Contents of Module 1

Introduction to Citrus Production

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.

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.

definition

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

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.

The Citrus Industry in Southern Africa

Citrus has been exported from South Africa for more than 100 years. The industry has a long and successful history of constant growth, innovation and forward thinking.

The Citrus Growers Association of Southern Africa (CGA) represents the growers of export citrus in South Africa, Swaziland and Zimbabwe. The CGA was established in 1998 to bring cohesion back into the citrus industry after deregulation. The CGA has the responsibility of looking after research, market access and development, information, transformation and logistics on behalf of citrus growers, who pay them a levy on every carton of export citrus to fund these activities.

Citrus Research International (CRI) is a subsidiary of the CGA that looks after citrus research. The CRI manages the Citrus Improvement Scheme, which is discussed in more detail in a later section of this guide.

The CGA represents citrus growers spread over nineteen production regions in Southern Africa, covering a wide variety of climatic and geographical areas. Citrus is grown commercially in seven of the nine provinces in South Africa, with the Free State and Gauteng being the only exceptions.

Since 2006, South Africa has been the second largest exporter of fresh citrus in the world, after Spain, although it is only the 12th largest producer in the world. Southern African oranges, grapefruit, lemons and soft citrus is exported to more than sixty countries worldwide, and total foreign exchange earnings reached R4.8 billion in 2007/2008 (July to June). If wine is counted as an agricultural product, citrus is the second biggest agricultural foreign exchange earner, only just behind wine that stands at R5.2 billion. The fresh fruit sector earned a total of R10.2 billion in foreign exchange in this period, which is a third of export earnings for all agricultural products.

Since 2007 the total number of citrus export cartons (15kg equivalent) has been touching the 90 million mark. Of the about 2 million tons of citrus produced in Southern Africa annually, around 69% is exported, 7% is processed (mostly as fruit juice), and the remaining 24% is sold on the local fresh produce markets.

In 2008, more or less 56,000ha was under citrus production, divided into about 1,750 production units. There are about 350 commercial citrus packhouses around the country. The citrus industry directly employs about 60,000 workers, of which around 25% is in permanent positions. It is estimated that the industry supports the livelihood of about 1 million Southern Africans.

practical

Activity 1.1 – Worksheet

Answer the following questions after reading the information above, and speaking to the nursery manager or your workplace mentor or coach:

- ✓ Citrus is not indigenous to Southern Africa. Where does citrus originally come from?
- ✓ If citrus trees are not indigenous, why are they propagated and grown in South Africa?
- ✓ In which geographical area of Southern Africa are you located?
- ✓ Does citrus grow well as an agricultural crop in this area? Give reasons why.
- ✓ Does each citrus farm in your geographical area propagate its own citrus trees? If not, where do the new trees come from?

summary

Introduction to Citrus Production

- Citrus originates from the subtropical regions of south-east Asia.
- Citrus production is largely concerned with management of the practices and processes that manipulate the tree to produce high yields of marketable fruit.
- Trees take three or more years before bearing fruit that can be marketed, after which yields steadily increase to 40 to 70 t/ha, depending on cultivar and variety, after a further 4 to 7 years.
- 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.
- The Citrus Growers Association (CGA) represents all the export citrus farmers in Southern Africa.
- Citrus Research International (CRI) is a subsidiary of the CGA that takes care of research in the industry and that is responsible for the Citrus Improvement Scheme.
- The CGA represents citrus growers spread over nineteen production regions in Southern Africa.
- There are about 1,750 citrus production units and 350 packhouses that employ around 60,000 permanent and temporary workers.

Introduction to Citrus Propagation

Introduction

information

PLEASE NOTE

Scientific terms are used and explained in this learning material. It is important that you learn these terms, as they are used to refer to the various plant parts, processes, and other concepts in the rest of this program. A glossary of these terms is provided as an addendum to the program for easy reference.

definition

Propagation

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

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.

