FACILITATOR GUIDE

Plant Propagation

Level 3

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Title:		**Explain the Propagation of Plants**					
Applied Title:		**Explain the Propagation of Citrus Plants**					
Field:		Agriculture and Nature Conservation					
Sub-Field:		Primary Agriculture					
SETA (SGB):		AgriSETA					
Skills Area:		Propagation					
Context:		Citrus Production					
US No:	116220	**Level:**	3	**Credits:**	4	**Notional Hours:**	40
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Directions

1. Learning Material

This guide has developed to assist the facilitator in presenting this unit standard. The guide contains all necessary material to ensure that the facilitator will be able to assist the learner to attain the competencies required by the unit standard.

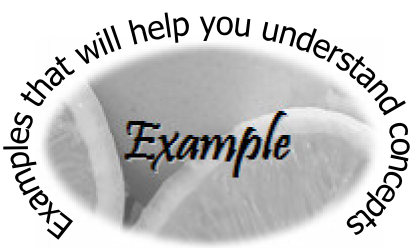
This set of learning material consists of the following guides:

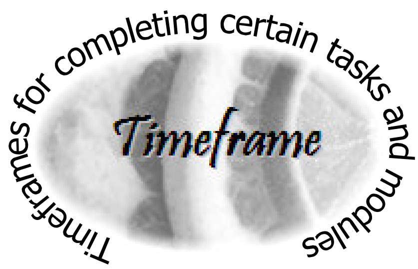
- ***Learner guide*** that contains all the information required by the learner to attain competency in this unit standard
- ***Facilitator guide*** that is a copy of the learner guide but contains additional instructions for the facilitator.
- ***Assessment Guide for Assessors and Facilitators*** that contains all the documentation needed by the assessor and facilitator to assess the competency of the learner against this unit standard.
- ***Assessment Guide for Learner and Learner Workbook*** that contains the documentation required by the learner to complete the assessment, along with the worksheets and practical exercises that the learner needs to complete as part of the formative assessment.

Please ensure that you are familiar with the contents of all of these guides before presenting this unit standard.

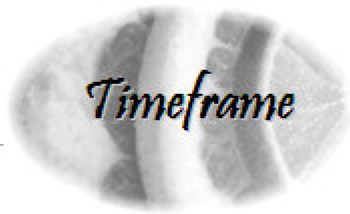
Although the learner and facilitator guide contains all the information required for attaining competency in this unit standard, references to additional resources (both printed and electronic) are provided for further study by the learner.

Information in boxes is indicated by tags that show:





2. Learning Program Timeframe



This is a summary of the timeframe for this learning program. You will be reminded of the time allowed for each module as you work through the guide.

Process	***Total Allocated Time***	***Theoretical Learning***	***Practical Learning***	***Activities***
Complete Program (Including summative assessment)	**40h**	**22h 15min**	**17h 45min**	**7**
Learner Orientation and Ice Breaker	30min	15min	15min	n/a
Purpose, Introduction and Learner Directions	30min	15min	15min	n/a
Revision of Level 2	1h	45min	15min	n/a
Session 1 (Chapter 1)	8h 15min	5h	3h 15min activities	1-2
Session 2 (Chapter 2)	8h	5h	3h activities	3
Session 3 (Chapter 3)	8h	5h	3h activities	4-5
Session 4 (Chapter 4)	7h 45min	5h	2h 45min activities	6-7
Preparation for Assessment and Revision	6h	1h	5h observing or working in a citrus nursery	n/a

3. Technical Program Specifications

Format	Programmed instruction workshop, combined with structured internship format as prescribed for learnership, skills program or short course.
Target Learner Description	A typical level 3 learner would have been exposed to the working world for some time as a team member, and would now be ready to emerge as a team leader or supervisor. **EE Ratios:** 1 Male:1 Female 8 PDI:2 W 1 Employed:1 Unemployed
Articulation Options	Nil formal in place
Delivery Mode	A combination of small group mode and individual mode

Training Method and Activities	**Program Instruction:** This program forms part of an apprenticeship where coaches provide practical training in the fields requiring functional competency. The theoretical study section of the training is conducted as a 4-day workshop in the Cohort group format. Additional training activities include buzz groups, rotating role-plays, simulations, games and brainstorming sessions, and group discussions.
Learner Support Strategies	Learners are inducted by "explore strategies to learn program". Learners are supplied with all resources and aids as required by the program, including: • Objects and devices such as equipment • Manuals and guides • Visual aids

Facilitator Tip

This unit standard is aimed at level 3 learners.

- A typical level 3 learner would have been exposed to the working world for some time as a team member, and would now be ready to emerge as a team leader or supervisor.
- Explain concepts and define words in a simple, clear and concise method throughout the learning program to help the learner where possible.
- Ensure that you spend extra time on concepts surrounding leadership, presentation skills, responsibility and accountability, as well as critical problem solving skills.
- Take special care to facilitate for ALL learners. Allow them opportunities to share experiences and prior knowledge, to translate into their mother tongue for each other, and to enjoy the learning process.
- The examples given in this resource guide might be for a different geographical area or commodity to what the learner is exposed to. Please adapt your examples according to the learning context.

4. Facilitator's Checklist

Facilitator Tip

This checklist has been designed to assist you in delivering the best possible facilitation to the learners. Please use it and supply whatever resources you might have in short supply at your venue of learning.

Preparation	***Yes***	***No***
Content Knowledge I have sufficient knowledge of the content to enable me to facilitate with ease.		
Application Knowledge I understand the program matrix and have prepared for program delivery accordingly.		
Ability to Respond to Learners Background and Experience I have studied the learner demographics, age group, experience and circumstances, and prepared for program delivery accordingly.		

Preparation	***Yes***	***No***
Enthusiasm and Commitment I am passionate about my subject and have prepared my program delivery to create a motivating environment with real commitment to success.		
Enterprise Knowledge I know and understand the values, ethics, vision and mission of the Citrus Academy and the service provider under whose auspices the program will be conducted, and have prepared my program delivery, reporting and administrative tasks accordingly.		
Equipment Checklist:		
Learner Guides: 1 per learner		
Learner Assessment Guides: 1 per learner		
Writing material and stationery for facilitator and learner		
White board and pens		
Flip chart paper		
Proxima projector and screen		
Notebook computer and program disk		
Documentation Checklist:		
Attendance register		
Course evaluation		
Learner course evaluation		
Portfolios of evidence		

5. Proposed Floor Plan

No floor plan is prescribed for this training module.

Introduction

1. Purpose

The learner achieving this unit standard will be able to propagate plants.

Learners will gain specific knowledge and skills in plant propagation 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***
NQF2	Literacy and Numeracy	
2	116119	Demonstrate an understanding of plant propagation
2	116077	Monitor water quality
3	116272	Demonstrate a basic understanding of the physiological functioning of the anatomical structures of the plant

Facilitator Tip

It is important to ensure that the learners who are undertaking this learning program has already completed the correct prior learning modules, to ensure that they are not unfairly disadvantaged by the learning process, and can be supported accordingly.

Do not forget to complete the Diagnostic Assessment (Step 3 in the Assessment Guide).

Revision of Level 2

Timeframe

You have to complete this section as follows:

Total time	Theory	Practical
1h	45min	15min

Facilitator Tip

Utilise this opportunity to determine the knowledge levels of the learners and to identify learners who might not have the required level of knowledge. This will assist you in identifying areas in the learning program where additional time will have to be spent. Encourage participation from learners and remind them to share their knowledge and experience with the rest of the group.

1. Environmental Requirements

- Propagation means the multiplication of plants of a specific type.
- Environmental conditions that must be controlled during plant propagation are humidity, aeration, light quality and quantity, temperature and moisture.
- Humidity is important for a plant to carry on metabolic processes at desired rates.
- Plants require an environment with sufficient oxygen and carbon dioxide for respiration and photosynthesis, respectively, to take place. Tunnels in which plants are propagated are ventilated.
- All plants require light for photosynthesis. Red light is used to stimulate seed germination.
- The temperature during germination must ideally be maintained at 29°C to optimise growth and prevent heat injury.
- A uniform and constant supply of good quality water is required for the propagation of healthy plants. Over-irrigating seedlings is as dangerous as under-irrigating.

2. Propagation Methods and Tools

- Plants can propagate through sexual (seeds) and asexual (vegetative using plant parts) means.
- In citrus, seed propagation and vegetative propagation is used together to produce new plants.
- Seed propagation is used to produce seedlings that are used as rootstock.
- Vegetative propagation is used to graft a bud of the fruit cultivar onto the rootstock seedling, referred to as budding.

- Budding is a form of grafting, which is a form of vegetative propagation.
- Seeds from specific cultivars with desired qualities are used for producing rootstocks.
- Seeds can be bought from certified sources, or extracted from the fruit of rootstock trees that have been established for this purpose.
- Seeds are propagated in sand seedbeds in the open, or in seed trays in germination rooms.
- Budding is done when the bark of the rootstock seedling is "slipping" by making an inverted T-cut on the stem of the seedling, cutting a bud piece from the bud-wood, inserting the bud piece into the T-cut, and wrapping the join with clear tape.
- After about two weeks the wrapping is removed, and if the union was successful, growth energy is directed to the bud by looping or topping the rootstock seedling.
- Plants are staked for support and directed growth.
- Propagating plants through cuttings involves treating the lower tip of a twig of a plant with growth hormones, planting it in a growth medium and allowing it to form roots.
- Tissue culture propagation in citrus involves growing plants from a micro-portion of plant material in-vitro in a laboratory.
- Propagation tools that are commonly used are budding knives, budding tape, pruning shears, a sharpening stone and sterilisation liquid.
- Propagation tools must be sterilised to prevent the development of pathogens.

