LEARNER GUIDE

Plant Nutrition & Soil Management

Level 2

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Title:		**Understand Basic Soil Fertility and Plant Nutrition**					
Applied Title:		**Understand Basic Soil Fertility and Plant Nutrition**					
Field:		Agriculture and Nature Conservation					
Sub-Field:		Primary Agriculture					
SETA (SGB):		AgriSETA					
Skills Area:		Plant Nutrition and Soil Management					
Context:		Citrus Production					
US No:	116053	**Level:**	2	**Credits:**	5	**Notional Hours:**	50
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Based on the Production Guidelines of:

Supported by:

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

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Directions

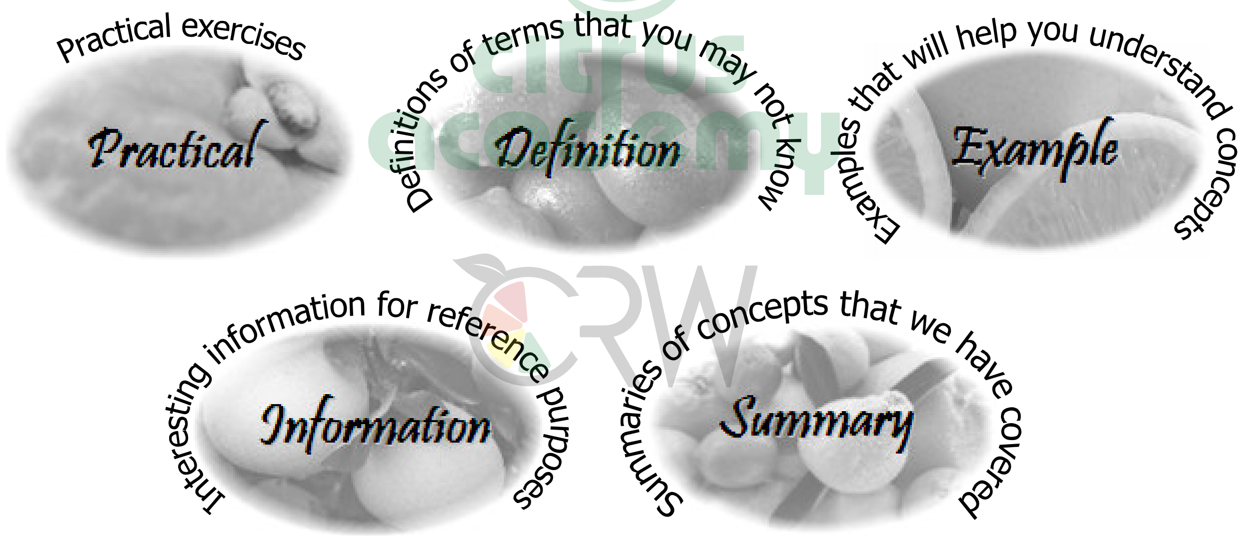
This learning material has been developed to assist the learner wishing to complete this unit standard. The guide contains all necessary learning to ensure that the learner will attain the competencies required by the unit standard.

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 apply basic soil nutrient preparations in a safe, effective and responsible manner for the benefit of plant/crop growth and with consideration for the environment.

Learners will gain specific knowledge and skills in soil nutrients and preparation 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*
1 (ABET 4)	Literacy and Numeracy	
1	116206	Fertilise soil and attend to basic plant nutrition
1	116156	Collect agricultural data
1	116199	Demonstrate a basic understanding of the structure and function of a plant in relation to its environment

Introduction to Citrus Production

1. Introduction

This learning material has been developed in the context of citrus production, which means that the skills area is dealt with in terms of and as applied to citrus production. To help the learner place the material in the right context, it is necessary for the learner to understand the background to citrus production, and the manner in which a citrus plant produces fruit.

2. Background

Citrus originates from the subtropical regions of south-east Asia. In the wild, citrus trees in these regions produce fruit all year round, and the fruit are small, poorly coloured and blemished. In the absence of effective production practices, citrus trees do not produce fruit suitable for the market.

Citrus production is largely concerned with management of the practices and processes that manipulate the tree to produce high yields of marketable fruit. Production management, together with the selection of superior varieties and plant improvement, can be seen as an on-going effort to influence the natural tendencies of the tree.

Consumers want the fruit of their choice to be available at all times. Fruit should look good, be unblemished, well-coloured (superior exterior quality), taste good (high interior quality) and be of the right size. At the same time, the citrus producer wants orchards that will provide high yields over an orchard lifespan of 18 to 30 years. On top of all this, the citrus orchard must be managed in such a way that production practices have the least possible impact on the natural environment. Commercial citrus production management is about achieving these objectives efficiently and cost effectively.

3. Citrus Planting

Citrus trees are planted in rows in orchards. The planting distance, also called tree spacing or espacement, between rows and between trees within rows, is determined by numerous factors including climate, variety, and soil type. A typical tree spacing is 6m between rows by 3m between trees, meaning that 555 trees per hectare (ha) are planted (1ha = 10,000 m^2).

Once planted, trees take three or more years before bearing fruit that can be marketed. Thereafter, per tree and per hectare yields steadily increase to 40 to 70 t/ha – depending on cultivar and variety – after a further 4 to 7 years. If the trees are well looked after, this level of production will remain fairly constant until trees start to decline naturally.

Yield

Yield refers to the amount of fruit produced, and can be expressed in terms of:

Tree yield	kg per tree	kg/tree
Orchard yield	tons per hectare	t/ha
Export yield	15kg carton equivalents per hectare (10kg carton equivalents for soft citrus)	cartons/ha

4. Lifespan

The average economic lifespan of a commercial citrus orchard varies between 18 and 30 years, and can be as high as 30 to 60 years in hot, dry areas. Citrus is therefore viewed as a long-term crop. For citrus production to be profitable, the orchard must produce high yields of quality fruit every year, and do this consistently over a long period of time.

In citrus production the challenge is therefore to make production decisions and take actions to ensure high annual production of marketable fruit, while ensuring that these decisions and actions contribute to the long-term sustainability of the orchard.

5. Citrus Plant Phenology

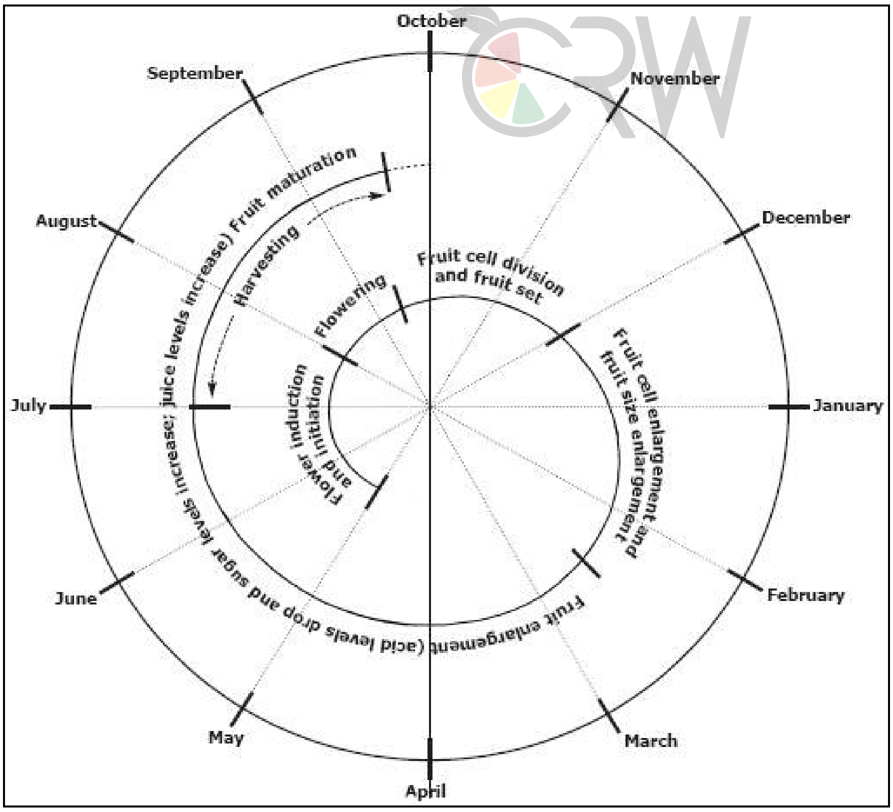
Definition

Phenology

Phenology refers to regularly recurring biological phenomena and the environmental and climatic factors that influence them. In citrus, phenology specifically refers to the annual cycle of the citrus tree.

