LEARNER GUIDE

Plant Propagation

Level 2

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Title:		**Demonstrate an Understanding of Plant Propagation**					
Applied Title:		**Demonstrate an Understanding of Citrus Plant Propagation**					
Field:		Agriculture and Nature Conservation					
Sub-Field:		Primary Agriculture					
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Skills Area:		Propagation					
Context:		Citrus Production					
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Directions

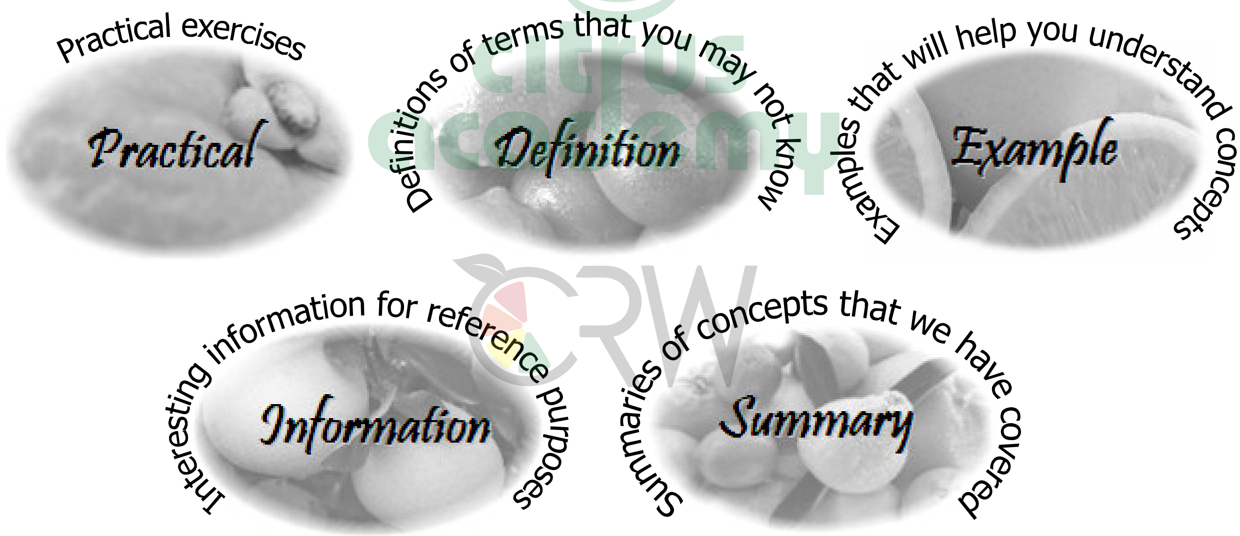
This learning material has been developed to assist the learner wishing to complete this unit standard. The guide contains all necessary learning to ensure that the learner will attain the competencies required by the unit standard.

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

The learner achieving this unit standard will have the ability 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 a learner attempting this unit standard will show competence against the following unit standards or equivalent:

NQF Level	***Unit Standard Number***	***Unit Standard Description***
NQF4	Literacy and Numeracy	
1	116205	Propagate plants
1	116156	Collect agricultural data
2	116053	Understand basic soil fertility and plant nutrition
2	116060	Utilise and perform minor repair and maintenance tasks on implements, equipment and infrastructure