3. Successful and Unsuccessful Propagation

- Indicators of successful propagation are trueness-to-type, freedom from pathogens and pests, and the health of the plant.
- Indicators of unsuccessful propagation are deviations from type, diseased plants, mixed cultivars and inferior plant quality.
- Environmental conditions must be maintained to ensure successful propagation.

Propagation

Propagation in citrus production refers to the multiplication of plant material that is of a specific cultivar and variety, and that possesses more desirable characteristics, such as yield, fruit size and shape and internal quality.

Dormancy

Dormancy refers to the ability of certain plant-parts, such as seeds, to suspend metabolic processes until ideal environmental conditions occur.

Metabolic Processes

Metabolic processes refer to organic chemical processes inside a cell that enable life.

Humidity Humidity, also referred to as *relative humidity*, is the amount of water vapour in the air at a given temperature, and is expressed as a percentage. This means that at 20% relative humidity, 20% of any given volume of air will consist of suspended water molecules.
Respiration Respiration refers to the process during which the plant takes up oxygen (O_2) and releases carbon dioxide (CO_2).
Photosynthesis Photosynthesis refers to the chemical reaction that takes place when the plant takes up CO_2, which combines with water molecules in the plant to produce carbohydrates, which is food for the plant. O_2 is released during this process.
Ovule The ovule is a small structure inside the ovary of a seed plant that contains the female reproductive cells inside the embryo sac, and which develops into a seed after fertilisation.
Embryo The embryo is a plant in its earliest stage of development before an organism becomes self-supporting. Once the embryo begins to grow out from the seed, or germinate, it is called a seedling.
Meiosis Meiosis is a type of cell division in organisms that reproduce sexually and results in cells with half the number of chromosomes of the original cell.
Rootstock Rootstock means the root or part of a root used for plant propagation. In reference to grafting, the rootstock is that part of a grafted plant that supplies the aboveground plant parts.
Grafting Grafting refers to any process of inserting a part of one plant into or onto another plant in such a way that they will unite and grow as a single unit.
Apical Dominance Apical dominance refers to powerful tip growth that suppresses the growth of lateral buds.

Chapter 1

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

Demonstrate an understanding of the function of environmental requirements for propagation within a specific agricultural production context

Timeframe

You have to complete this section as follows:

Total time	***Theory***	***Practical***
8h 15min	5h	3h 15min activities

1. Introduction

Facilitator Tip

Start this session by leading a group discussion in which you pose the question: "What does a citrus plant need to grow?" Elaborate on how one would supply a citrus plant with these requirements in an environment such as a propagation nursery.

Controlling the environmental factors to imitate nature to a certain extent during propagation is essential for a successful outcome. In nature, plants develop slowly to reach maturity. Citrus propagation aims at emulating the natural process and enhancing it.

This requires an understanding of the natural environment in which citrus plants develop and an understanding of variations of these conditions. It is also necessary to have a thorough understanding of the metabolic processes of plants because environmental conditions determine how successfully plants are able to complete these processes.

2. Metabolic Plant Processes

Facilitator Tip

Revise the term "metabolism" with the learners, referring back to the requirements of the plant as discussed at the beginning of this session. Be alert to learners that do not understand the processes of photosynthesis and respiration. Do not overcomplicate explanations with too many technical terms. Compare respiration for instance with breathing in animals, asking where the "lungs" of the plant would be. This should keep the learners alert and encourage lateral thinking.

Plant growth is a result of a series of biochemical reactions that take place in the plant. It is essential to understand the principles of two of these processes, namely photosynthesis and transpiration, to better understand the influence of environmental conditions on propagation.

2.1. Photosynthesis

At germination, red light triggers the emergence of the radicle, or root, which in turn initiates the elongation of the hypocotyls (stem) and the development of leaves. After leaves emerge, chlorophyll and other compounds are synthesised through absorbed energy. Chlorophyll is the main pigment responsible for photosynthesis. Photosynthesis occurs throughout the lifespan of the plant, and is the initial step of growth after seed germination.

The formula below summarises the process of photosynthesis:

$$6CO_2 + 12H_2O \xrightarrow{\text{Light Energy}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

During photosynthesis, the plant absorbs CO_2 through the leaves and green cells, and water through the roots. With the heat generated in the plant through light and plant molecule movements, the plant manufactures sugars (carbohydrates), oxygen, and water molecules. Kinetic energy is released and used to activate particles in the plant.

2.2. Respiration

The reverse reaction of photosynthesis is referred to as respiration, where oxygen (O_2) from the air is used and carbohydrates in the plant are broken down into carbon dioxide (CO_2), which is released in the air. Water molecules are diffused from the leaf surface into the surrounding air. The diffusion of water molecules, in the form of water vapour, is the core of the transpiration process.

Transpiration is driven by light intensity, water vapour in the air, and the moisture level in the growth medium or soil. In the plant, transpiration is expressed through turgid cells, opened stomata, which are small openings on the surface of the leaf, and CO_2 diffusion into leaves. The rate of transpiration is closely related to the amount of water vapour in the surrounding air and the amount of water vapour diffused to the surface of the leaf.

When the moisture in the surrounding air increases, plant transpiration decreases. Conversely, when the moisture in the surrounding air decreases, the transpiration rate increases. In other words, the transpiration rate increases in dry air environments, and decreases in moist air environments. The quantity of moisture that is contained in the surrounding air is influenced by the ambient temperature. Warm air contains more water vapour than cold air.

Light intensity influences transpiration through leaf surface temperature. Higher leaf surface temperatures result in an increased transpiration rate. At temperatures above 30°C however, the stomata on the leaves of citrus plants begin to close, and the rate of photosynthesis and transpiration decreases.

The water available to the roots of the plant also influences the rate of transpiration. Less water results in stunted growth with short internodes and small leaves, resulting in a reduced surface area for photosynthesis and transpiration. As the rate of water absorption decreases, the plant struggles to find the necessary moisture to support metabolic processes. Transpiration uses the little water available, resulting in the wilting of the plant. At extreme wilting point, no food (energy) is manufactured as there is virtually no photosynthesis taking place, and the plant is forced to use up all its reserves to survive.

At the other extreme, excess water results in increased cell-size and a normal transpiration rate occurs initially. However, under anaerobic conditions, being conditions where the roots are drenched in water, the plant is starved of oxygen and suffocates it in the process. Such conditions are also conducive to the development and spread of pathogens like rhizotocnia (damping off) and phytophthora (root rot).

3. Environmental Factors for Propagation

Facilitator Tip

Take sufficient time to work through all the factors required for successful propagation. Constantly remind learners of the consequences if any of these requirements are not met. Use examples of comparing the needs of humans to the needs of plants, for example "What happens if you don't eat?" and "What happens if the plant doesn't receive nutrients?", "What happens if you don't drink water" and "What happens to plants if they never receive water?". Also constantly remind learners of how these requirements are met in a propagation environment.

If time permits, visit a nursery and show the control and supply of these factors.

The environmental conditions that need to be controlled for plants to grow successfully are categorised in three classes, being:

- ***Atmospheric conditions***, including light, water, humidity, temperature, and gas exchange
- ***Biotic conditions*** refer to conditions in the root-zone with regard to bacteria, fungi an viruses, to insects, and to weeds.
- ***Edaphic conditions***, including physical soil properties (texture, porosity, temperature) and chemical soil properties (pH, mineral nutrients, gas exchange), and container properties

Citrus plants respond to the environmental conditions through growth rate. Where factors are well managed, better growth is achieved, while retarded growth and even loss of plants may result from an environment that is not well managed.

Every environmental factor plays a specific role, both on its own and in interaction with other factors. In this section, each factor is discussed with the assumption that all other factors are favourable.

3.1. Atmospheric Conditions

Citrus is a sub-tropical species, and its propagation is more successful in a climatic environment that resembles the sub-tropics more closely.

The time of the day and season of the year are factors the propagator has to consider when planning to propagate citrus. For instance, the best time for budding is when the temperature is between 25°C and 30°C, and when the process of photosynthesis is active with opened stomata, turgid cells, abundant sugars for growth, and CO_2 diffusion is increasing.

3.1.1. Light

Light manipulation is a very important factor in propagating citrus. Seed germination is activated with increased light intensity. The bud-take rate is influenced by the sap flow, and rates of transpiration and photosynthesis in the plant, which in turn is influenced by light intensity.

Two light sources are used, being the sun (solar radiation) and artificial lights. Understanding solar radiation is important before planning any manipulations. Intensity alone is not sufficient if the quality of the light is not also considered.

The sun radiates up to 10,000 lux of light on a clear, sunny day and about 3,200 lux on an overcast day. A fluorescent light discharges 1,400 lux. In nature, light intensity decreases with the presence of clouds or dust in the atmosphere. Propagation structures that draw light primarily from the sun experience the same fluctuations in intensity. Fluctuations in intensity trigger different responses from the plant in terms of its growth rate. High light intensity causes more chlorophyll to be synthesised and a greater gross rate of photosynthesis.

