LEARNER GUIDE

Plant Nutrition & Soil Management

Level 4

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Title:		**Implement Soil Fertility and Plant Nutrition Practices**					
Applied Title:		**Implement Soil Fertility and Plant Nutrition Practices**					
Field:		Agriculture and Nature Conservation					
Sub-Field:		Primary Agriculture					
SETA (SGB):		AgriSETA					
Skills Area:		Plant Nutrition and Soil Management					
Context:		Citrus Production					
US No:	116311	**Level:**	4	**Credits:**	3	**Notional Hours:**	30
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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

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Directions

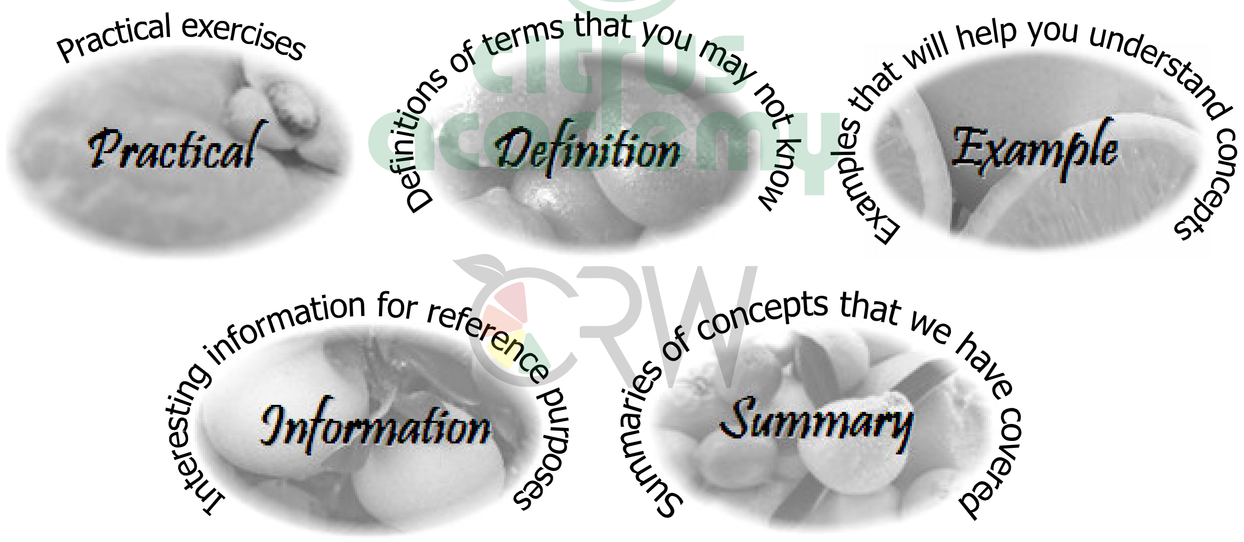
This learning material has been developed to assist the learner wishing to complete this unit standard. The guide contains all necessary learning to ensure that the learner will attain the competencies required by the unit standard.

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 set up and supervise the implementation of soil preparation and maintain and conserve soil in a safe, effective and responsible manner with consideration to the environment.

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***
NQF3	Literacy and Numeracy	
3	116267	Manage soil fertility and plant nutrition
4	116312	Implement a data collection plan
4	116288	Execute sustainable resource use and quality control
4 (F)	116320	Plan and maintain environmentally sound agricultural processes

Revision of Level 3

1. Nutrient Applications

- Fertilisers are applied as soil applications (manual application, mechanical application and fertigation) or foliar sprays.
- In every application, fertiliser must be measured correctly, collected from storage, measured accurately, prepared according to prescriptions if necessary, and applied as prescribed. In some cases, application equipment must be calibrated.
- The total amount of fertiliser required for any application is calculated by using the fertilisation program.
- Fertiliser must be measured carefully to avoid over- or under-application. Pay attention to liquid fertilisers used in fertigation or foliar applications for which the mass is indicated on the fertilisation program and not the volume.
- When collecting fertiliser from storage, the description, active ingredient and mass of each bag and the seals on half-full bags must be checked.
- In soil applications, fertiliser must only be applied to the zone wetted by irrigation.
- Foliar applications are done with spray machines and the leaves must be wetted thoroughly.
- The instructions for fertigation systems differ and must be followed carefully.

2. Sampling

- Sampling procedures must be followed carefully to ensure that the results of analyses are accurate and meaningful.
- In preparation for sampling, demarcate the orchards and trees, prepare a list of samples, ensure that the sampling containers are clean and properly marked, allocate specific tasks to specific team members and ensure that they are aware of proper procedure, and health and safety instructions.
- With leaf sampling, ensure that the leaves that are taken is on young shoots, that the leaf is taken from a fruit-bearing shoot, and that not more than two leaves are taken from a tree.
- With soil samples, ensure that the correct number of sub-samples are taken, that samples are taken at a depth of 20-30cm, that the sub-samples are mixed thoroughly, and that samples are taken from the wetted area under the canopy of the tree.
- After samples have been taken, mark it off on the list, seal the containers properly and keep it in the shade.
- Before dispatching samples, separate the leaf and soil samples, check and order the samples, and record them on a consignment note.
- Samples must be recorded to facilitate communication between the farm and laboratory. The most important record is the consignment note.

3. Nutritional Deficiencies

- The status of various nutrients in the tree has a marked effect on fruit quality. Nitrogen, phosphorous, potassium and calcium play the most important role.

- To correct the nutrient status of the tree, the cause of the over- or under-supply must be known. Applying more fertiliser may not be an effective remedy.

