LEARNER GUIDE

Plant Nutrition & Soil Management

Level 5

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Title:		**Manage Soil Systems**					
Applied Title:		**Manage Soil Systems**					
Field:		Agriculture and Nature Conservation					
Sub-Field:		Primary Agriculture					
SETA (SGB):		AgriSETA					
Skills Area:		Plant Nutrition and Soil Management					
Context:		Citrus Production					
US No:	116371	**Level:**	5	**Credits:**	10	**Notional Hours:**	100
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Based on the Production Guidelines of:

Supported by:

Unit standard alignment and assessment tool development:
Cabeton Training and Development

Project coordinator:
Jacomien de Klerk

Table of Contents

Directions

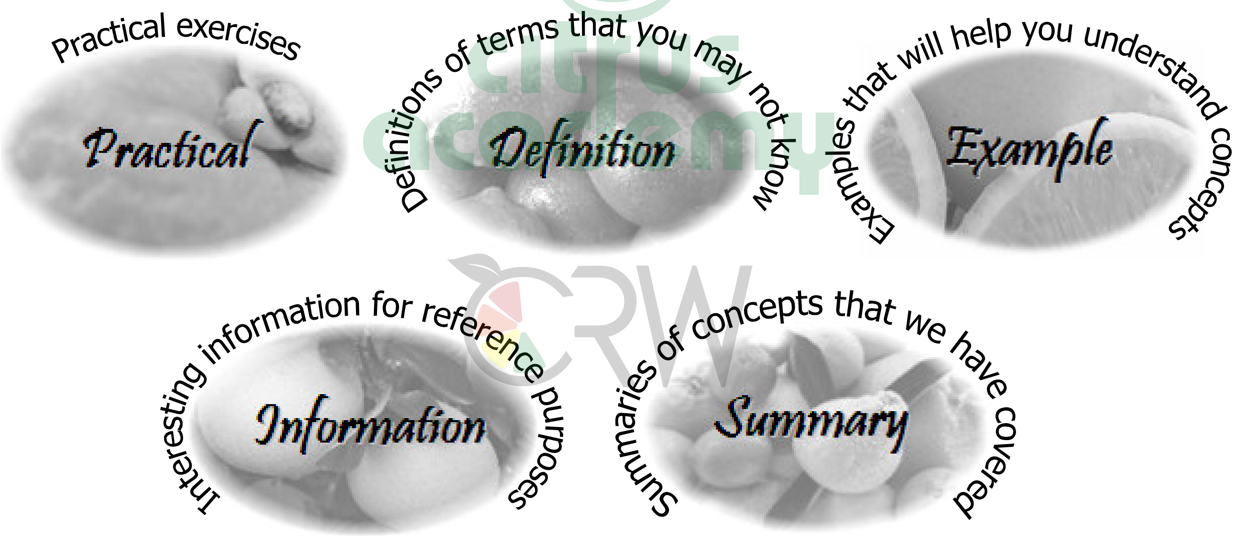
This learning material has been developed to assist the learner wishing to complete this unit standard. The guide contains all necessary learning to ensure that the learner will attain the competencies required by the unit standard.

The learner guide is accompanied by a Learner Assessment Guide. Please ensure that you have access to this guide as well.

The learner guide was designed to be used by a learner during the presentation of a skills program based on the unit standard, and to be kept afterwards by the learner for reference purposes. The learner assessment guide was designed to be completed during and after the presentation of the skills program, and forms part of the assessment process.

Although this learner guide contains all the information required for attaining competency in this unit standard, references to additional resources, both printed and electronic, are provided for further study by the learner.

Information in boxes is indicated by tags that show:



Introduction

1. Purpose

A learner achieving this unit standard will be able to set up and manage a soil fertility and plant nutrition plan.

Learners will gain specific knowledge and skills in soil and plant nutrition and will be able to operate in a plant production environment implementing sustainable and economically viable production principles.

They will be capacitated to gain access to the mainstream agricultural sector, in plant production, impacting directly on the sustainability of the sub-sector. The improvement in production technology will also have a direct impact on the improvement of agricultural productivity of the sector.

2. Learning Assumed to Be in Place

It is assumed that the learner has successfully completed the unit standards listed below:

NQF Level	***Unit Standard Number***	***Unit Standard Description***
NQF4	Literacy and Numeracy	
4	116311	Implement soil fertility and plant nutrition practices

Revision of Level 4

1. Interpretation of Recommendations

- A fertilisation program is developed on an annual basis and contains information on all the applications that has to be made during the year.
- The best fertilisation programs are specifically developed for the orchard or farm, and make use of the soil and leaf analyses data and data from the orchard, such as yield data and previous applications.
- A proper fertilisation program contains details for each orchard, including the orchard number, the cultivar and variety, special instructions, and details of soil applications and foliar applications, including the name of the fertiliser, the rate of application and the time of application.
- From the fertilisation program, application programs for soil applications and foliar applications are developed for each month for the whole farm.
- The solubility and salt index of the fertilisers, the clay content of the soil, and the rooting depth of the plants are the major factors regulating the efficiency of an application and must therefore be taken into account when a decision is made on whether to split applications.
- The total per orchard that is calculated on the application program is used to monitor the effectiveness of the application, by comparing this volume / mass with the volume / mass that is actually applied.
- Foliar applications programs are developed in the same way, but the total amount of spray material required is also calculated.
- Based on the application programs, the types and amounts of fertiliser that must be ordered every month is calculated.
- Fertilisers that has been recommended on the fertilisation program can be substituted by other fertilisers that have a similar nutrient content as long as the chemistry of the replacement chemical and its reaction in the soil and on the leaf will not create unwanted side-effects, and the recommended mass or volume is adjusted to compensate for variations in concentration of the active ingredient(s).

2. Implement a Soil Utilisation Plan

- Based on a soil survey, a soil map is developed that demarcates soil boundaries.
- Areas are identified for orchard establishment based on slope, soil depth, clay content, stratification, and soil salinity.
- The slope of the site must make vehicle movement possible, and plays a role in row orientation, surface drainage and erosion.
- Citrus requires a minimum soil depth of between 30cm and 50cm, depending on the type of irrigation used, and can be improved through ridging.
- The optimum clay content for citrus production is between 5% and 20% for micro-jet irrigation and between 5% and 35% for drip irrigation. The clay content of soil influences its water holding capacity, the volume of easily available water, its cation exchange capacity, and its aeration.

- Stratification restricts water movement through the soil profile, and all stratification must be removed during soil preparation.
- It is difficult and expensive to remove salts, because the cause of the salinity also has to be removed.
- If the accumulation of salts in soil is due to poor drainage, such soils should be avoided, and soils with salts accumulated anywhere in the 60cm to 100cm should be dealt with cautiously.

3. Interpretation of Nutrient Deficiency Symptoms

- Nutritional deficiency symptoms should never be used as the basis for developing a fertilisation program, because the deficiency would already have had an adverse affect on production.
- Leaf and soil analyses are used to identify deficiencies in time.
- The most common deficiency symptoms are for nitrogen, magnesium, copper and iron.
- Deficiency symptoms must be used in conjunction with analyses to develop a nutrient management program, with specific remedies for specific deficiencies.
- Leaf samples are usually taken from February to May to evaluate the nutritional status of citrus trees. Taking leaf samples to confirm a deficiency during other times of the year must be done cautiously.

4. Managing Soil Improvement

- The basic soil preparation methods that are employed in citrus production are loosening, mixing and ridging.
- Loosening, also referred to as ripping, is about loosening the soil without changing the layering.
- Mixing is used where stratification in the soil has to be eliminated.
- Ridging means removing soil from the inter-row spaces and using it to make ridges on which the trees will be planted, and is used mostly to improve the soil depth.
- Maintaining the soil after establishing the orchard involves protecting the surface against erosion, minimising compaction, guarding against salinisation, and limiting acidification.
- Establishing a natural grass cover is the best method to protect the soil against erosion.
- The major causes of accelerated compaction are vehicle traffic, high precipitation rates and salinisation.
- Regular soil analyses are able to detect increased salinisation, while subsoil sampling is required to monitor soil acidity.
- Proper recordkeeping is essential for proper soil and plant nutrition management, especially records of leaf and soil analyses.

Definition

Nutrient Deficiency

A nutrient deficiency is when there is not a sufficient quantity of a specific nutrient element and the plant cannot complete a certain physiological process as a result.

Soil Penetrometer

A soil penetrometer is an instrument that measures soil strength. Soil strength is the resistance of soil against penetration of roots, or against the probe when using the instrument. Soil strength is expressed in *mega-Pascal per square centimetre*, written as MPa/cm^2 or $MPa\ cm^{-2}$.

Field Water Capacity (FWC)

Field Water Capacity (FWC) is reached when a soil is allowed to drain freely after it was saturated with water. This is the point where no free water is present in the soil. All the water present is bound to the soil particles.

pH

pH indicates the acidity or alkalinity of any substance, in this case soil, on a scale of 1 to 14. pH can range from 1 (extremely acidic) to 14 (extremely alkaline). A pH value of 7 is neutral. Plant sap has a pH of 5.8 and the pH of human blood is almost 7. Soil with a low pH is referred to as ***acidic***. Soil with a high pH is referred to as ***alkaline***.

Electrical Conductivity

Electrical conductivity refers to the ability of soil paste to conduct an electrical current and can be expressed in various units. The international standard unit is Siemen.

Resistance

Resistance is the opposite of electrical conductivity, and refers to the resistance of a soil paste to conducting an electrical current. Resistance is expressed in ohms.

Lime

Lime is added to soil that is too acid. Lime applications can be done as part of soil preparation before the trees are planted or as part of the fertilisation program after the trees have been planted.

Respiration

Respiration is an energy-producing oxidation process in cells, the complete chemical and physical process in which oxygen is delivered to plant cells and carbon dioxide and water are given off.

Homogenous

Homogenous means having a uniform composition and structure. In terms of soil, it means creating a consistent rooting zone with no layering or chemical barriers, such as radical changes in soil pH.

Global Positioning System (GPS)

GPS uses latitudinal and longitudinal coordinates to pinpoint any position covered by communication satellites.

Fixation Fixation is the process where the water-soluble and hence plant-available form of a nutrient is converted to a water insoluble form. The fixed nutrient cannot readily be converted back to a water-soluble form and will remain unavailable for a considerable period.
Pedology Pedology is the scientific study of soil properties and the classification of soil types. A pedologist therefore studies the processes of soil development and is involved in soil profile analyses and soil surveys.
Gumming Gumming refers to the excretion of gum in droplets or patches. It can occur as a result of deficiencies such as a copper deficiency, but may also be due to injuries or adverse climatic conditions such as frost, heat and drought.
Chelate A chelate is a chemical compound in which metallic and organic atoms are combined.

Chapter 1

After completing this chapter, the learner will be able to:
Interpret soil and leaf analysis and make appropriate nutrient application recommendations

1. Introduction

Soil analysis is done before planting citrus trees and subsequently on an annual basis from the third year after the orchard is planted.

The analytical results of leaf and soil analysis are presented in many ways, but should always contain basic information regarding the element determined and the procedures followed. Stating the method used is especially important for the soil analysis, but also to some extent for the element N in the leaf analyses. In South Africa, the method used in leaf analyses is only reported if it deviates from the standard.

Interpreting leaf and soil analyses is a systematic process of questions and answers. It starts by comparing the available norms or reference standards with the analytical data.

2. Interpreting Soil and Leaf Analyses Results

2.1. Soil Analyses

Soil analysis is done to simulate the mass of nutrients a plant will extract from the soil. During the analysis process, soil chemists endeavour to extract a nutrient, such as P, by using a specific solution for a very short period, such as 60 seconds, to simulate what the tree would be able to obtain from the particular soil in six to twelve months.

A variety of extractants are used for this purpose. None is superior to the others, but certain procedures reflect a more accurate relationship between a soil-plant-system than others. It is therefore important to note the procedures used when results of a soil analyses are reported.

The procedures used in South Africa are shown below. The optimum values for the different methods may vary.