Understanding the phenology of the citrus tree is essential to understanding the reasoning behind many of the practices and actions employed in citrus production. For example, the timing of fertiliser applications is linked to the phenology of the tree, with most fertilisers being applied at appropriate times to optimise flowering, fruiting, fruit development and fruit maturation.

The figure and table below set out the annual cycle of the citrus tree with regard to fruit production. Please note that this figure and table reflect the approximate flower and fruit development cycle of a valencia orange tree, and that the phenology of various cultivars differ.



Stage	Description	Time Period
Flower Induction and Initiation	Flower initiation is the induction and differentiation of vegetative buds into flower buds at a cellular level, and cannot be seen with the naked eye.	May to July
Flowering	Flowering or "bloom" is when blossoms appear on the tree.	August to Mid-September
Cell Division and Fruit Set	Cell division is the period when cells making up the fruit increase in number. Fruit set is the period from flowering or "bloom" until the end of fruitlet drop, after which the final fruit load is determined.	Mid-September to November
Cell Enlargement and Fruit Growth	Cell enlargement is the period during which cells making up the fruit increase in size. Fruit growth is the period during which the fruit grows and develops.	December to Mid-February
Fruit Maturation and further Fruit Growth	During this period fruit enlarges further and matures internally, meaning that the flavour, sugars and acids reach their optimum levels.	Mid-February to September
Harvest		July to September

It is important to note the term **citrus season** refers to the period from when flower initiation begins to the harvest. The season is generally from the beginning of August of one year to the end of July of the next year, although harvesting may extend to September and October for late cultivars.

6. Citrus Learning Material

The following citrus specific learning material is available from the Citrus Academy:

Skills Area	Description
Enterprise Selection, Planning and Establishment	Concerns itself with identifying the various components of an agricultural enterprise, and with the selection and planning processes for a new enterprise, and looks at the physical layout of a farm, with specific reference to infrastructure, orchard layout, etc.
Propagation	Concerns the various methods and requirements for the multiplication of plant material of specific varieties that possess desired qualities.
Crop Establishment	Concerns the establishment of a new citrus orchard, in terms of the physical planting of trees and the care for young trees.
Plant Structures and Functions	Considers the structure and function of various plant parts and the manner in which nutrients, water, air and sunlight is taken up and processed.
Plant Nutrition and Soil Management	**Concerns itself with plant nutrients, in terms of the requirements of the citrus plant and the supplementation of nutrient elements through fertilisation, with specific reference to the timing and manner of application.**
Water Quality	Considers the various factors that influence water quality and manners in which water quality can be measured and controlled. Considers furthermore the effect of water quality on tree and fruit growth and development, in combination with effective irrigation, fertilisation and pest control.

Skills Area	***Description***
Plant Manipulation	Concerns various types of physical and chemical plant manipulation, with specific reference to pruning, girdling and the application of plant growth hormones, and tools and equipment used for this purpose.
Irrigation	Looks at the technical aspects of orchard irrigation, with reference to the types of irrigation systems, the installation of new irrigation systems, and the repair and maintenance of an irrigation system. Also concerns irrigation scheduling, and measures to ensure effective irrigation.
Pests, Diseases and Weeds	Concerns the identification of pests, diseases and weeds that threaten citrus production. Also considers various methods of effective control, and the planning required for this purpose.
Crop Protection	Looks at the practical application of crop protection agents through various methods, with specific reference to tools and equipment used, and health and safety requirements.
Food Safety	Concerns the requirements in terms of health and safety, and environmental control for ensuring food safety and hygiene.
Harvesting	Looks at the process of determining fruit maturity through maturity indexing, the harvesting of fruit, and the tools and equipment used for this purpose.
Conservation	Considers the impact of farming practices on the environment, with reference to the measures required to minimise this impact and protect the environment.
Marketing	Concerns the factors influencing citrus marketing, and the development of an effective marketing plan.
Production Management	Concerns the actions and processes involved in effective production management, with specific reference to the coordination of the various production tasks and processes and the creation of a strategic plan for the enterprise.
Industry Overview	An overview of the citrus industry and the various institutions involved.
Packhouse Practices	Concerns the specific principles and practices that are employed in the packhouse environment, and specifically: • Citrus Product Characteristics • Understanding Citrus Fruit Markets • Health and Safety in the Packhouse • Personal Hygiene Requirements for Packhouse Personnel • Understanding and Maintaining the Cold Chain • The Role of Quality Checks in the Packing Process • The Application of Fruit Treatments • The Application of Pre-Sorting Prior to Packing • Receiving Fruit into the Packhouse • Grading Fruit in the Packhouse • Packing and Packaging Materials • Palletisation of Packed Fruit • Storage of Fruit • Dispatch and Transportation of Packed Fruit • Understanding Automated Packing Solutions

Chapter 1

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

Accurately prepare and measure the appropriate quantity and quality of required soil nutrient applications

Information

Please Note

A lot of information is supplied in this learning material. It is important that you study and understand the principles that are taught, but it is not necessary to memorise all the information. Use the material as a source of reference when applying the principles.

1. Introduction

All plants need the following to grow and produce food, and to successfully complete their lifecycles:

- Sunlight
- Water
- Air (containing oxygen and carbon dioxide)
- Nutrients (food), also called *mineral nutrient elements* or *essential nutrient elements*

Different kinds of plants need the above elements in different quantities. You for instance know that some plants in a garden, such as ferns, prefer to grow in the shade, while others prefer full sun. In the same way, some plants need a lot of water, while others get along with very little water.

Different kinds of plants also need different kinds of nutrients, and different quantities of specific nutrients, just like different animals need different kinds of food in different quantities. Plants get nutrients from the soil and the irrigation water, and fertilisers must supply what these two cannot supply enough of naturally.

If a citrus tree is provided with the correct essential nutrient elements in the correct chemical formula and quantities at the right time, it helps the plant to grow well and produce a lot of good quality fruit. To do this, we need to know:

- Which nutrients does this plant need?
- How much of these nutrients does this plant need?
- When during its annual cycle does the plant need these nutrients?
- What is the best way to apply these nutrients?

2. The Role of Essential Nutrient Elements in Citrus Production

Soil is composed of minerals, including the essential nutrient elements that are required for plant growth. Each essential nutrient element has a special role or roles in the physiology of plants. These nutrients are called essential elements, because without them plants cannot complete their lifecycle from seed through the vegetative and reproductive stages to the seed stage. The essential elements are grouped into macro and micro nutrient elements.

Citrus trees require relatively large quantities of the following essential nutrient elements, also referred to as ***macro nutrient elements***:

- Carbon (C)
- Oxygen (O)
- Hydrogen (H)
- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Calcium (Ca)
- Sulphur (S)
- Magnesium (Mg)

The following essential nutrient elements are required in smaller quantities, and are referred to as ***micro nutrient elements***:

- Sodium (Na)
- Copper (Cu)
- Iron (Fe)
- Manganese (Mn)
- Zinc (Zn)
- Boron (B)
- Molybdenum (Mo)
- Chloride (Cl)

Please Note

While you are not required to learn the chemical symbols of the nutrient elements, it will be useful because the elements are referred to by their symbols in the rest of the learning material.

The first three macro nutrient elements are supplied to the plant by the air and water, and are not part of the fertilisation program itself. We therefore generally refer to fourteen essential nutrient elements.

3. Nutrient Applications

Nutrients that are applied to plants are commonly referred to as fertilisers. Fertilisers are supplied to citrus trees in one of the following ways:

- ***Soil applications***, which is when the fertiliser is applied to the soil.

- ***Foliar applications***, which is when the fertiliser is mixed with water and sprayed onto the leaves of the plant.

There are three methods that are commonly used for soil applications, being:

- ***Manual Application*** – The application of granular and powdered forms of fertiliser to the surface of the soil by hand.

- ***Mechanical Application*** – The application of granular fertilisers, powdered fertilisers and slurries, or suspended fertilisers, by way of mechanical equipment.

- ***Fertigation*** – The applications of liquid of water-soluble powdered fertiliser by means of the irrigation water.