4. Soil Properties

- Physical and chemical soil properties play a role in plant nutrition. The impact of the physical properties is mostly indirect and that of the chemical properties mostly direct.

- In as far as soil texture is concerned, the higher the clay content of the soil, the less air is available for the roots.

- If the soil structure is destroyed, it has an adverse effect on root development and root health, and leads to weaker water penetration, aeration and internal drainage.

- A minimum soil depth of 30cm for rooting is required for citrus production, with a rooting depth of 40cm to 50cm for micro-jets and 60cm to 70cm for drip irrigation considered as optimal.

- For the development of a healthy root zone, a soil strength of less than 1,800 to 2,000 mega Pascal per cm2 (MPacm-2) is required.

- In terms of soil stratification, the guideline for too great a difference is more than 1.5 times the clay content from one layer to the next.

- In terms of soil aeration, for optimal root development and activity, the spaces filled with air at FWC should be about 10% of the total soil volume.

- Optimum soil pH(water), where all the nutrients are available, is said to be between 5.5 and 6.5.

- When the soil resistance is too low, meaning when the salt index is too high, the plants need energy to overcome the osmotic pressure in order to absorb water and nutrients. When the resistance is too low, the mass of nutrients available for absorption might be too low if not supplemented in time.

- The higher the soil fertility, up to a certain point, the better the yields, provided all other production factors such as irrigation are optimal.

- Organic material influences almost all the physical and chemical factors.

- The purpose of soil preparation is to create a homogeneous rooting zone with no physical and chemical barriers that will restrict root development, root health and root activity.

- The purpose of a soil survey is the evaluation of the profile(s) of the soil, and it is done by evaluating the inside of a profile pit.

- Profile pits are surveyed by marking the positions of the various layers and by taking samples from the layers.

- Profile pits with the same horizons are grouped together. The area is demarcated into soil types based on the grouped profiles and a soil map is developed.

5. Soil Preparation

- Soil preparation must be done correctly before planting, because corrective cultivation is very seldom successful.

- Proper soil preparation involves a soil survey, the selection of appropriate implements, and the proper execution of the decided actions.

- The objective of soil preparation is to provide tree roots with a homogeneous volume of soil with no drastic changes in physical and chemical properties.

- The profile properties that are important in meeting the objective of soil preparation are texture, layering, strength (compaction), aeration, drainage and depth.

- The two most important chemical properties of soil that have an influence on the methods used in soil preparation are pH and salt content.

- The two methods used during soil preparation are mixing and loosening.

- Mixing is used when soil layers must be mixed to create a homogenous region and where chemicals must be incorporated into the soil during preparation.

- Loosening is used where mixing is not required.

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.

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.

Chapter 1

After completing this chapter, the learner will be able to:
Interpret recommendations and set up nutritional programs based on recommendations

1. Introduction

Citrus production, as is the case with all other crops, has a specific timetable for the application of nutrients. For certain nutrients, timing of application is especially important, while others have a longer and less specific application period.

A fertilisation program is usually developed in advance for a year, and contains the details of all applications that are to be made during that time. Based on the fertilisation program, an application program is developed.

2. Fertilisation Programs

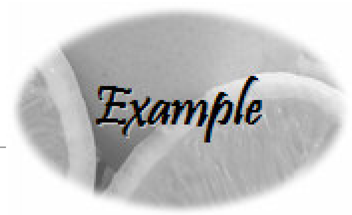
Various institutions supply fertilisation programs, varying from basic, general programs to very specific programs. General programs are of little value in a commercial citrus production unit. The best programs are those that have been developed for a specific orchard, based on specific data from the orchard.

Such specific programs utilise leaf and soil analyses data for the current year, as well as historic analytical data. The leaf and soil analyses data is supported by information on the previous applications, including what, how much and when, and information on the previous and current crop, including yields and fruit quality.

All these factors are taken into consideration to formulate the best fertilisation program for the farm and for specific orchards. The best fertilisation program is one that will result in the best possible fruit volumes and quality, and therefore give the highest economic profit, without sacrificing sustainability. A good fertilisation program contains the following details for each orchard:

- Orchard number or reference
- Cultivar and variety
- Details for soil applications:
  - Name of fertiliser
  - Rate of application, being quantity in grams (g) to be applied per tree
  - Time of application
- Details for foliar applications:
  - Name of fertiliser
  - Rate of application, quantity in grams (g) or millilitre (ml) to be mixed per 100l water
  - Time of application
- Additional information or special instructions

Below is an example of a fertilisation program. From this program the manager develops application programs for soil applications and foliar sprays.



Fertilisation Program

FERTILISATION PROGRAM – CITRUS			
Orchard:	Orchard 10	**Size:**	3.0ha
Cultivar/Variety:	Delta Valencias	**Trees per ha:**	316
Fertiliser		***Quantity***	***Application Time***
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: Manganese and Solubor are compatible. Spread the lime over the entire area allocated per tree.			

3. Fertilisation Application Programs

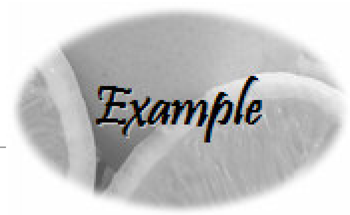
The best practice is to develop a fertilisation application program for every month for the whole farm, in which the applications of all the orchards are summarised on one working document for each month. Soil applications and foliar applications are summarised separately, resulting in two application programs for each month.

To the information that is obtained from the fertilisation program, other information is added, such as the size of each orchard and the number of trees per hectare. The fertilisation program usually prescribes the rate of application as volume or mass per tree or per ha. By adding the orchard size and tree numbers, the total volume of fertiliser required per orchard can be calculated.