Introduction to Citrus Production

1. Introduction

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

2. Background

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

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

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

3. Citrus Planting

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

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

Yield

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

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

4. Lifespan

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

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

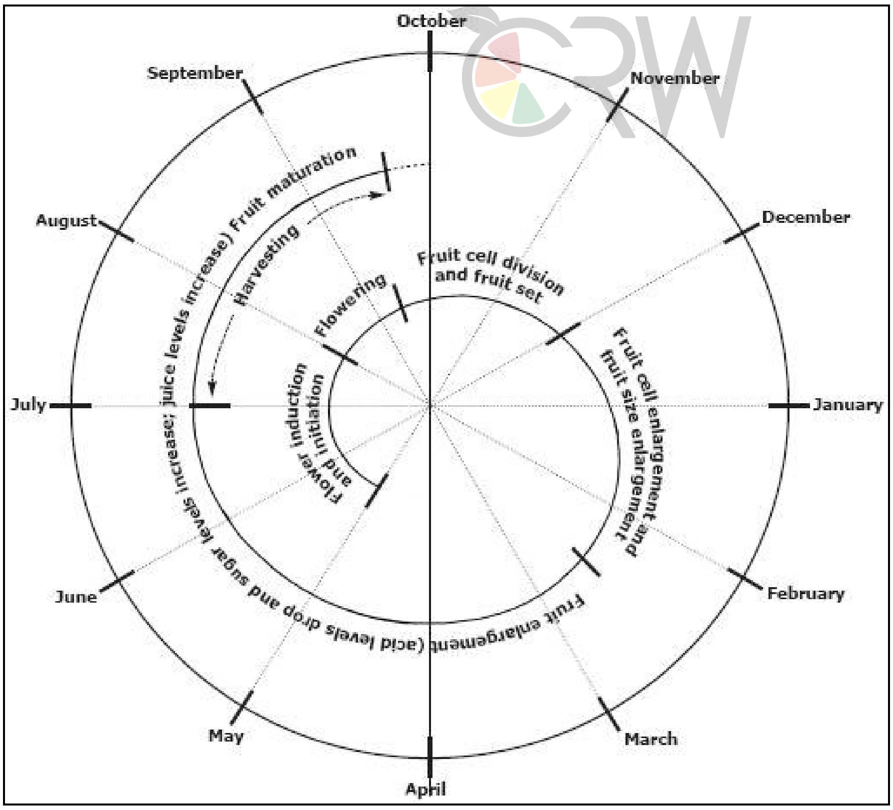
5. Citrus Plant Phenology

Phenology

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

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

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



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

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

6. Citrus Learning Material

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

Skills Area	***Description***
Enterprise Selection, Planning and Establishment	Concerns itself with identifying the various components of an agricultural enterprise, and with the selection and planning processes for a new enterprise, and looks at the physical layout of a farm, with specific reference to infrastructure, orchard layout, etc.
Propagation	**Concerns the various methods and requirements for the multiplication of plant material of specific varieties that possess desired qualities.**
Crop Establishment	Concerns the establishment of a new citrus orchard, in terms of the physical planting of trees and the care for young trees.
Plant Structures and Functions	Considers the structure and function of various plant parts and the manner in which nutrients, water, air and sunlight is taken up and processed.
Plant Nutrition and Soil Management	Concerns itself with plant nutrients, in terms of the requirements of the citrus plant and the supplementation of nutrient elements through fertilisation, with specific reference to the timing and manner of application.

Skills Area	*Description*
Water Quality	Considers the various factors that influence water quality and manners in which water quality can be measured and controlled. Considers furthermore the effect of water quality on tree and fruit growth and development, in combination with effective irrigation, fertilisation and pest control.
Plant Manipulation	Concerns various types of physical and chemical plant manipulation, with specific reference to pruning, girdling and the application of plant growth hormones, and tools and equipment used for this purpose.
Irrigation	Looks at the technical aspects of orchard irrigation, with reference to the types of irrigation systems, the installation of new irrigation systems, and the repair and maintenance of an irrigation system. Also concerns irrigation scheduling, and measures to ensure effective irrigation.
Pests, Diseases and Weeds	Concerns the identification of pests, diseases and weeds that threaten citrus production. Also considers various methods of effective control, and the planning required for this purpose.
Crop Protection	Looks at the practical application of crop protection agents through various methods, with specific reference to tools and equipment used, and health and safety requirements.
Food Safety	Concerns the requirements in terms of health and safety, and environmental control for ensuring food safety and hygiene.
Harvesting	Looks at the process of determining fruit maturity through maturity indexing, the harvesting of fruit, and the tools and equipment used for this purpose.
Conservation	Considers the impact of farming practices on the environment, with reference to the measures required to minimise this impact and protect the environment.
Marketing	Concerns the factors influencing citrus marketing, and the development of an effective marketing plan.
Production Management	Concerns the actions and processes involved in effective production management, with specific reference to the coordination of the various production tasks and processes and the creation of a strategic plan for the enterprise.
Industry Overview	An overview of the citrus industry and the various institutions involved.
Packhouse Practices	Concerns the specific principles and practices that are employed in Packhouse environments, and specifically: • Receiving • Sorting • Grading • Fruit Sizing • Cold Chain Management • Packing • Palletising • Storage • Dispatch • Fruit Markets • Fruit Quality • Fruit Treatment • Health and Safety • Hygiene • Product Characteristics

Chapter 1

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

Recognise the environmental requirements for propagation in a specific agricultural production context

1. Introduction

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.

Man has propagated plant material almost as long as he has cultivated the land to produce food. For a long time, plant material was propagated mainly by using the seeds of existing plants.

Better methods were discovered over time that allowed the farmer to retain the desirable qualities of the plant material, while eliminating some of the less desirable qualities. Through these methods, the farmer was also able to eliminate the variations between plants of the same cultivar and produce more consistently.

Today, citrus farmers buy their plant material from commercial citrus nurseries. The farmer is able to obtain plant material of a wide variety of cultivars that have qualities most suited to his specific environment.

2. Environmental Requirements for Citrus Propagation

Plants produced by propagation must be healthy and adhere to specified standards. To achieve this, the following factors are monitored closely:

- Humidity
- Aeration
- Light quality and quantity
- Temperature
- Moisture

In nature, there is an interaction between these factors and they all affect each other. In a controlled environment, such as a nursery, light is an influential factor in this interaction. Light changes the temperature, which in turn affects the humidity level.

A plant has the natural ability to regulate its level of activity according to environmental conditions, such as at specific levels of temperature and humidity. Extremes in temperatures and humidity can cause plant growth to stop, which may lead to the plant dying if the conditions persist.

Environmental conditions therefore play an important role in the ability of a plant to grow and in general plant health. Effectively regulating these factors enables one to propagate and grow healthy plants. Controlling these factors is important in all propagation methods, but even more so for cuttings. A cutting is a separate plant part and care must be taken that the metabolic processes continue without interruption, otherwise the plant-part will not survive. There is no element of dormancy in this case.

Definition

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.

2.1. Humidity

Definition

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.

Humidity levels are especially important in allowing the plant to carry on with its metabolic processes at desired rates.