Fertilisers can be from organic (natural and synthetic) or inorganic (chemical) sources. Mixtures of the two are also available in South Africa. The most common essential nutrient elements contained in fertilisers are nitrogen, phosphorus and potassium. They are available in compounds containing one, two or all three of these nutrient elements. Nitrogen is available in the organic form, inorganic form or mixtures of both forms.

Compost is a form of organic fertiliser, and is normally made by allowing plant material to decompose. Compost is however not commonly used in commercial citrus production, because the quantities that are required are too large, and because it is difficult to determine and control the nutrient element content of compost. Other examples of organic fertilisers are chicken droppings and cattle manure. Because organic fertilisers are not used in citrus production, only commercially available fertilisers are discussed in this material.

4. Commercially Available Fertilisers

Plant nutrients are available in a chemical form in a number of commercially available fertilisers. Fertilisers are found in the following forms:

- ***Granular*** – Rough granules which are used in soil applications.
- ***Powdered*** – Fine powder that are either used for soil applications or mixed with water for foliar applications or fertigation.
- ***Liquid*** – Liquid fertilisers that are mixed with water for foliar applications or fertigation.

In table 1.1 is a list of the fertilisers commonly available in Southern Africa, showing the nutrient element that each fertiliser provides to a plant.

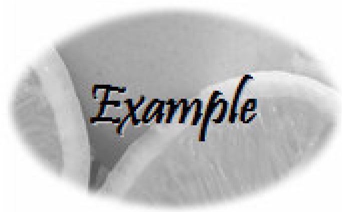
Fertiliser	***Nutrient Elements***	***Nutrient Content***
Potassium Chloride	K and Cl	50% K*, 50% Cl*
Potassium Sulphate	K and S	% K*, % S*
Potassium Nitrate	K and N	38% K, 13% N
Mono Potassium Phosphate (MKP)	K and P	29% K, 24% P
Calcitic Lime	Ca	minimum 35% Ca
Dolomitic Lime	Mg	maximum 10% Ca and minimum 4,3% Mg
Gypsum	Ca and S	235 Ca, 19% S
Calcium Nitrate	Ca and N	17% Ca, 12% N
Magnesium Nitrate	Mg and N	10% Mg 10% N
Magnesium Sulphate	Mg and S	10% Mg, 13% S
Limestone Ammonium Nitrate (LAN)	N	28% N
Urea	N	46% N
Ammonium Sulphate	N	21% N, 23% S
Ammonium Nitrate	N	19-34% N
Ammonium Sulphate Nitrate	N	27% N, 12% S
Single Super Phosphate	P, Ca and S	10% P, 22% S, % Ca
Mono Ammonium Phosphate (MAP)	N and P	11-12% N and 22-26% P

Table 1.1: Fertilisers Commonly Available in South Africa

5. The Fertilisation Program

We have seen that citrus trees require a range of nutrients in different quantities to grow well. Certain nutrients are applied to trees regularly every year. The fertilisation manager develops a fertilisation program every year for the nutrients that have to be applied regularly. The program is based on the tree age and the yield of the trees during the previous season, from which the amount of nutrients that the tree would have used to produce the fruit can be calculated.

Soil and leaf analyses are used to further guide the development of the fertilisation program, and to detect deficiencies of specific nutrients, which in turn allows for further refinement of the fertilisation program to prevent further deficiencies. Soil and leaf sampling and analyses are discussed in greater detail in chapter 2.



Typical Fertilisation Program

FERTILISATION PROGRAM – CITRUS			
Orchard:	Orchard 10	**Size:**	3.0ha
Cultivar/Variety:	Delta Valencias	**Trees per ha:**	316
Fertiliser		***Quantity***	***Time of Application***
Soil Applications		**g per tree**	
Limestone Ammonium Nitrate (LAN)		500g	July
LAN		250g	August
LAN		250g	September
Potassium Chloride (KCL)		500g	September
Dolomitic Lime		4000g	October
Foliar Sprays		**g per 100l water**	
Low Biuret Urea		1000g	July
Manganese Sulphate		200g	October
Solubor®		150g	October
Remarks:			

Once the fertilisation program has been developed, preparations can be made to apply the fertilisers at the prescribed time.

6. Preparing for a Fertiliser Application

The preparations required for a fertiliser application are:

- Calculating the amount of fertiliser required
- Collecting the fertiliser from the storeroom
- Measuring the fertiliser to determine the volume relevant to the weight

If a mechanical applicator is used, it may also be necessary to calibrate the equipment.

6.1. Calculating the Amount of Fertiliser Required

When fertiliser is applied, one must be careful to make sure that it is done accurately. If a mistake is made, the citrus trees might have too much or too little nutrients available to it, which could cause problems with the crop or the way in which the trees grow.

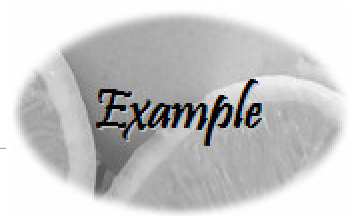
Before the fertiliser can be collected from the storeroom, the total amount of fertiliser required for the application must be calculated from the fertilisation program.

The fertilisation program typically indicates the amount of fertiliser that has to be applied per tree. To calculate the total amount of fertiliser required for a specific orchard, the amount of fertiliser per tree is merely multiplied by the number of trees in the orchard, as in the following formula:

Total Amount of Fertiliser Required = Fertiliser per Tree (g or ml) x Number of Trees in Orchard

In many cases, the number of trees in the orchard must also be calculated, as it is normally stated as a number per hectare. The following formula is used for this purpose:

Number of Trees in Orchard = Orchard Size in Hectare (ha) x Number of Trees per Ha



Calculating the Total Fertiliser Requirement

Using the above example of a fertilisation program, the total amount of LAN needed for the July application is calculated as follows:

Number of Trees in Orchard = Orchard Size in Hectare (ha) x Number of Trees per Ha
= 3.0ha x 316
= 948 trees in the orchard

Total Amount of Fertiliser Required = Fertiliser per Tree (g or ml) x Number of Trees in Orchard
= 500g x 948 trees
= 474,000g (/1,000 to convert to kg)
= 474kg

We have therefore calculated that 474kg of LAN is required for the July application to orchard 10.

Once the total amount of fertiliser required for the orchard has been calculated, the fertiliser can be collected from the storeroom and taken to the orchard for application.

6.2. Collecting Fertiliser from Storage

In line with the standards of good agricultural practises (GAP) fertilisers must be stored according to their type and packaging. Fertilisers have a fairly long shelf-life, provided it is stored in the manner prescribed by the suppliers. However, contamination can occur and bags might lose their labels. If in doubt of the contents or concentration of any fertiliser, take samples and send it for analysis.

To ensure that the correct fertilisers are selected, double-check the concentration of the active ingredient specified on the bag or container, because some fertilisers are supplied in more than one concentration. Zinc nitrate are supplied in formulations with an active ingredient (Zn) concentration ranging from 5.5% to 16%.

The mass of every bag must also be compared with the instruction. Granular and powdered fertilisers are supplied in 25kg or 50kg bags, with LAN mostly supplied in 50kg bags.

Using the example above, ten 50kg bags, i.e. 500kg of fertiliser will be collected from the storeroom. Half a bag should be left after the application, and this should be returned to the storeroom and sealed properly for future use. When collecting fertiliser from the storeroom, check that there are no half-used bags that should be used first.

Once the correct fertiliser and its concentration are confirmed, the required number of bags or containers can be loaded.

6.3. Measuring Fertilisers

It is important to apply the correct amount of fertiliser, because, apart from the cost implication, over-application can be as harmful to the tree as under-application.

In the case of manual application, the amount of powdered or granular fertiliser that is to be applied is normally stated on the fertilisation program in g/tree. This prescribed mass per tree cannot be weighed for every tree, because this would take a long time and be unproductive. It is easier to determine the volume that corresponds with the mass that is prescribed, by following the steps below.

- Carefully weigh the prescribed mass of fertiliser;
- Determine the volume of the mass of fertiliser;
- Make scoops to hold the exact volume of fertiliser that is required, by for instance cutting used tins to the correct size. Each worker must be supplied with a scoop of the correct and exact same size;
- Apply one or two scoops of the specified fertiliser.

In the case of fertigation and foliar applications, the liquid or powdered fertilisers are measured or weighed carefully and added to the prescribed volume of water.