Light quality refers to wavelength, measured in nanometres (nm), and is associated with the colour of the light as perceived by the human eye. Light is classified in eight bands, ranging from ultraviolet (<280 nanometres) to near infrared (>1,000 nanometres) and includes the visible range, being violet, blue, green, yellow, orange, and red light. Fluorescent plant lights used in germination rooms are rich in red light (610-700 nanometres) and deficient in the far red (700-730 nm). Enzymes and proteins are activated when subjected to light and initiate radicle emergence and elongation, and ultimately seedling growth.

Beyond the germination room, solar radiation is the main source of light, with quality closer to 700nm where CO_2 absorption is at its optimum. At this spectrum, coupled with higher light absorption rates, light indirectly affects the rate of transpiration as enzymes are denatured at higher leaf-surface temperatures. The accumulation of starch – which absorbs less water than sugar – in the leaf cells results in stomata closing and a reduced transpiration rate.

A lower light absorption rate adversely influences the transpiration rate. In this case, sugars are not transformed to starch, but maintain turgid leaves for a longer time leading to a reduced starch level in the plant. With starch being the form of carbohydrate that is used in respiration, this results in a reduced photosynthesis rate.

3.1.2. <u>Humidity</u>

Relative humidity, or the water vapour level in the ambient air, regulates the gross transpiration rate of plants. The level of humidity, or relative humidity (rh), is generally below 80% in the sub-tropics where citrus originates from. Ideal conditions for propagation requires a high rh, being between 80% and 95% and occasionally reaching 100%.

In an environment where the water vapour level is high, it takes longer for the water molecules on the leaf surface to evaporate, meaning the exchange factor is lower. Where relative humidity is low, the transpiration rate increases.

These fundamentals are important for the manipulation of rh in the propagation environment. Seed germination requires high humidity around the seed, where respiration is normal, allowing the seed to absorb more water molecules, which in turn hydrolyses insoluble foods to soluble forms. As respiration increases the radicle emerges and elongates, but if it decreases the storage life of the seed is longer, meaning that the hydrolysis of stored foods does not take place, and thus no germination takes place.

Seedling growth and development also depends on the transpiration rate because this directly relates to photosynthesis. Plants require an environment where the processes of transpiration, respiration and photosynthesis can take place at normal rates. In such an environment, CO_2 is rapidly diffused into leaves and transformed in carbohydrates that are used for growth. The same applies to budded seedlings.

For cuttings, high humidity ensures that leaves do not lose their turgidity, and that they continue with photosynthesis and respiration while roots are developing. A more detailed process will be discussed in propagation structures.

The figure below shows the variations in humidity relative to the time of day and the temperature.

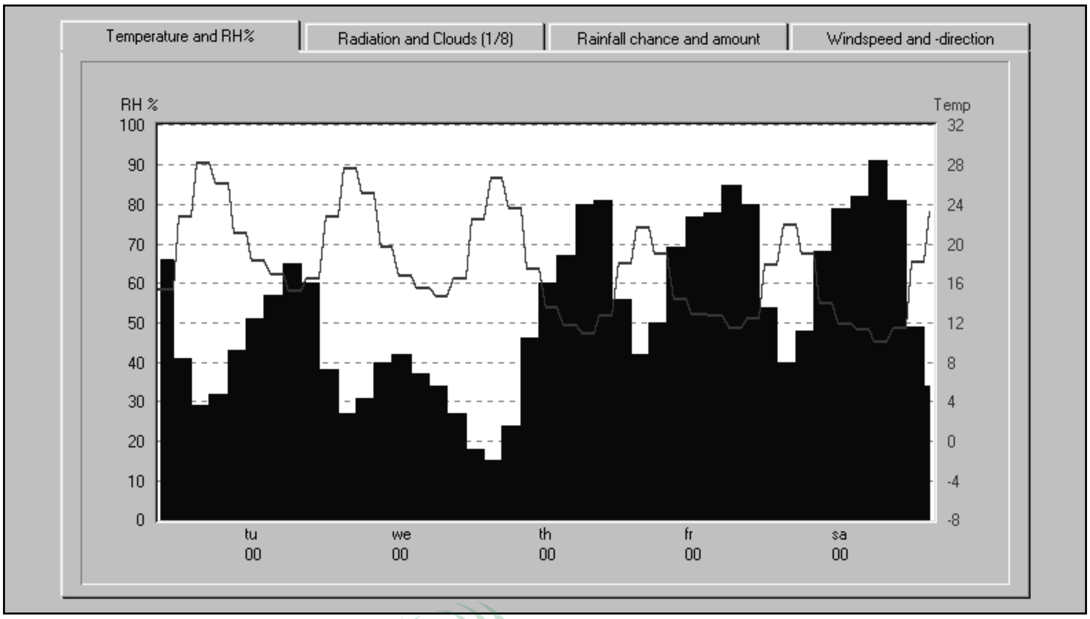


Figure 1.1: Letsitele Weather Records – Week 28/11/2004
(Courtesy of Du Roi QMS)

3.1.3. Temperature

From seed germination to the healing of the bud union, temperature plays a major role in propagation of citrus plants. Germination requires relatively high temperatures, with a range of between 27°C and 32°C, with an average of 29°C being considered optimal.

Within this range, the propagator has to identify the temperature at which the processes of photosynthesis and respiration are optimal. This point, identified as 29°C in general, makes large quantities of carbohydrates (sugars) available for plant growth and development. Cell division and elongation is at an optimum and vigorous growth is expressed through large and healthy leaves, thicker stems, and denser, healthy roots.

Higher temperatures, in the region of 35°C or more, reduce the rate of photosynthesis, exhausting stored reserves of carbohydrates. The increase in temperature also alters molecular structures of enzymes and proteins.

If the temperature falls below 12°C, growth is affected because the physical properties of water in the plant are altered, becoming less fluid and reducing the rate of molecular movement in the plant. This translates to a reduced rate of compound translocation and catalytic reactions which can lead to plant death.

Extended exposure to temperatures below 10°C causes cold injuries to plants, mainly to new shoots. This is the reason why citrus cannot be propagated without costly protective measures in areas where frost occurs.

3.1.4. Water

The management of water supply is very important. Water plays a role in keeping the plant cells turgid, as a catalyst in biochemical reactions in the plant, and in the translocation of manufactured compounds.

Water is the major regulator of growth. It is taken up through the roots and is used in the metabolic processes, including transpiration and photosynthesis. During transpiration the plant loses water and cells lose their turgidity, and the lost water has to be replenished.

Mineral nutrients are commonly supplied to plants through water, either by using water as the channel of application (fertigation) or by the water dissolving the fertilisers progressively when manual soil applications are used.

The movement of nutrients is governed by the principles of osmosis and mass diffusion. Salts move from areas with higher concentrations to areas with low concentrations (osmosis) or are simply taken up as part of the water compounds that get absorbed (mass diffusion).

Osmosis

Osmosis is the flow of water and other liquids through a semi-permeable membrane, such as the thin membrane underneath the shell of an egg, from an area with a low concentration of dissolved matter, such as salts, to an area with a high concentration of dissolved matter, so that the concentration imbalance is gradually evened out.

Diffusion

Diffusion is the spontaneous spreading of something such as particles, heat, or momentum. The phenomenon is readily observed when a drop of coloured water is added to clear water, or when smoke from a chimney dissipates into the air. In these cases, diffusion is the result of turbulent fluid motion rather than chemical reactions or the application of external force. In cell biology, diffusion is described as a form of "passive transport", by which substances cross membranes.

Ultimately, the quality and quantity of water applied to citrus plants being propagated is crucial. As mentioned earlier, too little and too much water impacts on growth.

Water quality refers to the pH and salt concentration (electrical conductivity) levels in the water and how these affect plant metabolism.

The influence of pH must be considered in relation to nutrient availability and uptake, while the salt concentration relates to the abundance of nutrients in solution ready for absorption. A pH range between 5.8 and 6.2 is recommended for optimum interaction in the root-zone.

Salts have a corrosive effect on root growth, and exposure to higher concentrations of above 2.00mS/cm for more than seven days burns roots, and sensitive rootstock plants, such as Swingle Citrumelo, display necrotic leaves.

3.1.5. Aeration

Gaseous exchange, in both the leaf and root areas, ensures that growth and development take place normally. Oxygen availability in the root zone and its subsequent uptake rate is essentially the factor that governs root development and the ability of roots to perform their roles, being structural stability, feeding, and respiration. Healthier roots develop in a medium where the air-water balance is right.

Surface air movement directly influences the quantity of CO_2 available for uptake by the leaf area. Air movement, if not controlled, has a draining effect on the level of CO_2 available. This leads to a deficit, resulting in poor growth and development.

3.2. Biotic Conditions

Biotic conditions refer to the biological conditions in which plants are propagated, and specifically to:

- Bacteria, fungi and viruses in the rhizosphere
- Insects
- Weeds

3.2.1. Bacteria, Fungi and Viruses

Facilitator Tip

It is very important to emphasise the problems that can occur in the propagation environment if pathogens are present, and the repercussions it may have for the entire industry.

Definition

Rhizosphere

The rhizosphere, also referred to as the root-zone, is the soil zone that surrounds the roots of the plant. This zone influences the roots and is in turn influenced by the roots.

In the rhizosphere there can be positive interactions that boost root development or negative interactions that impede root development. The selection of seedlings as rootstocks depends on their ability to produce a strong and extensive root system, to anchor the plant, and to absorb nutrients.