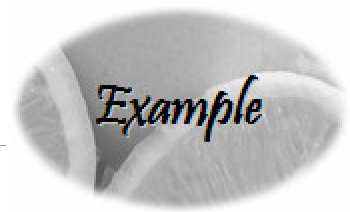
Soil Analysis Methods Used in South Africa

Test	*Methods Used in RSA*
pH	• pH (water) • pH (KCl) • Calcium chloride • 1:2 water extract • Saturation extract
P	• Bray 1 • Bray 2 • Olsen

	• Ambic • Truog • Citric acid • 1:2 water extract
K, Ca, Mg and Na	• Ammonium acetate • Ambic • 1:2 water extract
Zn, Mn, Fe and Cu	• 0,1 N HCl • Ambic • 1:2 water extract • EDTA,
B	• Hot water • 1:2 water extract

The analyses required for existing orchards include the pH, P, K, Ca, Mg and Na as well as the calculations for the relative percentages of each of the four cations. The analyses done for soils to be used for new plantings also include the determination of the clay, silt and sand content, the cation exchange capacity, and resistance.

Subsequent soil sampling and analyses for new orchards are limited to the soil properties that will change. Soil properties like the clay content, water holding capacity and cation exchange capacity will not change over the lifespan of a citrus orchard.



Soil Analysis Report

Sunshine Farm
P.O. Box 43
Hoedspruit
0164

21st May 2010

SOIL ANALYSES REPORT

Lab Number	S21004	S21005	S21006	S21007	S21008
Your Reference Number	A	B	C	D	E
pH (Water)	5.38	6.18	5.32	7.45	8.21
pH (KCl)	4.91	5.34	4.51	6.56	7.75
P (Bray 1) mg/kg	45	17	23	21	31
Potassium AmAc mg/kg	85	110	72	241	272
Calcium AmAc mg/kg	213	320	184	1,316	2,215
Magnesium AmAc mg/kg	76	164	47	361	442
Sodium AmAc mg/kg	11	5	8	68	143
Potassium %	11	8	12	6	4
Calcium %	54	49	60	63	69
Magnesium %	32	42	26	29	23
Sodium %	3	1	2	2	4

The K%, Ca%, Mg% and Na% are calculated as follows:

mg per kg K / 390 / S = %K
mg per kg Ca / 200 / S = %Ca
mg per kg Mg / 120 / S = %Mg
mg per kg Na / 230 / S = %Na
mg per kg K / 390 + mg per kg Ca / 200 + mg per kg Mg / 120 + mg per kg Na / 230 = Total cations in me per 100g = S-value

In acid soils the exchangeable acid can also be added to the total cations.

The reference standards or norms for soil from existing citrus orchards are set out in table 1.1.

Element	***Method***	***Optimal Range for Citrus***	***Comments***
pH	2:5 soil: water	6.00 to 7.50	Measures what the root experience
	2:5 soil: 1N KCl	5.50 to 7.00	Includes reserve acid
P	Bray 1	25 to 50	Little correlation between soil and leaf P levels
K, Ca, Mg and Na	Ammonium acetate	K = 5 to 7,5% Ca = 70 to 75% Mg = 20 to 25% Na = <3.00% of the total cations of a soil with a neutral pH	The actual levels will vary according to the clay content of the soil

Table 1.1: Reference Norms (Standards) for Soil in Existing Citrus Orchard

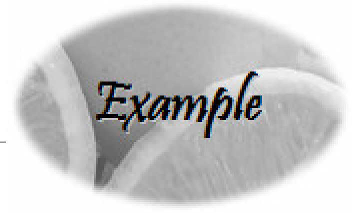
The interpretation of the results of the soil analyses report is done according to the following steps:

- Ensure that the methods used to analyse the soil are the same as those used to set the reference norms.
- Evaluate the results one by one against the reference norms.
- Mark those above the norms with a + and those below with a -.
- If the pH is too low, decide on the type of lime to be applied by evaluating the magnesium status of the soil. The magnesium status is both the actual and the Mg%. If the magnesium status is too low or on the lower side of the optimal range, apply dolomitic lime. If the magnesium status is acceptable or high, apply calcitic or hydrated lime.
- The rest of the evaluation should be done in conjunction with the interpretation of the leaf analyses data.

2.2. <u>Leaf Analyses</u>

The first step in evaluating a leaf analysis report is to compare the results with the appropriate set of standards or norms.

Ensure that the leaf sample was taken according to the same method that was used to compile the norms. In other countries, citrus leaf samples may be taken differently and other methods of analyses may be used.



Leaf Analysis Report

Sunshine Farm

P.O. Box 43
Hoedspruit
0164

21st May 2010

LEAF ANALYSES REPORT						
Lab Number		L8772	L8773	L8774	L8775	L8776
Your Reference Number		A	B	C	D	E
Nitrogen (Total)	**%**	2.18	2.11	2.45	2.19	1.89
Phosphorus	**%**	0.11	0.15	0.13	0.14	0.16
Potassium	**%**	0.89	1.23	0.45	1.35	0.92
Calcium	**%**	3.25	3.72	4.12	5.21	3.71
Magnesium	**%**	0.23	0.41	0.38	0.53	0.55
Sulphur	**%**	0.24	0.27	0.15	0.27	0.25
Chloride	**%**	11	5	8	68	143
Sodium	**mg/kg**	11	17	9	2151	1674
Copper	**mg/kg**	11	8	12	6	4
Iron	**mg/kg**	54	49	60	63	69
Manganese	**mg/kg**	112	82	212	29	23
Zinc	**mg/kg**	27	31	22	18	13
Boron	**mg/kg**	48	66	71	2117	231
Molybdenum	**mg/kg**	0.06	0.12	0.04	1.42	2.11

The set of reference standards or norms is as follows:

Nutrient Element	***Cultivar***		***- -***	***Optimal***	***++***
N	Valencias	In hot areas	<1.90	2.30-2.60	>2.80%
		Other areas	<1.90	2.10-2.30	>2.50%
		< than 6 years old	<2.10	2.40-2.60	>2.80%
	Midseason Varieties		<1.90	2.10-2.30	>2.50%
	Clementine		<1.90	2.20-2.40	>2.60%
	Tangelo		<2.20	2.60-2.75	>3.00%
	Satsuma	Owari	<1.90	2.10-2.30	>2.50%
		Miho Wase	<1.90	2.10-2.40	>2.50%
	Navel	Bahianinha	<2.00	2.30-2.50	>2.70%

Nutrient Element	***Cultivar***		***- -***	***Optimal***	***++***
		Other	<2.10	2.40-2.60	>2.80%
	Lemons		<1.90	2.10-2.60	>2.80%
	Grapefruit		<1.70	1.90-2.20	>2.40%
P	Satsuma		<0.12	0.16-0.20	>0.24%
	Grapefruit		<0.10	0.14-0.16	>0.20%
	All other cultivars		<0.10	0.12-0.14	>0.16%
K	Valencia		<0.60	0.90-1.80	>2.00%
	Midseason Varieties		<0.60	0.90-1.80	>2.00%
	Clementine		<0.60	0.90-1.60	>1.80%
	Tangelo		<0.60	0.90-1.25	>1.50%
	Satsuma		<0.60	0.90-1.50	>1.75%
	Navel		<0.50	0.70-1.10	>1.50%
	Lemon		<0.60	0.80-1.20	>1.25%
	Grapefruit		<0.60	0.80-1.00	>1.25%
Ca	All Cultivars		<2.50	3.50-6.00	>7.00%
Mg	All Cultivars		<0.20	0.30-0.50	>0.75%
S	All Cultivars		<0.15	0.20-0.30	>0.50%
Cl	All Cultivars				>0.65%
Na	All Cultivars				>4.000mg/kg
Cu	All Cultivars		<3	5-20	>40mg/kg
Fe	All Cultivars		<35mg/kg		
Mn	All Cultivars		<25	40-150	>300mg/kg
Zn	All Cultivars		<15	25-100	>200mg/kg
B	All Cultivars		<40	75-200	>300mg/kg
Mo	All Cultivars		<0.05mg/kg		

Table 1.2: Reference Standards for Leaves

The second step is to determine why the concentration of the element is not in the optimum range. Sub-optimal levels may be due to other factors. Other measures, apart from increasing nutrient levels by applying more fertilisers, may have to be considered to rectify the problem.

If the results of the leaf analysis are interpreted purely by comparing it to leaf norms, the wrong deduction can very easily be made.

A "normal" N level can for instance be due to the trees being fertilised with nitrogen shortly before sampling, in which case the "normal" level will be due to erroneous practices. Nitrogen should not be applied at that time of the year – sampling is done in March or April – and the seemingly normal level of N is in fact misleading.

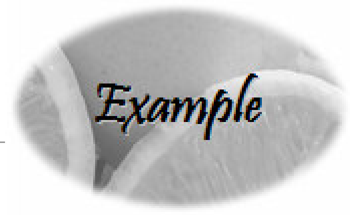
Nutrient Element	***Possible Cause***	***Possible Remedy***
N	**Too Low Concentration**	
	Too much fertiliser applied at a time	Split the mass / volume of fertilisers applied at any time
	Excess leaching	Reduce the application of water to wet the root zone only
	Phytophthora infection of the roots	Test the roots for Phytophthora and act accordingly
	Low efficiency of applied fertilisers	Foliar sprays with low biuret urea or potassium nitrate
	Too High Concentration	
	Too much fertilisers applied	Reduce the application rate
	Applications done too late	Correct the application time(s)
	Nitrogen reserve of the soil is too high	Consult an expert
P	**Too Low Concentration**	
	Too high soil pH	Apply single or double super phosphate in a narrow strip on the soil
	Too low soil pH	Apply lime to increase the pH to 6.50
	Note: Foliar sprays with phosphates are not effective	
	Too High Concentration	
	Too much P applied	Reduce application with drippers and stop applications for a season or more where micro-jets are used. Use leaf and soil analyses to monitor the situation.
	P sprayed before sampling to reduce acids	Take the leaf sample before spraying commences
K	**Too Low Concentration**	
	Too high concentration of magnesium in the soil or water	Use potassium nitrate to apply some of the nitrogen required
	Nematodes	Test the roots for nematodes and act accordingly
	Salinity	Locate the source and act accordingly
	Low efficiency of applied fertilisers	Foliar sprays with potassium nitrate
	Poor root-health	Take remedial actions
	Old trees	Rejuvenate the root system
	Compaction	Corrective actions with mechanical implements may be used, but are not always successful
	Too High Concentration	
	Application too high	Reduce or omit further applications
	Young trees	Set more fruit to reduce the negative impact
	Late applications of potassium sprays	Correct spraying program

Nutrient Element	*Possible Cause*	*Possible Remedy*
Ca	**Too Low Concentration**	
	Climatic conditions	Ensure that enough available calcium is present in the root-zone during the critical period from bud-break to petal drop
	Low pH	Apply lime
	Salinity	Locate the source and act accordingly
	Low calcium saturation	Apply lime, gypsum or calcium nitrate
	Note: Foliar sprays with calcium have limited success	
	Too High Concentration	
	Leaves were too old when sampled	Correct sampling procedure
	Calcium sprays applied shortly before leaf sampling	Take the leaf sample before spraying commences
Mg	**Too Low Concentration**	
	Too high concentration of potassium in the soil	Apply magnesium nitrate foliar sprays
	Low pH	Apply dolomitic lime
	Foliar sprays with potassium nitrate	Apply magnesium nitrate foliar sprays
	Too High Concentration	
	Too much magnesium applied	Reduce or omit further applications
	Mg content of the soil/water too high	Concentrate on effective K nutrition
S	**Too Low Concentration**	
	Too low concentration of S in the soil	Apply sulphates to the soil Efficacy of foliar sprays is unknown
	Too High Concentration	
	Too much applied	Reduce or omit further applications
Cu	**Too Low Concentration**	
	Too low concentration of Cu in the soil	Apply foliar sprays Efficacy of soil applications depend on other soil factors
	Too High Concentration	
	Residue from pesticide spray	The Cu is on and not in the leaf and seldom causes toxicity
Fe	**Too Low Concentration**	
	Too high pH in the soil	Apply Fe-EDDHA in August
	Water logging	Improve scheduling and drainage
	Note: Foliar sprays with iron chelates are not effective	
	Too High Concentration	
	Too much bicarbonate in the water, Fe is precipitated and the trees take up more Fe to satisfy their requirements, only for the Fe to be precipitated again	Acidify water if used in drip systems

Nutrient Element	***Possible Cause***	***Possible Remedy***
Mn	**Too Low Concentration**	
	Too high pH in the soil	Apply foliar sprays
	Recent liming	Apply foliar sprays
	Too High Concentration	
	Residue from pesticide spray	If Dithane was used, the levels can become toxic and another fungicide should be used
	Very acid soils	Apply lime
Zn	**Too Low Concentration**	
	Too high pH in the soil	Apply foliar sprays
	Recent liming	Apply foliar sprays
	High P status	Apply foliar sprays
	Note: Soil applications to mature trees are not effective	
	Too High Concentration	
	Residue from pesticide or foliar spray	The Zn is on and not in the leaf and seldom causes toxicity
B	**Too Low Concentration**	
	Too high pH in the soil	Apply foliar sprays
	Recent liming	Apply foliar sprays
	Note: Applications of boron to the soil are quite effective under most soil conditions	
	Too High Concentration	
	Too much B in the water or soil	Decrease in production will result only under extreme conditions, in which case area or water source must be abandoned
Mo	**Too Low Concentration**	
	Too low soil pH	Apply lime Apply foliar sprays
	Too High Concentration	
	Alkaline conditions	Toxicity is unknown in citrus

Table 1.3: Causes of Nutritional Imbalances

Before reliable interpretations can be made of leaf analyses data, it is necessary to take other orchard information into account. Orchard information for the twelve-month period preceding the sampling must be available.