7. Applying Fertilisers

Most fertilisers can now be applied without any further preparation. For manual application, fertiliser bags or containers are transported to the orchards and the required number of bags is off-loaded at each orchard. For fertigation and foliar applications, the fertiliser is merely mixed with the amount of water prescribed in the fertilisation program.

The feeder-roots of a citrus tree are concentrated in the area from the trunk of the tree to about 50cm outside the drip-line of the tree. This is normally the area that is wetted when the tree is irrigated.

Fertilisers are applied manually in the following manner:

- Irrigate the orchard for about 30 minutes before application to demarcate the area in which the feeder-roots grow;
- Scoop the required amount of fertiliser from the bag;
- Spread the fertiliser evenly on the wetted area, with little or no fertiliser against the trunk of the tree.

Summary

Chapter 1

- Plants need sunlight, water, air (oxygen and carbon dioxide) and nutrients in varying quantities to grow well and produce food. Nutrients are also called essential nutrient elements.
- To grow citrus successfully, we need to know which nutrients are required, the quantities of nutrients required, the right time to apply them, and the best way to apply them.
- Essential nutrient elements are divided into macro and micro nutrient element groups.
- Essential nutrient elements play various roles in the physiological processes in plants, some of which are still not understood.
- Nutrients, or fertilisers, are applied through soil applications (manual or mechanical), foliar applications, and fertigation.
- Fertilisers can be from organic (natural or synthetic) or inorganic (chemical) sources. In commercial citrus production inorganic, commercial fertilisers are mostly used.
- Compost and manure are forms of organic fertilisers that are produced by allowing organic material to decompose.
- Commercial fertilisers are available in granular, powdered and liquid form.
- A fertilisation program is developed to provide for the application of fertilisers that need to be applied during a specific period, usually a year.
- Soil and leaf analyses are used to guide the development of the fertilisation program and to detect nutrient deficiencies and excesses.
- When the fertilisation program has been developed, preparations are made for the fertiliser applications by calculating the total amount of fertiliser required, collecting the fertiliser from storage and measuring the fertiliser to determine the volume relative to the weight prescribed on the fertilisation program.
- The total amount of fertiliser required is calculated by determining the number of trees in the orchard, and multiplying that with the amount prescribed per tree.
- When fertiliser is collected from the storeroom, the active ingredient and the weight of the bags must be checked.
- The volume of fertiliser that must be applied to each tree is determined by weighing the required amount. Scoops of the exact volume are made to be used during the application.
- Fertilisers are applied manually by irrigating the orchard first to demarcate the area where the feeder roots are concentrated, and then scooping the correct amount of fertiliser and applying it to the wetted area.

Practical

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

Chapter 2

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

Take an appropriate sample for nutrient analysis

1. Introduction

We have already seen that plants need nutrients in varying quantities to grow well and complete its lifecycle and physiological processes.

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.

This results in a reasonably specific and identifiable symptom for each element. It is very important to have a good understanding of nutrient deficiency symptoms.

Once symptoms of a possible nutrient deficiency have been detected, the deficiency must always be confirmed by a leaf or soil analysis. Not all abnormalities that are detected are necessarily due to nutrient deficiency. Certain pests and diseases can impact on the ability of the tree to take up nutrients, which means that although the tree are showing symptoms of nutrient deficiency, it is not due to a short supply of the nutrient, but to the presence of the pest or disease.

A fertilisation program can never be developed purely in response to nutrient deficiencies that have been detected. By the time nutrient deficiency symptoms appear, the deficiency has already impacted on the growth and production of the tree. It is essential to have a proactive approach to plant nutrition.

To take proper preventative action, tools are needed to diagnose the nutritional status of the trees. Leaf and soil analysis are diagnostic tools that are used to monitor the nutritional status of the trees. Crop information is added to the data gathered from analyses, and a refined diagnostics system is developed in this manner.

2. Sampling and Nutrient Analysis in Citrus Production

In citrus production, soil samples are taken and analysed to determine the nutrient status and certain chemical and physical properties of the soil. Analytical results of the chemical and physical properties and the nutrient contents of the soil are used during soil preparation, to correct properties that are not ideal for citrus production. Some properties can best be corrected during soil preparation.

Soil analyses are used once the orchard has been planted to monitor the nutrient content of the soil. This helps to determine the concentration of the nutrients available to the plant, so that supply of nutrients can be optimised.

Leaf analyses are used to determine the nutrient status of the plant. Fruit analyses are not used for this purpose in citrus production. Fruit sampling and analyses are used only for maturity indexing during harvesting, which means determining whether fruit are ready to be picked. Fruit are observed for nutrient deficiency symptoms, but not analysed.

Fertiliser samples are sometimes taken if the label on the packaging has been lost, or if there is uncertainty regarding the composition of the fertiliser.

3. Guidelines for Sampling

The idea behind sampling is to "take the orchard to the laboratory". The first principle of any sampling is therefore that a sample must be **representative** of the bulk of the medium that is being sampled. A sample is not a piece or a section of a unit, but rather a unit reduced to a manageable volume.

All the equipment used during sampling, including cups, spatulas, buckets, and mixing equipment, must be thoroughly cleaned before sampling begins to avoid contamination of samples. The equipment is washed and rinsed with clean water.

4. Sampling Procedures

In this section, we look at procedures used for taking the following samples:

- Leaves
- Soil
- Fertiliser

To comply with the first principle of sampling, and to minimise the effects of other factors on the nutritional status of the trees, soil and leaf samples are taken at and from the same set of trees every year. Two to four rows that represent the orchard in all respects are selected for sampling, and are referred to as the index blocks or rows. The rows are marked, and samples for that orchard are always taken from these trees.

4.1. Leaf Sampling Procedure

Leaf sampling for citrus in Southern Africa are done between February and May. Sampling of a specific orchard, or the whole farm, should be done at the same time every year, for instance the second week of March. Leaves are picked from behind fruit and sampling should therefore be done before harvesting, especially with early varieties such as Satsuma.

The following procedure is followed:

- Enter the path between two of the rows in the index block and pick leaves from every second tree on the left and right, as illustrated in figure 2.1.

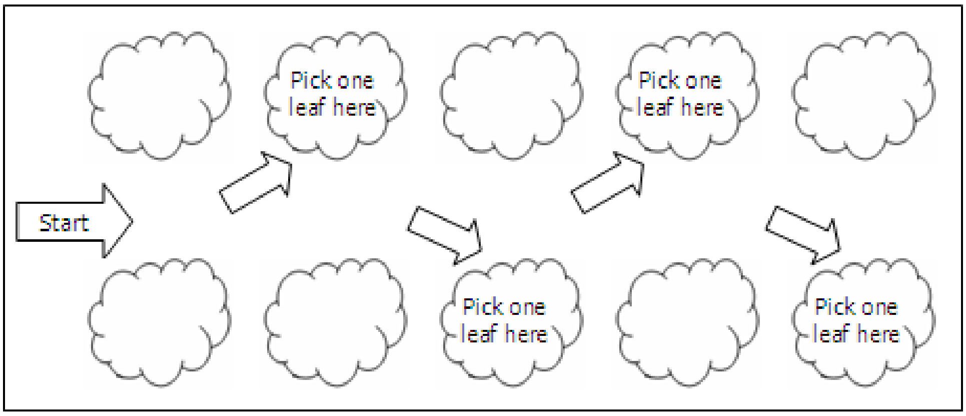


Figure 2.1: Leaf Sampling

- Pick 50 to 100 leaves per sample.

- Pick only healthy undamaged leaves.

- Pick leaves that are between 1 and 2 metre from the orchard floor, between about the waist and head of a person of average height.

- Pick leaves from **fruit bearing** twigs, as illustrated in figure 2.2.

