			1.25 - 2.0	
Magnesium	Mg %			0.3 - 0.8	
Iron	Fe mg/kg			50 - 300	
Manganese	Mn mg/kg			50 - 350	
Zinc	Zn mg/kg	< 14		20 - 50	
Copper	Cu mg/kg			10 - 50	
Boron	B mg/kg			20 - 50	

SPECIES:
PIGEON PEA (*Cajanus Cajan*)

Plant Part: Youngest mature leaf blade.
Stage of Growth: Early Flowering.
Other Conditions:

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %	< 2.38		> 4.0	
Phosphorus	P %	< 0.07		0.12	
Potassium	K %	0.9		1.2 - 2.6	
Sulphur	S %			0.16 - 0.32	
Calcium	Ca %	0.08		0.84 - 1.2	
Magnesium	Mg %	0.03	0.11 - 0.16	0.18 - 0.24	
Iron	Fe mg/kg	< 166		151 - 191	
Manganese	Mn mg/kg	< 17		19 - 95	
Zinc	Zn mg/kg			7 - 48	
Copper	Cu mg/kg		1 - 10	10 - 12	
Boron	B mg/kg	< 10		10 - 52	

SPECIES:
PINEAPPLE (*Ananas Comosus*)

Plant Part: Youngest mature leaf blade (D leaf).
Stage of Growth: During vegetative growth before flower initiation.
Other Conditions: Do not sample immediately after fertiliser application. Collect 10 leaves from representative area. Stack the leaves in one column and cut across at 150 mm from the base. Analyse this basal white tissue sample

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %				
Phosphorus	P %			0.18 - 0.22	0.30
Potassium	K %	< 2.8		0.32 - 0.38	> 0.42
Sulphur	S %				
Calcium	Ca %	< 0.004	0.007 – 0.011	0.013 – 0.018	
Magnesium	Mg %	< 0.01	0.014 – 0.020	0.023 – 0.027	> 0.04
Iron	Fe mg/kg			80 - 150	
Manganese	Mn mg/kg			150 - 400	
Zinc	Zn mg/kg			15 - 70	
Copper	Cu mg/kg			10 - 50	
Chlorine	Cl mg/kg			0.2 – 0.8	

SPECIES:
POTATO (*Solanum Tuberosum*)

Plant Part: Youngest mature leaf blade and petiole.
Stage of Growth: Early flowering.
Other Conditions:

Nutrient		**Deficient**	**Low**	**Optimum**	**High**
Nitrogen	N %	2.0	2.0 - 4.5	5.5 - 6.5	
Phosphorus	P %	< 0.20	0.20 - 0.30	0.35 - 0.55	
Potassium	K %	< 3.0	3.0 - 4.5	4.5 - 6.5	
Sulphur	S %	< 0.20	0.20 - 0.30	0.30 - 0.50	
Calcium	Ca %	< 0.70	0.70 - 1.20	1.20 - 2.00	
Magnesium	Mg %	< 0.25		0.30 - 0.50	
Iron	Fe mg/kg			70 - 150	> 800
Manganese	Mn mg/kg	< 20	20 - 50	50 - 300	
Zinc	Zn mg/kg	< 10	10 - 20	20 - 60	
Copper	Cu mg/kg	< 3		6 - 20	
Boron	B mg/kg	< 10	10 - 20	30 - 60	

SPECIES:
RICE (*ORYZA SATIVA*)

Plant Part: Y blade.
Stage of Growth: Panicle initiation.
Other Conditions:

Nutrient		**Deficient**	**Low**	**Optimum**	**High**
Nitrogen	N %			2.6 - 3.2	
Phosphorus	P %			0.18 - 0.29	
Potassium	K %			1.0 - 2.2	
Sulphur	S %				
Calcium	Ca %			0.19 - 0.39	
Magnesium	Mg %			0.16 - 0.39	
Iron	Fe mg/kg			74 - 192	
Manganese	Mn mg/kg			252 - 792	
Zinc	Zn mg/kg			33 - 160	
Copper	Cu mg/kg				
Boron	B mg/kg				

SPECIES:
SUGAR CANE (*Saccharum Spp.*)

Plant Part: A section 20 cm long (10 cm above and below the mid-point) of the top visible dewlap blade (midrib discarded).
Stage of Growth: Rapid growth at 4 - 7 months.
Other Conditions:

Nutrient		**Deficient**	**Low**	**Optimum**	**High**
Nitrogen	N %			> 2.0	
Phosphorus	P %			> 0.2	
Potassium	K %	< 1.1		1.3 - 2.0	
Sulphur	S %			> 0.12	
Calcium	Ca %	< 0.15		> 0.18	
Magnesium	Mg %			0.08 - 0.35	
Iron	Fe mg/kg			> 50	
Manganese	Mn mg/kg			> 15	
Zinc	Zn mg/kg			> 13	
Copper	Cu mg/kg			4 - 12	
Boron	B mg/kg			2 - 10	