Orchard Information Reports

Sunshine Farm

Hoedspruit, Limpopo

Orchard Information – Citrus

Orchard Information			
Orchard Number:	A	**Type of irrigation:**	Micro-jets
Cultivar:	Valencias	**Fertigation:**	No
Selection:	Deltas	**Area Planted:**	2.8ha
Rootstock:	Rough lemon	**Trees per Ha:**	416
Sampling Date:	11 March 2005	**Planting Date:**	Oct 1995

Crop Information			
Yield – Previous Season:		45t/ha	
Yield – Estimate This Season:		50t/ha	
Fruit size:	OK	**Juice %:**	OK
Skin Quality/Colour:	OK	**Acid %:**	Too low
TSS:	OK	**Physiological Disorders:**	None

Fertilisers Applied (g or ml/tree)

Type	***Quantity Date***	***Quantity Date***	***Quantity Date***	***Quantity Date***
LAN	500g Jul 05	250g Aug 05		
Single Supers	1000g Sept 05			
KCl	500g Oct 05			

Foliar Sprays Applied(g or ml per 100 litres water)

Type	***Quantity Date***	***Quantity Date***	***Quantity Date***	***Quantity Date***
Low biuret urea	1000g Jul 05	1000g Oct 05		
Zinc nitrate	2x150ml Oct 05			

Sunshine Farm
Hoedspruit, Limpopo

Orchard Information – Citrus

Orchard Information			
Orchard Number:	E	**Type of irrigation:**	Micro-jets
Cultivar:	Navels	**Fertigation:**	No
Selection:	Washington	**Area Planted:**	4.15ha
Rootstock:	Rough lemon	**Trees per Ha:**	416
Sampling Date:	11 March 2005	**Planting Date:**	Oct 1990

Crop Information			
Yield – Previous Season:		25t/ha	
Yield – Estimate This Season:		35t/ha	
Fruit size:	Too large	**Juice %:**	OK
Skin Quality/Colour:	OK	**Acid %:**	Too low
TSS:	OK	**Physiological Disorders:**	None

Fertilisers Applied (g or ml/tree)

Type	***Quantity Date***	***Quantity Date***	***Quantity Date***	***Quantity Date***
LAN	750g Jul 05	350g Aug 05	150g Sep 05	
Gypsum	2000g Sept 05			
KCl	250g Oct 05			

Foliar Sprays Applied(g or ml per 100 litres water)

Type	***Quantity Date***	***Quantity Date***	***Quantity Date***	***Quantity Date***
Low Biuret Urea	1000g Jul 05	1000g Oct 05		
Zinc Nitrate	150ml Oct 05			
Manganese Sulphate	200g Oct 05			

3. Nutrient Requirements for Citrus

Crops differ in the amount and ratio of the fourteen essential nutrients they require for optimal production. These differences are also found between cultivars of the same crop. Citrus is no exception.

Nutrient requirements are based on the mass of each element removed by the crop and the specific reactions of the nutrients in the soil. These reactions determine the eventual efficiency of a nutrient application.

Table 1.4 reflects the average volume of essential nutrient element removed by 1,000kg of citrus:

Nutrient	***Chemical Symbol***	***Removal Figures kg/1,000kg (1 ton)***
Nitrogen	N	2.500
Phosphorus	P	0.500
Potassium	K	1.500
Calcium	Ca	0.500
Magnesium	Mg	0.350
Sulphur	S	0.150
Sodium	Na	0.005
Chloride	Cl	0.005
Copper	Cu	0.002
Iron	Fe	0.005
Manganese	Mn	0.005
Zinc	Zn	0.002
Boron	B	0.002
Molybdenum	Mo	?

Table 1.4: Volumes of Essentials Nutrient Elements Removed by 1,000kg of Citrus

For different cultivars and / or selections, the nitrogen, phosphorus and potassium removal figures are adjusted as follows:

Nutrient	***Cultivar / Selection***	***Removal Figures kg/1,000kg (1 ton)***
N	Navels	2.500
	Clementines and Valencias	2.000
	Lemons and Minneolas	3.000
P	Satsumas	0.750
	Grapefruit	0.600
	All other citrus	0.500
K	Navels, Lemons and Grapefruit	1.000
	Clementines and Valencias	2.000
	Other citrus	1.500

Table 1.5: Nitrogen, Phosphorus and Potassium Removal Figures for Different Cultivars

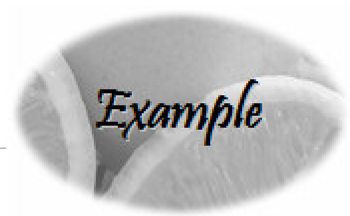
The second basis for distinguishing between the requirements of citrus for different nutrients is the efficiency rate of the application. This depends on other factors such as irrigation, clay content, salinity, age and climate.

The following serves as a guideline to evaluate the efficiency of the applications of N, P and K fertilisers. Efficiency is calculated as the mass removed by the fruit as a percentage of the mass applied.

Nutrient	***Irrigation***		
	Micro-Jet		***Dripper***
	<15% clay	**>20% clay**	
N	70-80%	75-85%	75-90%
P	35-50%	25-40%	60-75%
K	60-70%	35-50%	70-80%

Table 1.6: Efficiency of Nitrogen, Phosphorus and Potassium Applications

When formulating a fertilisation program, these two factors, namely crop removal and efficiency, must also be considered. It is quite easy to calculate the removal and express it as a percentage of the mass of the nutrient applied.



Calculating Nutrient Efficiency Rate

A navel orchard planted on a soil containing 15% clay is irrigated by micro-jets and yields 55 tonnes fruit per ha. During the previous season, it was fertilised with 600kg limestone ammonium nitrate (LAN) per ha. The efficiency rate can therefore be calculated as follows:

Nutrient Mass Removed (kg/ha)

Mass Removed = Yield per ha (T) x Removal Rate for Navels
55t x 2.5kg = 137.5kg N removed per ha

Nutrient Mass Applied (kg/ha)

Mass N Applied = Fertiliser per ha (kg) x % Active Ingredient (Nutrient)
600kg/ha x 0.28 = 168kg N applied per ha

Efficiency Rate (%)

Efficiency Rate = (Mass Removed / Mass Applied) x 100
137.5kg / 168kg x 100 = 81.8% efficiency

According to the above table the efficiency of the nitrogen application was acceptable.

Low efficiency rates may be due to various factors. Table 1.7 sets out the possible causes and remedies for low efficiency rates.

Cause	***Action***	***Comment***
Alternate bearer	Girdling	Sometimes the cause of poor performance has nothing to do with fertilisation per se.
Excessive leaching	Reschedule the irrigation following the application of LAN	Apply only enough water to wet the top 20cm of the root zone. This will ensure that more N is taken up by the roots during the cool months of August / September.

Cause	*Action*	*Comment*
All the LAN was applied at one time	Split the total mass to be applied into two or three applications during July or August to October.	The first application must still be done in July or August.
The application was miscalculated	Recalculate the mass to be applied based on the previous yield and redo the calculation of the N efficiency.	Adjust the recommended application for the coming season.

Table 1.7: Causes and Remedies for Low Efficiency Rates

4. Principles Used in Compiling a Fertilisation Program

After the evaluation process is completed, recommendations can be made to maintain or strive to the optimal nutritional status. The principle of any fertilisation program is to support economic, optimal crop production. Optimal status is very seldom achieved within one season and in some cases, will never be achieved. Records of year-on-year analysis results are kept to monitor progress in working towards an optimal nutritional status.

The optimal nutritional status must also be viewed in relation to profits. Correcting certain imbalances – such as a high magnesium status, which impacts on the potassium status, which in turn influences fruit size – could be so costly as to be uneconomical. In such cases other horticultural techniques must be applied to increase fruit size and profits.

An effective fertilisation program will contribute to optimal yield. Note that optimal and not maximum yield is the aim. Economic crop production is a compromise between various crop factors to get the best possible returns. High volumes of fruit often consist of small fruit that do not bring the best returns. The aim is to produce enough fruit of marketable and exportable size.

Compiling a fertilisation program is about knowing what, how much and when to apply fertilisers. To develop a basic program that can be used for individual or grouped orchards, the following information is required:

- Cultivar
- Irrigation type
- Clay content of the soil

4.1. Type and Quantity of Application

The type and quantity of fertilisers to be applied are determined by three factors, namely:

- The current status of the element as measured by leaf and soil analyses indicates what to apply. In short, all elements that are not within the optimum range, and for which the status cannot be explained by other factors as discussed above, must be supplemented.

- The previous application rate serves as another indication of what and how much to apply. If 100kg N was applied per ha in the previous season and the leaf analyses indicate a below optimum level, the 100kg N was too little in the orchard conditions. The next application need to be more than 100kg per ha. How much more depends on the current and expected yield.

- The current and expected yields and fruit quality indicate how much to apply. A crop of 1,000kg (1 metric ton) removes the masses of nutrients as shown in tables 1.4 and 1.5 from the trees in the orchard. These figures are used to determine the application rates for the coming season.

4.2. Timing of Application – Seasonal Nutrient Requirements

Nutrients must be applied at specific physiological stages, i.e. specific application times are used for certain nutrients. The timing of application of certain nutrients, specifically nitrogen, furthermore impacts on the size and quality of the yield.

4.2.1. Nitrogen

Timing the application of nitrogen is one of the most important factors in the fertilisation program for citrus. Nitrogen must be applied in such a way as to ensure that the nitrogen status of the trees reaches two important levels, being:

- High nitrogen levels during bud-break, blossom and fruit-set is essential to set a good crop and support the phases of cell division and cell growth. (Please refer to the Citrus Phenology Chart that is contained in the **Introduction to Citrus Production** section in the learner guide for ***Understand Basic Soil Fertility and Plant Nutrition on NQF level 2***). To increase the nitrogen status to this high level, applications of nitrogen fertilisers are made from July to October.

- During late summer into autumn the nitrogen status of the trees should be at a low level. The low nitrogen status ensures that carbohydrates accumulate in the tree to serve as energy source during the ensuing cell division and cell growth for the coming crop. A low nitrogen status will also promote colour break and internal fruit quality of the current crop.

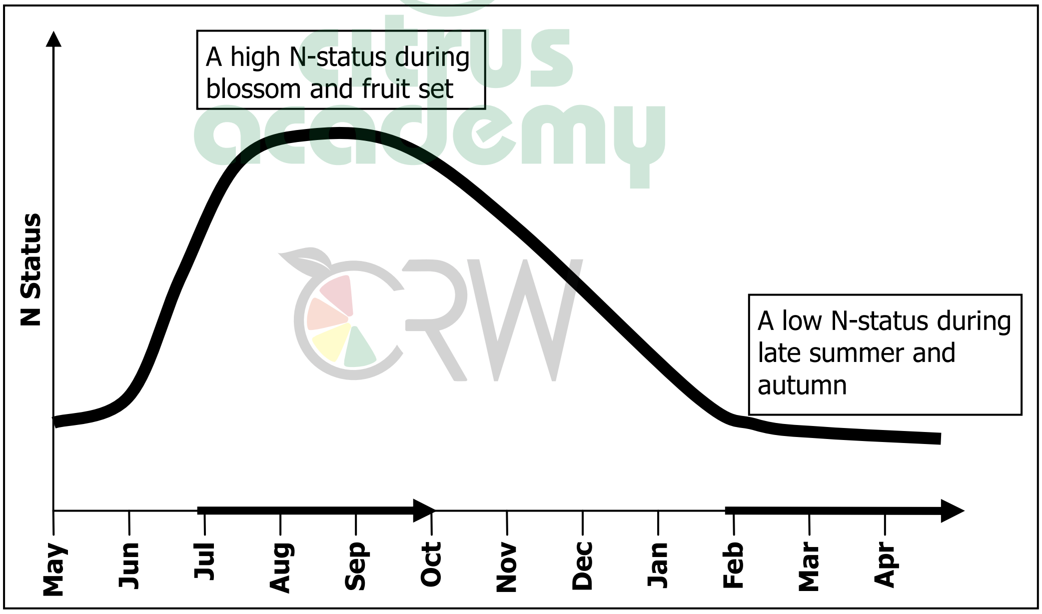


Figure 1.1: Seasonal Nitrogen Requirements

Nitrogen status of citrus leaves is measured during February to May which coincides with the lower N-status required.