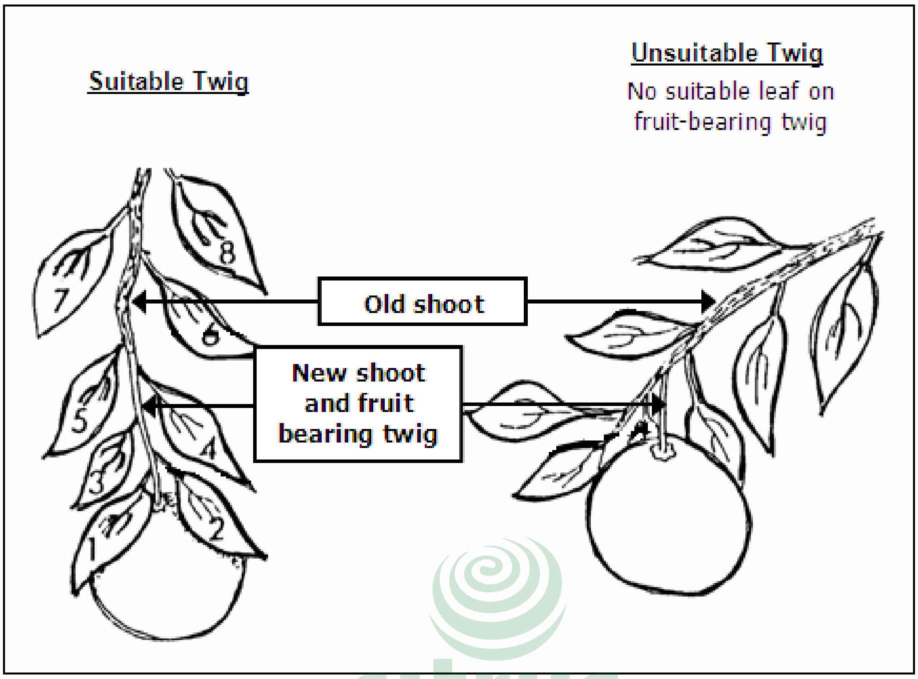


Figure 2.2: Selecting a Suitable Terminal (Time of Sampling February to May)

- Put the leaves in a new, clean plastic bag.

- Squeeze the air out of the bag and close it tightly.

- Label the sample as is prescribed in section 5. Never put a label in the sample bag with the leaves.

- Keep the samples until they are dispatched to the laboratory in the shade or in a cool place, but do not freeze the samples.

4.2. Soil Sampling Procedure

- Take soil samples from the same index block where the leaf sample was taken.

- Identify areas under every second to fourth tree for collecting small samples, or sub-samples, which will be used to make up the eventual sample.

- Remove any visible plant debris from the surface of the soil, but take care not to remove the top soil.

- Take the sub-sample from the surface down to a depth of 30cm depth using a spade or soil auger.

- A total of between 15 and 20 sub-samples is taken per index row.

- Collect all sub-samples in a plastic bucket.

- Mix the soil in the bucket and place about 500g in a plastic bag to form the sample that will be sent for analysis.

- Seal the bag tightly.

- Label the sample as is prescribed in section 5. Never put a label in the sample bag with the soil.

4.3. Sampling Procedure for Granular or Powdered Fertilisers

- Select at least 1% of the bags that are to be tested and take a small sample, or sub-sample, of 200g from each bag.
- Take the 200g from the top, middle and bottom of the bag.
- Put all these sub-samples in a plastic bucket and mix it thoroughly.
- Put 500g of the mixed sample in a suitable clean plastic bag.
- Seal the bag properly.
- Label the sample as is prescribed in section 5. Never put a label in the sample bag with the fertiliser.

A spatula used for taking grain samples can also be used. In this case press the spatula into the top, middle and bottom of the bags and collect these sub-samples in a bucket. When sampling is done for a legal dispute, the Registrar of Fertilisers prescribes specific procedures and samples must be taken in the presence of both parties to the dispute.

4.4. Sampling Procedure for Liquid Fertilisers or Fertiliser Solutions

- Select at least 1% of the containers to be tested and take a sub-sample of 200ml from each container.
- Put all the sub-samples in a plastic bucket and mix it thoroughly.
- Put 500ml of the mixed sample in a suitable, clean plastic bottle.
- Seal properly.
- Stick or tie a label to the bottle, as prescribed in section 5.

5. Labelling Samples

- Attach a label to the plastic bag or bottle, by either sticking it on or tying it on securely with string;
- Do not write the information directly onto the bag or bottle, because even permanent marker ink rubs off during transport;
- Never place a label inside the bag with the sample;
- If more than one sample is sent, at least one of the labels should contain all the details of the sender, including:
  - Name;
  - Address;
  - Telephone number;
  - Fax number;
  - Contact person
  - Details of analysis required in case of fertiliser samples and special instructions, where required;
  - Order number, where used;
  - Type of sample;
  - Sample reference, for instance the orchard number or store number.

- The labels on the remainder of the samples can reflect only the name, sample reference and type of sample.

Remember that the sample reference, whether it is a name or number, must mean something to the sender. The laboratory report will contain this reference and the sender must be able to connect the results with the relevant fertiliser batch. Keep the reference simple, however. A reference such as "Orchard 27 near dam" is unnecessary, if there is only one orchard 27. The word "orchard" can even be left out in the case of leaf, soil and fruit samples, as these samples are always taken from orchards.

Be consistent in the manner in which references are used, so that all farm employees that handle the samples will understand it. These simple rules make the whole process of recording, reporting and recordkeeping much easier.

Example

Leaf Sample Labels

27 Deltas	**Leaf Sample**
AA Farming P.O. Box 21 Nkwalini 3816	**Tel:** (035) 460-0066 **Fax:** (035) 460-5467
Order Number: SF20212 **Contact:** J. Ralepele (082-987-6543)	

27 Deltas	**Leaf Sample**
AA Farming	

Soil Sample Labels

A5 Eurekas	Soil Sample
ZZ Citrus P.O. Box 998 Citrusdal 7340	Tel: (022) 923-4567 Fax: (019) 923-8899
Order Number: IO100098 Contact: S. Jacobs (074-918-2736)	

A5 Eurekas	Soil Sample
ZZ Citrus	

Fertiliser Sample Labels

STORE 1	**Potassium Chloride**
Sunshine Farming **P.O. Box 20** **Hoedspruit** **1380**	**Tel: (015) 332-1112** **Fax: (015) 332-1115**
Order: SUN4219 **Contact: Brian Beytel (083-888-3333)** **Analyses Required: Total K and Cl**	

STORE 1	**Potassium Chloride**
Sunshine Farming	
Analyses Required: Total K and Cl	

6. Preparing and Packaging the Sample

- Keep samples of all types in a cool, dry place away from direct sunlight until ready for dispatch. Ensure that the samples are kept apart from possible sources of contamination.

- Before packing the samples, ensure that all the samples are labelled correctly, and that the labels are legible.

- Check the samples against the **Samples Dispatched** list as they are being packed.

- Pack the samples in a sturdy box and fill the box with packing material such as bubble wrap or newspaper to steady and protect them.

Summary

Chapter 2

- A nutrient deficiency means that there is not enough of a specific nutrient for the plant to complete a physiological process.
- Nutrient deficiencies of each nutrient cause very specific symptoms.
- Nutrient deficiencies are confirmed by doing leaf and soil analysis.
- Fertilisation programs cannot be developed in response to a detected nutrient deficiency as the deficiency would already have had a negative influence on the growth and production of the plant.
- Sampling and analyses are used as a diagnostic tool.
- Soil analyses are used to determine the chemical composition and nutrient content of the soil, and certain physical and chemical properties.
- Leaf analyses are used to determine the nutrient status of the plant.
- Fruit sampling is not used to determine the nutrient status of the plant in citrus production, but is only used for maturity indexing.
- Fertiliser samples are taken and analysed if there is uncertainty about the content of the container or the chemical composition.
- A sample must be representative of a unit.
- Sampling equipment must be washed thoroughly with clean water before being used.
- Leaf and soil samples must be taken at the same trees every time.
- Leaf samples are taken in South Africa between February and May before harvesting.
- Between 50 and 100 leaves must be taken for a leaf sample from fruit-bearing twigs.
- Soil samples are taken by combining a number of smaller samples, or sub-samples, and taking a sample from the mixture.
- Sub-samples are also taken from fertilisers and mixed. The final sample is taken from the mixture.
- Sample labels must contain all the necessary information, with at least one label containing all the contact information of the farm or producer.

Practical

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

Chapter 3

After completing this chapter, the learner will be able to: **Understand the properties and the composition of soil**

1. The Importance of Soil

Although plants can grow and produce without soil, such as with hydroponics and soilless cultures, trees in commercial orchards need soil to:

- ***Stay Upright*** – Plants anchor in the soil with their roots. This means that their roots must be able to go deep into the soil.
- ***Get Nutrients*** – Plants take up, or absorb, food or nutrients from the soil through theirs roots. Plants can also absorb nutrients through their leaves, or foliage, but most often they use their roots.
- ***Get Water*** – Plants take up or absorb water through their roots from the soil.
- ***Get Oxygen and Carbon Dioxide (Air)*** – The roots of a plant, like the rest of the plant above the soil, also need to "breathe", and the air that the roots need, is taken up from the soil.