In the rhizosphere micro-organisms such as microbes, fungi and bacteria, and even viruses are found. Some of these are considered beneficial as they create and promote a healthy environment for roots to develop in. This is achieved either by colonising areas that would have been occupied by pathogenic organisms, or by breaking down organic and mineral compounds found in the growth media into units that can be taken up easily by the plant roots.

Nitrobacteria are an example of bacteria that contributes to positive interaction. Nitrobacteria are involved in the breakdown of compounds such as ammonia – found in humus – to more usable forms of nitrogen such as ammonium and nitrates. In terms of propagation, the uptake and subsequent use of nitrogen is important for growth.

The biggest downside of using such organisms extensively is the time factor. Micro-organisms are governed by a population dynamic principle that is based on an increase in individuals as more food is made available. It takes a long time for populations to increase to critical levels and the propagator often does not have enough time on hand. In other instances, it may be necessary to add extra 'food' to avoid competition in the root-zone.

Other micro-organisms found in the rhizosphere are disease causing agents by virtue of their parasitic and pathogenic nature. Phytophtora species fall in this category. They grow on plant parts such as roots and cause diseases such as root rot and collar rot, destroying the plant in the process. Infected plants show yellowing of the veins of the leaves, with leaves turning yellow and dropping off under severe infections leading to the death of the plant. Severe infections lower the ability of the plant to undertake metabolic processes.

For successful propagation, the propagator has to aim for positive interaction by growing the seedlings in suitable media where root development is promoted. Growth media mixes range from inert, for example perlite, vermiculite, rock, stone, sand, to organic, which includes compost, peat, potting soil. The choice is made by the propagator in line with the economical and environmental factors.

It is crucial that citrus trees are propagated free from pathogens for the survival of the industry.

3.2.2. Insects

Facilitator Tip

Revise the concept of harmful versus beneficial insects and identify these organisms that will typically be found in a propagation environment.

Insects are categorised in two groups, being beneficial insects and non-beneficial insects, depending on the nature of their interaction with the plant.

Insects are considered as beneficial if they can live on the plant and in the micro-environment without causing any damage, but rather support and protect the plant. Non-beneficial insects feed on plant parts, destroying them in the process, or infect the plant with disease.

Non-beneficial insects that cause damage of economical proportion are considered pests. Included in this category are insects such as red mites, red scale, mealybugs, aphids, leafminer, and thrips.

In the nursery, with young trees that are very vulnerable and require the most out of metabolic processes, insects that reduce the plant's ability to produce and transform important compounds, such as carbohydrates and proteins, are considered pests. Damage mainly occurs with the destruction or distortion of the leaf structure. Red scale, red mites, thrips and mealybug all distort the leaf surface, rendering it less effective for photosynthesis. Orange dog, looper, and leafminer achieve the same by reducing the leaf surface area.

Beneficial insects include *Aphytis lingnanensis*, *Chilocorus nigritus*, and *Cryptolaemas montrouzieri*. Beneficial insects either feed on pest insects, in which case they are referred to as predators, or disturb their lifecycle through parasitic activities, such is the case with *Aphytis* which lays eggs in developing red scale. When the eggs hatch, the young insects feed on the host insect.

3.2.3. Weeds

Facilitator Tip

Remind learners of why plants would be classified as weeds, and that it does not only refer to classified weeds and invader plants, but to any unwanted plant interfering with the nutrient and water supply of the wanted plants.

Weeds have a negative impact on the growth of seedlings, because they compete with other plants for nutrients and water.

Because of the adaptability of weeds and their ability to survive under difficult conditions, weeds present a challenge that seedlings cannot meet. The environment in which seedlings are raised, being well-aerated, optimally irrigated, and enriched with nutrients, also presents ideal growing conditions for the much hardier weeds, allowing them to spread faster and colonise the medium, starving the seedlings from nutrients and water.

Weeds are also potential hosts to pest insects and must therefore be controlled not only inside the nursery, but also around it. An area of about six meters around the nursery should be cleared to assist in reducing the impact of insects on seedlings. This is not considered an effective pest control measure, but is rather a measure for good housekeeping.

3.3. Edaphic Conditions

Definition

Edaphic

The term edaphic means the effect of soil characteristics, especially chemical and physical properties, on plants and animals. For the purpose of this section, edaphic conditions refer to the properties of the growth medium, whether it is soil or another substance.

Not all plants are grown in soil, with some grown in soilless media, such as pine-bark which is commonly used for container grown seedlings in South Africa. In addition to pine-bark, there are other media that can be used in different combinations. One can consider using sawdust, peanut shell, river sand, composted organic material, and ash mixed in different proportions that allow optimum root development. However, it is crucial for the propagator to establish the chemical and physical properties of the growth medium and that the medium is free from harmful pathogens.

Should plant material be used as a medium for plant propagation, it has to be well composted to avoid competition from micro-organisms. Otherwise these micro-organisms use up nutrients, especially nitrogen, to continue with the composting process, which results in reduced availability of nutrients for plant growth. Beyond the competition, there are organic acids, also referred to as tannins, found in plant materials that have to be allowed time to get to an inactive stage.

The properties of the growth medium are important because they determine what can be grown in the medium, and they give an indication of the possible behaviour of the growth medium, and as a result the plant, under certain conditions relating to air, water and temperature.

3.3.1. Physical Growth Medium Properties

Facilitator Tip

Show as many physical examples of growth media as you can possibly obtain and discuss each medium's properties and why it would or would not be chosen for citrus propagation.

Generally, physical soil properties refer to the texture, structure, depth, stratification and aeration of the soil. In terms of propagation, physical growth medium properties refer to the texture, structure and aeration of the soil. Soil depth and stratification are controlled in the nursery environment.

Water and air are components of the growth medium that are kept in a specific balance to allow optimum plant growth. The balance comes into play in relation with the solid particles of the medium. In a container, the mix should have enough air to supply the roots, enough water for physiological and metabolic processes to take place, and solid particles to anchor the roots.

The texture and particle size of the medium greatly influence root development. Pine-bark presents a coarser texture with irregular surface and structure, which determines the direction in which the roots will grow and the ease with which they will spread into the container. Because of its coarseness, and other chemical properties that will be discussed later, pine-bark is known to be less effective in holding water for a long time, which has to be taken into account in irrigation management.

A complementary property in this regard is the size of particles making up the growth medium. A growth medium with small particles tends to compact easily, making the soil less permeable and therefore impeding the movement of roots and water. Growth medium with small particles could also have excessive water holding capacity, which has the potential to promote disease development, such as root rot, and starve the plants of air and nutrients.

Larger particles on the other hand have a reduced water holding capacity. The bigger the particles, the less water can be held for uptake by plants.

The ideal growth medium for citrus propagation has in the region of between 14% and 20% air-filled porosity, with a particle sizes ranging between 10mm (about 25% portion) and 14mm (about 30% portion) in the case of pine bark. Different propagators select different combinations that are more suited to their environment.

3.3.2. <u>Chemical Growth Medium Properties</u>

Chemical properties are defined as those characteristics of the growth medium that cannot be seen or felt, but that influence reactions that take place in it. These include the pH, salinity (expressed as electrical conductivity), and potential gas exchange reactions.

Reactions between certain minerals produce by-products that have a secondary impact on root development. Some of these by-products can accumulate causing high salinity, while others can lead to medium acidification or render the rhizosphere alkaline. Growth medium pH is essential since it affects the availability of nutrients for uptake by plant roots. Remember that a pH of 7 is neutral, while a lower value indicates acidity and a higher value alkalinity.

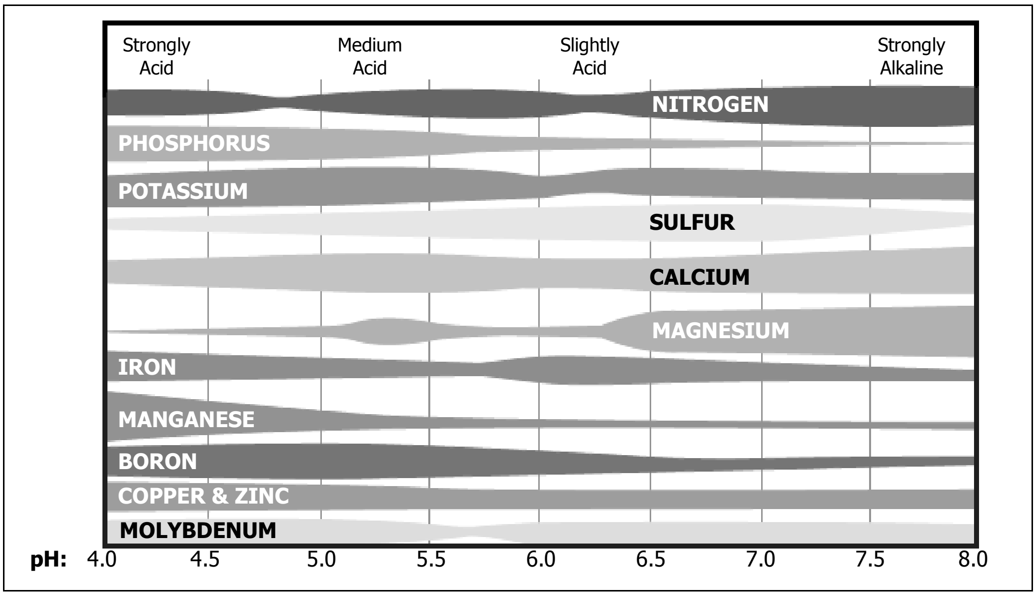


Figure 1.2: The Effect of Soilless Medium pH on Nutrient Uptake
(Courtesy of Ocean Agriculture (Pty) Ltd)