The amounts and frequency of N-applications for both micro-jet and drip irrigation are determined by:

- The soil type and specifically texture (only micro-jets)
- The current status of the element as measured by leaf analyses
- The current pH of the soil
- The previous application rate
- The current and expected yields

4.2.2. Phosphorus

Citrus trees accumulate phosphorus and when requirements increase during cell division and cell growth stages, P is mobilised and relocated to the sites where required.

The timing of phosphorus applications is therefore not that important when micro-jets are used. Applications are however best suited during September to November when root-flushes are expected.

Only one application in a narrow strip is required, and only if the leaf analysis shows a deficiency. There is no correlation between the P-level in the soil and the level in the leaf.

When micro-jets are used, P applications are not required every year. With drip irrigation, P needs to be applied continuously between August and December every year. The amounts and frequency will be determined by:

- The current status of the element as measured by leaf and soil analyses
- The previous application rate
- The current and expected yields

4.2.3. Potassium and Magnesium

Potassium and magnesium are very mobile cations in plants and can be relocated as and when required. Plants accumulate K and Mg during times of high supply and low demand and use that during times of high demand.

With micro-jets, K and Mg fertilisers are applied in one two or more applications during September to February. With drip-irrigation, potassium and magnesium are applied continuously from July to January and even into February. The amounts and frequency with both micro-jets and drippers are determined by:

- The soil type and specifically texture
- The current status of the element as measured by leaf and soil analyses
- The previous application rate
- The current and expected yields

4.2.4. Sulphur

Sulphur is not mobile in the plants and needs to be supplied in August if the leaf analyses indicate a deficient level. When a "below optimal" level is indicated by leaf analyses the S can be applied during September to December. Maintenance applications can also be done during this period.

4.2.5. Calcium

Calcium has a unique physiology, which renders fertilisation with calcium the most complicated of all nutrients. Although fairly easy and simple to apply, enough calcium in the root-zone is no guarantee that the fruit will get enough Ca at all times.

Applications of calcium fertilisers during August to October should give the best results. With micro-jets, one application in August or September should be enough. With drippers, the application must be regular and extended to October.

Tables 1.8 and 1.9 give an approximate indication of how applications of the nutrient elements discussed above will be spread over a year, indicated as a percentage of the total requirement per month.

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Nitrogen	50%	30%	20%					
Phosphorus			100%					
Gypsum		100%						
Potassium				50%	50%			
Lime				100%				

Table 1.8: Approximate Distribution of Fertilisers per Month as Percentage of Total Requirement for Orchards under Micro-Jet Irrigation

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Nitrogen	30%	25%	15%	10%	10%	5%	5%	
Phosphorus		20%	20%	20%	10%	10%	10%	10%
Calcium		40%	40%	20%				
Potassium			20%	20%	20%	20%	20%	
Magnesium					25%	25%	25%	25%
Sulphur					25%	25%	25%	25%

Table 1.9: Approximate Distribution of Fertilisers per Month as Percentage of Total Requirement for Orchards under Single-Line Drip Irrigation

4.3. Foliar Applications

Foliar applications of nutrients form an integral part of citrus production. The micro nutrient elements, except iron, are very effectively supplied by means of foliar sprays. Even some of the macro-nutrient elements, such as nitrogen, potassium and magnesium, can be effectively supplied in this manner. Developing a foliar application plan involves at least four categories, namely:

- Copper sprays
- Other micro nutrients
- Corrective applications of macro nutrient elements (N, K and Mg)
- Manipulative sprays with urea and potassium nitrate

Timing of foliar sprays with potassium nitrate and urea is important because these two fertilisers are involved in manipulating processes. Timing of micro-nutrient applications is only important in the case of copper sprays, with chemicals of low solubility like copper oxychloride or copper hydroxide, which must be applied before blossom. The timing of application through the year for foliar sprays for orchards under micro-jet and drip irrigation is listed in the table below.

Fertiliser	Jul	Aug	Sep	Oct	Nov	Dec	Jan
UREA	Y[1]			Y[2]			
Copper	Y						
Potassium	Y[1]	Y[3]			Y[4]		
Magnesium	Y[1]			Y[2]			
Manganese	Y[5]			Y			
Zinc	Y[5]			Y			
Boron	Y[5]			Y			
Molybdenum				Y			

Table 1.10: Approximate Distribution of Fertilisers per Month as Percentage of Total Requirement for Orchards under Single-Line Drip Irrigation

[1] When urea or potassium nitrate is used as a manipulative spray is must be applied 8 weeks prior to the 50% bloom stage.

[2] Urea can also be applied to supply nitrogen later in the season. It is usually applied during October but can be applied up to February. It is better to supplement nutrients present in deficient concentrations before the flowering stage.

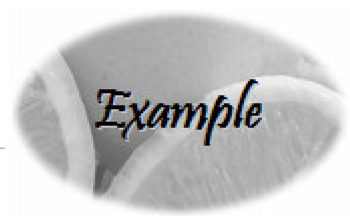
[3] Potassium sulphate can also be applied to increase the potassium level prior to blossom where fruit set need not be increased.

[4] Potassium nitrate can also be applied in November to increase the K-status.

[5] Usually Mn, Mg, Zn and B are applied in October, but when these concentrations are too low, it is advisable to add these nutrients before blossom.

5. Compiling a Fertilisation Program

To better illustrate how the principles above is used to develop a fertilisation program, we will analyse the results of the soil and leaf samples, and the orchard information from orchards A and E, as stated in section 2.



Fertilisation Programs

LEAF ANALYSES REPORT			
Lab Number		L8772	L8776
Your Reference Number		A	E
Nitrogen (Total)	**%**	2,18	- - 1,89
Phosphorus	**%**	- 0,11	+ 0,16
Potassium	**%**	- 0,89	0,92
Calcium	**%**	- 3,25	3,71
Magnesium	**%**	- - 0,23	+ 0,55
Sulphur	**%**	0,24	0,25
Chloride	**%**	0,11	0,03
Sodium	**mg/kg**	11	1674
Copper	**mg/kg**	11	- 4
Iron	**mg/kg**	54	69
Manganese	**mg/kg**	112	- - 23
Zinc	**mg/kg**	27	- - 13
Boron	**mg/kg**	- - 48	+ 231
Molybdenum	**mg/kg**	0,06	2,11

SOIL ANALYSES REPORT		
Lab Number	S21004	S21008
Your Reference Number	A	E
pH (Water)	5.38	8.21
pH (KCl)	4.91	7.75
P (Bray 1) mg/kg	45	31
Potassium AmAc mg/kg	85	272
Calcium AmAc mg/kg	213	2215
Magnesium AmAc mg/kg	76	442
Sodium AmAc mg/kg	11	143
Potassium %	11	4
Calcium %	54	69
Magnesium %	32	23
Sodium %	3	4

Orchard A

- The N-status is too high and the application of 750g LAN per tree was done at the right time.
- The foliar spray of urea in October is probably unnecessary.
- The crop of 45 tons per ha is equal to 108kg fruit per tree and that will remove 216g N or 771g LAN from the trees.
- The application of 750g LAN is therefore just right for last year's crop.
- The expected crop will require 240g N or 860g LAN per tree.

Recommendation: Apply 650g LAN per tree in July and 250g in August. The pH of the soil is low, therefore LAN is a good source of N.

- The P-status is low in the leaf but adequate in the soil.
- P was applied last year.
- The low pH of the soil will reduce the availability.
- Liming can take care of the unavailability.
- The magnesium status of the soil is low and the % Mg is high, but the actual level could be slightly too low.

Recommendation: Apply 4,000g dolomitic lime per tree in October.

- The potassium status of the leaves is too low. The actual potassium content of the soil is also too low although the %K is high.
- Fruit size is not a problem, and foliar sprays are therefore not yet required.

Recommendation: Apply 500g potassium chloride per tree in September and 250g in October.

- The calcium status of the leaves is too low. Link that to the too low % Ca in the soil and the low pH and the lime applications is justified again.
- The magnesium status of the leaves is deficient and justifies the application of foliar sprays.

Recommendation: Apply two foliar sprays each of 1250g magnesium nitrate per 100 litre water in October.

- Although the status of zinc is adequate, it is due to the zinc nitrate spray in October the previous year.

Recommendation: To maintain this level, apply 150ml zinc nitrate per 100 litres water in October.

- The boron status in the leaves is low.

Recommendation: Apply 150g Solubor® per 100 litres water in October.

The fertilisation program for 2006 for orchard A will be as follows:

FERTILISATION PROGRAM – CITRUS			
Orchard:	Orchard A	**Size:**	2.8ha
Cultivar/Variety:	Delta Valencia	**Trees per ha:**	416
Fertiliser		***Quantity***	***Time of Application***
Soil Applications		**g per tree**	
Limestone Ammonium Nitrate (LAN)		650g	July
LAN		250g	August
Potassium Chloride (KCL)		500g	September
Potassium Chloride (KCL)		250g	October
Dolomitic Lime		4000g	October
Foliar Sprays		**g per 100l water**	
Low Biuret Urea		1000g	July
Zinc Nitrate		200g	October
Magnesium Nitrate		150g	October
Solubor®		150g	October
Remarks:			

<u>Orchard E</u>

- The N-status is deficient for navels. The application of 1250g LAN per tree was done at the right time.
- The second foliar spray of urea in October is still not effective enough.
- The previous year crop of 25 tonnes per ha is equal to 60kg per tree and removed only 150g N or 536g LAN from the trees.
- The application of 1250g LAN is therefore much higher than the removal.
- The expected crop of 35 tonnes per ha will require 210g N or 750g LAN per tree.
- Nitrogen is not being utilised by the trees effectively. The efficiency rate is only 43% for the previous crop and 60% for the current crop.
- Investigate the condition of the root system. Phytophthora will reduce the efficacy of the N application.

Recommendation: Apply 2x400g LAN per tree in July, 350g in August and 250g in September. The pH of the soil is high, and although LAN is a good source of N a more acidifying source like ammonium nitrate can be used.

- The P-status is high in the leaf and adequate in the soil.
- No recommendation for application of a P-source.
- The magnesium status of the soil, the % Mg and the leaf level are high.
- No need to apply magnesium.
- The potassium status of the leaves is acceptable and no problems with fruit size are experienced.

Recommendation: Repeat the application of 250g potassium chloride per tree in September.

- The calcium status of the leaves and soil is satisfactory. No applications were done to create this situation. Therefore maintain the status quo.
- The copper is too low. Copper was not applied. Therefore one spray with copper is required.

Recommendation: Apply 150g copper oxychloride per 100 litres water in July.

- The zinc and manganese levels are deficient. Therefore extra zinc and manganese sprays are required.

Recommendation: Apply 2x150ml zinc nitrate plus 2x200g manganese sulphate per 100 litres water in October.

- The boron status in the leaves is satisfactory.

The fertilisation program for 2006 for orchard E will then be as follows:

FERTILISATION PROGRAM – CITRUS			
Orchard:	Orchard E	**Size:**	4.15ha
Cultivar/Variety:	Navels Washington	**Trees per ha:**	416
Fertiliser		***Quantity***	***Time of Application***
Soil Applications		**g per tree**	
Limestone Ammonium Nitrate (LAN)		2 x 400g	July
LAN		350g	August
LAN		250g	September
Potassium Chloride (KCL)		250g	October
Foliar Sprays		**g per 100l water**	
Low Biuret Urea		1000g	July
Low Biuret Urea		1000g	October
Copper Oxychloride		150g	July
Manganese Sulphate		2 x 200g	October
Zinc Nitrate		150ml	October
Remarks:			

<u>Chapter 1</u>

- Interpreting leaf and soil analyses is a systematic process of questions and answers, starting with comparing the available norms or reference standards with the analytical data.
- Soil analysis simulates the mass of nutrients a plant will extract from soil.
- The first step in evaluating a leaf analysis report is to compare the results with the appropriate set of standards or norms.
- The second step is to determine why the concentration of the element is not in the optimum range.
- In interpreting leaf analysis, it is necessary to take other orchard information into account.
- Nutrient requirements are based on the mass of each element removed by the crop and the specific reactions of the nutrients in the soil.