Soil is made up of minerals, air spaces, water and organic material. The physical and chemical properties of soils are determined by the concentration, form and ratios of these components. The ability of roots to grow, take up nutrients and water, and "breathe" is influenced by the physical and chemical properties of the soil.

It is very important that one develop a thorough understanding of soil properties, and find answers to these questions:

- What kind of soil will best allow citrus plants to take nutrients and air?
- What kind of soil will best allow the roots of citrus plants to penetrate to an optimal depth
- What kind of soil will best allow ample aeration for the roots of citrus plants?
- What kind of soil will absorb enough water that the roots can obtain without much effort?
- What kind of soil will allow ample draining of excess water best?

The optimal, or ideal, soil properties for citrus cultivation are discussed in this chapter. In most cases, the soil that is available for cultivation is not ideal in every way, in which case steps can be taken to correct or at least improve the conditions.

2. Physical Soil Properties

The physical properties of soil are – to a great extent – fixed and will not change over years. These properties play a vital role in the sustainable productivity of soils. Most of the physical properties can be evaluated visually on site. The most important physical properties of soils are:

- Texture
- Structure
- Depth
- Layering or stratification
- Aeration

2.1. Texture

The texture of soil is determined by the ratio in which clay, silt and sand are present. It is a fixed property of a soil. The various combinations are grouped into textural classes ranging from clay to sand.

The texture of soil can be determined in a laboratory, but can be estimated fairly accurately in the field. To do the field test:

- Take about 50g soil;
- Add water to wet the soil;
- Knead it into a thick paste;
- Roll the soil between the palms of your hands into a sausage; and
- Try to make a circle.

The textural classes are determined as described in table 3.1.

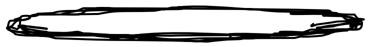
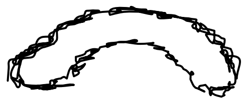
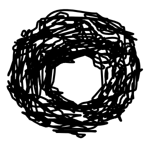
Textural Class	***Shape of Sausage***	***Clay Content***	***Illustration***
Sand	It is not possible to roll a sausage in the palm. The soil does not stick together.	Less than 10%	
Loamy Sand (LoSa)	It is possible to roll a sausage, but the sausage cannot be bent at all without cracking or breaking.	10 to 15%	
Sandy Loam (SaLo)	The sausage can be bent slightly, with the tips bent downwards for about 10mm without the sausage cracking in the middle.	15 to 25%	
Sandy Clay Loam (SaClLo)	The sausage can be bent down at the tips to about 20mm without cracking in the middle.	25 to 35%	
Sandy Clay	The sausage can be bent to form a semi-circle without cracking in the middle.	35 to 50%	
Clay	The sausage can be bend to form a complete circle without cracking in the middle	>50%	

Table 3.1: Soil Textural Classes

The average size of the clay particles is <0.002mm, that of silt 0.05mm to 0.002mm and sand 0.05mm to 2mm. Another aspect of texture is the content of particles larger than 2mm. This fraction is referred to as gravel and/or stones. When the gravel content of the soil exceeds 10%, it should be taken into account in the interpretation of the chemical composition of the soil. Gravel dilutes the concentration of available nutrient elements.

Clay and humus are the active materials in soil. The humus content of a soil can be increased, but is more often decreased by agricultural practises. The clay content, however, is a fixed property and cannot be changed economically. The type and concentration of clay determines the cation-exchange capacity, water-holding capacity, aeration, and many other soil properties. The ideal soil for citrus production contains less than 50% small particles (fine sand, silt and clay) and less than 25% clay.

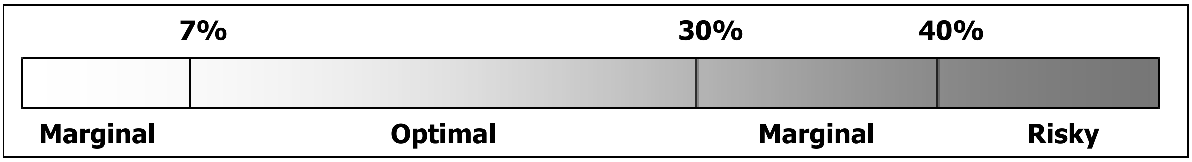


Figure 3.1: Clay Content of Soil vs. Suitability for Citrus Production

2.2. Structure

Soil structure refers to the manner in which all the soil particles, including organic material, are arranged to form structural units. The structural units are named according to their physical appearance, as describe in table 3.2.

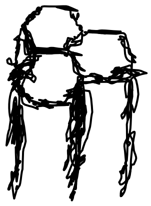
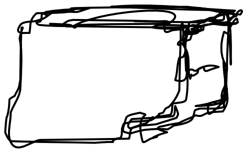
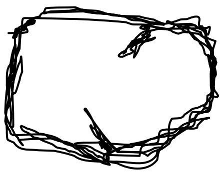
Structural Unit	***Description***	***Illustration***
No structure	This is usually the case in sandy soils where soil particles do not stick together. The soil falls apart when removed from the profile.	
Plate-like	The natural cracks are horizontal.	
Prismatic	The vertical cracks are better displayed than the horizontal ones. The units are 2 to 5 times as long as they are broad.	
Blocky	The vertical and horizontal cracks are evenly developed and the dimensions of the units are about the same. The units have sharp edges and smooth faces. The units range in size from 1mm to 50mm.	
Granular	These units have rounded edges with rough faces. They range in size from 1mm to 10mm. When wet, these units trap more air than the blocky or prismatic units.	

Table 3.2: Soil Structural Units

Soil structure is a very important property that regulates important factors such as aeration, water penetration and drainage. If the structure of the soil is destroyed, the soil becomes anaerobic, meaning that it contains no oxygen, and is water-logged.

2.3. Depth

The depth at which impermeable layers and / or parent material are present determines soil-depth.

Soils with a depth of less than 500mm are generally regarded as soil of low potential. However, in citrus production the effective depth is also important. The effective depth is the depth to which citrus roots can penetrate with ease. Usually, this is the depth to which the soil strength is less than 2,000MPa/cm^2.

Soil strength increases with depth, and it is measured with a soil penetrometer.

Definition

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}.

2.4. Layering or Stratification

It takes about 1,000 years to form a 25mm layer of soil. When soil is being formed, soil particles are separated and accumulate at different depths. Soils are also carried and deposited by water and wind to form layers with different soil properties.

Layers have an influence on the potential of the soil. Roots do not grow and water does not move easily from one layer to another if the properties, especially the texture, differ too much.

The texture of the soil must not change by more than 50% between any two layers in a soil profile. For instance, if the top soil contains 20% clay and the next layer more than 30% (50% of 20+20 =30), the stratification of the soil is too severe and will impede root growth and water movement.

2.5. Aeration

Plant roots "breathe", or respirate, which means using oxygen and excreting carbon dioxide, and a constant replenishment of the air in the soil is required. The rate at which air moves through soil depends on factors such as pore-size, which in turn depends on the texture, structure and strength of the soil.

The pores in the soil are filled with water and air, and the ratio depends on the water content of the soil at that point. At field water capacity (FWC), the air content is at a minimum. As the tree roots absorb the water in the soil, the air content in the soil increases.

Definition

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.

If the soil drains poorly or slowly, the pores are filled with more water than at FWC and less air is present. Water-logged soil contains very little oxygen, which is referred to as anaerobic conditions, and these conditions can cause roots to die.

3. Chemical Soil Properties

The chemical properties of soil are constantly in a state of flux (changing), and can be changed, although this may sometimes prove prohibitive because of high costs. The most relevant chemical properties of soils are:

- pH
- Resistance or electrical conductivity

- Salinity
- Fertility level
- Cation exchange capacity
- Organic matter

3.1. pH

Definition

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***.

When the pH of soil is measured, a suspension of the soil is prepared. The suspension can be prepared using water, 1 N potassium chloride (KCl) or other solutions. It is therefore necessary to state the suspension used when reporting the pH of the soil. pH values are reported for instance as pH(water) or pH(KCl). pH(water) is on average one unit higher than pH(KCl) for the same soil.