SPECIES:
SWEET POTATO (*Ipomoea Batatas*)

Plant Part: 7th to 9th open leaf blades
Stage of Growth: 28 days after transplanting.
Other Conditions:

Nutrient		**Deficient**	**Low**	**Optimum**	**High**
Nitrogen	N %		4.0	4.2 – 5.0	
Phosphorus	P %		0.22	0.26 – 0.45	
Potassium	K %		2.6	2.8 – 6.0	
Sulphur	S %		0.34	0.35 – 0.45	
Calcium	Ca %		0.76	0.90 – 1.2	
Magnesium	Mg %		0.12	0.15 – 0.35	
Chlorine	Cl mg/kg				0.9 – 1.5
Iron	Fe mg/kg		33	45 – 80	
Manganese	Mn mg/kg		19	26 – 500	1600
Zinc	Zn mg/kg		11	30 – 60	70 – 85
Copper	Cu mg/kg		4 - 5	5 – 14	15.5
Boron	B mg/kg		40	50 - 200	220 – 350
Molybdenum	Mo mg/kg		0.2	0.5 - 7	

SPECIES:
TARO (*Colocasia Esculenta*)

Plant Part: The 2nd youngest open leaf blade
Stage of Growth: 2nd months
Other conditions:

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %	1.80	3.7	3.9 – 5.0	
Phosphorus	P %	0.28	0.33	0.5 – 0.9	
Potassium	K %	1.50	4.6	5.0 – 6.0	
Sulphur	S %		0.26	0.27 – 0.33	
Calcium	Ca %		2.0	2.6 – 4.0	
Magnesium	Mg %	0.09	0.15	0.17 – 0.25	
Iron	Fe mg/kg		56	68 – 130	
Manganese	Mn mg/kg		21	26 – 500	1133
Zinc	Zn mg/kg		22	22 – 50	400
Copper	Cu mg/kg		3.8	5.8 – 35	
Boron	B mg/kg		23	26 – 200	

SPECIES:
TOMATO (*Lycopersicon Esculentum*)

Plant Part: 13 leaves
Stage of Growth: Sample 1 cm above ground when 7 leaves > 1 cm long.
Other Conditions: Sample the whole shoot or top

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %	<3	3 - 4	4 - 6	
Phosphorus	P %	<0.40	0.40 – 0.65	0.65 – 1.20	
Potassium	K %	<3	3 - 4	4 – 6	
Sulphur	S %				
Calcium	Ca %	<1.0	1.0 – 1.5	1.5 – 2.5	
Magnesium	Mg %	<0.3	0.3 – 0.4	0.4 – 0.8	
Iron	Fe mg/kg			100 – 300	
Manganese	Mn mg/kg	<25	25 – 50	50 – 500	
Zinc	Zn mg/kg	<20	20 - 30	50 – 500	
Copper	Cu mg/kg			5 – 15	
Boron	B mg/kg			40 - 100	

SPECIES:
YAM *(Dioscrea Alata.)*

Plant Part: Leaf with petiole at 3rd month, Lamina/petiole at 4th month, Youngest matured leaf with petiole at 4th month.
Stage of Growth: At 3rd, 4th and 4th months.
Other Conditions:

Nutrient		Deficient	Low	Optimum	High
Nitrogen	N %			1.86 – 3.71	
Phosphorus	P %			0.20 – 0.38	
Potassium	K %			2.27 – 4.80	
Sulphur	S %			0.17	
Calcium	Ca %			0.65 – 1.80	
Magnesium	Mg %			0.26 – 0.33	
Iron	Fe mg/kg				
Manganese	Mn mg/kg				
Zinc	Zn mg/kg				
Copper	Cu mg/kg				
Boron	B mg/kg				

TROPICAL PASTURES

It has proved difficult to obtain comprehensive data for nutrient levels in tropical grasses and legumes and the data given in the next three pages is gathered from a number of sources.

Reuter and Robinson (1986) give partial data for a number of grasses and legumes. For many of the species the critical levels are similar and the available data was averaged to provide an indication only of nutrient levels for these and other species. For grass the mean is calculated from data for green panic, kikuyu, pangola and setaria, while for legumes data for centro, phalaris, siratro and stylo was used.

SPECIES:
TROPICAL GRASSES (Average values)

Plant Part:	Whole stem.
Stage of Growth:	About 50 days after emergence.
Other conditions:	

Nutrient		Approximate Optimum
Nitrogen	N %	
Phosphorus	P %	0.22 - 0.32
Potassium	K %	2.0 - 4.0
Sulphur	S %	> 0.12

SPECIES:
TROPICAL LEGUMES (Average values)

Plant Part:	Whole stems.
Stage of Growth:	Pre-flowering or Flowering.
Other conditions:	

Nutrient		Approximate Optimum
Nitrogen	N %	2.0 - 3.5
Phosphorus	P %	0.2 - 0.35
Potassium	K %	1.0 - 2.5
Sulphur	S %	0.2 - 0.35
Zinc	Zn mg/kg	20 - 50
Copper	Cu mg/kg	5 - 10

The FAO Tropical Feeds Database (Göhl, 1992) gives protein content data for a number of grasses and legumes. These are summarised below as % of dry matter with nitrogen level calculated from the protein (divided by 6.25). It should be noted that the values given represent the composition of the analyzed samples and are not necessarily optimum levels.