- The second basis for distinguishing between the requirements of citrus for different nutrients is the efficiency rate of the application.
- The principle of any fertilisation program is to support economic, optimal crop production at the lowest input cost. The type and quantity of fertilisers to be applied are determined by three factors, being the current status of the element as measured by leaf and soil analyses, previous application rates, and current and expected yields and fruit quality.
- Nutrients must be applied at specific physiological stages, and the timing of application of certain nutrients, specifically nitrogen, impacts on the size and quality of the yield.

Complete activities 1, 2 and 3 in the **Learner Workbook**.

Chapter 2

After completing this chapter, the learner will be able to:

Optimise soil utilisation plan according to crop and soil requirements
Create and implement a database for soil management

1. Introduction

Citrus is produced economically in many types of soil, of which the majority does not comply with the definition of an optimal soil. In fact, an optimal soil is seldom found in nature and most soils need to be modified chemically or physically to get close to optimal conditions. Thereafter, managing the soil and horticultural practises can add to the effective utilisation of a suboptimal soil.

2. Components of a Soil Utilisation Plan

A soil utilisation plan is applicable to a specific site, with the aim of optimising the growing conditions for the trees. The plan must include actions to improve what can be improved and to manage that cannot be improved.

A soil utilisation plan starts with a soil survey, including descriptions of the soil profiles, follows with laboratory reports and concludes with recommendations for optimum soil utilisation.

The minimum requirements for a soil survey and profile description are the following:

- Slope and aspect
- Total soil depth
- Effective soil depth
- Parent material or material underlying the soil
- Stratification – Presence of stones, impervious layers, etc.
- Texture
- Structure
- Information on water logging and aeration
- Chemical composition
- Surface drainage

The optimal soil conditions for citrus cultivation must also be available for evaluating the utilisation plan, including the optimal ranges to which the site, soil and/or profile can be improved.

Soil Property	***Optimal Range or Standard***	***Comments***	***Evaluation***
Physical Soil Properties			
Potential Depth	>500mm	The required depth is also a function of: • Irrigation system type and the level of irrigation management. The shallower the available rooting-depth, the more efficient the irrigation management	The soil survey indicates the potential soil depth. If it is below the optimal standard, the following option can be considered to increase depth: • Cultivating deeper • Changing irrigation type or management

Soil Property	Optimal Range or Standard		Comments	Evaluation
			has to be. Drip irrigation generally requires a deeper root system than micro-jets. • Soil texture – Using a drip system on sandy soil results in less lateral movement of water and therefore a deeper rooting depth is required, otherwise the required level of management will be too high. With micro-jets and clayey soil, the roots will do better near the surface and hence less depth is required. • Soil strength	• Planting on ridges
Texture	Optimal	7-30% clay	Soil texture determines aeration, leaching and water holding capacity (WHC), which can be controlled through irrigation to some extent.	Not much can be done to change the texture, but cultivar and root-stock selection and other horticultural practices can be changed.
	Marginal	<7% 30-40%		
	Risky	>40%		
Structure	Structure is important in loamy and clayey soils but not in sandy soils.		If the soil in its natural state is structured, then the structure must be maintained under orchard conditions.	Ensure that the mechanical operation and irrigation stabilise the structure.
Layering	The general standard is no layering of any sort in the rooting zone. The variance factor of clay content between consecutive layers must not be larger than 1.5.		In the soil profile, layers can be very thin (a few mm thick) or represents a soil horizon of several cm.	The pre-planting soil preparations must aim to remove all layers to produce a homogeneous root-zone.
Aeration	Aeration depends on soil structure and the presence of macro pores. Poor aeration cannot be tolerated		Symptoms of poor aeration (current and historic) can be detected in the profile.	If poor aeration is historic, ensure that the causes are no longer present. If current, consider the possible solutions and costs and decide on appropriate method or abandon the site.
Strength	<2000 MPa		The soil strength in the potential rooting volume must everywhere be less than 2000Mpa. Stone and clods larger than 500ml in diameter can be considered as dead volume as far as water	Ensure that during soil preparation less than 20% of the soil volume is occupied by large clods. Where large stone and gravel represents more than 20% of the volume, the volume of soil

<table>
<tr><th>Soil Property</th><th colspan="2">Optimal Range or Standard</th><th>Comments</th><th>Evaluation</th></tr>
<tr><td></td><td colspan="2"></td><td>and nutrients are concerned. It can also create anaerobic pockets.</td><td>available to the trees must be increased accordingly.</td></tr>
<tr><td>Surface Drainage</td><td colspan="2">Water must be able to drain from the area freely and quickly. No depressions where water can accumulate must be near the trees.</td><td>Surface drainage and erosion go hand in hand. The faster the rate of surface drainage, the higher the risk of erosion. Allowing natural grass to establish in the space between rows is a simple way of combating erosion. During the early stages when the natural cover is not yet properly established, erosion is however a real threat.</td><td>If the slope is very steep, ensure that a grass cover is established quickly. This process can be promoted by seeding the area with a selection of natural grasses.</td></tr>
<tr><td>Infiltration Rate</td><td colspan="2">The infiltration rate at FWC should be greater than the application rate. For most soils an infiltration rate of 6-9 mm/h is applicable.</td><td>The infiltration rate depends on the soil type and can be decreased by salinity in the soil, application of water with a SAR exceeding 3.00, application force and several other factors. Crusting is the most common factor that reduces the infiltration rate. The infiltration rate should be taken into account in the irrigation system design.</td><td>Ensure that the application rate is less than the infiltration rate at FWC.</td></tr>
<tr><td colspan="5">Chemical Soil Properties</td></tr>
<tr><td>pH (water)</td><td colspan="2">6.50-7.50</td><td>The potential of soils with a pH of less than 6.5 can be improved by liming. Increasing the pH of a soil by incorporating lime is usually cheaper and easier than decreasing the pH. Soil with a pH exceeding 8.50 indicates the presence of hydroxides, which is more harmful than carbonates. Acidification and leaching of dissolved salts are required when the pH must be decreased.</td><td>Increasing the pH of acid soils is an economical and practical solution to improve the potential. Decreasing the pH is seldom feasible and expert advice must be sought.</td></tr>
<tr><td rowspan="3">Resistance (Ohms)</td><td>% Clay</td><td>Ohms</td><td rowspan="3">Resistance is an indication of the salinity (salt content) of the soil.</td><td rowspan="3">Not much to be done to change the salt content or resistance, but horticultural practices like</td></tr>
<tr><td>>35%</td><td>250-500</td></tr>
<tr><td>20-35%</td><td>500-750</td></tr>
</table>

Soil Property	***Optimal Range or Standard***		***Comments***	***Evaluation***
	10-15%	750-1000		draining, reclamation, and rootstock and cultivar selection, cultivar, etc. can be employed to lessen the impact.
	<10%	>1000		
Fertility	P (Bray 1)	25-50	It is more efficient to incorporate the lime, gypsum and phosphates before planting.	The pre-plant operations must correct the fertility status, especially pH, %Ca and P.
	%K	5-7%		
	%Ca	70-80%		
	%Mg	15-20%		
	%Na	<1%		
Salinity	SAR	<3	The SAR should be determined in the saturated extract of the soil.	If the SAR exceeds 3%, establish the cause of the high Na content. It could be the irrigation water, low calcium/pH, poor drainage and/or too little leaching. If the cause can be corrected, develop a management plan to correct and maintain the SAR at <3%.
	%Ca	70-80%		
	See resistance above			
CEC	No standard for the production of fresh fruit has been set		The CEC depends on the type and concentration of the clay. Citrus is produced on soils with a CEC of <1,00 to >20me%	This is not a criterion to evaluate the suitability of a soil, but must be considered when planning irrigation and/or fertilisation.
Organic Material	No standard for the production of fresh fruit has been set.		Various C:N ratios can be applied depending on the type of organic matter. For compost, it should be 20, for manures and organic fertilisers <12.	Cannot be evaluated at this time.
Biological Soil Components				
Organic Material	No standard for the production of fresh fruit has been set.		The organic matter content of soil depends also on the clay content and cultivation practises.	Cannot be evaluated at this time.
Active Biomass	No standard for the production of fresh fruit has been set.		This is a relative new development in commercial agriculture and is at this stage limited to organic production.	Cannot be evaluated at this time.
Biological Content	No standard for the production of fresh fruit has been set.		The general agreement at this stage is that tree crops prefer a fungal dominated population in the soil.	Cannot be evaluated at this time.

Table 2.1: Optimal Soil Property Ranges for Citrus Cultivation

3. Evaluating a Soil Utilisation Plan

Based on these requirements, the soil utilisation plan for citrus production can now be evaluated.

It is important to incorporate a costing budget with the plan, as correcting or improving soil properties can be very expensive and sometimes cannot be justified based on expected benefits. The expected impact on yield and / or fruit quality also forms an integral part of an utilisation plan. Instead of spending money on creating optimal conditions, one can be prepared to accept a lower yield at a lower input cost.

The evaluation of a soil utilisation plan includes the following steps:

- An assessment of the properties and components that can be corrected, changed or improved.
- An assessment of the impact on production of those properties and components that cannot be improved or corrected.
- ***Cost-Benefit Analysis*** – The initial cost of correcting or improving suboptimal properties usually represents the major part of the total cost, but there are also the ongoing costs of maintaining the improvements. The cost of maintaining a ridged orchard include aspects of weed control, more frequent irrigation and more demanding harvesting practices, which must be weighted against better production, longer productive life and fewer treatments to control root pathogens. The cost of managing the current status without any costly improvements might be lower and this course of action may be more sustainable in the long term.
- ***Environmental Impact Assessment*** – Certain improvements, such as acidification and leaching, have a negative impact on the environment. During acidification, salts are dissolved and have to be removed from the soil profile and/or root-zone. These dissolved salts are deposited somewhere and could contaminate the water streams or adjacent soils.
- ***Comparative Evaluation*** – Other profile pits in the same land is dug to confirm or reject the fundamentals of the utilisation plan.

4. Designing a Soil Utilisation Plan

Designing a soil utilisation plan should is based on a survey of the proposed site, followed by the evaluation of each physical, chemical and biological property. Designing an utilisation plan, as opposed to evaluating it, is concerned with the identification of the limiting factors as well. This can be done by completing the table below.

Property That Need to Be Corrected / Managed	***Implications If Not Corrected***	***Possible Corrective Action***	***Cost of Corrective Action (R per ha)***	***Recommendation***

Table 2.2: Design of Soil Utilisation Plan

Once this has been done, the final plan can be submitted for approval. Keep in mind that the application of the plan can apply for the entire life of the orchard. The utilisation plan should also include the elements of maintaining optimal soil conditions. Apart from events that can be foreseen, several maintenance task need to be done as soon as they are required, for instance the repairing of a ridge when damaged by a tractor wheel.

Example

Soil Utilisation Plan Evaluation

Property That Need to Be Corrected / Managed	***Implications If Not Corrected***	***Possible Corrective Action***	***Cost of Corrective Action (R per ha)***	***Recommendation***
pH (water) is 5.25	Retarded development of root system	Incorporate 8 tons dolomitic lime per ha	R750.00	Apply lime as recommended
Sandy layer 10-20cm deep	Layering will restrict even root development and impair irrigation	Mixing with a mould board plough	R1,550.00	Mix the 3 layers (0-10, 10-20 and 20+) to a depth of 30cm. Mix the lime and supers with the soil at the same time.
Potential effective rooting depth of 35cm	Drippers cannot be used. Micro-jets can be used, but more water will be required	Ridging to create a depth of 40cm for micro-jets or 60cm for drippers	The lower water consumption with drippers outweighs the cost of ridging	After mixing, ridge to 60cm high and use drip irrigation.
P (Bray 1) = 15mg/kg	Retarded root development and growth	Apply 300kg single supers per ha	R675.00	Mix supers with 30cm layer of soil before ridging

Soil Maintenance Plan

Maintenance Action	***Procedure***	***Frequency***
Maintain water lane at bottom of orchard, repair and mow	Restore grass cover Slash grass	Monthly during summer, otherwise whenever disrupted.
Apply gypsum	Spread over wetted area	As soon as runoff is evident

5. Soil Preparation Methods

Soil preparation involves two basic soil preparation methods, namely mixing and loosening.

5.1. Mixing

Mixing is the physical process where the soil is mixed in an up-down motion to reduce the heterogeneity of the soil profile.