Means of Propagation

Plants are able to propagate (reproduce) in two ways, both of which are used in the commercial propagation of citrus plants, being through:

- Sexual propagation
- Asexual propagation

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 (genesis) of a plant embryo.

definition

Ovule

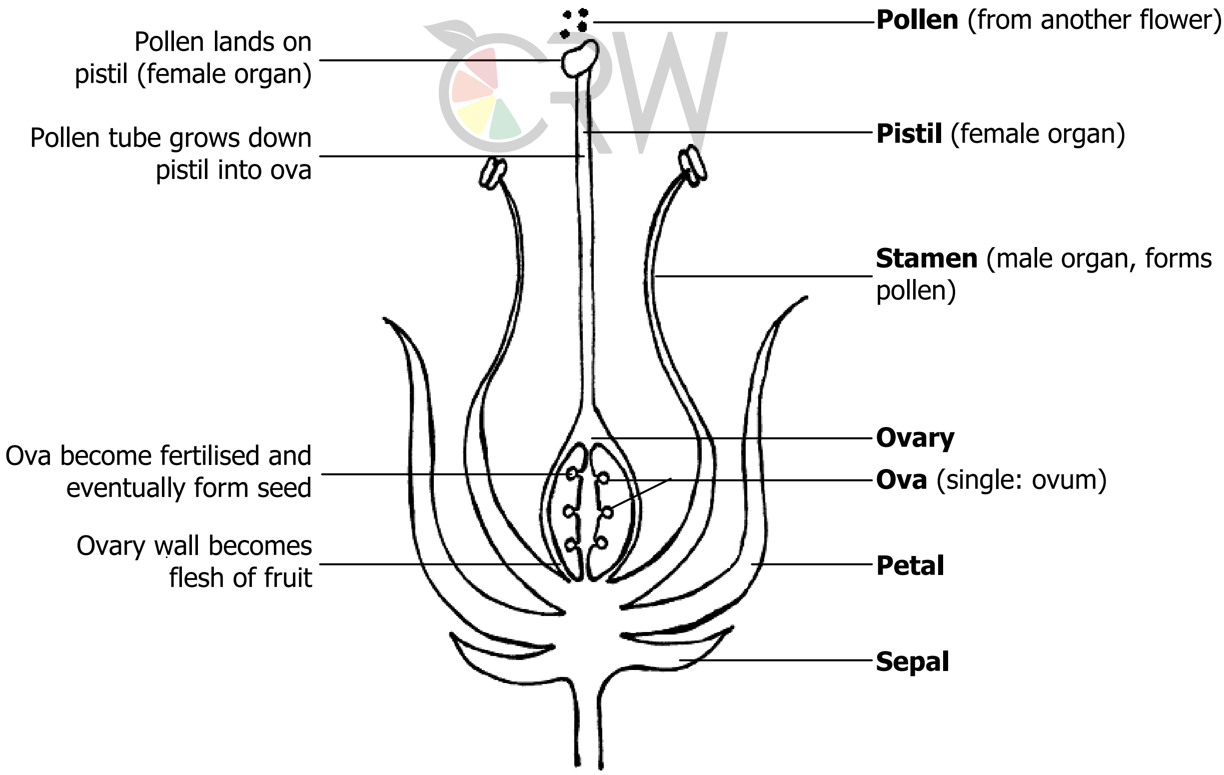
The ovule is a small structure inside the ovary of a seed plant that contains the female reproductive cells inside the embryo sac, and which develops into a seed after fertilisation.

Embryo

The embryo is an organism in its earliest stage of development before it becomes self-supporting. Once the plant 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' 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.



definition

Meiosis

Meiosis is a process in organisms that reproduce sexually during which the cell nucleus divides into four nuclei, each of which contains half the usual number of chromosomes.

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 initial embryo development.

Asexual Propagation

Asexual propagation is when plants are propagated not through seed, but through existing 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.

This process is also referred to as vegetative propagation or plant tissue culture. Plant cells are forced to divide and grow during vegetative propagation. These cells 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
- If the plant does not produce viable seeds, such as bananas, pineapples, and seedless grapes
- If the plant produces seed that is difficult to germinate or has a very short storage lifespan, such as cotoneaster and willow
- Bypassing the juvenile stage of plant growth when the plants will not flower and bear fruit

Methods of Propagation

The methods generally used to propagate plants commercially are:

- Seed propagation
- Vegetative propagation
- Tissue culture propagation

Seed Propagation

Seed is the means by which most plants propagate naturally, and has therefore always been the most common means of commercial 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 growth medium.

definition

Rootstock

Rootstock means the root or part of a root used for plant propagation.

Vegetative Propagation

The three main forms of vegetative propagation are:

- Grafting (budding)
- Cuttings
- Shoot tip grafting

Grafting (Budding)

definition

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.

Budding is the method where the bud-eye, along with some bark, is taken from a bud stick, referred to as budwood, and inserted into the rootstock seedling. The budwood, 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.

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 trees in an existing orchard.

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.

A section of the plant is cut either from the rootstock seedling or the scion variety, treated in a fungicide mix and the end dipped in a growth hormone. The cutting is then planted in a growth-medium for rooting, which takes about two weeks. The rooted cutting is transferred to a hardening-off area after six weeks.