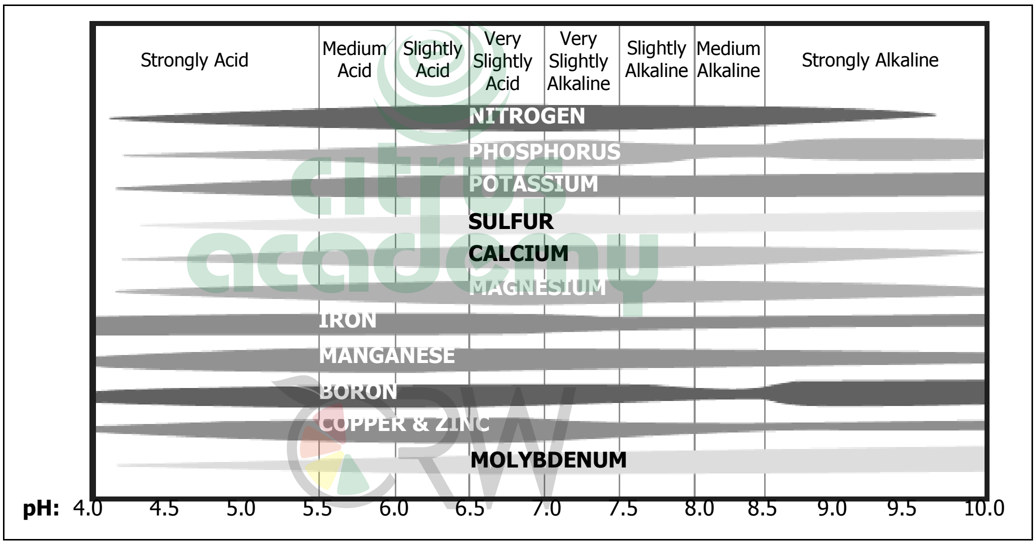


Figure 1.3: The Effect of Soil pH on Nutrient Uptake
(Courtesy of Ocean Agriculture (Pty) Ltd)

Once the pH of the medium is known, the propagator, with the knowledge of the species being propagated, must work to achieve and maintain the recommended range within the medium. The main objective is to maintain a balanced and stable pH in the root-zone.

The salinity level of the medium is also of great importance. Salinity is measured and expressed in units of Siemens (S) per either metre or centimetre; deci-siemens (dS) and milli-siemens (mS) are the most commonly used. The conversion is of 1dS/m = 1mS/cm.

Certain levels of salinity are beneficial to the plants because nutrients are made available for plant uptake. Low levels of salts are favourable and can be adjusted to desired levels with the use of fertilisers. However, higher levels affect growth and might cause root die-back even in the absence of pathogens.

3.3.3. Container Properties

Facilitator Tip

Where possible, discuss the properties of containers while showing physical examples of the containers used in citrus propagation.

Container properties are determined by the material used for the containers in which plants are grown. Different materials can be used as containers for citrus propagation, with the choice ranging from polyethylene bags through pots to sisal sacs.

Heat retention and diffusion from the media in the container is a very important aspect of propagation, since the temperature in the root-zone affects the development of the plant. High temperatures of about 27°C and up will lead to increased water evaporation from the medium, which can have severe consequences and may even result in roots dying.

Lower temperatures also affect root growth. At temperatures in the region of 12°C and below, most the metabolic processes of subtropical plants, including citrus, slow down.

Black coloured polyethylene bags are the most commonly used containers in the South African citrus nurseries. Their properties to absorb and distribute heat in the medium are satisfactory, especially during the colder periods of the year.

In addition to root growth stimulation, the bag requires much less storage space, costs less, and is more degradable. These are the major considerations that have made the plastic bag a better option compared to for example plastic pots.

4. Problems within the Propagation Environment

Facilitator Tip

As a suggestion for facilitating this session, write the common problems encountered in the propagation environment on slips of paper, place it in a hat and have groups choose a problem from the hat. Allow time for groups to break away and research the cause of the problem, its prevention and its solution. You might have to supply the groups with literature, brochures and video footage from nurseries to conduct this research. Allow the groups to report back and comment on each other's conclusions.

As discussed before, all the environmental factors have to be manipulated in concert to produce quality results. The key challenge in citrus propagation is to produce plants with the desired properties at reasonably low cost in the shortest possible time.

Problems likely to occur relate to manipulating environmental factors to mimic nature as closely as possible and to induce natural responses from the plant in a shorter period of time. It is important to remember that in nature, these factors combine and biochemical processes take place at a slower pace.

Temperatures rising far out of range in tunnels and greenhouses is a common problem if either the extractor fans and / or the wet-wall pads, or both, are not working properly. If the problem cannot be fixed easily, doors are kept open and the back of the tunnel or the greenhouse is opened to allow air movement.

In germination rooms, temperatures may also rise out of range. In this case, lights are the most probable cause, and the propagator must carefully select certain lights to switch off temporarily. Where citrus is propagated through cuttings, bottom heating might be required if basal temperatures are not within the required range. Bottom heating can be avoided by timing the propagation period.

The humidity level often drops below the required level in germination rooms or in tunnels or greenhouses. Wetting the floor assists in building up the relative humidity, and plants, if already transplanted as single units, are mist-sprayed with a knapsack sprayer at least every 10 minutes, depending on the temperature.

Aeration, or ventilation, is used at night to remove excess CO_2 in the tunnels and to replenish the O_2 levels. However, this could be problematic in the winter periods, as the ambient air temperature outside the structure may be too cold and could cause damage to the plants. The propagation structure must be aerated carefully to reach the required range, taking all factors into consideration.

Facilitator Tip

Summary

This is an opportunity to check the progress that learners have made.

Allow time for the learners to read through the summary and to gauge their own progress. Make sure that each and every learner gets and opportunity to ask questions.

Summary

Chapter 1

- Environmental conditions impact on the growth rate of plants, by mostly impacting on two metabolic processes, being photosynthesis and respiration, or transpiration.
- During photosynthesis, the plant absorbs CO_2 and water, and uses heat to manufacture sugars (carbohydrates), oxygen, and water molecules.
- During respiration O_2 from the air is used to break down carbohydrates in the plant into energy that is used by the plant, CO_2 that is released into the air, and water molecules that are dispersed from the surface of the leaf.
- When the moisture in the surrounding air increases, plant transpiration decreases and light intensity influences transpiration through leaf surface temperature.
- Three classes of environmental conditions impact on plant growth, being atmospheric conditions, biotic conditions and edaphic conditions.
- Atmospheric conditions refer to light, humidity, temperature, water and aeration.
- Seed germination is activated by increased light intensity and light impacts on the rate of photosynthesis and respiration. Fluorescent lights are used in germination rooms to promote seed germination, and natural light is used in tunnels and shade houses.
- Relative humidity impacts on the transpiration rate of plants.
- Temperature impacts on photosynthesis and respiration rates. Germination requires relatively high temperatures, with a range of between 27°C and 32°C, with an average of 29°C being considered optimal.
- Water plays a role in keeping the plant cells turgid, as a catalyst in biochemical reactions in the plant, and in the translocation of manufactured compounds.
- Aeration in the leaf and root areas allows gaseous exchange that ensures that growth and development take place normally.
- Biotic conditions refer to bacteria, fungi and viruses in the rhizosphere, insects and weeds.
- Certain types of bacteria, fungi and viruses in the root-zone are beneficial and have a positive

impact on the growth of the plant, while others are non-beneficial and have a negative impact.

- Insects are also classified as beneficial and non-beneficial. Examples of beneficial insects are *Aphytis lingnanensis*, *Chilocorus nigritus*, and *Cryptolaemas montrouzieri*, while non-beneficial insects include red mites, red scale, mealybugs, aphids, leafminer, and thrips.
- Weeds negatively impact on the growth of seedlings because they compete for water and nutrients.
- Edaphic conditions refer to physical and chemical properties of the growth medium in the root-zone, and the properties of the contained in which the plant is grown.
- Soilless media that are also used in nurseries include pine-bark, sawdust, peanut shell, river sand, composted organic material, and ash.
- In terms of propagation, physical growth medium properties refer to the texture, structure and aeration of the soil. Soil depth and stratification are controlled in the nursery environment.
- Chemical growth medium properties are those characteristics that cannot be seen or felt, but influence reactions that take place in it and include the pH, salinity, and potential gas exchange reactions.
- Container properties are determined by the material used for the containers in which plants are grown.

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

<u>Activity 1 – Group Discussion</u>

Allow time for groups to break away to discuss the activity. Allow for groups to report their findings and comment on each other's conclusions. Remind learners to answer the activity based on the overall conclusions drawn from all the groups' feedback.

Timeframe: 1h 30min

<u>Activity 2 – Worksheet</u>

Remind learners to answer this worksheet based on their experience and by conducting further research, if necessary. The answers to the questions will not necessarily be found in the learner guide and answers might vary from nursery to nursery.