Mixing is done by a variety of methods and implements, of which the plough is the most common implement. In the ploughing process, the soil is sliced and turned in a manner that brings the subsoil to the top and the topsoil deeper into the subsoil. If this process is repeated, homogeneous topsoil is created which distinctively differs from the subsoil. The most noticeable differences are soil colour, soil strength and the concentration of phosphorus.

Below this homogeneous topsoil is a layer very much still in its original state with a much higher soil strength. These two layers are usually separated by a plough sole of variable depth, depending on the implement and thickness. The plough sole is created when the soil at the bottom edge of the implement is compacted during ploughing. The compaction is enhanced by continuously using the same implement on the soil. The depth of the plough sole is equal to the cutting depth of the implement.

The most common implements used for mixing are dish ploughs of various sizes carrying any number of dishes. Tractor size and type are important factors. The depth that can be reached with wheel tractors is much less than with crawlers.

5.2. Loosening

Loosening is a process where the soil is not mixed but only loosened. This is done by lifting the soil with an implement and letting it down without mixing. This lifting process does not change the soil profile, but decreases the soil strength.

Tine implements are used to loosen the soil in this manner. A variety of tine implements are available and an even greater number of modifications are done on these implements to suit the preparation requirements of the soil profile. Please note that ordinary tine implements without a wing at the tip are usually not efficient to loosen the soil to a desirable depth of 60cm or more.

Apart from these two basic processes, combinations are used to create the required profile modification. Modifications made to implements vary from welding wings to ripper tines, to cutting mould boards of ploughs to match the profile. These modifications have developed into a fine art based on scientific research and ploughs can be modified to fit the requirements exactly. However, this is a specialised job and can only be performed by a contractor using heavy equipment.

These two methods are also used when ridges are prepared.

5.3. Ridging

Ridging is the process where some of the soil between rows of trees in moved to the areas where the trees will be planted, creating a ridge with a greater depth than the natural soil. Ridging was originally developed with the main purpose of increasing the effective rooting depth, but other advantages and disadvantages have subsequently been discovered and researched.

The advantages of ridging are:

- Ridging converts too shallow soils to soils with an optimal rooting depth.
- Due to the shallower cultivation depth, the energy cost to prepare the orchard and the total mass of fertilisers and lime required should be less.
- Surface drainage is improved.
- Ridged soil is warmer, which is an advantage in areas with cold winters or springs.
- Motor traffic control is easier because rows are clearly demarcated.

The disadvantages of ridging are:

- Soil that has been ridged dries out quicker than soil in flat lands, which is exacerbated by the higher soil temperatures in ridges. This poses a problem especially in hot areas and when the trees are young with the soil surface exposed to the sun.
- Erosion of the valleys between ridges is aggravated, especially in the early stages in the establishment of the orchard.
- Harvesting is more complicated on the undulating surface and with increased relative height of the trees.

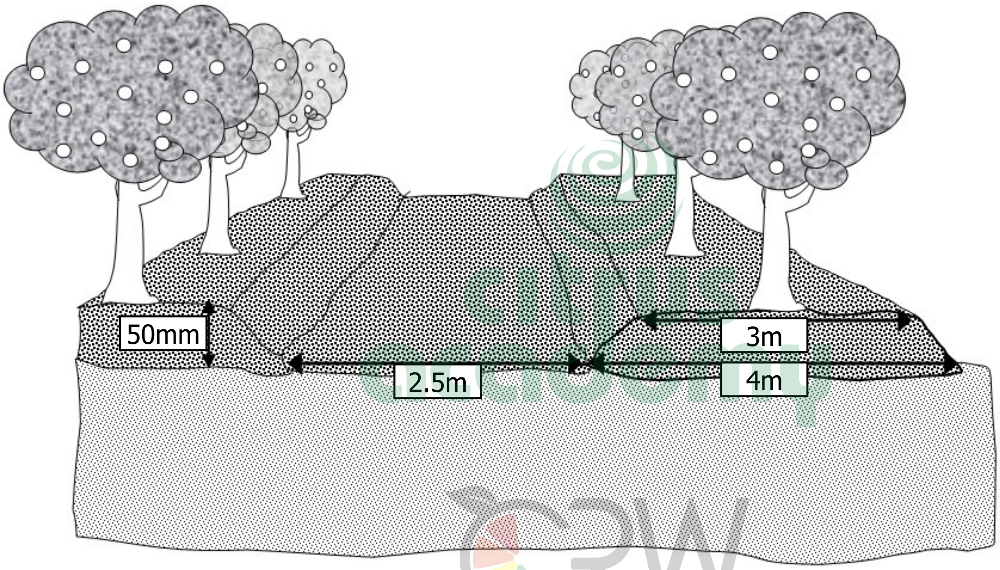
Ridging can best be explained with the help of a practical example.

Example

Ridging

In an area proposed for citrus plantings, the soil survey indicates a suitable layer of soil to a depth of 30cm. Below this layer is a clayey layer, which will reduce internal drainage and cause all sorts of problems. To overcome the limitation of effective depth, ridging is considered.

The spacing of trees will be 7m between rows and 3m between trees. To create a ridge, strips of soil 3m wide and 30cm deep is moved from between rows and placed on a strip of 4m where the trees will be planted, creating a strip of suitable soil 3m wide at the crest, 4m wide at the base and 50cm to 60cm deep.



6. Soil Preparation Records

Records must be kept of the soil preparation actions that are employed. To the basic information of the date, cultivation depth, preparation method, and chemicals that are applied, one can add information on the type of implements used, the contractor that was employed, drainage that was installed, the directions ploughed, etc.

Example

Database for Soil Preparation

Orchard	*Date*	*Cultivation Depth*	*Preparation Method*	*Chemicals Applied*
1	May 1985	50cm	Loosening	Lime and supers
2	June 1990	75cm	Loosening	Supers
3	June 1990	35cm	Mixing and ridging	Lime

7. Soil Improvement Methods

Soil improvement methods are grouped into physical, chemical and biological.

7.1. Physical Improvement Methods

Physical methods include soil preparation methods as describe above.

Apart from that, subsurface drainage is used in soils where the internal drainage is unsatisfactory. The simplest draining system consists of trenches through the orchard. The trenches are dug to a depth of +70cm, or to the top of the impervious layer. The trench is filled halfway with stones, covered with plastic (old fertiliser bags) and then closed up with soil. The water will move horizontally towards the trench and then in the trench down the slope until it is released outside the orchard. If a simple trench cannot drain the orchard, it would be wise to consult an irrigation- or drainage engineer to design an adequate drainage system.

Levelling is another physical soil improvement method. However, due to the improvements in the design sophistication of irrigation systems and equipment, levelling is hardly done these days in citrus orchards.

7.2. Chemical Improvement Methods

Chemical improvements needs depend on the soil analyses. This will include any or all of the following:

- Liming materials, such as dolomitic and calcitic limes, oxides and hydroxides and mixtures of these, are mixed into the soil to increase the pH and supply Ca and Mg.
- Gypsum is used to supplement Ca without changing the pH.
- Phosphates and other nutrient sources are used to supplement the supply from the soil.

7.3. Biological Improvement Methods

Apart from mulching, other biological methods are not employed in citrus cultivation at this time. Mulching is used with non-bearing trees to protect the soil surface and reduce evaporation. Due to the lack of material, logistical problems with the transport and application of mulches, and the eminent danger of veld fires, mulching is not practised widely.

Any coarse organic material can be used as mulch. The most popular are veld grasses, straw, sugar cane tops and maize stalks. Plastic mulches are used, but mostly during severe droughts only.

Chapter 2

- Optimal soil is seldom found in nature and most soils need to be modified chemically or physically to get close to optimal conditions.
- A soil utilisation plan is applicable to a specific site, with the aim of optimising the growing conditions for the trees.
- The minimum requirements for a soil survey and profile description are information on slope, total soil depth, effective soil depth, parent material or material underlying the soil, stratification, texture, structure, water logging and aeration, chemical composition, and surface drainage.

- A costing budget must be included with the soil utilisation plan, as correcting or improving soil properties can be very expensive and sometimes cannot be justified based on expected benefits.
- The evaluation of a soil utilisation plan includes the following steps: assessment of the properties and components that can be corrected, changed or improved; assessment of the impact on production of those properties and components that cannot be improved or corrected; a cost-benefit analysis; an environmental impact assessment; and a comparative evaluation.
- Designing an utilisation plan, as opposed to evaluating it, is concerned with the identification of the limiting factors as well.
- Soil preparation involves two basic soil preparation methods, namely mixing and loosening.
- Mixing is the physical process where the soil is mixed in an up-down motion to reduce the heterogeneity of the soil profile.
- Loosening is a process where the soil is not mixed but only loosened.
- Soil improvement methods are grouped under physical, chemical and biological methods.
- Physical improvement methods include soil preparation methods, improving sub-surface drainage, and levelling.
- Chemical improvement methods involve the addition of lime, gypsum, phosphates and other nutrient sources.
- Mulching is the only biological improvement method that is used in citrus cultivation at this time.

Complete activity 4 in the **Learner Workbook**.

Chapter 3

After completing this chapter, the learner will be able to: **Keep all records regarding soil properties and use to build a database for future reference**

1. Introduction

There is no standard for recordkeeping on citrus farms. The type of data that is recorded, and the manner in which records are kept, depend on the information required by the management of the farm. The more accurate and readily available information is to management, the more effective the decision-making process. In recent years, computer software has been developed to assist with recordkeeping and information processing. In this chapter, we look at the type of information related to soil and fertilisation that should be recorded.

The purpose of a soil management database is to:

- Keep record of various soil properties
- Keep record of changes in properties
- Avoid redoing what was previously done
- Predict future changes in order to take corrective steps well before production is affected

Although soil is a living organism, some properties will not change significantly over a period of 100 years. It is therefore not necessary to measure these properties every year. However, soil is also a heterogeneous entity and certain properties may change in a small area. This is more true of alluvial soils or soils under monoculture for many years.

In citrus production fertilisers are applied in isolated areas beneath the canopy, and areas with different chemical composition are created as a result. This makes soil sampling more challenging and the analytical results more variable.

Information stored in a database must be reliable. Under certain circumstances, it may even be necessary to measure fixed properties several times in order to capture the heterogeneity of the soil.

2. Categorising Different Types of Data

2.1. Soil and Site Data

Soil properties can be categorised into groups that will not change, those that can be change temporarily and those that can change over a relative short period.

2.1.1. Fixed Properties

- ***Texture*** – Texture, including the clay, silt and sand content. Some practises, such as sieving or removal of stones, can change the gravel and stone content and thereby increase the total clay content of the soil volume, but the clay : silt : sand ratio will remain the same.

- ***Soil Depth*** – Soil depth can be considered a fixed property, unless major actions are taken to move the soil. When flood irrigation was practised, levelling the soil and changing the depth was done more often. With micro irrigation, levelling is no longer practised. Where ridging is used soil depth is considered a temporarily variable property.

- ***Water Holding Capacity*** – Part of the total WHC of a soil is dependent on the organic material content and will therefore change only when this property changes drastically. The local soils utilised for citrus production contain little organic material and the change in WHC is therefore limited.

- Slope and aspect

2.1.2. Temporarily Variable Properties

- ***CEC*** – Part of the total CEC of a soil is dependent on the pH and organic material content and will therefore vary as these two properties vary.

- ***pH*** – Ammonium nitrogen will acidify soil and the magnitude and permanency of this change depends on the buffer capacity of the soil. In limed soil, even when mixed properly, pockets of lime create volumes of soil with vastly different pH levels. Even on a micro scale, small volumes of soil can be acidified, but after a period of time the pH of the total volume will return to a different level. The pH of soils containing high concentrations of salts, such as carbonates, cannot easily be changed and pH can therefore be regarded as a temporarily variable property.

- ***Soil Depth*** – Ridging can be considered as a temporary change in soil depth. When the orchard is due for replanting, the soil is flattened and, if required, ridged again.

2.1.3. Variable Properties

- ***pH*** – The permanency of the change in pH depends on the buffer capacity of the soil. The pH of the soil can vary with depth as well as horizontally. This variation is created by fertilisation, irrigation and other horticultural practises.

- ***Fertility*** – Fertility, including the level of all essential nutrients, varies depending on fertilisation, irrigation and other horticultural practises. Soil fertility is measured annually or at least biannually.

- ***Salinity*** – Salinity is regarded as a variable soil property, because it can change very rapidly depending on the quality of irrigation water and internal drainage of the soil.