The ideal relative humidity for citrus propagation ranges between 80% and 95% for seed germination and production of cuttings, and in the region of 60% outdoors for budding and seedbed methods. Seed germination is faster at higher humidity levels, as is the 'take' in cuttings. In warm and dry areas, the level of humidity often falls below 55% on hot summer days, making budding more delicate and requiring close monitoring.

2.2. Aeration

Plants can only grow and survive in a balanced environment, where both oxygen (O_2) and carbon dioxide (CO_2) are sufficient. The processes of respiration and photosynthesis make use of both O_2 and CO_2 to sustain the growth and development of the plant.

Definition

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.

In the open and under shade-cloth or in open seedbeds, the ambient air movement is sufficient to aerate plants. In structures such as tunnels, ventilation becomes important. Ventilation extracts from tunnels 'old' air, which may have an excess of O_2 or CO_2 produced by plants during the day and night respectively, thereby maintaining a balanced environment.

Figure 1.1: Tunnels with Extractor Fans

2.3. Light

All plants require light for growth to take place. Light is essential for photosynthesis, while light quality, which is determined by the wavelength of the light, influences germination.

Plants in structures, such as greenhouses and shade-houses, require adequate light for the process of photosynthesis. If the plant does not receive enough light, which may be due to shading or over-crowding, it displays symptoms of retarded growth.

In seed germination, red light, with a wavelength of 660 nanometre (nm), is used in chambers to stimulate germination. Fluorescent tubes are commonly used as an artificial source for red light for this purpose. These lights are used extensively and kept on for as long as possible. It is not uncommon to have lights on 24 hours a day, week-round.

The depth of sowing also determines the time seeds take to geminate, because light cannot penetrate deeply into the soil. With no or inadequate light, weak seedlings of poor quality are produced. These seedlings display an excessive elongation, referred to as **etiolation**.

Figure 1.2: Light in Germination Room

2.4. Temperature

If heat and light, which cause an increase in temperature, is not controlled properly, plants may suffer from heat injury. The ideal temperature for propagation is 29°C, and it must be monitored closely.

In propagation chambers the temperature can often be maintained at this ideal level by keeping lights on for longer. Heaters are used in some areas. The heat increases humidity in the chambers when trays are drenched and or floors are dampened.

2.5. Moisture

Moisture is essential for germination and healthy plant growth.

Too much water deprives the plant roots of oxygen, and can promote the development of diseases such as root rot, damping off, and collar rot. The other extreme is insufficient water supply which is detrimental to all plants, but even more so to young seedlings. A uniform and constant water supply is required for seed germination to produce healthy and vigorous seedlings, and for seedlings to grow into healthy plants.

In all propagation methods, the properties of the growth-medium determine the quality and quantity of water that will be available for uptake by the plant. A good medium is one that has a low salinity level, a good water holding capacity, which is the amount of water that the medium retains, of between 55% and 60%, and the ability to make water available and to allow lateral water movement.

In the case of germination, the seed – and seedling at a later stage – has to be kept in media wetted to field capacity, being the maximum amount of water that a particular soil can hold. The moisture level in the plant at the time of budding (grafting) is critical for the survival of the bud. A healthy and normal sap flow in the plant integrates the bud easily with the plant.

Chapter 1

- 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.

Complete activity 1 in the **Learner Workbook**.

Chapter 2

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

Identify appropriate propagation methods and applicable tools for specific agricultural production systems

1. Introduction

In this chapter, the various methods used in propagation are described, along with the tools that are required. The choice of methods depends on the propagator and his goals.

2. Means of Propagation

Plants are able to propagate in two ways, both of which are used in the commercial propagation of citrus plants. These means are through:

- Sexual propagation
- Asexual propagation

2.1. Sexual Propagation

Sexual propagation means that the male cells produced by the pollen, fertilises the female reproductive cells, called **ova** (singular: **ovum**) in the **ovule** and an **embryo** is formed, which is part of a **seed**. This is called plant **embryo genesis**, which literally means the creation of the embryo.

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.

When embryo genesis occurs naturally in the plant as a result of sexual fertilisation, the embryos are called **zygotic** embryos. The term zygotic embryo derives from the name for a fertilised ovum, which is called a **zygote**.

One zygotic embryo develops as a result of the fusion of the ovum inside the ovule with a male cell from the pollen. Each of these cells will have previously undergone **meiosis** and carry the genetic material of the parent plants. On fusion, the zygotic embryo contains the genes of both parents and is a hybrid between the two. The new plant will therefore have characteristics from both parent plants, and will be a completely unique new plant.

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.

The ovule develops into a seed, which germinates and give rise to a seedling. In the ovule, the embryo sac is contained within the **nucellus** which is surrounded by a membrane. The nucellus cells that surround the embryo are rich in various nutrients and plant growth regulator substances, often referred to as plant hormones. The nucellus acts as a nutritional source that sustains the initial embryo development.

In citrus, a somewhat unusual process occurs where some of the nucellar cells develop into **nucellar embryos**. The number can vary, with up to six nucellar embryos developing in some cultivars. These cells do not undergo meiosis and contain the full set of maternal chromosomes, meaning that the nucellar embryos are deemed to be the same as the mother plant. For this reason, seed can be used in the production of true-to-type rootstocks.

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.