When developing the fertilisation application program, specifically for foliar sprays, consideration must be given to other production practices, such as crop protection applications. The fertilisation application program must be coordinated with other production practices to ensure that the right fertiliser is applied at the right time.

3.1. Soil Application Program

The soil application program for the farm is a summary of all the prescribed soil applications for every orchard for a specific month. Using the fertilisation program in the example above as a starting point, the following **Soil Application Program** can be developed.



Soil Application Program

SOIL APPLICATION PROGRAM							
Month:	July 2006						
Product:	Limestone Ammonium Nitrate (LAN)						
Orchard	***Size (ha)***	***Trees per ha***	****Total Trees***	***Recommend (g per tree)***	*****Total Recommend per Orchard (kg)***	***Applied (g per tree)***	***Total Applied per Orchard***
A	3.5	316	1,106	650g	719kg		
B	2.0	316	632	500g	316kg		
C	4.1	556	2,279	250g	570kg		
D	3.2	416	1,331	500g	666kg		
Total					**2,271kg**		

*Total Trees = size (ha) x trees per ha
** Total Recommended per Orchard (kg) = total trees x recommended g per tree / 1,000

i.e. * 3.5 ha x 316 trees per ha = 1,106 trees
** 1,106 trees x 650g per tree = 718,900g / 1000 = 719kg

When fertilisers are applied, conditions of high concentrations are created which may not necessarily suit the plant. It may well be that the fertiliser should not be applied in one dosage during the month, and more information is required as to how the fertilisers should be applied.

When 500g LAN per tree is applied at one time, the high concentration of ammonium nitrate, the active ingredient in LAN, may result in temporary soil salinity, which may affect the roots and lead to reduced absorption. The high concentration of ammonium nitrate can also not be absorbed within a short period of time and subsequent irrigation might leach the nitrogen beyond the reach of the roots.

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. Leaching is less of a problem in clayey than sandy soils. The buffer capacity of clayey soils is also much better than that of sandy soils and the increase in temporary salinity due to the application of ammonium nitrate will therefore be less.

The salt index of fertilisers further indicates desirability of splitting the application. Fertilisers with a high salt index, such as potassium chloride, are more likely to be split into multiple applications than calcium nitrate, which has a low salt index. To prevent such problems and improve the absorption of nitrogen, the application of 500g can be split into two applications during the month of 250g each. Note that this is not always practical on large farming estates, as the man-hours required for the application is doubled when the application is split.

Under certain conditions it may however be better to apply fertilisers in one application, rather than splitting the application. Soils can fix phosphorus and potassium and to overcome the fixing capacity of the soil, one heavy application may be more effective than a number of small applications.

Definition

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.

Calculating the efficiency of a nitrogen application is a simple method to quantify the possible loss due to leaching and disrupted absorption. This does however not apply to potassium and most other fertilisers.

After the Soil Application Program has been compiled, planning is done for application scheduling during the month, meaning which orchard will receive its application during what time of the month, taking into consideration available manpower and equipment. Please note that if a number of applications are done in the same orchard in consecutive months, care should be taken to ensure that the applications are done on more or less the same day of each consecutive month.

In practise, it is quite difficult to apply exactly the recommended quantity per tree to all of the trees in orchard. It is therefore necessary to calculate the actual average rate of application after the application has been done. This is done by dividing the total quantity applied by the number of trees, and thus calculating the average application per tree.

The actual average quantity per tree may vary somewhat from the recommended quantity per tree, but it is important to ensure that this variation is not larger than 10%. In terms of the example above, the variation should therefore be between 618g and 683g per tree in the case of orchard A.

Soil application programs are developed for August, September and October as well, with two separate programs for the application of LAN and potassium chloride in August and September.

3.2. Foliar Application Program

A foliar application program is developed in a similar manner, although the calculations are somewhat different.

The recommended foliar applications are supplied in g or ml per 100l water. The size of the trees plays an important role in the total amount of spray material that will be required. On average, between 2,000 and 2,500 litres of material are sprayed per hectare on mature citrus trees in a medium-cover spray, which is required for foliar feeding.

The average actual application per hectare is calculated once the application has been done to ensure that the variance between the recommended quantity and the actual applied quantity does not vary by more than 10%.

A foliar application program is developed for October as well. Note that it was stated in the fertilisation program that the Manganese Sulphate and Solubor® sprays are compatible, and can therefore be sprayed at the same time.

Foliar Application Program

FOLIAR APPLICATION PROGRAM							
Month:	July 2006						
Product:	Low Biuret Urea						
Orchard	***Size (ha)***	***Litres per ha***	****Total Litres***	***Recommend (g per 100l)***	*****Total Recommend per Orchard (kg)***	***Applied (g per ha)***	***Total Applied per Orchard***
A	3.5	2,500	8,750	1,000g	88kg		
B	2.0	2,250	4,500	0	0		
C	4.1	1,250	5,125	0	0		
D	3.2	1,750	5,600	1,000g	56kg		
Total					**144kg**		

*Total Litres = size (ha) x litres per ha
** Total Recommended per Orchard (kg) = recommended g per 100l / 100 x total litres / 1,000

i.e. * 3.5 ha x 2,500 litres per ha = 8,750 litres
** 1,000 g per 100l / 100 = 10g per litre x 8,750 litres = 87,500g / 1000 = 88kg

Please Note: The volume applied per ha varies due to a variation in trees size and, to some extent, the inter-row spacing. While 2,500 litres per ha is an indication of the requirement, the real parameter is "to the point just before runoff".