Timeframe: 1h 45min

Chapter 2

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

Monitor environmental conditions in the propagation area within a specific agricultural production context

Timeframe

You have to complete this section as follows:

Total time	Theory	Practical
8h	5h	3h activities

1. Introduction

In citrus propagation, the environmental factors are critical, and they must be monitored and manipulated to maximise the success rate. The starting point is the monitoring of the environmental conditions.

In the previous chapter, we identified atmospheric, biotic and edaphic conditions as the environmental conditions that affect citrus propagation. Biotic and edaphic conditions are not likely to change in a short period of time, since they depend on the choice of growth medium and on the effectiveness of ongoing management tasks, such as weed control. Scouting for pests and symptoms of diseases are continuously done in the nursery.

Atmospheric conditions however can change in a very short space of time and must be monitored and controlled very carefully wherever possible.

2. Monitoring Environmental Conditions

Facilitator Tip

Ask a propagation expert to explain monitoring methods to learners during a visit to a nursery.

A wide range of electronic and manual control systems are used to monitor environmental factors. The most important factors are:

- Light
- Humidity and Temperature
- Water
- Aeration

2.1. Light

Generally, light is not measured in citrus nurseries in South Africa. Should it however become necessary, it may be monitored by a light-meter, such as Goldilux. This device measures the intensity (illuminance) of the visible spectral radiation falling on the detector in a given environment. Intensity is measured in lux or footcandles.

Another option is using external probes to measure light. Such probes are plugged into a light-meter. The internal detector of the light-meter is automatically disconnected and the reading displays the quantity and the units measured with the probe.

2.2. Humidity and Temperature

Humidity is monitored using a battery operated Hygro-Thermograph meter, which measures and records both rh and temperature, such as a Thies CLIMA. This apparatus uses graph paper on which data is recorded for a specific period such as 1 day, 7 days or 31 days. The graph paper is replaced at the end of the period.

High-tech devices, such as Hanna Instruments HI91610, are also used. In addition to supplying the user with the accurate data of rh and temperature at the touch of a button, it gives the option of storing the information, which can then be transferred to a computer for analysis.

Electronic control systems that can be linked to a computer are also available for the monitoring of humidity and temperature. These generally come with additional options such as light intensity sensor, heating or cooling commands, and ventilation and dehumidification commands. As such, they provide the ultimate control mechanism to ensure optimum conditions for plant growth and development.

For citrus propagation, the recommended humidity level in enclosed structures is in the region of 80%, with an approximate 10% variation.

2.3. Water

Moisture levels are measured using soil moisture sensors which convert pressure, or water tension, in the soil to centibars of suction. Tensiometers may be used to measure available soil moisture in the root-zone. They are placed in the soil at different depths for better representation of the moisture front in the soil. Lengths of tensiometers range from 15cm to 180cm for different rooting depths.

If citrus seedlings are grown in containers in a citrus nursery, the containers do not provide enough depth for long and thick devices such as Irrometers. Although a 15cm Irrometer could be used, it is more appropriate to use hand-held probes.

Irrigation water represents a high risk area for a citrus nursery with regard to the presence of harmful pathogens, such as fungi and nematodes. To ensure that the water is not contaminated and free of harmful pathogens, the water must be treated.

Treatments begin with the flocculation, being the precipitation of silts and organic material, of the water stored in a reservoir. Flocculation makes use of aluminium sulphate based products, such as AluFloc. The amount of AluFloc that is used depends on the amount of soil particles and other organic material in the water. The flocculated, or clear, water is then filtered using a sand filter to remove any silt or organic material that was not precipitated successfully.

Any remaining propagules and harmful pathogen spores, such as Phytophtora and Pythium, are eradicated through chlorination at 2-3ppm preferably using chlorine gas, or otherwise sodium hypochlorite (Jik) or granular chlorine (HTH).

Definition

Propagules

Propagules are the shoots, seeds, or other parts that plants use to spread or propagate, either sexually or vegetatively.

Monitoring water quality requires a constant monitoring of the level of free chlorine available in the irrigation water. This can be done by using a swimming pool kit, or more sophisticated methods, such as Hanna Instruments HI9011. The presence of pathogen spores can only be detected through laboratory tests which should be done on a regular basis.

Chemical water quality factors are monitored by using pH and EC meters, which are combined in some devices. For improved nutrients uptake, the pH of the solution has to be between 5.8 and 6.2 with a maximum of 6.5. pH levels outside this range impair nutrient uptake. Critical levels are below 4.5 and above 7.5.

Electrical conductivity (EC) is used to monitor the salinity in the irrigation water, which may cause build-up in the root-zone. Excessive salinity may lead to death of seedlings. Levels above 2.5mS/cm are considered unacceptably high and such water has to be avoided. Initial water EC of less than 0.3mS/cm is the ideal for fertigation.

2.4. Aeration

The programming and monitoring of aeration is referred to as ventilation. Ventilation is used to reduce temperature or humidity, and to reduce CO_2 and increase O_2 levels in more sophisticated climate control units. Most commonly, climate control units are set for dehumidification and temperature reduction.

3. Unforeseen Changes in Environmental Conditions

Although there are several services that provide weather forecasts with high levels of accuracy, the unpredictability of the weather remains a risk.

Where natural conditions are controlled to some extent, such as in shade-houses, the propagator has to balance the conditions taking into account the level of other factors required. Under extreme unexpected heat conditions, irrigation can for instance be timed to coincide with periods of the day when the stomata are still open and transpiration is taking place, which is generally before 10h00 and after 15h30.

4. Adjusting Environmental Conditions

Facilitator Tip

Remind learners that adjustments to conditions in the propagation environment should never be done without express permission and only by those trained to do so. Rather report the problem!

In tunnels, the use of electronic sensors ensures a better control of the propagation environment. The propagator can set and alter parameters accordingly by the push of a button.

Under shade-cloth, quick adjustments are not possible. Ventilation is passive and relies on wind movement. The major adjustments the propagator can make, relate to the percentage of shade-cloth to reduce light intensity and temperature. Shade-cloth, also referred to as thermal sheets, comes in different colours and percentage shading, the most commonly used for citrus propagation being black and white.

5. Recordkeeping

Recordkeeping is a managerial function that ensures that operations are monitored properly. If this function is neglected, inaccurate records can lead to poor decision-making. Based on previous records, the propagator can project future operational needs with a greater degree of accuracy. Although conditions may change, there is a greater probability that the same trend will be repeated.

Recordkeeping systems vary from hand-written records to using well-structured forms detailing operations undertaken to the computerised systems. Records must always be verified before they are stored for future use. It is common practice to have a dual recordkeeping system, being manual and computerised, to provide a cross-check of records.

Records that are commonly kept include:

- Records of water treatments for Phytophtora and other pathogens
- Records of environmental conditions
- Pest and disease scouting records
- Chemical use data containing information of the chemicals that were used, the target pest or disease and the concentrations
- Water quality test results
- Growth medium test results
- Type and amount of fertiliser used

Facilitator Tip

Summary

This is an opportunity to check the progress that learners have made.

Allow time for the learners to read through the summary and to gauge their own progress. Make sure that each and every learner gets and opportunity to ask questions.

Summary

Chapter 2

- Biotic and edaphic conditions are not likely to change quickly, but atmospheric conditions can change in a short space of time and must therefore be monitored.
- Light is not generally monitored in citrus nurseries, but can be measured by a light-meter.
- Humidity and temperature is monitored using a battery operated Hygro-Thermograph meter.
- Tensiometers and irrometers are used to measure soil moisture content, while laboratory analyses are used to monitor water quality.
- Unforeseen changes in atmospheric conditions are mostly due to changes in weather conditions.

- Records are kept of atmospheric conditions and of all actions that are taken in the nursery.

Practical

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

Facilitator Tip

Activity 3 – Research and Discover

Arrange for a site visit to a propagation nursery to give learners an opportunity to obtain answers to the questions posed in the activity.

Timeframe: 3h

Chapter 3

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

Demonstrate an understanding of the general propagation procedures and select appropriate procedures within a specific agricultural production context

Timeframe

You have to complete this section as follows:

Total time	***Theory***	***Practical***
8h	5h	3h activities

Facilitator Tip

Where possible, demonstrate the techniques discussed below or show video footage of these techniques being performed. Remind learners of the precautions needed in terms of health and safety and of how to limit damage to the plants while performing the techniques.

1. Introduction to Budding

Budding is a form of grafting, which is a vegetative plant propagation method where a scion bud from a selected tree of the desired cultivar and variety and with desirable traits is inserted into a rootstock seedling to produce a tree.

The term budding therefore refers to bud grafting, meaning a technique of grafting using a single bud as the graft scion where each part, the scion and the rootstock, have distinct roles to play.

2. Rootstock Selection

Facilitator Tip

Remind learners of the need for rootstocks in citrus propagation and point out the rootstock and scion parts of an adult citrus tree. Be alert to learners who might still hold misconceptions about the scion properties being changed by the rootstock. Encourage learners to use the table for future reference and point out that they do not need to learn this information. During the discussion around rootstock selections, concentrate on the rootstocks most commonly used in the specific area and the reasons for these choices.

Healthy rootstock seedlings are produced and raised through germination. The choice of the rootstock depends on the following factors:

- Predictable performance in environmental conditions in the orchard, which include the water quality, and the physical and chemical properties of the soil, such as soil pH and salinity;
- Resistance or tolerance to diseases;
- Compatibility with the scion;
- The market entrance timing in relation to time to maturity; and
- Internal fruit quality

The characteristics of the most commonly used rootstocks are shown in the table below.