2.2. Asexual Propagation

Asexual propagation is when plants are propagated not through seed, but through plant material. When a plant is propagated in this way it has exactly the same characteristics as the plant from which the material was taken. Plant cells are forced to divide and grow, in a process that is also referred to as **vegetative propagation** or **plant tissue culture**. The cells that are used are called **somatic cells**, which are physically formed cells derived from actual plant cells.

Plants are propagated asexually for the following reasons:

- Preserving the genetic characteristics of a particular plant.
- Propagating plants that do not produce viable seeds, such as bananas, pineapples, and seedless grapes.
- Propagating plants that produce seed that is difficult to germinate or has a very short storage life, such as cotoneaster and willow.
- Bypassing the juvenile stage of plant growth when the plants will not flower and bear fruit.

3. Methods of Propagation

The methods generally used to propagate plants commercially are:

- Seed propagation
- Vegetative propagation
- Tissue culture propagation

Citrus plant propagation most commonly makes use of a combination of two propagation methods, being seed propagation for producing the rootstock, and vegetative propagation using a scion of the required variety for the fruit producing part of the tree. This allows the propagator to make an exact copy of the parent plant, while retaining the advantages of growing plants from seeds, such as retaining a strong root system.

Grafting, and more specifically budding, is the technique most used for vegetative propagation of citrus.

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.

A plant part, or scion, is grafted onto the rootstock seedling. The scion then grows to form the fruit-producing part of the plant. The scion is taken from a plant of the variety of fruit that the grower eventually wishes to produce. The scion that is used in citrus propagation is a bud, or bud-eye, which is inserted into a cut on the seedling. The process is therefore referred to as budding. Remember that budding is a form of grafting, which is a form of vegetative propagation.

The advantages of this dual propagation method can be summed up as follows:

- ***Cultivar and Variety Development*** – Cultivars and varieties are developed and perfected over many years of breeding and selection, and have superior horticultural characteristics, such as the ability to produce fruit of high external and internal quality. These characteristics must be retained consistently during propagation, and vegetative propagation is more effective in this regard, because the new plant is an exact copy of the original plant.

- ***Adaptability to Soil*** – Citrus plants are grown in a variety of soil types. Certain traits of the plant determine its ability to survive and grow in less than ideal soil conditions, such as its rooting pattern, tolerance to salinity or acidity, drought tolerance, and pathogen (disease) resistance. These are the required traits of the rootstock, meaning that certain rootstocks are able to adapt better to soil conditions than others, and better than the plant of the actual cultivar or variety that is being grown.

- ***Genetic Segregation*** – With few exceptions, seeds do not produce true-to-type seedlings, meaning that seedlings are not identical in all aspects to the plant from which the seed was taken. A seed is formed from the pollen (male) from one plant and the ovum (female) of another plant, in other words two parents were involved, and both parents contribute characteristics to the embryo, or seed. Although there is a possibility that the seedling will have superior characteristics, more than likely it will be inferior.

- ***Prolonged Juvenility*** – Plants propagated through seed takes a longer time, from 5 to 8 years, to reach maturity and to bear fruit.

- ***Excessive Vigour and Thorniness*** – Plants propagated through seed grow too vigorously, and produce long and hard thorns.

3.1. Seed Propagation

Seed is the manner in which most plants propagate naturally, and has therefore always been the most common means of propagation. In citrus production, seed is used to produce rootstocks. A seedling, or seedlings, develop from a seed, which is then used as rootstock for the qualities that it transmits to the scion and ultimately to the fruit, and for its adaptability to the soil.

Seed propagation produces disease-free plants and represents a crucial stage in the production cycle. The process begins with seed germination, which is dependent on environmental factors as discussed in chapter 1, and on seed viability, meaning the ability of the seed to germinate and grow into a seedling.

Seeds used for rootstock come from a tree with known and desired qualities. Seed from common, edible citrus fruits, such as sweet orange, grapefruit or mandarin, can be used for growing rootstock plants at home, but are generally not recommended for commercial purposes.

Rootstock cultivars have been identified, or developed through breeding programs, which may not have edible fruit, but are excellent rootstock plants. There are many hundreds of selections, however for commercial purposes, only twenty to thirty are used worldwide. In Southern Africa the following rootstocks are most commonly used:

- Rough lemon
- Volckameriana
- Swingle Citrumelo
- Carrizo Citrange
- Troyer Citrange
- X639 (Cleopatra X P. Trifoliata)
- C-35
- MXT
- Yuma citrange
- Other lesser used varieties such as Rangpur lime, Sunki Beneke and Yuzu

In the table below, the characteristics of the most commonly used rootstock are listed.