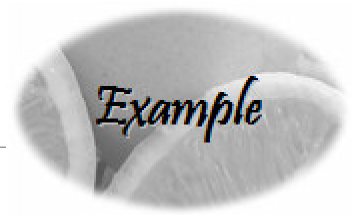
4. Maintaining Stock Levels and Placing Orders

Ordering of fertilisation must be coordinated with the production manager and the administrative staff. Ensure that documentation is provided to the responsible person in good time, and ensure that the manager is aware of all orders that are to be placed.

The fertilisation program for the next season – remember that a season is deemed to be from the beginning of August of one year to July of the next year – is usually prepared during March to June. During this period, leaf and soil samples are analysed and the results used inter alia to formulate the fertilisation program. March to June is also the harvesting period for the early cultivars and a good time to evaluate the yield and quality of the late cultivars. Ordering should start during May or June to ensure that stocks are on hand when the very important application of nitrogen starts in July or August.

The time required between ordering and delivery depends on the agreement between manager and supplier. Ensure however that the fertilisers will be delivered in time if orders are placed for instance thirty days prior to the application date. Economic considerations could limit the time between ordering and delivery. If payment is made on delivery, one would not submit an order in March for fertiliser required in July.

Requirement reports, such as the one in the example below, are developed for each fertiliser and each month, and are done for the low biuret urea required in July (foliar spray), LAN and potassium chloride required in September, the lime in October and manganese sulphate and Solubor® in October.



Fertiliser Ordering

FERTILISER REQUIREMENTS						
Product:	Limestone Ammonium Nitrate (LAN)					
Orchard	***Required July***	***Order Date***	***Delivery Date***	***Required August***	***Order Date***	***Delivery Date***
A	719			277		
B	316			158		
C	570			570		
D	666			333		
Total	**2,271**	**03/06/06**		**1,338**	**02/07/06**	

5. Substitution of Recommended Fertiliser

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

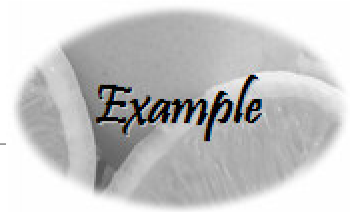
Table 1.1: Nutrient Content of Commercially Available Fertilisers

Recommended fertilisers and chemicals for foliar sprays can be substituted with an equivalent elemental basis provided that:

- 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).

The person responsible for the formulation of the fertilisation program should be consulted before substitutions are made. Fertiliser manufacturers may also be able to assist in this regard. The rate of application for the replacement fertiliser is calculated as follows:

> Rate of application for recommended product x % active ingredient in recommended product / % active ingredient in replacement product = rate of application for replacement product



Fertiliser Substitution

- Borate A, containing 16% B, can substitute Solubor®, containing 20% B. The application rate must be changed accordingly, i.e. if 150g per 100l was recommended, 187.5g Borate A per 100 litre water should be applied, calculated as follows: 150x20/16 = 187.5
- LAN (28% N) can be substituted by ammonium sulphate (21% N) but keep in mind that the acidification of ammonium sulphate is more than twice that of LAN. The calculation in this case is: 500g LAN x28/21=667g ammonium sulphate
- Double super phosphate (20% P) can be substituted by twice as much single super phosphate (10,5% P)

Chapter 1

- A fertilisation program is developed on an annual basis and contains information on all the applications that have 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 with the volume 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 have 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).

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

Chapter 2

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

Implement soil utilisation plan for specified crops

1. Selecting the Appropriate Soil

For a permanent crop such as citrus, which can be in the same soil for more than fifty years, proper selection of the soil is essential. One is however limited by the soil types on the farm and has to select the best available. Citrus is often not planted in ideal soils and the subsequent horticultural practises should endeavour to compensate.

In evaluating soils for citrus production one strives to get as close to the optimum soil characteristics as possible. The selection process starts with a proper soil survey, as described in the learning material for ***Manage Soil Fertility and Plant Nutrition in a Citrus Production Environment*** on NQF level 3, during which different soil boundaries are demarcated. This is a fairly specialised job and should be done by an experienced pedologist.

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.

Once the soil types are mapped, areas are demarcated for investigation for the specific purpose of development of citrus orchards. If you have a choice, select the best area based on the following characteristics or soil properties:

- Slope
- Depth
- Soil texture
- Stratification
- Salinity

This process should culminate with the creation of a map with the positions of the various orchards overlaying the map produced by the soil survey. Once this is done, soil preparation and the irrigation layout can be planned.

2. The Influence of Soil Characteristics

The soil properties listed above influence decisions on orchard layout, irrigation design, soil preparation and orchard floor maintenance.

2.1. Slope

Commercial citrus production requires the use of fairly heavy machinery, such as spray- carts and picking trailers. During soil preparation, the tractors and implements used to prepare the soil must also be able to drive safely.

The slope must therefore not be so severe that workers and equipment are put in danger. A flat surface with a slope of less than two degrees is however also not suitable, as surface drainage of rain water will be too slow.

Slope is also important for row orientation, surface drainage and erosion. Planting on contours is no longer done and if the slope poses any potential problems with surface drainage and / or erosion, orchard layout should be adapted accordingly.

The orchard roads and vehicle paths between rows are usually protected by grass-cover. If the orchard layout facilitates water movement at a moderate speed, erosion can be avoided. Row orientation is more important in the southern parts than in the northern parts of Southern Africa and can be changed to facilitate surface drainage.

2.2. Depth

Citrus requires a minimum soil depth of 30cm to 40cm where micro-jet irrigation is used, and 40cm to 50cm where drip irrigation is used, provided the material below this potential root-zone will not restrict drainage.