The optimal pH(water) of soil for citrus production is 6.50 to 7.50. When the pH(water) drops below 5.30, too much aluminium is present in the soil. Aluminium is toxic to the roots and root growth will be affected. If the pH(water) is above 7.50, nutrient elements like phosphate, zinc and manganese become insoluble and deficiencies can be induced.

In soils with a neutral to acid pH reading, the pH level of the subsoil is usually lower than that of the top soil.

3.2. Electrical Conductivity and Resistance

Definition

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.

The resistance of soil is important in citrus production, because it is an indication of the total dissolved salts in the soil solution. Measuring resistance is a quick method to scan the soil and if any sample is too salty, the electrical conductivity (EC) of the soil paste is measured.

3.3. Salinity

Salts accumulate in soils primarily because of poor drainage and because the irrigation water is saline. This is usually a slow process that affects the fertility of the soil and eventually also the physical properties, especially the soil structure.

3.4. Fertility Level

Fertility is a collective expression to describe the status of the soil in terms of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and, to some extent, nitrogen (N). Fertile soil contains enough of these nutrient elements to sustain plant growth.

Having not enough plant nutrients in the soil is less of a problem in commercial agriculture than having too much. As we have already seen, it is quite easy and fairly cheap to add nutrient elements to the soil. It is however seldom easy and cheap, if possible at all, to remove excess nutrients or to correct huge imbalances. For commercial citrus production, the ideal soil contains:

- Between 25 and 50mg/kg phosphorus (P) (Bray 1);
- A ratio of 5% to 7,5% potassium (K)
- A ratio of 70% to 80% calcium (Ca)
- A ratio of 20% to 25% magnesium (Mg); and
- Less than 1% Na

3.5. Cation Exchange Capacity (CEC)

Clay particles carry electrical charges of which the majority is negative. These negative charges can attract and bind with cations in the soil solution. The cations which are positively charged forms "salt" with the clay and can be displaced by any other cation.

The magnitude of negative charges present to absorb cations, is referred to as the cation exchange capacity (CEC) of the soil, and is expressed in centi-molar charge per kg soil (cmol+/kg). Organic matter also has a CEC, as well as an anion exchange capacity similar to the CEC, but that absorb negatively-charged anions.

The CEC of soil depends on the clay content, the type of clay, and the organic matter in the soil. Under certain circumstances CEC may be pH dependant, meaning that it will change when the pH changes.

3.6. Organic Matter

Organic matter in soil ranges from dead plant and animal material, organic debris, microbial debris and all stages of humus. Humus is processed and condensed organic matter and it takes thousands of years to reach a stable form.

Humus contributes to the activity in soils and consists of humus acid (or humates, the salts of humic acids), fulvic acid (or fulvates, the salts of fulvic acid) and humins (a very stable form).

Chapter 3

- Plants need soil to stay upright and to get nutrients, water and air (oxygen and carbon dioxide).
- It is important to understand chemical and physical soil properties to understand their influence on the ability of plants to grow.
- Soil with optimal properties is not always available for cultivation, and steps can be taken during soil preparation to correct or at least improve the conditions.
- Physical soil properties include texture, structure, depth, layering (stratification) and aeration.
- Texture is a fixed soil property and ranges from clay to sand.
- Soil with a clay content of between 7% and 30% is optimal for citrus production.
- Soil ranges from having no structure to being granular. Soil structure determines the aeration, water penetration and drainage of the soil.

- Soil with a depth of at least 500mm is required for citrus production.
- Soil layers are formed over many years, and the differences in the properties of soil in various layers determines the ability of water and roots to move from one layer into the next.
- Aeration refers to ability of the soil profile to supply air to the roots. Poorly drained soil becomes water-logged and anaerobic, which can cause roots to die.
- Chemical soil properties include pH, resistance and electrical conductivity, salinity, fertility level, cation exchange capacity, and organic matter.
- pH indicates the acidity of soil. The optimal pH(water) of soil for citrus production is between 6.5 and 7.5.
- Electrical conductivity and resistance indicate the salinity of the soil.
- Soil salinity affects soil fertility and physical soil properties.
- Soil fertility indicates the ability of soil to sustain plant growth.
- The cation exchange capacity of soil determines the ability of soil particles to bind with nutrients and keep them available to plants.
- Organic matter in soil consists of dead plant and animal material, organic and microbial debris, and humus. Humus contributes to the activity in soil.

Complete activity 5 in the **Learner Workbook**.

Chapter 4

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

Identify and interpret the basic symptoms of nutritional deficiencies in crops

1. Introduction

In chapter 1 we discussed the role of essential nutrient elements. There are fourteen essential nutrient elements, so named because without any one of the fourteen, the plant cannot complete its lifecycle. The mass of plant material and fruit produced by the plant is determined by the concentration of the most limiting element.

Essential nutrient elements are grouped in macro elements, of which the plant needs relatively large quantities, and micro elements, of which the plant needs relatively small quantities.

We have also seen that a deficiency of a specific element causes specific symptoms to appear. In this chapter, we will look at the specific symptoms that can be detected.

2. The Role of Essential Nutrient Elements

Before we look at the symptoms caused by nutrient deficiencies, we need to understand the role that each essential nutrient element plays in the physiological processes of a plant.

The role of each element is complex and elements are involved in many physiological processes of which some are still not understood. In the table below, the roles of the essential nutrient elements are summarised.

Information

Role and Function of Essential Nutrient Elements (Summarised)

Essential Nutrient Element	***Function***
Nitrogen (N)	Nitrogen forms part of all protein and enzyme molecules and is therefore involved in almost every physiological process in plant production.
Phosphorus (P)	Phosphorus is involved in all energy transfer reactions in the plant. It is also part of the nucleic acids in cells.
Potassium (K)	Potassium has many roles, including cell-division and transport of photosynthetic products from the leaves to the roots and other parts.
Calcium (Ca)	Calcium forms a vital part of all cell-walls, keeping the cells together in the same way as cement in a brick wall.
Magnesium (Mg)	Magnesium forms the centre metal ion in the chlorophyll molecule, which is required for photosynthesis, apart from its role in other physiological processes.

Sulphur (S)	Sulphur is involved in the production of the sulphur-containing amino acids and in reproductive processes. A sulphur deficiency will reduce flowering and fruit set.
Sodium (Na)	Sodium can replace potassium to some extend in certain plants.
Chloride (Cl)	Chloride is a micro-nutrient, with plants requiring about 20mmg per litre in their nutrient solution. Chloride is involved in the reactions where water molecules are split during photosynthesis.
Other micro nutrient elements Cu, Fe, Mn, Zn, B and Mo	Are involved in many physiological reactions as catalysts.

For a more detailed description of the roles of the essential nutrient elements, please refer to the classic publication of **Homer D Chapman: Mineral Nutrition of Citrus**.

3. The Most Limiting Element

We have seen that the ability of the plant to grow and produce food is determined by the level of most limiting nutrient element.

There is an optimum level for every nutrient element. The portion of that optimum level that is available to the plant determines the plants ability to complete the processes related to that element. The element of which the lowest portion is available is the most limiting element, because the plants ability to grow will be limited to this portion, or percentage.

This effect can be illustrated by trying to fill a drum or barrel with holes at various levels in its side. Each hole represents the percentage of the optimal concentration of a nutrient element that is available to the plant. To fill the drum, one first has to block the lowest hole, representing the element that is at the lowest percentage of its optimum concentration, which in the illustration below (figure 4.1) is K. Thereafter, you can fill the drum to the level where phosphorus (P) becomes the most limiting element.