	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
Phytophthora	Susceptible	Tolerant	Tolerant	Susceptible	Tolerant	Tolerant
Citrus nematodes	Susceptible	Tolerant	Susceptible	(Not known)	Tolerant	Tolerant
Soil Factor						
Poor drainage	Sensitive	Tolerant	Sensitive	Sensitive	Sensitive	Sensitive
High clay content	Sensitive	Intermediate	Intermediate	Sensitive	Tolerant	Intermediate
High sand content	Tolerant	Intermediate	Sensitive	Intermediate	Intermediate	Intermediate
High chlorides	Tolerant	Intermediate	Sensitive	Intermediate	Sensitive	Sensitive
High pH	Tolerant	Sensitive	Sensitive	Tolerant	Sensitive	Sensitive
Drought	Tolerant	Tolerant	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

	Rough-lemon	***Swingle Citrumelo***	***Carrizo Citrange***	***X639***	***C-35***	***MXT***
Fruit quality	Low	Good	Good	Good	High	High
Rind colour development	Intermediate	Late	Early	Early	Intermediate	Intermediate

Table 2.1: Characteristics of Rootstocks Commonly Used in Citrus Propagation
Adapted from Citrus Rootstocks: The Choice You Have – Louis A. Von Broembsen

Seeds can either be purchased from certified sources or the propagator can establish and maintain trees for rootstock seed production to assure uniformity of rootstocks year after year. For the survival of the industry certified sources are recommended, mainly because the seeds are guaranteed to be free from diseases and true-to-type.

Rootstock seeds are extracted from mature and ripe fruits. The simplest means of extraction is making a horizontal, shallow cut into the fruit, just deep enough to avoid cutting the seeds. Twist the two halves apart and collect the seeds by using an electric juicer. The seeds are separated from the accompanying pulp by repeated washing.

Large-scale operations make use of a crusher, which separates the seeds from the pulp, rag and peel by using jets of water. The crushed fruits can also be treated with pectinase enzymes at controlled temperatures, while constantly stirring. The enzyme treatment essentially digests the pulp, rag and peel, leaving the seeds intact.

Extracted seeds are surface-sterilised, air-dried and vacuum-packed for storage. Properly treated and packaged seeds can be stored in a refrigerator at 5°C for four to six months with little loss in viability.

Seed sizes vary, and the table below gives an indication of the number of seeds contained in a litre volume. Larger numbers indicate smaller seed size.

Cultivar	***Seeds per Litre***
Carrizo Citrange	2,600
Swingle Citrumelo	3,100
Roughlemon	5,600
Cleo x Trifoliate (x639)	4,800
Minneola x Trifoliate (MXT)	3,100
Yuma Citrange	4,000
Volckameriana	6,800

Table 2.2: Quantity Seeds per Volume

Seed germination is achieved through two major methods, being:

- Sand seedbeds in the open; and
- Germination trays in closed rooms

3.1.1. <u>Sand Seedbed Germination</u>

Seeds are planted in a sterile river-sand bed in the open, where they are watered regularly. After germination, seedlings are kept in the coarse river-sand until ready to be budded. Inferior plants are removed and only vigorous ones are selected for budding.

In other citrus-producing countries, such as the USA and Egypt, this practice is still in use, while it has been mostly phased out in South Africa where germination trays are commonly used.

3.1.2. Seed Germination Trays

Seed germination trays used for seedling production are first washed with clean water and then sterilised with a fungicide, such as copper oxychloride at 200g/100l.

Trays are filled to three-quarter level with a propagation media, normally vermiculite. Seeds are spread and arranged in such a way that all can germinate with as little obstruction as possible. When germination is obstructed, bench roots and other seedling malformation can occur. Germination takes place in a sterile room where high humidity and temperature can be maintained.

Certain seeds produce more than one, generally three, seedlings per seed. One of the seedlings is from the zygotic embryo, while the others are the nucellar, or **apomictic**, seedlings, which are exact copies of the mother-plant. Apomictic seedlings are of great significance in plant propagation, since they are the uniform and true-to-type seedlings. The vigour and freedom from viruses of apomictic seedlings are other superior traits.

Healthy seedlings with straight roots and a minimum of three differentiated leaves are transplanted into tubes or cavities where each seedling occupies a cavity.

Figure 2.1: Transplanting Seedlings

3.2. Vegetative Propagation

Grafting, in the form of budding, is the main method of vegetative propagation used on citrus around the world and in South Africa.

3.2.1. Budding

Budding is the method where the bud-eye, along with some bark is taken from a bud stick, referred to as bud-wood, and inserted into the rootstock seedling. The bud-wood, which forms the fruit bearing part of the tree, referred to as the scion, is cut from a plant of the selected fruit variety with desirable traits.

Budding is done when the bark of the rootstock is "slipping", meaning when the bark separates easily from the wood. The most appropriate period for budding in South African nurseries that use shade-houses is from end August to April. In the case of plants that are kept in greenhouses with a controlled environment, the bark slips anytime the plant is actively growing, which is practically year-round.

In commercial citrus propagation, bud-wood is obtained only from sources that are certified to be free of diseases, such as Tristeza and Exocortis. These sources are strictly managed and regularly tested and evaluated for presence of diseases. New sources of scion material are kept in quarantine to prevent the spread of diseases, from or to other citrus areas. The material is first 'cleaned' of all known diseases before being released for propagation purposes.

The procedure used for budding is as follows:

- Make an inverted T-cut into the bark on the stem of the rootstock.

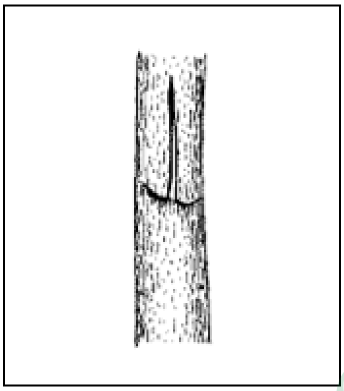


Figure 2.2: Inverted T-Cut on Stem of Seedling

- Cut a very thin slice of bark and a piece of wood beneath the bud evenly and smoothly from the bud-wood (scion material) with a knife.