Where the potential effective rooting depth is limited, it can be improved by ridging. Ridging places the suitable soil from the between-row area on top of the in-row area, creating a thicker layer of soil where the trees will be planted. For ridging to be effective, an inter-row spacing of more than 5 metres and a minimum suitable soil depth of 25cm are required. An in-row area with a depth of 50cm and a width of 250cm can be created under such conditions.

Ridging is also helps to demarcate the paths for the vehicles to drive in to avoid re-compaction of the soil after planting.

Ridging furthermore lowers the preparation cost. Power required in soil preparation increases exponentially with depth, hence cost will also be more. Where large quantities of lime are required, ridging can reduce the quantity by reducing the depth. For example, where 10 tonnes of lime has to be mixed in with the top 50cm soil layer, it can be done more easily and cheaper if 5 tonnes is mixed with the top 25cm, and then ridged.

Keep in mind however that ridging makes harvesting more difficult due to the undulating surface the pickers have to walk on.

2.3. Soil Texture

The optimum soil 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. These are all factors that will influence the final product.

The water holding capacity and volume of easily available water has an influence on the irrigation scheduling, yield and fruit size. The cation exchange capacity influences the frequency of fertiliser application, leaching of nutrient cations and utilisation of potassium. Inhibited utilisation of potassium reduces fruit size. Poor aeration affects the root system negatively. Under anaerobic conditions, roots cannot function properly and diseases like Phytophtora proliferate.

2.4. Stratification

During soil preparation, all forms of stratification, or layering, must be removed, meaning that layers in the soil are broken up and mixed with the help of machinery. The type and depth of the layers determine the implements required. The less layers present in a soil, the lower the preparation cost, as soil with little or no stratification can merely be loosened.

Stratification restricts water movement and root development, resulting in soil volumes with few roots. These volumes become water logged and create pockets in the soil where root-rot starts. These unoccupied volumes also contain water and nutrients that are unavailable to the plant due to a lack of roots. During soil preparation, all forms of layering must be eliminated.

2.5. Salinity

Salts accumulated in a soil for a reason. If the accumulation is due to poor drainage and high concentrations of sodium are also encountered, such sites should be avoided.

It is usually difficult and expensive to remove salts, because the causes of accumulation also have to be removed. However, if the high salt content is due to a lack of leaching, the site can be reclaimed. Consult a specialist to determine the reclamation process, cost and impact.

Calcium carbonates can also accumulate in the subsoil due to limited leaching. Depending on the depth of accumulation, the soil can still be utilised successfully. Soils with salt accumulated anywhere in the top 60cm to 100cm should however be dealt with cautiously.

Measuring the resistance or electrical conductivity of the soil in solution will help to identify accumulated salts. Soil layers with resistance readings of less than 250Ω for soils with a clay content of 35%, to 500Ω for soil with less than 10% clay should be investigated intensively before preparation can start. Consult an expert.

While accumulated salts also include nutrients, it usually contains high concentrations of sodium, calcium, chlorides, sulphates and carbonates. The chemical conditions in the layers where the salts accumulated restrict root development and function.

Where sodium is the dominant cation, the conditions damage the structure of the soil and hence the physical properties required for proper root functions. Where calcium and carbonate are dominant, the pH will reduce the availability of many nutrients such as Fe, Mn, Cu, Zn, P and K. Where chloride and sodium are the dominant ions, the osmotic pressure of the water in that zone will restrict utilisation of water by the trees.

Chapter 2

- 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.

Complete activity 3 in the **Learner Workbook**.

Chapter 3

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

Identify and interpret symptoms of nutritional deficiencies and make full recommendations

1. Introduction

Deficiency symptoms develop as a result of a physiological process that cannot be completed. Symptom normally appears about six weeks after the nutritional deficiency occurs. Using nutritional deficiency symptoms to prepare a nutritional program is therefore closing the gate after the horse has bolted. In commercial citrus production, the occurrence of deficiencies must be avoided and strategies should be in place to monitor the nutritional status of the trees continuously.

One such strategy is annual leaf and soil analyses. It is however possible for the concentration of certain nutrient elements to drop to "below normal" and even "deficient" levels without being noticed in the analytical process. Supplemental to leaf and soil analyses, the trees in the orchard must be monitored for these hidden deficiencies. Observations must be reported when supplying orchard information to the person preparing the fertilisation program.

2. Symptoms of Nutrient Deficiencies

Prominent nutrient elements that develop hidden deficiency symptoms are nitrogen, magnesium, copper and iron.

2.1. Nitrogen

Nitrogen is a mobile nutrient in plants and relocates to areas where it is required the most. The nitrogen in old leaves is relocated to new leaves shortly before the old leaves are dropped. This is a natural process which starts when the leaves are about twenty-four months old.

Leaves of under the age of twenty-four months can however be dropped prematurely when the tree experienced a shortage of nitrogen, with the nitrogen from these leaves relocated to younger leaves on the same or other twigs. The leaves receiving the relocated nitrogen will have an elevated concentration, but at the cost of the older leaves. If the leaves with elevated nitrogen concentration are picked during sampling, the leaf analysis will present an untrue reflection of the nitrogen status of the trees. The actual nitrogen status is disguised by relocating nitrogen.

Nitrogen Relocation

To explain what happens during the relocation of nitrogen and premature leaf drop, the following calculation is helpful:

When the leaf analysis indicates a nitrogen content of 2%, the unsaid assumption is that the trees have a normal leaf-cover. However, if N was relocated from 20% of the leaves to the leaves sampled, this 2% N at an 80% leaf-cover actually would have been 1.6% N if no leaf drop occurred. Therefore, although the leaf analysis indicates a "below normal" nitrogen status, the actual status is actually "deficient".