	Rough-lemon	***Swingle Citrumelo***	***Carrizo Citrange***	***X639***	***C-35***	***MXT***
Disease Factor						
Exocortis	Tolerant	Tolerant	Sensitive	Susceptible	Susceptible	Susceptible
Tristeza	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant
Phytophtora	Susceptible	Tolerant	Tolerant	Susceptible	Tolerant	Tolerant
Citrus nematodes	Susceptible	Tolerant	Susceptible	(Not known)	Tolerant	Tolerant
Soil Factor						
Poor drainage	Susceptible	Tolerant	Sensitive	Sensitive	Tolerant	Sensitive
High clay content	Sensitive	Intermediate	Intermediate	Sensitive	Tolerant	Intermediate
High sand content	Tolerant	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
High chlorides	Tolerant	Intermediate	Sensitive	Intermediate	Sensitive	Sensitive
High pH	Tolerant	Sensitive	Sensitive	Tolerant	Sensitive	Sensitive
Drought	Tolerant	Intermediate	Intermediate	Sensitive	Sensitive	Sensitive
Replant	Sensitive	Tolerant	Intermediate	Sensitive	Tolerant	Intermediate
Tree Performance						
Tree growth rate	Vigorous	Moderate	Moderate	Moderate	Slow	Moderate
Final tree size	Large	Medium	Medium	Medium	Small	Medium
Cold hardiness	Poor	Good	Good	Good	Good	Good
Longevity	Fair	Good	Good	Fair	Good	Good
Yield per tree	High	Good	Good	Good	Good	Good
Fruit quality	Low	Good	Good	Good	High	High
Rind colour develop	Intermediate	Late	Early	Early	Intermediate	Intermediate

Table 3.1: Characteristics of Commonly Used Rootstocks
Adapted from Citrus Rootstocks: The Choice You Have – Louis A. Von Broembsen

Rootstocks are produced through seed propagation. Seeds are bought from certified sources or collected from the fruit of rootstock variety trees that are grown specifically for this purpose. The seeds are sown either outside in sand seedbeds, or, more commonly in South Africa, in seed-trays that are kept in a controlled environment in germination rooms. All seed trays are clearly marked with water-proof identification labels stating the variety, date sown and source code.

Due to various reasons that lead to losses, about double the quantity of seeds required for rootstock to be budded, is sown. Reasons for losses include:

- Death of seedlings due to diseases which result from excess water in the growing medium, such as damping-off and phytophtora.
- Off-types, which are seedlings that are not genetically true-to-type.
- Albinism, which is a condition that expresses itself at the seedling stage if not treated properly.
- Seeds that have been sown deeper and take longer to germinate, which lead to the considerable risk of seedlings emerging with defects associated with reduced levels of chlorophyll.
- The medium used is also a potential cause for losses. Compacted media makes radicle development more difficult because there is less space for the radicle to navigate freely. A larger number of seedlings produced will have bench roots, which are tap roots that are distorted and bent in stead of being straight.

The best seedlings are transplanted into trays with individual cells filled with bark mixed with a slow release fertiliser. These seedlings are raised to become rootstocks for budding. The seedlings trays are normally kept in tunnels where the environment can be regulated.

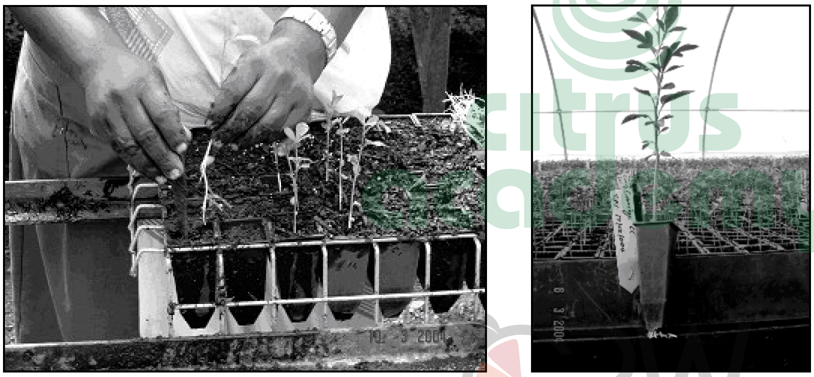


Figure 3.1: Carrizo Rootstock in Cavities

Three to four months after transplanting from the germination tray into the seedling trays, the seedlings are transplanted into bigger containers, such as four litre polyethylene bags and placed in shade-cloth structures to grow and develop for budding.

At this stage, losses may occur through selection, as more seedlings may display unwanted traits that have been hidden previously. These seedlings are referred to as off-types.

Management at this stage is concerned with creating an environment conducive to transpiration and photosynthesis taking place at a good rate. Each batch of seedlings retains its identity label.

Figure 3.2: X639 Rootstock Labelling

Budding takes place about four to six months after the seedlings are transplanted.

The bud itself comes from a twig cut from the selected cultivar with desired traits. The twig constitutes the bud-wood and is referred to as the **scion**. The bud-wood must have enough food reserves for the bud to survive before it is taken over by the rootstock cambium.

3. Bud-Wood Selection

All bud-wood that is used in certified citrus nurseries in South Africa is provided by the Citrus Foundation Block (CFB) which is situated in the Eastern Cape. The CFB falls under the management of Citrus Research International (CRI). The bud-wood is certified to be true-to-type, meaning that the type and cultivar of the bud-wood is guaranteed. The bud-wood is also certified to be free of all known graft-transmissible diseases, such as exocortis, except for a mild strain of tristeza virus that is specifically inoculated into the bud wood source plants and acts as a protection factor against severe strain infection.

The selection of the bud-wood plays an important role in achieving success. The selection has to be done at the right growth stage. Scion material is collected from healthy and young twigs that are actively growing. The shape of the bud-wood is not clearly prescribed. Some propagators use buds from well rounded bud-wood sticks, while others prefer using those from slightly angular shaped sticks.

4. Budding Procedure

The ultimate goal of the propagator is to produce a successful union between the scion and the rootstock. To ensure a successful union, the propagator must aim at maximum contact between cambiums of the rootstock and scion. To this end, tissues must be matched correctly, and care must be taken to ensure that they are bound and remain in contact.

Budding in nurseries is carried out at a time of year that promotes the success of the operation and subsequent union. The most ideal time is in late spring and summer when the sap flow is optimal in the rootstock. There must be clear signs of growth on the rootstock, such as new leaves and shoots.

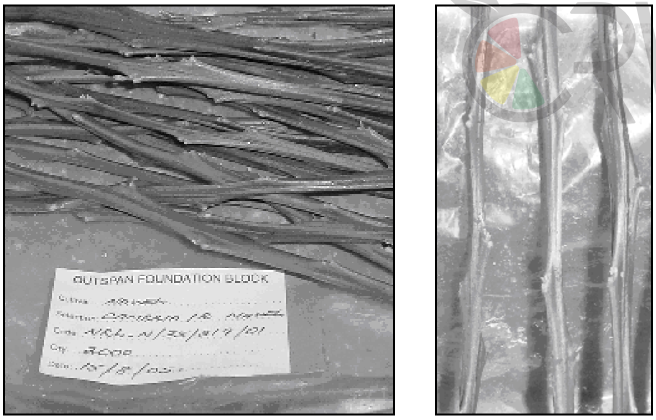


Figure 3.3: Bud-wood from the Foundation Block

An inverted T-cut is made on the stem of the rootstock at a height of about 20cm above the growth medium. For the sake of uniformity, the propagator ensures that the height of budding is the same throughout.

The depth of the cut is shallow, being just deep enough to lift the bark. The thickness of the stem is important because it has to lend itself to manipulation. The thinner the stem, the more difficult it is to bud onto.

Figure 3.4: The Inverted T-Cut: Vertical Cut (left) and Lateral Cut (right)

The scion is inserted into the T-cut and pressed down firmly to ensure that the tissue comes into contact. The joint is wrapped and sealed to allow the wounds to heal.

Figure 3.5: Inserting the Bud-piece Into the T-Cut

Figure 3.6: Wrapping

5. Hygiene and Safety

Sanitation and hygiene have to be monitored very closely during plant propagation to prevent contamination. Cultivated citrus species, including rootstocks and scions, are susceptible to a range of pathogens ranging from bacteria to viruses and fungi.

Most of these pathogens are transmissible through cutting tools. Pathogens infest the vascular cambium, and any cut that reaches the vascular cambium therefore has the potential to contaminate the tool used and to transmit the infection to other plants.

6. Tools Used for Budding

Facilitator Tip

Where possible, show examples of the tools, pointing out the critical control points of these tools and emphasizing health, hygiene and safety practices.

During budding, cutting tools are used. Budding knives are used to remove the bud-piece from the bud-wood and to make the inverted T-cut. Pruning shears are used for cutting the rootstock seedling above the bud union and for pruning away unwanted branches at a later stage. These tools are sterilised using bleach in a 30% solution after every 100 plants have been budded, or every time the propagator moves from one tree to the next while cutting plant material.