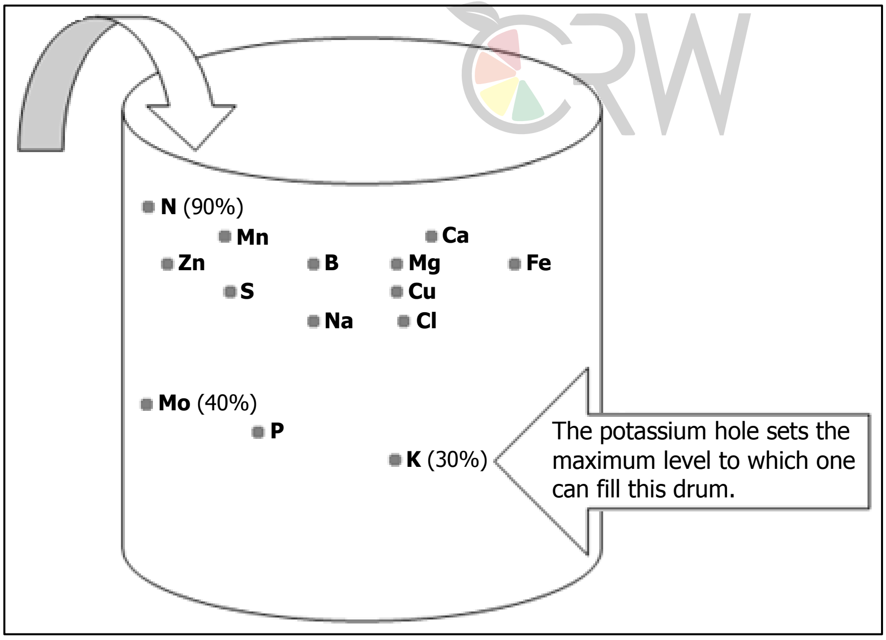


Figure 4.1: Illustration of Most Limiting Essential Nutrient Element

If you first block the nitrogen (N) hole before blocking the K hole you still will not be able to fill the drum to more than 30%. Blocking a whole means bringing that element up to its optimum concentration, or to 100%. To fill the drum all nutrient elements must be present at their respective optimal concentrations, or 100% level.

Getting the N level to 100% and not the K level will not enable the plant to produce at 100% capacity. Although molybdenum is required in very small quantities compared to nitrogen, the shortage of this element will still cause the plant to produce at only 40% of its capacity in the illustration (figure 4.1).

Fertilisation of commercial citrus production is about keeping all holes blocked at the lowest cost.

4. Nutrient Deficiency Symptoms

The most important features of nutrient deficiency symptoms are:

- The leaf should display the same characteristics on the left-hand and right-hand side of the midrib. This is important in distinguishing between nutrient deficiencies and other leaf symptoms.
- Nutrient deficiency symptoms first appear on either new or old leaves. From there the symptom can spread to the entire plant.
- Certain nutrient deficiency symptoms appear first or more noticeably in the fruit.
- Nutrient deficiency starts with mild symptoms and develops into severe symptoms.
- Sometimes more than one deficiency symptom appears on the same leaf making identification difficult.
- Sometimes the nutrient deficiency symptom is blurred by a symptom caused by factors other than nutrient deficiencies.

Symptoms of Nutrient Deficiencies in Citrus

Nutrient Element	***First Plant Part to Display Symptoms***	***Mild Expression***	***Severe Expression***
Nitrogen (N)	Old leaves	Yellowing of all old leaves, to a light yellow colour.	Yellowing of all leaves just before or during new leaf flush resulting in leaf drop.
Phosphorus (P)	Fruit	Open centre resembling over-matured fruit.	Thick skins and puffy fruit with high acid levels.
Potassium (K)	Fruit	Small fruit	Small fruit with thin skins combined with a low yield. On young trees the leaves may turn bronze.
Calcium (Ca)	Fruit	Increase creasing incidence (physiological disorder). Not yet confirmed.	Chlorosis (yellowing) of very young leaves and dieback of growth tips.
Magnesium (Mg)	Old leaves	Chlorosis of front of leaf from tip and sides of leaf. Inverted green V with open end of V at petiole side appears as symptom develops.	Leaf drop and decrease in fruit set.

Sulphur (S)	New leaves	Yellowing to butter-colour of new leaves on green twig.	Extremely reduced fruit set.
Copper (Cu)	New leaves	Extra large leaves on strong new growth.	Gum pockets in albedo (white part of the peel) of fruit. Fruit is small, thin-skinned and hard.
Iron (Fe)	New leaves	Yellowing of lamina (leaf blade) of young leaves leaving well-defined network of small veins.	Reduced fruit set.
Manganese (Mn)	New leaves	Inter-veinal yellowing of normal-sized leaf, almost over entire leaf. Broad green areas around veins and chlorotic areas between veins are most obvious symptoms.	Increase in number of leaves affected.
Zinc (Zn)	New leaves	Interveinal yellowing of small-sized leaf, starting at tip of leaf. Resembles manganese deficiency, but appears on small leaves and chlorosis starts at tip of the leaf.	Increase in number of leaves affected and reduction in fruit size.
Boron (B)	New leaves	Corking of midrib vein on underside of leaf. Resembles symptoms of cold damage on leaves.	Gum pockets around centre of the fruit. Fruit size reduced.

5. Rectifying Nutrient Deficiencies

The first response to detecting nutrient deficiency symptoms is to report to the orchard supervisor or manager. Citrus farms should have reporting procedures in place that allow the relevant information to reach the persons responsible for taking corrective action as soon as possible.

The presence of nutrient deficiency symptoms is a sign of an unsuccessful fertilisation program. Deficiency symptoms appear long after the shortage has an impact on the plant and/or production. The fertilisation program should provide for methods to identify and correct short supplies of any essential nutrient element before it impacts on the tree and/or crop.

Symptoms of a mild deficiency can be tolerated during certain times of the year. In a commercial orchard the impact on yield and quality is sometimes not worth the cost of correcting a mild and seasonal deficiency.

Rectifying nutrient deficiencies are seldom a simple matter of applying the nutrient. Very often the deficiency is the result of factors other than an absolute short supply. A deficiency can also be induced by other factors. ***Inducing*** a deficiency means that these factors convert the nutrient into an unavailable form or a form which is physiologically less active. To improve the supply of the specific nutrient, one needs to determine why its supply is not optimal and try to correct that.

Once it has been applied to the plant, there is unfortunately no guarantee that the active form will last long enough to result in the required physiological reactions. To maintain optimal concentrations of the available nutrient elements in the trees, enough of the nutrient in the available form must be present to be utilised by the plant.

The table below lists that most common causes of and factors associated with nutrient deficiencies, and the corrective measure that can be taken.

Information

Causes and Corrective Actions for Nutrient Deficiencies

Nutrient Element	*Causes of Deficiency and Factors that Can Induce a Deficiency*	*Corrective Actions*
Nitrogen (N)	Too little applied	Increase the application
	Too much lost due to leaching	Split application and control irrigation
	Phytophthora (root rot) (limits ability of plant to take up nitrogen from soil)	Treat the disease and apply nitrogen through foliar sprays in the meantime
Phosphorus (P)	Too little applied	Increase the application
	Soil pH too high	Not much can be done
	Soil pH too low	Apply lime to soil
Potassium (K)	Too little applied	Increase the application
	Mg supply too high	Apply K through foliar sprays
	Trees old	Not much can be done
	Nematodes	Treat the pest
Calcium (Ca)	Too little applied	Increase the application
	Climatic conditions	Increase application during critical periods
	Soil pH too low	Apply lime to soil
Magnesium (Mg)	Too little applied	Increase the application
	K supply too high	Apply Mg through foliar sprays
	Soil pH too low	Apply lime to soil
Sulphur (S)	Too little applied	Increase the application
Copper (Cu)	Too little applied	Increase the application
	Soil pH too high	Apply Cu though foliar sprays
Iron (Fe)	Too little applied	Increase the application
	Soil pH too high	Use soil application of chelate that is stable at high pH
	Over-irrigation	Reschedule the irrigation
Manganese (Mn)	Too little applied	Increase the application
	Soil pH too high	Apply Mn through foliar sprays
	Recent application of lime	Apply Mn through foliar sprays
Zinc (Zn)	Too little applied	Increase the application
	Soil pH too high	Apply Zn through foliar sprays
	Too much P applied	Apply Zn through foliar sprays
Boron (B)	Too little applied	Increase the application
	Too low pH in the soil	Apply lime to soil

Chapter 4

- The plant's ability to complete its physiological process, grow and produce food depends on the concentration of the most limiting element.
- Each nutrient element has a very specific role and function in the metabolism or life of a plant.
- The most limiting element is the nutrient element present at the lowest percentage of its optimum concentration. Even if only one nutrient element is not at optimum concentration, the plant will be limited in its ability to grow.
- Nutrient deficiency symptoms are specific to the nutrient that is not at the optimum level, but can be blurred by a combination of deficiency symptoms or symptoms of other factors.
- The fertilisation program should provide for keeping nutrient elements at optimum levels. Mild deficiencies can be tolerated during certain times of the year.
- The cause of the deficiency has to be identified in order to deal with it effectively.

Complete activities 6, 7 and 8 in the **Learner Workbook**.

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