The symptoms of this process are:

- The entire tree is a slightly lighter green than normal
- The oldest leaves turn deep yellow colour and drop
- Twigs have leaves at the tips and few or none at the middle or base
- The tree is sparsely foliated with only one or two generations of leaves
- Excessive leaf drop occur a week before and during a vegetative flush

The nitrogen concentration in the leaves decreases but stabilises at a level in the "below normal" range, not indicating that this status is sustained by relocated nitrogen from leaves dropped prematurely. The leaves on the tree have a reasonable nitrogen status but this "fairly good" status is applicable to much fewer leaves.

Additional information is required to interpret the analytical data if the trees are growing under abnormal conditions or showing abnormal symptoms such as sparse foliation.

2.2. Magnesium

Magnesium is also a very mobile nutrient and the same process as with nitrogen occurs when the supply of magnesium is too low. Magnesium deficiency symptoms are more prominent on seeded cultivars. The symptoms in this case are:

- No change in the green appearance of the entire tree
- The oldest leaves develop yellowing from the sides and tip backwards towards the petiole, leaving a unique inverted V-shaped green area with its broadest side at the petiole
- Twigs have leaves at the tips and few or none at the middle or base
- The tree is sparsely foliated with only one or two generations of leaves
- Excessive leaf-drop occurs during the onset of spring and/or during a vegetative flush
- Excessive leaf-drop can also occur after a foliar application of potassium, as applications of potassium will aggravate the hidden magnesium deficiency

The magnesium concentration in the leaf decreases but stabilises at a level in the "below normal" range, not indicating that this status is sustained by relocated magnesium from leaves dropped prematurely. The leaves on the tree have a reasonable magnesium status but this "fairly good" status will only be applicable to much fewer leaves.

2.3. Copper

Copper moves slowly through the citrus tree. When a strong vegetative flush develops, the supply of copper to the leaves formed on the new twigs might be too low and copper deficiency symptom develops. The symptom will be more pronounced on the basal leaf of the twig and will be less and less obvious towards the tip of the twig. During the subsequent days, the supply of copper will continue and will reach the "normal" level in the affected leaves, but the deficiency symptom will remain.

The typical leaf symptom of copper deficiency is abnormally large leaves. The leaves at the base of a twig are two to four times the normal size and are sometimes the shape of a boat. When copper deficiency symptoms appear on leaves of a twig exceeding 50cm in length, it can be attributed to a natural slow supply of copper. However, if symptoms appear on shorter twigs, the copper supply must be supplemented.

Gumming is often connected to a copper deficiency but gumming is a natural response of the tree to many adverse conditions and not only a copper deficiency.

Definition

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.

2.4. Iron

Iron is present in leaves in physiologically active and inactive forms. Traditional leaf analyses cannot distinguish between these forms and only indicates the total iron content.

The availability of iron depends on external factors such as soil pH and the concentration of bicarbonates in the soil, the water and the plant. When the soil pH is high, less iron is available to be taken up by the plant. Once taken up, the iron can be inactivated by bicarbonates. Bicarbonates are present in the irrigation water, but also in the cell-sap in the plant. Inactive iron accumulates in the leaves and forms part of the iron concentration detected during analysis. A plant can therefore suffer an iron deficiency although the leaf analysis indicates normal, high or excess concentrations of iron. Leaf analyses are only useful when the results indicate a low to deficient iron concentration.

Iron is not relocated in the plant and deficiency symptoms develop on the newly formed leaves. The symptoms are more prominent during winter and at the lower shaded part of the canopy.

A typical symptom of iron deficiency is the development of a light green leaf blade with prominent green veins spread over the entire leaf. Even the very fine veins remain green on a yellow background.

2.5. Other Deficiency Symptoms

Table 3.1 contains complete details of nutrient deficiency symptoms in citrus.

Nutrient Element	***First Plant Part to Display Symptoms***	***Mild Expression***	***Severe Expression***
Nitrogen (N)	Old leaves	Yellowing of all the old leaves, to a light yellow colour.	Yellowing of all leaves just before or during a new leaf flush which will result 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 incidence of creasing, which is a physiological disorder. This has however not been confirmed yet.	Chlorosis (yellowing) of very young leaves and dieback of growth tips.

Nutrient Element	***First Plant Part to Display Symptoms***	***Mild Expression***	***Severe Expression***
Magnesium (Mg)	Old leaves	Chlorosis of the front part of the leaf from the tip and sides of the leaf. An inverted green V with the open end of the V at the petiole side appears as the symptom develops.	Leaf drop and decrease in fruit set.
Sulphur (S)	New leaves	Yellowing to the colour of butter of emerging leaves on a green twig.	Extremely reduced fruit set.
Copper (Cu)	New leaves	Extra large leaves on strong new growth.	Gum pockets in the albedo (white part of the peel) of the fruit. Fruit is small, thin skinned and hard.
Iron (Fe)	New leaves	Yellowing of the lamina (leaf blade) of young leaves leaving a well defined network of small veins.	Reduced fruit set.
Manganese (Mn)	New leaves	Inter-veinal yellowing of a normal-sized leaf, almost over the entire leaf. Broad green areas around the veins and chlorotic areas between veins are the most obvious symptoms.	Increase in the number of leaves affected.
Zinc (Zn)	New leaves	Interveinal yellowing of a small-sized leaf, starting at the tip of the leaf. Resembles manganese deficiency, but appears on small leaves and the chlorosis starts at the tip of the leaf.	Increase in the number of leaves affected and reduction in fruit size.
Boron (B)	New leaves	Corking of the midrib vein on the underside of the leaves. This resembles the symptoms of cold damage on leaves.	Gum pockets around the centre of the fruit. Fruit size is reduced.