This method is not used for commercial propagation because it is management intensive and requires expensive structures and high-tech equipment.

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 speed at which viruses move in plant cells and the speed at which the plant cells divide. This means that new cells can be removed and used for propagation 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.

This method is used only in the laboratory at the very start of developing a new cultivar to ensure that the first budwood is free from viruses. It is not used to propagate plant material commercially, but only to ensure that you have budwood that is free from viruses to start commercial propagation. Shoot tip grafting is used at the laboratories of the Agricultural Research Council and Citrus Research International in Nelspruit.

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 citrus nurseries as techniques discussed above have proved adequate and economically viable. The limiting factor with tissue culture propagation is the costs associated with establishing and running such facilities.

Citrus 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, mostly in the form of budding, where a scion of the required variety for the fruit producing part of the tree is used. 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. This is known as **dual** propagation.

Grafting, and more specifically budding, is the technique most used for vegetative propagation of citrus. 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 rootstock seedling. The process is therefore referred to as budding.

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, to produce plants with 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.
- **Prolonged juvenility** – Plants propagated through seed takes a longer time, from 5 to 8 years, to reach maturity and to bear fruit. Using the dual method of propagation results in trees coming into production sooner. Juvenility is excessive vigour and thorniness, meaning that plants grow too vigorously and produce long and hard thorns if propagated through seed.

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 good nutritional status.

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.

Dead buds, diseased plants, mixed cultivars, and inferior plants are the main indicators of unsuccessful propagation. Although not common, mutant expressions, such as fruit and / or leaf variegations and fruit deformation, also occur as deviations from the desired traits.

practical

Activity 1.2 – Workplace Interview

Interview a workplace expert, and ask them to explain the following. Record the answers in your own words to reflect your understanding.

- ✓ How does tissue culture work?
- ✓ Is tissue culture applied in citrus propagation? How?

Activity 1.3 – Workplace Observation and Flow Diagram

Observe the dual method of propagating citrus in the workplace, and ask mentors and coaches to explain the methods and processes to you. Draw a flow diagram showing the sequential actions that are required during the dual methods of citrus propagation. Ensure that you indicate the time periods that lapse in between different actions on your flow chart.

Activity 1.4 – Mind Map

Draw a simple mind map to explain to a new team member how you know whether propagation of a citrus tree is successful or unsuccessful.

summary

Introduction to Citrus Propagation

- Plants can propagate through sexual and asexual means.
- Sexual propagation makes use of seeds, while asexual propagation makes use of other plant parts.
- In citrus, seed propagation and vegetative propagation is used together to produce new plants.
- Seeds from specific cultivars with desired qualities are used for producing rootstocks.
- 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.
- 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.
- 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.

The Citrus Plant

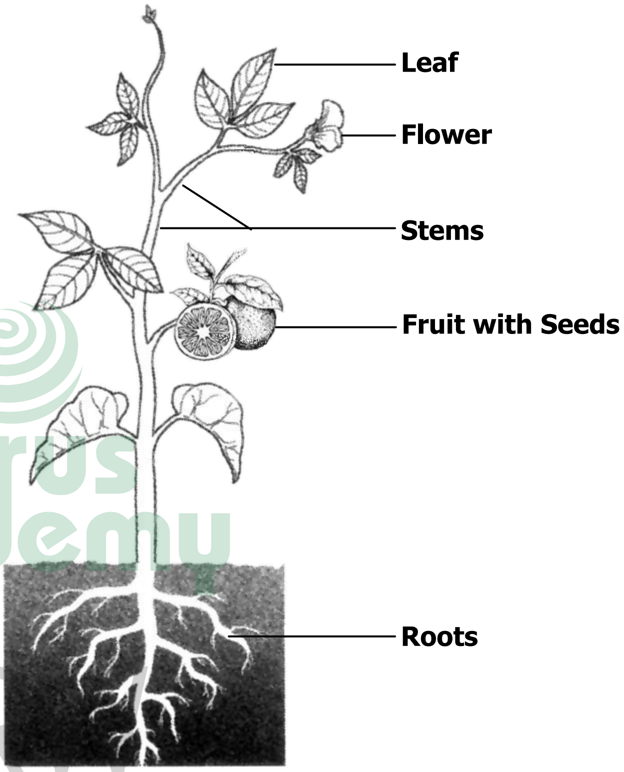
Introduction

Understanding the structures of plants (plant anatomy), and the functions of plants (plant physiology) enables us to understand what plants need to grow optimally. It also makes it possible to understand what can go wrong in the growth of a plant and how to prevent damage to a plant.