TROPICAL GRASSES

Whole plant to cutting or grazing height sampled

Species	Protein %	Nitrogen %	Growth Stage or weeks after last harvest
Batiki Bluegrass *(Ischaemum aristatum)*	10.4	1.7	3 - 8
Elephant grass *(Pennisetum pupurem)*	9.0	1.4	8 - 10
Guatemala grass *(Tripsacum fasciculatum)*	7.9	1.3	8 - 10
Guinea grass *(Panicum maximum)*	8.8	1.4	6 - mature
Lucuntu grass *(Ischaemum timorense)*	9.8	1.6	mature
Nadi Bluegrass *(Dichanthium carioseum)*	7.0	1.1	mature
Pangola grass *(Digitaria decumbens)*	8.2	1.3	mature
Para grass *(Brachiaria mutica)*	8.1	1.3	mature

TROPICAL LEGUMES

Generally fresh aerial parts of plant sampled.

Species	Protein %	Nitrogen %	Growth Stage
Centro *(Centrosema pubescens)*	24.4	3.9	vegetative
Puero *(Pueraria phaseoloides)*	18.5	3.0	early vegetative - mature
Siratro *(Macroptilium atropurpureum)*	20.4	3.3	early vegetative
Townsville Stylo *(Stylosanthes humilis)*	20.9	3.3	fresh aerial - late vegetative

Evans et al (1992) give the averaged results from several samplings throughout the growing season for the composition of grasses and legumes growing on a range of soil types in Vanuatu. Although there is variation in the composition of the same species on different soil types, with some soils obviously being deficient in some nutrients, the results from up to five different soil types for each species are averaged here to give a single value.

GRASSES

Species	N %	P %	K %	Na %	Ca %	Mg %	S %	Cu mg/kg	Zn mg/kg
Signal *(Brachiaria decumbens)*	2.0	0.25	2.3	0.02	0.65	0.47	0.09	6	38
Guinea *(Panicum maximum)*	2.3	0.33	2.6	0.02	0.61	0.27	0.16	10	29
Koronivia *(Brachiaria humidicola)*	1.5	0.20	2.3	0.37	0.42	0.24	0.06	6	30
Buffalo *(Stenotaphrum secundatum)*	1.6	0.28	1.8	1.55	0.50	0.35	0.26	5	71
Para *(Brachiaria mutica)*	2.4	0.28	4.5	0.16	0.33	0.17	0.21	6	28
Setaria *(Setaria sphacelata, splenda)*	2.1	0.35	5.3	0.23	0.41	0.18	0.19	8	59

LEGUMES

Species	N %	P %	K %	Na %	Ca %	Mg %	S %	Cu mg/kg	Zn mg/kg
Glycine *(Neonotonia wightii)*	3.6	0.34	4.3	0.02	1.00	0.50	0.12	12	41
Centro *(Centrosema pubescens)*	3.3	0.25	1.8	0.07	1.74	0.54	0.20	12	46
Puero *(Pueraria phaseoloides)*	3.9	0.31	2.4	0.02	1.14	0.59	0.14	11	33
Hetero *(Desmodium heterophyllum)*	3.1	0.27	1.9	0.05	1.02	0.58	0.13	15	40
Siratro *(Macroptiliuatropurpureum)*	3.4	0.27	2.5	0.02	1.04	0.69	0.10	8	41

WATER ANALYSIS RESULTS

ELECTRICAL CONDUCTIVITY

Salinity Hazard Rating	EC µS/cm	Suitability of water for use in irrigation
low	< 250	Use with no restrictions.
medium	250 - 750	Use with moderate level of leaching (excess water) so that salts do not accumulate.
high	750 - 2250	Use only on soils with good drainage, special management to prevent salt accumulation and salt-tolerant crops.
very high	> 2250	Not suitable.

SODIUM ADSORPTION RATIO (SAR)

Sodium Hazard Rating	SAR	Suitability of water for use in irrigation
low	< 10	Use with no restrictions.
medium	10 – 18	Do not use on fine textured soils especially under conditions of low leaching.
high	18 – 26	Will produce harmful levels of exchangeable sodium in most soils. Use only on soils with good drainage, special management and organic matter and gypsum additions.
very high	> 26	Not suitable for irrigation water use.

NB. The total level of salts in the water affects the SAR at which damage to the soil structure would be expected to occur. The SAR figures given in the table are for water with electrical conductivity in the low range. As the salt level (EC) raises the SAR at which problems will be experienced is lowered.

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