Table 3.1: Nutrient Deficiency Symptoms in Citrus

3. Recommendations for Rectifying Deficiencies

As stated previously, deficiency symptoms should never be the basis for formulating fertilisation programs. Having a reactive policy to deficiency symptoms exposes the plants for at least six weeks to insufficient nutrient supply. In a commercial citrus production unit, this can be catastrophic.

The symptoms described above should be used in conjunction with the leaf and soil analyses and should form part of the process that culminates in the formulation of a fertilisation management plan.

3.1. Nitrogen

Nitrogen is supplemented by soil applications and / or foliar sprays depending on the time of the year and severity of the deficiency.

When a hidden nitrogen deficiency is detected in an orchard, it should be reported and rectified as part of the overall nitrogen application schedule. Nitrogen cannot be applied to citrus at any time during the year. Applying nitrogen at a time too close to harvesting will have an adverse effect on fruit colour development. All corrections should therefore be made during the timeframe for nitrogen applications.

If a serious deficiency is detected during January to June, one must consider the affects on the current and next crop before deciding on a nitrogen application.

3.2. Magnesium

Magnesium is supplemented by soil applications and/or foliar sprays depending on the time of the year and severity of the deficiency.

A magnesium deficiency can be corrected at any time of the year, as long as the correct carrier is used. Do not apply magnesium nitrate during August to 100% blossom or during March to June. Other sources of magnesium have fewer constrictions unless they contain plant available nitrogen.

3.3. Copper

Copper is applied as a foliar spray. When applied to small fruit, the sap from damaged cells react, causing a darker blemish. This accentuated blemish grows with the fruit and such fruit cannot be exported and are culled at picking. Copper products, especially copper suspensions, should therefore not be applied on trees carrying small and green fruit.

3.4. Iron

Iron deficiency is best rectified by an application of an appropriate chelate to the soil, preferably during August. Iron chelates are expensive and an application is only economically justifiable when more than 20% of the canopy shows iron deficiency symptoms. Where drip irrigation systems are used, much less chelate is applied and the cost can be justified even as a maintenance application.

Chelate

A chelate is a chemical compound in which metallic and organic atoms are combined.

When the irrigation water or nutrient solution is not acidified, use a chelate that is stable in an alkaline environment. On alkaline soils, the preferred chelate is EDDHA (ethylene di-amine, di-hydroxy tetra acetic acid), which is applied at a rate of 30g per m^2 at not more than 300g per tree.

4. Soil and Leaf Samples

Although soil samples can be taken at any time, except after an application of fertilisers, it has little value in diagnosing or confirming a nutrient deficiency symptom. In commercial citrus production, fertilisers are applied from July to December and, in certain cases, even as late as February. Soil sampling is therefore only reliable between February and June, which is the time to take soil samples to formulate the fertilisation program for the coming season.

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.

Norms to evaluate the results of leaf analyses are developed for a specific leaf type, at a specific position on the plant, taken at a specific physiological stage. This is called the diagnostic leaf. Deficiency symptoms seldom develop on this kind of leaf. Deficiency symptoms mostly develop on young or old leaves and reference norms are usually not available for the symptomatic leaves. Leaf analyses therefore sometimes fail to detect the deficiency and taking leaf samples have limited value. Other factors such as total biomass produced can complicate the interpretation of the results.

Chapter 3

- 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.

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

Chapter 4

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

Manage soil improvement according to soil properties

1. Appropriate Soil Preparation Methods

Preparation methods for soils are dictated by the profile properties, being stratification, texture, pH and salinity. Before soil preparation can be done effectively, a soil survey or at least field inspection of previously surveyed soil areas is therefore required. The basic soil preparation methods that are employed are:

- Loosening
- Mixing
- Ridging

At the time when flood or basin irrigation was still used extensively, levelling and / or contouring of the soil were required. With micro-irrigation systems, these methods are no longer required.

1.1. Loosening the Soil Profile

The principle of this method is to loosen the soil without changing the downward sequence, or layering. When the soil profile is not stratified, or no lime, gypsum and phosphate are required, the profile requires only to be loosened to reduce the soil strength in the top 40cm to 60cm.

Loosening involves the lifting of the soil by an implement and letting it down without any mixing, in an up-and-down motion, for which a ripper implement is used. For this reason, loosening is sometimes referred to as **ripping**.

The best loosening is achieved by ripping the soil in two directions, of which the deepest is down-slope. The angle between the two directions should be 60°. To improve the lifting action, wings are attached to the ripper tine at an angle of 30° with the horizontal at operating depth.

This preparation method is also suitable for soils with clayey, acid, saline or carbonate-rich subsoil. Under these conditions, the subsoil must never be brought to the surface.

1.2. Mixing the Soil Profile

This method is used to prepare soils that require mixing to eliminate stratification or when it is necessary to mix lime, gypsum, phosphates or other fertilisers into the would-be root-zone. The most common implements used for mixing are mould board or shear ploughs. Mixing usually follows loosening of the soil by ripper ploughs.

1.3. Ridging

When the depth of suitable soil is limited, the soil from the inter-row spaces can be moved to the area where the trees will be planted, thus excavating the vehicle paths and filling the planting area with more suitable soil. This creates ridges of suitable soil. The purpose and advantages of ridging are:

- Improvement in surface drainage
- Increase in soil temperature

- Increase in the depth of suitable soil
- Savings in fertiliser and energy cost
- Facilitation of the mixing of fertilisers
- Control of vehicle movement in the orchard, as ridges clearly indicate the inter-row paths and re-compaction of the soil is limited

Note that the spacing between rows of trees, called the inter-row spacing, varies from 5m to 7m in citrus orchards. The space required for spray machines and other orchard vehicles is 2.5 metres.