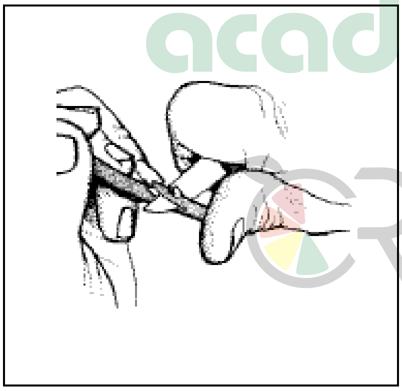


Figure 2.3: Cutting Bud-Wood

- Place the upper end of the bud piece beneath the bark flaps at the bottom of the inverted T-cut. Gently but firmly push it upward with the thumb.

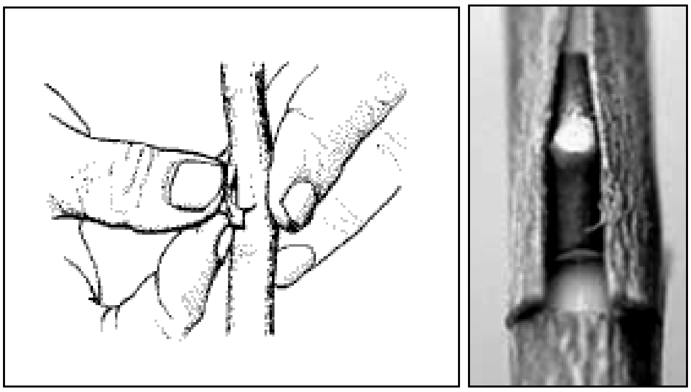


Figure 2.4: Inserting the Bud Piece

- Seal the join with a wrap (budding tape) to hold the bud firmly in place on the rootstock until union and healing of wounds is complete. The wrap will also prevent rain and irrigation water from entering the budding area, thereby reducing the risk of infection.

- Wrap the bud from below the incision, making several overlapping turns around the stem until the entire bud and incision are covered. Tuck the end of the tape beneath the last turn. Maintain firm pressure on the tape, but not so hard that it breaks. If the tape breaks it has to be removed and the wrapping started over again with a new strip.

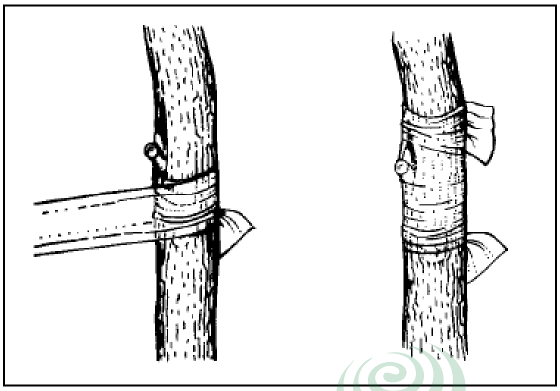


Figure 2.5: Wrapping the Budding Union

- After 15 to 20 days, when healing and union has occurred, remove the tape by making a vertical cut through it behind the budded area of the rootstock. A live bud will still be as green as it was when inserted, while a dead bud will look brown or blackish, meaning that it did not take. If the bud did not take, another spot on the rootstock is selected for re-budding.

- The growth energy of the seedling must now be directed to the green bud, forcing it to grow. The rootstock seedling is subjected to practises, such as looping or bending (gently bending the top of the rootstock above the union to tie it to itself) or topping (cutting off the seedling 5cm above the union) to direct all its energy into the bud. These practices break bud dormancy and force the bud to grow within one to three weeks.

Figure 2.6: Looping (left) and Topping (right)

- Other shoots that grow from the rootstock influence bud-growth. To reduce competition for food, trimming is done as soon as side-shoots are noticed on the rootstock.

- When the new scion shoot reaches 20cm to 25cm, insert a treated stake, such as a wooden cleat, a bamboo stick or twisted thick wire, alongside the plant extending 20cm into the medium and about 70cm above. Tie the plant to the stake for stability and directed growth. As the plant grows, it is continually tied up until it reaches the top of the stake.

Figure 2.7: Staked Trees

- When the plant reaches pencil-thickness at the top of the stake, it is topped to suppress apical dominance and to allow branching. The headed tree is ready to be planted.

Definition

Apical Dominance

Apical dominance refers to powerful tip growth that suppresses the growth of lateral buds.

Figure 2.8: Headed Trees Ready for Planting

Depending on the season, rootstock and scion type, the process from budding to ready for planting, takes about six to eight months.

Incompatibility between the rootstock and the scion is a possible problem that can occur. The selection of combinations has to be done taking this factor into account. In the table below the possible combinations for use in various climatic regions of Southern Africa are summarised.