2.2. Leaf Analyses Data

The leaf analyses data is utilised to predict the nutritional status of the trees in order to respond before any abnormality reduces production. Records of at least five years are required to make proper predictions. The simplest method of keeping leaf analyses data is a table on paper or electronically, which indicates the trends. If this data is linked to production data such as yield, fruit size, fruit colour, acid, skin texture, etc., its value is increased.

Example

Record of Leaf Analysis Data

Records of leaf analysis data is kept in tables such as the one below.

Nutrient Element		*2004*	*2005*	*2006*	*2007*
N	%	2.03	2.32	2.55	
P	%	0.14	0.13	0.12	
K	%	0.89	1.42	1.02	
Ca	%	3.65	3.55	3.72	
Mg	%	0.44	0.38	0.40	
S	%	0.22	0.25	0.24	
Cl	%	0.04	0.05	0.02	
Na	mg/kg	117	163	132	
Fe	mg/kg	89	92	94	
Cu	mg/kg	3	18	12	
Mn	mg/kg	78	71	113	
Zn	mg/kg	37	49	31	
B	mg/kg	88	112	93	
Mo	mg/kg	0.34	0.61	1.46	

This data can now be presented in any form that will make the interpretation and predictions easier. Bar or line graphs usually indicate trends clearly.

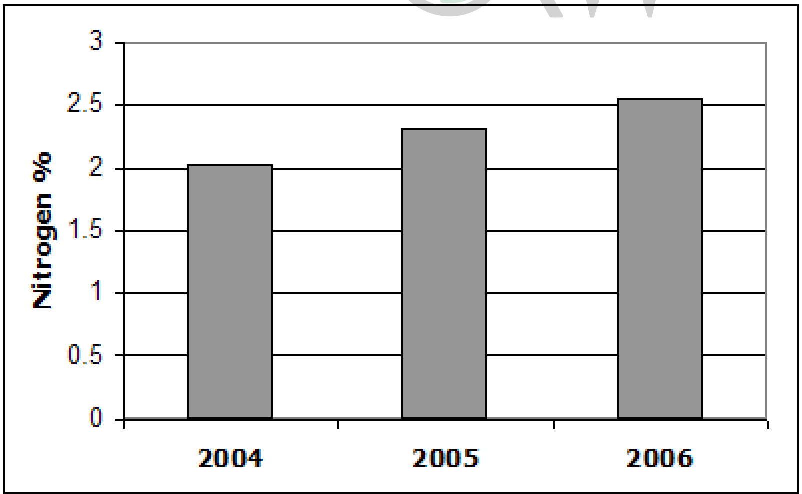


Figure 3.1: Historical Bar Graph of Nitrogen % in Leaf Analysis

2.3. Fruit Analyses Data

It is important to capture fruit analysis data that are linked to fertilisation, irrigation and other horticultural practises, including:

- Fruit size
- External fruit quality
- Internal fruit quality

Other abnormalities in fruit quality and size must also be recorded.

2.3.1. Fruit Size

The actual counts, or fruit size distribution, are recorded. The data can also be grouped according to the economical impact of the groups.

Example

Fruit Size Data

Records of fruit size data are kept in tables such as the one below.

Count	***105***	***88***	***72***	***60***	***56***	***48***	***40***
Cartons 2003	500	623	711	372	121	50	35
Cartons 2004	255	522	936	738	201	100	55
Cartons 2005	362	633	839	1010	100	58	32
Cartons 2006							

The actual number of cartons must be recorded, even though the final presentation will be different. However, it is difficult to make any conclusions based on this data without further calculations.

In the table above it is difficult to decide whether 2004 was a better year than 2003, because the total number of cartons must also be taken into account. Expressing the size distribution as a percentage of the total makes year on year comparisons easier.

Example

Fruit Size Data – % Counts

Count	***105***	***88***	***72***	***60***	***56***	***48***	***40***
Cartons 2003	21%	26%	29%	15%	5%	2%	2%
Cartons 2004	9%	19%	33%	26%	7%	4%	2%
Cartons 2005	12%	21%	28%	33%	3%	2%	1%
Cartons 2006							

This can further be simplified by grouping those counts with similar financial impact together. If counts 56 to 72, followed by 40 to 48, are the most profitable sizes to produce, it is now much easier to conclude from the table below that 2004 gave the best financial returns.

Fruit Size Data – Grouped Counts

Count	*88-105*	*56-72*	*40-48*
Cartons 2003	47%	49%	4%
Cartons 2004	28%	66%	6%
Cartons 2005	33%	64%	3%

2.3.2. External Fruit Quality

Records must be kept of the fruit colour and fruit colour development. Apart from keeping historical records of the fruit colour achieved every year, it is also important to record the average, minimum and maximum temperatures for the periods from March/April to June, because temperature has a marked influence on colour break. Other than colour, only abnormalities in skin properties are recorded and quantified, for example, 14% creasing. If the skin texture is acceptable, it is not necessary to record it.

2.3.3. Internal Fruit Quality

Internal quality factors include acid, total soluble solids (TSS), ratio and juice content. Only abnormalities in these factors are recorded.

3. Different Recordkeeping Systems

Currently, there is no standard recordkeeping system for citrus farms in South Africa and every citrus farm has its own system. Whether such a system is manual or computerised, it should have the basic ability to store data and facilitate comparative reports. Storing data in a spreadsheet is simple and cheap. Data for variable properties can be presented in graphic format which is easier to interpret.

Apart from recording data for individual orchards, it is also important to store the data generated during the soil survey. The survey is usually reported on by means of a soil map and report. On the soil map, the individual orchards are positioned, recorded, and numbered. From here on the records should be kept on an orchard basis, using their numbers as references.

Soil Analysis Data

Fixed Properties

Property				*Average*
Clay %	15.00	17.00	14.00	15.33
Silt %	11.00	9.00	11.00	10.33
Sand %	74.00	74.00	75.00	74.33
CEC me%	4.29	4.85	4.06	4.40
WHC mm/m	84	90	85	87
EAW mm/m	28	25	31	28

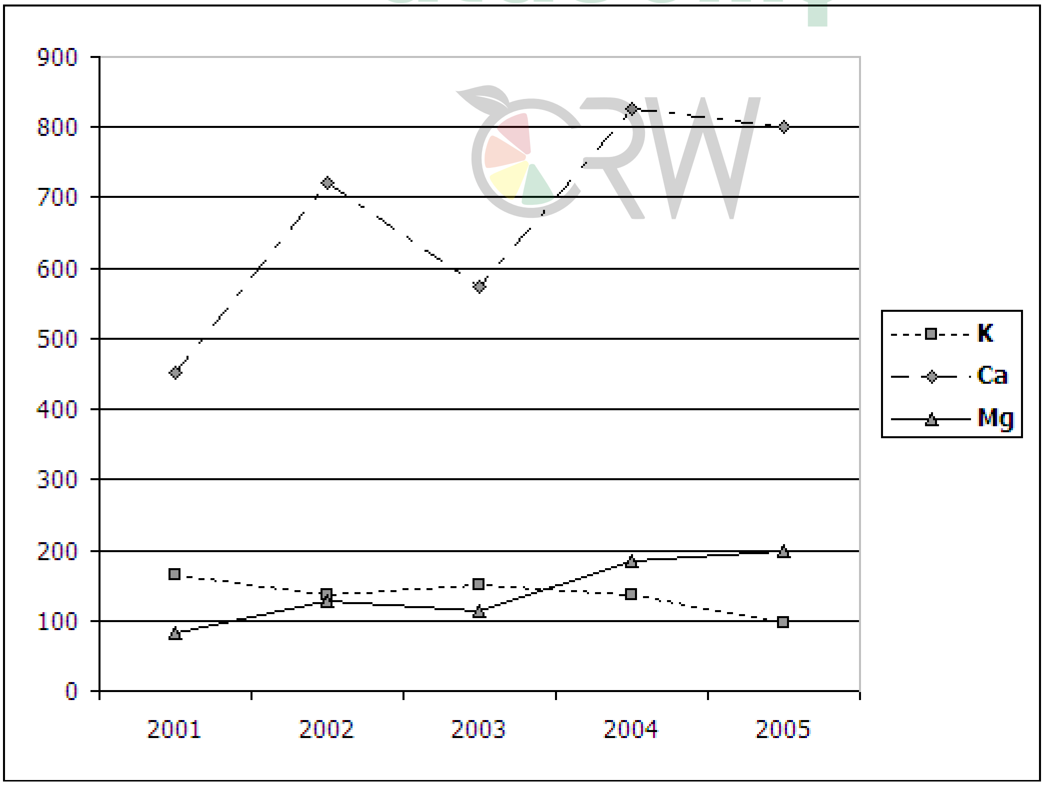
Variable Properties

Property	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
pH (water)	5.53	6.02	5.98	6.53	6.48	
P (Bray 1)	3	24	30	23	28	
K	166	137	150	137	97	
Ca	451	722	573	825	801	
Mg	83	127	114	184	200	
Na	8	11	6	15	6	
%K						
%Ca						
%Mg						
%Na						
%C	0.72	0.34	0.39	0.51	0.38	

Data of any or all these soil properties can also be kept in the form of a graph.

Example

Graphic Soil Property Data

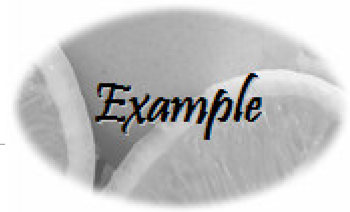


4. Data Extraction

The principles for any database system are that there should be:

- A place for everything and everything in its place
- One-second retrieval
- Minimum extraneous information that blur the important information
- Enough supporting information without distracting from the crucial issues

The most important reasons for data capturing and retrieval is to prevent the duplication of surveys and analyses of fixed properties and to take preventative action before the variable properties impact negatively on production. The chemical properties of soils are variable and by keeping records one can act in time.



Database for pH (Water) of Orchard Soils

Orchard	2000	2001	2002	2003	2004	2005	2006
1	5.88	6.45	6.31	6.19	6.13	6.06	
2	6.55	6.72	6.61	6.37	6.52	6.43	
3	6.53	6.22	5.84	6.49	6.38	6.25	
4	6.84	7.11	7.23	7.27	7.17	7.47	

- **Orchard 1** – From the database it can be deducted that orchard 1 was limed after the analyses of 2000. The soil reacted well and the pH was maintained above 6.00 until the analyses of 2005. It can be deduced that the pH of the soil will be below 6.00 in 2006, and, as a preventative measure, liming can be included in the fertilisation program for 2005 to prevent the pH to drop below the minimum value of 6.00.

- **Orchard 2 –** This soil is well buffered and there is no need for lime during 2005/2006.

- **Orchard 3** – The situation is much the same as that of orchard 1. However, the pH drop by about 0.15 pH units per year and the expected pH for 2006 will be about 6.10. Liming is therefore not required in 2005.

- **Orchard 4** – The pH of this soil is increasing steadily. Over the past six years, it increased from 6.84 to 7.47. This should be investigated and, if possible, corrected.

Information on soil pH is converted to more valuable management tools by using the database to prevent adverse conditions impacting on production.

Chapter 3

- The purpose of a soil management database is to keep record of various soil properties; keep record of changes in properties; avoid redoing what was previously done; and predict future changes in order to take corrective steps well before production is affected.
- Soil properties can be categorised into groups that will not change, those that can be change temporarily and those that can be changed over a relative short period.

- Fixed properties are texture, soil depth, water holding capacity, and slope and aspect.
- Temporarily variable properties are CEC, pH and soil depth (if ridging is used).
- Variable properties are pH, fertility and salinity.
- The leaf analyses records of at least five years are required to make proper predictions.
- Fruit analysis data are linked to fertilisation, irrigation and other horticultural practises, and include fruit size; fruit colour; skin properties; acid, TSS and ratio; juice content; and other abnormalities.
- The principles for any database system are that there should be a place for everything and everything in its place, one-second retrieval, minimum extraneous information that blur the important information, and enough supporting information without distracting from the crucial issues.

Complete activities 5 and 6 in the **Learner Workbook**.

Chapter 4

After completing this chapter, the learner will be able to:

Design a soil system management strategy
Create and implement a database for soil management

1. Orchard Development Phases

The lifespan of an orchard can be divided into five phases. During these phases, the emphasis of the soil management strategy shifts, although the basic elements remain the same. The phases are:

- Pre-planting
- Non-bearing
- Juvenile
- Mature
- Declining

1.1. Pre-Planting Phase

The emphasis during this phase is on creating optimal conditions. This will include the required mechanical preparations to loosen the soil and add the chemicals to optimise the fertility.