Before ridging, the required lime, gypsum or phosphates are mixed with the top 20cm to 30cm layer of soil. The ridges are then built with soil containing the right amounts of nutrients. The mixing process is more effective and cheaper when this method is used, while also saving on fertiliser cost.

The height of the ridge is determined by the thickness of the suitable layer of soil. If this layer is less than 20cm thick, ridging will not improve the potential of the soil sufficiently, although it also depends on the layer below this suitable layer. The disadvantages of ridging are:

- Higher soil temperature, which can be up to 5°C higher compared to a flat soil surface
- Increased evaporation of water
- Limitation in irrigation design, as only drip and micro-jets can be used
- The undulating surface which makes picking more difficult

2. Appropriate Soil Maintenance Methods

Maintenance of the soil after establishing the orchard involves:

- Protecting the surface against erosion
- Minimising compaction
- Guarding against salinisation
- Limiting acidification

2.1. Protection Against Erosion

The best method to protect the orchard-floor against erosion is to use a natural grass cover.

The orchard floor should not be kept completely free of weeds. The area underneath and between the trees should be weed-free, forming a strip one metre wider than the diameter of the tree canopies. On the rest of the orchard-floor, including the paths between the rows, a natural grass cover must be established as quickly as possible. This is not always possible in low rainfall areas because the paths between the rows are not irrigated.

The width of the grass-strip will decrease as the trees grow and must never reach underneath the canopy. The grass must be mowed frequently and the cuttings blown underneath the canopy. These strips of grass also harbour beneficial insects and play an important role in pest control.

2.2. Minimising Compaction

Compaction of the soil after soil preparation is inevitable, but must be minimised as much as possible. Orchard practises that accelerate compaction are vehicle traffic, while high precipitation rates and salinisation also play a major role.

Vehicle traffic has the most severe impact. All vehicles should be restricted to the 2.5m middle-section in the inter-row paths and must never drive closer to the trees than that.

When water is applied at a rate exceeding the infiltration rate of the soil, the soil particles floats and, on drying out, will settle in a more compacted state. This reduces the infiltration rate even more, with the consequences of more surface compaction. This is also referred to as crusting.

Salinity, and especially an increase in the sodium adsorption ratio (SAR) of the soil, accelerates crusting. Soil analyses will help detect the development of crusting, but the first symptom is runoff halfway through the irrigation cycle.

2.3. Guarding Against Salinisation

Apart from crusting, which is the first symptom of salinisation, accumulation of sodium or reduction of calcium deeper in the profile should be monitored continuously. For this purpose, regular soil analyses are required. Although the ratio of the cations is a good indicator of developing salinity, the subsoil should also be sampled from time to time. The intervals will be determined by the conditions prior to planting when the profile was analysed.

As indicators of developing salinity, the calcium to total cation ratio should be 70% to 75% and the sodium <3.00%.

2.4. Limiting Acidification

Acidification is more active in the sub- than the topsoil. Subsoil sampling is therefore more important to monitor the pH.

The ammonium form of nitrogen is the cheapest nitrogen source but also one of the greatest sources of acidification. Even in fertilisers like LAN, acidification can be a potential hazard for subsoil pH levels. Liming the subsoil alone is not possible and the pH of the sub-soils must be monitored annually. The frequency of sampling can only be determined by historic data.

3. Recordkeeping

During a soil survey, many soil properties are evaluated, analysed, described and recorded. Many of these properties are stable and will not change. These records are therefore valuable for replanting and for future developments, and should not have to be redone. The stable properties include:

- Slope
- Aspect
- Soil depth
- Clay content
- Structure
- Water-holding capacity
- Cation exchange capacity

The variable properties of soil are:

- pH
- Nutrient content
- Resistance

It is in this regard that soil and leaf analyses, especially historical data from routine leaf and soil analyses, have its value. This data indicates the direction in which the nutritional status of the soil and trees are moving. Records of the variable data should be kept in an easily accessible format for at least three years.

The format may vary, but should enable the reader to compare year-on-year figures with ease.

Example

Historical Data on Nutritional Status

NUTRITIONAL STATUS REPORT					
Orchard:	Orchard 10		**Cultivar:**	Delta Valencias	
Element	***2002***	***2003***	***2004***	***2005***	***2006***
N	2.11	2.45	2.50	2.01	1.87
P	0.11	0.14	0.11	0.12	0.10
K	1.56	1.32	1.09	0.94	0.88
Ca	3.65	3.62	4.06	4.11	3.83
Mg	0.31	0.37	0.41	0.38	0.37
S	0.22	0.19	0.25	0.27	0.23
Cl	0.04	0.01	0.19	0.33	0.47
Na	21	39	117	582	498
Cu	7	21	18	54	21
Fe	74	118	131	163	211
Mn	132	85	46	40	28
Zn	36	29	54	21	14
B	85	107	152	162	228
Mo	1.34	0.42	0.78	0.31	0.55

From the historic data a number of valuable tendencies can be identified, namely:

- The sharp drop in the N status for two consecutive seasons indicates possible problems with root-health.
- The potassium level is decreasing and requires serious attention. There is a danger that the level may drop to the point where fruit-size will be negatively affected.
- Chloride and sodium are accumulating in the soil-water-tree-system and could be indicative of salinity.
- The decrease in the manganese content points to increasing alkaline conditions in which manganese is less available.
- The increase in iron and boron concentration confirms to some extent the increase in salinity.

Summary

Chapter 4

- 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.

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

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