Scion Cultivar	***Rough-lemon***	***Swingle Citrumelo***	***Carrizo Citrange***	***X639***	***C-35***	***MXT***	***Volka-Meriana***
Hot, Warm and Intermediate Areas **Hot / Warm areas:** Tshipise, Letsitele, Lower Letaba, Hoedspruit, Malelane, Swaziland Lowveld, Pongola, Nkwaleni **Intermediate areas:** Marble Hall, Nelspruit, Ngonini Swaziland, Karino, Barberton, White River, Letaba, Levubu							
Navels	X	√	√	√	√	√	X
Delta Valencia	X	√	√	√	√	√	X
Turkey Valencia	X	√	√	√	√	√	?
Benny Valencia	√	√	√	√	√	√	√
DuRoi Valencia	√	√	√	√	√	√	√
Rose Grapefruit	X	√	√	√	√	√	X
Star Ruby Grapefruit	X	√	√	√	√	√	X
Eureka Lemon	√	X	X	√	X	√	√
Bears Lime	√	√	√	?	?	?	?
Clementine	X	√	√	√	√	√	X
Empress Mandarin	X	√	√	√	√	√	X
Cool and Cold Areas **Cold areas:** Eastern Cape Midlands, Gamtoos Valley, Sundays River Valley, Amanzi, Western Cape, Central KZN Midlands **Cool areas:** Rustenburg, Potgietersrust (Modimole), Lydenburg, Zebediella							
Navels	√	√	√	√	√	√	√
Delta Valencia	√	√	√	√	√	√	√
Turkey Valencia	X	√	√	√	√	√	?
Benny Valencia	√	√	√	√	√	√	√
DuRoi Valencia	√	√	√	√	√	√	√
Rose Grapefruit	X	√	√	√	√	√	X
Star Ruby Grapefruit	X	√	√	√	√	√	X
Eureka Lemon	√	X	X	√	X	√	√
Bears Lime	√	√	√	?	?	?	?
Clementine	X	√	√	√	√	√	X
Empress Mandarin	√	√	√	√	√	√	√

Table 2.3: Scion and Rootstock Combinations
Adapted from Citrus Rootstocks: The Choice You Have – Louis A. Von Broembsen

Note that apart from incompatibility, certain rootstocks may be suitable with certain varieties only in certain areas, but not in others. For example, navels on Rough Lemon rootstock are not suitable in the hot areas of Southern Africa, as the internal quality and rind colour development is poor, while in the cooler and cold areas this does not present a problem.

Sometimes cultivar change is required on older citrus trees in orchards. This procedure is referred to as top-working and involves grafting a scion of a new cultivar onto the existing trees.

3.2.2. Cuttings

Citrus propagation by cuttings is not common in commercial nurseries. However, it is another method that produces true-to-type trees of high quality.

Cuttings are only propagated in a controlled environment where humidity levels are between 80% and 95%, and not uncommonly at 100%. Required temperatures for successful propagation through this method are between 27°C and 32°C.

A section of the plant is cut either from the rootstock seedling or the scion variety, treated in a fungicide mix (Captab and Benlate) and the end dipped in a growth hormone, for example Seradix B. The cutting is then planted in a growth-medium for rooting. Two weeks later rooting takes place and the rooted cutting can be transferred to a hardening-off area after six weeks.

The disadvantage of this method is that it is management intensive and requires expensive structures and high-tech equipment.

3.2.3. 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. There is a lag time between the movements of viruses in plant cells compared to the speed of cells dividing in plants. This means that new cells, particularly in the meristem of new buds, are able to be removed before viruses reach them. One is therefore able to graft the virus free portion of the meristem of a bud onto a virus free rootstock, thus producing 'clean' plant material for commercial propagation.

3.3. Tissue Culture Propagation

Tissue culture propagation, also called micro-propagation, refers to procedures used to maintain and grow plants aseptically in an in-vitro culture. This is when plant cells are removed from an existing plant and new plants are grown from these cells in a controlled laboratory environment. This method is generally not used by commercial nurseries as techniques discussed above have proved adequate and economically viable.

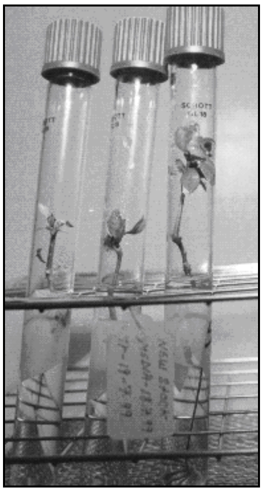


Figure 2.9: Rooted and Budded Rootstock in Test Tubes

Although producing a superior plant compared to those propagated by means of seedlings, tissue culture is used only for the production of a pathogen free plant material. The limiting factor is the costs associated with establishing and running such facilities.

4. Propagation Tools

The following tools are used in the propagation methods described above:

- ***Budding Knife*** – A razor sharp knife used to make cuts on the seedlings and to cut off the bud-eye. The knife must always be sharp and in a good working condition to prevent tissue damage to the plant when cutting through it. If tissue damage occurs, the graft will most likely fail.

- ***Budding Tape*** – Clear polyethylene strips, used to maximise contact between the bud and the rootstock until the union and the healing is complete. It also prevents drying and excess water from getting in and rotting the bud.

- ***Pruning Shears*** – Bud-wood is cut using pruning shears. Pruning shears are also used where cuttings are used for propagation.

- ***Sharpening Stone*** – All blades become blunt with use and require periodic sharpening. A sharpening stone, or wet stone, and honing oil are required.