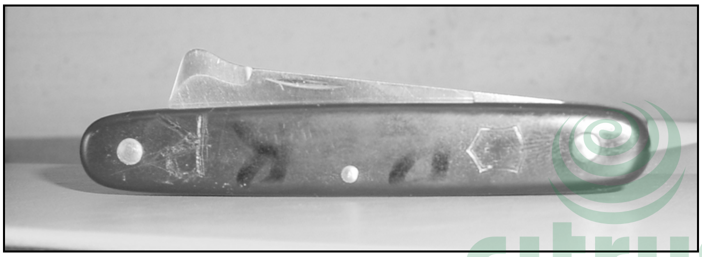


Figure 3.7: Budding Knife

After inserting the bud into the rootstock, it has to be wrapped using a polyethylene plastic strip to maximise the contact between the rootstock and the bud, and keep water out as it might infect and rot the bud.

7. Other Propagation Methods – Shoot Tip Grafting

In citrus propagation, shoot-tip grafting is the method used to eliminate any viruses that could be hosted in the plant material. Viruses tend to move more slowly in the plant in the new cells multiplying in the meristem of new buds, and one is therefore able to graft the virus free portion of the meristem of a bud onto a virus free rootstock.

Under laboratory conditions the procedure is as follows:

- Cleaning the growing point
- Rootstock preparation
- Grafting

7.1. Cleaning Growing Point of Material of Viruses

- Pick a 1cm to 10cm tip of a new shoot and place in a Petri dish to prevent it from drying out.
- Break off the large leaves under a stereo microscope.
- Sterilise for 5 minutes in a 7.5% Jik solution
- Rinse twice in sterile distilled water (SWD)
- Transfer to a third rinse solution until needed. If kept overnight, remove SWD and store at 4°C.

7.2. Rootstock Preparation

- Place a germinating rootstock seedling into a test tube with an artificial growing medium.
- Once the rootstock has etiolated, remove it from the test tube.
- Cut off the top to give about 5cm long stem and remove the cotyledons (seed leaves).
- Trim roots so that it can be easily replaced in the tube.
- Make a horizontal cut into the cortex approximately 10mm below the top.
- Cut down from above this cut to form a chip 1mm to 2mm long.
- Check that the bark comes freely away and then press it back to prevent drying out.

7.3. Grafting (STG)

- Under a stereo microscope, break off the remaining leaves of the shoot tip of the cultivar until the meristem dome is visible.
- Cut off the top 0.15mm of the meristem.
- Transfer to the stem of the rootstock in an upright position on the cambium.
- Plant the grafted plantlet into liquid medium in a test tube and label it with necessary details.
- Transfer the test tube to a growth room and monitor twice weekly.
- Remove rootstock outgrowths regularly.
- The grafted material should start to grow out after two to three weeks, about 5mm long with small leaves.

Facilitator Tip

Summary

This is an opportunity to check the progress that learners have made.

Allow time for the learners to read through the summary and to gauge their own progress. Make sure that each and every learner gets and opportunity to ask questions.

Summary

Chapter 3

- Budding is a form of grafting, where a bud from a selected tree is inserted into a rootstock seedling to produce a tree.
- The choice of the rootstock depends on predictable performance in environmental conditions in the orchard, resistance or tolerance to diseases, compatibility with the scion, market entrance timing in relation to time to maturity, and internal fruit quality.
- Rootstocks are produced through seed propagation and because losses of seedlings occur due

to a variety of reasons, double the amount of seed is sown.

- Rootstock seedlings are planted in seedlings trays and then transferred to larger containers three to four months later.
- Rootstocks are always labelled carefully with the cultivar, planting date and transfer dates.
- Budding takes place about four to six months after the seedlings are transplanted.
- All bud-wood that is used in certified citrus nurseries in South Africa is provided by the Citrus Foundation Block.
- To promote a successful union between the scion and the rootstock, maximum contact between the cambiums of the rootstock and the scion is required.
- Their must be signs of active growth in the rootstock and the bud-piece from which the scion is taken.
- An inverted T-cut is made on the stem of the rootstock and the bud is inserted and secured with a polyethylene plastic strip.
- Sanitation and hygiene is essential for preventing contamination, and especially cutting tools must be sterilised properly.
- Budding knives and pruning shears are the main tools that are used during budding.
- Shoot tip grafting is another propagation method that is used to eliminate viruses in the plant material.

Practical

Complete activities 4 and 5 in the **Learner Workbook**.

Facilitator Tip

Activity 4 – Group Discussion

Allow time for groups to break away to discuss the activity. Allow for groups to report their findings and comment on each other's conclusions. Remind learners to answer the activity based on the overall conclusions drawn from all the groups' feedback.

Timeframe: 1h 30min

Activity 5 – Flow Diagram

Remind learners about the lay out and logical flow of a flow diagram. Remind learners to base the flow diagram on an actual citrus propagation nursery and to include as much detail as possible.

Timeframe: 1h 30min

Chapter 4

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

Choose and apply the necessary tools for the propagation within a specific agricultural production context

Timeframe

You have to complete this section as follows:

Total time	***Theory***	***Practical***
7h 45min	5h	2h 45min activities

1. Propagation Tools

Facilitator Tip

It is recommended that the tools discussed are observed in an actual propagation environment and that learners constantly identify the following:

- "Why is this tool used for this task?"
- "What injuries can occur while working with the tool?"
- "How can injuries be prevented?"
- "What damage can the tool do to the propagation material and the propagation environment?"
- "How can damage to the propagation material and propagation environment be prevented?"
- "How should the tool be used, carried and stored?"
- "How should the tool be maintained?"

From seed germination to the time trees are dispatched, there are a host of operations that take place which require a variety of tools and equipment. Apart from the budding knife and shears mentioned in the previous chapter, the following tools and equipment is used regularly in a citrus nursery in South Africa:

- **Seed trays** are containers used to germinate seeds.

- **Seedling trays** are containers used to nurse and grow the seedlings before they are transplanted.

- **Watering cans** are used from the outset, germination to seedlings, when water is needed. Water cans are also used for drenching. There are two most commonly used types, being plastic and galvanized steel cans.

- **Knapsacks** are used for foliar feeding and pesticides sprays for which at least one knapsack is needed, with extra knapsacks for herbicide sprays.

- **Soil augers** are used for taking samples of the growth media in the root-zone for testing.
- **Jugs** are used to accurately measure substances.
- **Spades** are required mainly for handling bark.
- **Containers** are used for growing the seedlings and budded plants in. The most popular containers are plastic bags made to various specifications with perforated holes to allow drainage of excess water.
- **Mesh panels** are used to lift the plants from the ground to avoid direct contact with the soil, which can cause contamination.
- **Hose pipes with fan-sprayers** are used for watering the plants in containers. The fan sprayer helps to break the water in smaller jets and spreads it over a larger surface.
- **Stakes** or **cleats** are used to train budded trees so that they can grow straight. They are placed in bags alongside the young tree after the bud union has healed and grown strong enough to handle bending pressure.
- **Collection bags** are used to dispose of weeds that have been removed from the containers.
- **Wheelbarrows** provide a very efficient method of transporting plants when taking them out for customers or when grading and consolidating. When being used for these purposes, strict hygiene measures have to be adhered to.
- **Tying machines (tapeners)** are used for training the plant to grow straight. A tape and staples are inserted into the machine and the tree is tied to a stake placed alongside it in the bag.
- **Sweeping rakes** are used for cleaning in and around the nursery or shade-house.
- **Leather gloves** are used for certain operations such as staking to prevent injury while pushing the stake into the bag.

2. Health, Hygiene and Safety

In general, issues of health, hygiene and safety are addressed by the Occupational Health and Safety Act (OHSA). The health and safety of all persons working within and around the nursery has to be considered against all hazards that can be found in this environment.

As stated in the OHSA, there must be an anticipation, recognition, evaluation and control of conditions arising in or from the workplace, which may cause illness or adverse health effects to persons.

Personal protective clothing is the second line of defence after a sound health and safety policy. Protective clothing includes vinyl gloves, overalls, masks, and gumboots.

Other aspects to be included are a washing point for disinfection and cleaning in general, a dumping site for unwanted and used items, and specific disposal methods of used items

3. Storage of Tools

Tools used for propagation are stored in areas with controlled entrance and use. Access to these must be coordinated with a tools register that records the use of each tool and its condition before and after use. Gloves, overalls, masks, and gumboots are stored in locked cupboards. Wheelbarrows, sweeping rakes, watering cans, spades, and hosepipes are kept in a storeroom.

The propagator must ensure that tools are grouped according to their use and kept in suitable areas in terms of hygiene and safety.

Facilitator Tip

Summary

This is an opportunity to check the progress that learners have made.

Allow time for the learners to read through the summary and to gauge their own progress. Make sure that each and every learner gets and opportunity to ask questions.

Summary

Chapter 4

- The tools and equipment used commonly in South African citrus nurseries are seed trays, seedling trays, watering cans, knapsacks, soil augers, jugs, spades, planting containers, mesh panels, hose pipes, stakes, collection bags, wheelbarrows, tying machines (tapeners), rakes, and leather gloves.
- Health and safety is addressed by the Occupational Health and Safety Act (OHSA), which prescribes that conditions that may threaten the health and safety of workers must be anticipated, recognised, evaluated, and controlled.
- Tools and equipment must be stored in clean and dry facility that is kept safe and secure.

Practical

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

Facilitator Tip

Activity 6 – Worksheet

This is to be completed with the assistance of a propagation nursery and learners have to interpret the information in their own words and individually.

Timeframe: 1h

Activity 7 – Worksheet

Learners should use this opportunity to check their own progress and ensure that they have the knowledge required. Encourage own work and own interpretations from learners.

Timeframe: 1h 45min

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