1.2. Non-Bearing Phase

During the juvenile phase, the soil surface is unstable and bare, and exposed to climatic conditions and erosion. The emphasis is on protecting the surface and limiting re-compaction of the soil. Weed control between the trees in the rows and the establishment of a grass cover between rows require a lot of attention. The temperature of the bare soil can rise to above 60°C and no roots develop in the top 10cm of the soil. Mulching is a good option during this phase.

The emphasis during the non-bearing phase is to optimise conditions for vegetative growth in order to reach maximum trees size before fruit production starts. Vegetative growth decreases once the tree starts producing fruit. This phenomenon is related to cultivar and climate.

Fertilisers, especially nitrogen, are applied continuously during the months from August to March. Organic sources of nitrogen can be used successfully. Micro-nutrients are also applied regularly.

1.3. Juvenile Phase

During the juvenile phase, the quality of the fruit is not always good. Fertilisation and plant manipulation to increase fruit-set help to improve fruit quality. Young trees utilise soil potassium well, resulting in too large fruit of poor quality. The application of potassium must therefore be well managed.

1.4. Mature Phase

During the mature phase the canopies of the trees shade 70% to 80% of the surface, creating favourable conditions for root development near the surface. Weed control is limited to the edges and the emphasis now shifts to maintaining optimum chemical and physical conditions. Although the biological component is apparently the most important, too little information is currently available to develop sound strategies.

1.5. Declining Phase

The emphasis now shifts to creating or improving soil conditions that will prolong the economic life of the orchard. The productive life of a tree depends on various factors, with climate, cultivar selection and pest pressure being the most important. In the hot and humid area of Malelane, the expected lifespan of grapefruit trees is 15 to 20 years. In the Western Cape, with its cold winters and dry summers, navel trees can still produce economically at an age of 60 years.

During this phase, various symptoms develop which are not necessarily due to nutrient deficiencies. The symptoms are usually due to a diseased or restricted root system and include the following:

- Decrease in fruit size
- Dieback of twigs
- Slow or stunted shoot growth
- Inadequate leaf cover
- Small leaves
- Decrease in total yield
- Few feeder roots

2. Components of a Soil System Management Plan

2.1. Pre-Planting Phase

- Identify the limiting factors in the soil profile and site layout, including slope, aspect, layering, soil depth. (Refer to Chapter 2)
- Select the most suitable method to correct and / or to manage the limitations.
- Develop a soil utilisation and preparation plan, for example loosening, loosening plus mixing or ridging. (Refer to Chapter 2)
- Create a homogeneous root-zone of between 40 and 70cm depth.
- Optimise soil fertility by adding chemicals.

2.2. Non-Bearing Phase

- When planting the trees, use a garden fork when making a plant hole. A spade will create compaction on the sides, especially in clayey and wet soils.
- Protect the soil surface against erosion and scorching by the sun. Mulches or live plant covers can be utilised. The latter must not compete with the trees for nutrients.
- Apply nitrogen and micro-nutrients continuously. Nitrogen and micro-nutrients must be applied at least monthly where micro-jets are used and at least weekly where drippers are used.

2.3. Juvenile Phase

- Continue protecting the soil surface against erosion and scorching by the sun.
- Control the nutrient status, especially potassium, carefully to avoid poor quality fruit.
- Prevent crusting of the surface by optimising the calcium content of the soil.

2.4. Mature Phase

- Maintain optimum chemical conditions in the root zone using soil and leaf analyses and historical records to make judicious applications of fertilisers. The parameters include pH, fertility (status of P, K, Ca, Mg, and micro-nutrients in the soil and leaf) and salinity (Na, SAR and resistance).
- Maintain optimal physical conditions, including soil strength (compaction), drainage, stability of structure – especially on the surface – runoff (erosion protection), and water penetration.
- No parameters are available at this stage to evaluate and maintain biological factors.
- Maintain optimum physical and chemical conditions in the areas between rows. The most important aspects are erosion and surface drainage.
- Maintain optimum physical and chemical conditions in the perimeter areas.
- Avoid compaction of the soil.

2.5. Declining Phase

During this phase, the management plan focuses on those aspects that will prolong the economic lifespan of the trees. The components of the soil system management plan include the following elements:

- Improving soil compaction, by using corrective ploughing as an option. It entails the loosening of the soil on one side of the trees one year and on the other side the next year. This is done after harvesting. The irrigation at the cultivated side must be reduced until the roots resettle in the loosened soil. This method requires heavy tractors and an implement specially constructed for this purpose. A fairly new development which will also alleviate compaction is the introduction of soil fungi and organic material for them to proliferate. This is done with other crops but has not been researched with citrus. Contact a specialist to assists with both methods.
- Treatments to control nematodes and Phytophthora are now required more frequently. Ensure that enough information is collected to make a proper financial decision on the profitability of the treatments.
- Foliar sprays to assist the restricted roots are a very successful method to keep the nutrient status optimal. Nitrogen, potassium, magnesium and micro-nutrient elements can be supplied by means of foliar sprays.
- Irrigation schedules are adjusted to suit the decreasing water requirement of sick trees and to assist in treating the trees for Phytophthora.

3. Designing a Soil System Management Plan

A soil system management plan for an orchard or farm will seldom include all the elements listed in Chapter 2. Therefore, as an exercise in designing such a plan, the following scenario serves as an example.

Example

Database for pH (Water) of Orchard Soils

From a survey, the following soil properties were identified as not being optimal and requiring corrective action during soil preparation. We will use this information to design a soil utilisation plan during the Pre-Plant, Mature and Declining Phases

Properties to be Corrected / Improved	***Pre-Planting Phase Actions***	***Mature Phase Actions***	***Declining Phase Actions***
pH (water) is 5.84	Apply 8,000kg calcitic lime per ha to a depth of 50cm.	Test soil pH annually and start liming when pH approaches 6.10. Keep Ca% between 65% and 70%.	Test soil pH annually and start liming when pH approaches 6.10. Ensure that Ca% is above 75%.
Salinity is high (resistance of 150 ohms) at a depth of 80cm	Do not mix the soil in a down-up manner to keep the salts at the bottom.	Take soil samples at intervals of 20cm every 3 years to monitor salt movement.	Take soil samples at intervals of 20cm every 3 years to monitor salt movement.
P (bray 1) = 2 mg/kg	Apply 1,250kg single super phosphate per ha to a depth of 50cm.	Take leaf and soil samples every year and maintain optimum levels.	Take leaf and soil samples every year and maintain optimum levels.
Soil is layered – 0-25cm contains 17%, 25-35cm 5%, 35-80cm 20% and 80+cm 38% clay	0 to 60cm layer must be mixed to destroy the sandy layer at 25 to 35cm. **Do not** bring soil below 60cm to surface.	No post-planting monitoring or treatment required.	No post-planting monitoring or treatment required.
Potential effective rooting depth is 70cm	Create homogeneous soil layer from top to 60 or 70cm deep	No post-planting monitoring or treatment required.	No post-planting monitoring or treatment required.
Nutrient status of the soil	Optimise actual and relative concentrations of K, Ca, Mg and Na.	Take leaf and soil samples every year, maintain optimum levels. Utilise foliar sprays to supplement soil applications.	Take leaf and soil samples every year, maintain optimum levels. Utilise foliar sprays to supplement soil applications
Soil strength	Ensure that vehicle drivers are aware of compaction danger, and trained to drive in correct areas.	Measure soil strength in root-zone annually after good rains.	Measure soil strength in root-zone annually after good rains.
Crusting / Water penetration		Instruct irrigation staff to report water runoff immediately. Re-assess soil analyses, consider liming or application of gypsum.	Instruct irrigation staff to report water runoff immediately. Re-assess soil analyses, consider liming or application of gypsum.

The soil utilisation plan during the non-bearing phase will be as follows:

- Apply nitrogen once per month during August to March.
- Apply foliar sprays containing urea, copper, manganese, zinc and boron once per month from August to March.

The soil utilisation plan during the juvenile phase will be as follows:

- Take leaf and soil samples every year and maintain optimal nutrient levels.
- Apply urea in July to improve fruit set.

The soil system management plan is revised regularly. The soil may respond to treatments and cultivation in an unforeseeable manner and continual improvements are required. Research and developments in chemicals, implements and techniques may also require adjustments to original plan.

Using the database of an orchard on similar soil may be useful when designing the plan for an orchard.

4. Evaluating the Sustainability of a Soil System Management Plan

The sustainability of a soil system management plan is determined by the affect of the actions on the soil and environment. It also depends on production practices and the level to which the plan is and can be implemented in the production environment. If the plan calls for the incorporation of 10 tonnes lime to a depth of 50cm and no implements are available to do this, the soil system management plan cannot be implemented, indicating that a plan is only sustainable if it can be implemented.

The implementation of a soil systems management plan also depends on the economy on the farm. In the Western Cape heavy equipment is readily available for soil preparation, due mainly to a shortage of good soils and the resulting necessity of more intensive soil preparation. In the Northern parts of the country, more good soils are available and the demand for heavy machinery is smaller, resulting in higher costs and reduced availability.

The soil systems management plan forms a part of the entire management plan for the farm. To evaluate a soil system management plan, the other components of the management plan should also be considered or accepted as being sustainable.

The evaluation of the soil systems management plan is a process and should also utilise the skills of other staff and disciplines.

In evaluating the sustainability of the soil system management plan, the following questions should be asked:

- Does the plan address all the limitations identified during the soil survey?
- Do the recommendations make sense and are they based of scientific evidence and/or practical experience?
- Can the recommendations for correcting limitations be applied on the specific property? If not, what alternatives are available?
- Is the management of those factors that cannot be corrected feasible?
- What are the implications of not managing these factors effectively?
- What level of management and labour skills are required to apply the plan?

5. Evaluating the Suitability of a Nutrient Management Plan

Plant nutrients are supplied to the trees by the soil, water and atmosphere, and those that are still lacking, by means of fertilisers. Therefore, a suitable nutrient management program should first of all evaluate what is supplied by the soil and water.

This can be done by means of analyses of the soil and irrigation water. Leaf analysis is a better indicator of the ability of the trees to utilise the nutrients in the soil and the water. What is found lacking in the leaf analysis must be supplemented by fertilisers and / or foliar sprays.

The suitability of a nutrient management plan can be assessed in the following steps:

- Leaf analyses indicate which nutrient elements need extra supplementation.
- The yield is used to calculate the rate at which nutrient elements, especially nitrogen, must be applied.
- Soil analyses are used to evaluate which type of the fertiliser will be the most appropriate form.
- The previous application program is used to evaluate the rate of application.

Example

Evaluation of Nutrient Management Program

Type	***Quantity Date***	***Quantity Date***	***Quantity Date***	***Quantity Date***
LAN	650g Jul 06	250g Aug 06		
Dolomitic Lime	4,000g Oct 06			
KCl	500g Sep 06	250g Oct 06		

- Is the application of LAN in line with the expected yield and the previous application, and does the nitrogen level in the leaf indicate the need for any changes to the previous application?
- Are the suggested application-times correct?
- Is LAN the most suitable source of nitrogen for the soil?
- Does the pH of the soil indicate that liming is required and is dolomitic the best type?

All the other components of the recommended nutrient management plant can be evaluated in the same manner.

Summary

Chapter 4

- The lifespan of an orchard can be divided into five phases, being pre-planting, non-bearing, juvenile, mature and declining.
- The emphasis of the soil management strategy shifts depending on the phase, although the basic elements remain the same.
- During the pre-planting phase limiting factors are identified and the methods for dealing with these factors are selected, a homogenous root-zone is created through soil preparation, and soil fertility is optimised through chemical treatment.

- During the non-bearing phase the soil surface is protected against erosion and scorching by the sun and nitrogen and micro-nutrients are applied continuously.
- During the juvenile phase, the soil surface is protected against erosion and scorching, the nutrient status is controlled, and the calcium content of the soil is managed to prevent crusting.
- During the mature phase, optimal chemical and physical soil conditions are maintained in the root-zone and in the areas between rows, including preventing compaction, crusting, and erosion.
- During the declining phase, an optimal nutrient status is maintained, and efforts are made to correct compaction and erosion and to treat and control nematodes and Phytophthora.
- The sustainability of a soil system management plan is determined by the affect of the actions on the soil and environment, the production practices on the farm, and the financial position of the farm.
- The suitability of a nutrient management plan is evaluated by assessing leaf analysis reports, soil analysis reports, yield, and previous application programs.

Practical

Complete activities 7, 8, 9 and 10 in the **Learner Workbook**.

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