- ***Sterilisation Liquid*** – Knives and shears must be periodically cleaned and sterilised properly with a solution of 10% bleach (Jik).

5. Sanitation

The propagation of a citrus tree, most commonly, begins with raising a seedling to be used as rootstock. At this stage, the plant is at a vulnerable stage. Germination takes place in a warm and humid environment that is also conducive to the development and growth of pathogens that cause diseases. The most common pathogens are Phytophthora that cause root rot, and pythium, that causes damping-off.

To prevent the infection by pathogens, sanitation and sterilisation is essential.

Seeds may be an entry point for diseases, and the propagator must ensure that they are treated with fungicides. The standard treatment as recommended by the South African Citrus Improvement Programme (CIP) is as follows:

- Heat treat seeds in water at 51.5°C for 10 minutes
- Dip seeds in 8-hydroxy-quinoline sulphate (1% a.i.) for 5 to 10 minutes
- Surface dry the seeds slowly in a cool, shaded location
- Vacuum-pack the seeds in plastic bags and store at 5°C

Although seed treatment reduces the possibility of infections, infected fruits should be avoided when collecting seeds. Only healthy fruit still hanging on the tree are to be used, as rotten fruit and fruit lying on the ground might carry brown rot (Phytophthora) and contaminate the medium.

Sanitation treatment is extended to the media used, the containers, floors and benches. Propagation media, such as perlite and vermiculite, are sterile and classified as very low-risk by virtue of the temperatures they are subjected to during their processing.

For budding and cuttings, sterilisation of pruning shears and budding knives ensures that the propagation material remains virus-free. Sterilisation is accomplished by cleaning tools thoroughly with clean water and wiping the blades with a solution of 10% chlorine bleach (Jik). The solution should not be kept for more than five hours. A wetted cotton swab kept in a capsule is used to periodically treat propagation tools during nursery operations. Budding tools should be sterilised every time varieties are changed.

Because the bleach solution (Jik) is corrosive to most metals, sterilised tools must be rinsed in clean tap water, dried thoroughly and given a light coating of protective oil at the end of the day to prevent rust. A mixture consisting of 390ml clean tap water, 100ml clear vinegar, and 10ml oil provides long-term protection from rust. Blunt knives and pruning shears must be sharpened using a sharpening stone.

Chapter 2

- 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.

Complete activity 2 in the **Learner Workbook**.

Chapter 3

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

Distinguish between successful and unsuccessful propagation under specific agricultural production contexts

1. Introduction

Propagation is an important process in citrus production, and its success is determined by the end-result. The Citrus Improvement Programs (CIP) has set standards for trees sold by nurseries in South Africa. Accredited nurseries produce trees that comply with these standards and any trees that do not meet these requirements, are considered substandard.

2. Indicators of Successful Propagation

- ***Trueness-to-Type*** – The horticultural traits of the plant and particularly the fruit, such as yield, shape, size and internal quality, should be identical to those of the mother plant in a given environment.
- ***Freedom from Pathogens and Pests*** – Viruses, bacteria and certain pests are a threat to the survival of the citrus industry and must not be present in propagated plant material. Once a plant has been infected, the pathogen may become part of the plant, which could then spread to adjacent plants or orchards. From the orchards it could spread to adjacent farms and later on to other production regions. Propagating plant material from an accredited source will ensure success.
- ***Healthy Plants*** – The young nursery tree should have a healthy root system free of root diseases such as Phytophthora. The stem should be straight with no rootstock side-shoots. The leaves should be green indicating a good nutritional status.

The South African citrus industry, through the Citrus Improvement Programme (CIP), has the responsibility of ensuring that plant material complies with all of the above criteria. The Citrus Foundation Block (CFB) near Uitenhague in the Eastern Cape is the single site where all propagation material is produced, and from where it is supplied to accredited citrus nurseries in South Africa. Any movement of plant material outside of this scheme is illegal and is regulated by the Department of Agriculture, Forestry and Fisheries.

3. Indicators of Unsuccessful Propagation

Failure to produce trees that meet set standards is a potential source of conflict between the propagator and the citrus farmer, who may suffer financial loss as a result.

Although not common, mutant expressions, such as fruit and / or leaf variegations and fruit deformation, are deviations from the desired traits.

Dead buds, diseased plants, mixed cultivars, and inferior plants are the main indicators of unsuccessful propagation.

Unsuccessful propagation indicators are not to be viewed from a completely negative perspective. Cultivar development and improvement programs around the world have made use of some of these deviations to produce new cultivars. The known source of Bennie Valencia orange is a case in point. Standing in the middle of a late Valencia orchard, these trees expressed traits that are different to the surrounding trees. Fruits had a rounder shape, a sweeter taste, a thicker rind, were bigger in size and juicier, and matured earlier. Subsequently, a new variety was developed.

4. Environmental Factors for Successful Propagation

Good and rapid growth is important for both the propagator (nurseryman) and the fruit producer (farmer) since trees are brought to bear fruit sooner. To produce such a tree, environmental conditions must be regulated.

The environmental conditions described in chapter 1 must be maintained to ensure successful propagations of healthy, disease-free, and true-to-type plants.

Summary

Chapter 3

- 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.

Practical

Complete activities 3 and 4 in the **Learner Workbook**.

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