Plant Structures

Most plants are made up of the following parts:

- Seeds
- Roots
- Stems and trunks
- Leaves
- Flowers
- Fruit



practical

Activity 1.5 – Experiential Learning

Go outside and find a weed. Try to keep it intact, including its roots, leaves, flowers and possibly seeds. Paste the weed in your workbook and label the plant parts.

Functions of Seeds

The seed is the starting point of a plant. The seed already contains specific parts that later develop into parts of the plant, such as a radicle that later develops into the roots of a plant. Once all of these parts have developed from the seed, the plant is able to grow and perform certain processes that enable it to produce fruit, which contains more seeds.

Every plant has a unique seed, meaning that the seed of every plant is different from those of other plants. Seeds can be tiny, such as those of certain types of garden flower plants, or they can be large, such as the red seeds of a cycad plant. They can be sticky, so that they will stick to the coats or paws of animals, or they can be light and winged, so that the wind can carry them.

Functions of Roots

Roots are typically at the bottom end of a plant. Roots possess a root cap, have no nodes, and never bear leaves or flowers directly. In some plants roots may be used as scions in asexual propagation. The principal functions of roots are to:

- Absorb nutrients and moisture
- Anchor the plant in the growth medium
- Furnish physical support for the stem
- Serve as food storage organs

The citrus tree has a tap root system, consisting of a substantial tap root and a number of lateral or side-roots that grow horizontally. The root system is relatively shallow, growing only to the depth of 30cm to 60cm. The lateral roots constitute the majority of the root system. These feeding roots are the end ramifications of the root system and are usually fibrous. Active growth of the roots is cyclical, with growth taking place when the shoots are not actively growing. In citrus, there are usually three or more growth flushes per year.

Functions of Trunks and Stems

Stems are structures which support buds and leaves and serve as conduits for carrying water, minerals, and sugars. The three major internal parts of a stem are the **xylem**, **phloem**, and **cambium**. The xylem and phloem are the major components of a plant's **vascular** system. The vascular system transports food, water and minerals.

Above ground, the citrus tree consists of a main stem, or trunk, from which branches develop, which in turn develop a number of further and smaller branches, on which the leaves are borne. The citrus tree is therefore a complex, branched tree. This growth habit has implications for production practices.

Citrus trees have thorns, especially juvenile trees and certain groups, such as lemons. Thorns are modified stems, formed in the axils of leaves. Initially, the citrus tree grows from the apical bud, but soon begins to produce **lateral meristems**, commonly known as buds, in the axils of the leaves, and the branching starts with increasing complexity as the tree ages.

Functions of Leaves

The principal function of leaves is to absorb sunlight for the manufacturing of plant sugars through a process called **photosynthesis**. Leaves have a flattened surface so that a large area is available for efficient absorption of light energy.

definition

Photosynthesis

Photosynthesis literally means production through light (photo=light, synthesis=production) and is the metabolic process by which green plants turn carbon dioxide and water into food using energy obtained from sunlight.

Metabolism (Metabolic Processes)

Metabolism, or metabolic processes, means the ongoing series of chemical interactions that take place in every living organism that provides the energy and nutrients to sustain life.

Citrus trees are evergreen, but leaves live only for about three years depending on conditions. During early leaf growth, the leaves are net importers of carbohydrates, becoming contributors only once fully expanded at four to six weeks old. They reach maximum capacity after about six months.

Functions of Flowers

Plants have flowers of many different shapes and sizes, with many variations in shape, number of flower parts and the arrangements of these parts. On fruit producing plants, such as citrus, flowers are also referred to as blossoms. Flowers are the reproductive parts of plants and are responsible for the production of sex cells. After fusion of the male and female sex cells a zygote is produced, which develops into an embryo within the seed. The seed gives rise to a new flowering plant of the same kind.

Functions of Fruit

The fruit develops from the ovary contained in the flower. The fruit normally contains seeds that contain zygotic embryos. The fruit protects the seeds and helps them to disperse.

practical

Activity 1.6 – Write Key Notes

Use the plant that you pasted in activity 1.5, and write key notes next to each label explaining the function of the plant part. Make sure you refer to:

- ✓ Seeds
- ✓ Fruit
- ✓ Roots
- ✓ Stems or trunks
- ✓ Leaves
- ✓ Flowers

Citrus Phenology

definition

Phenology

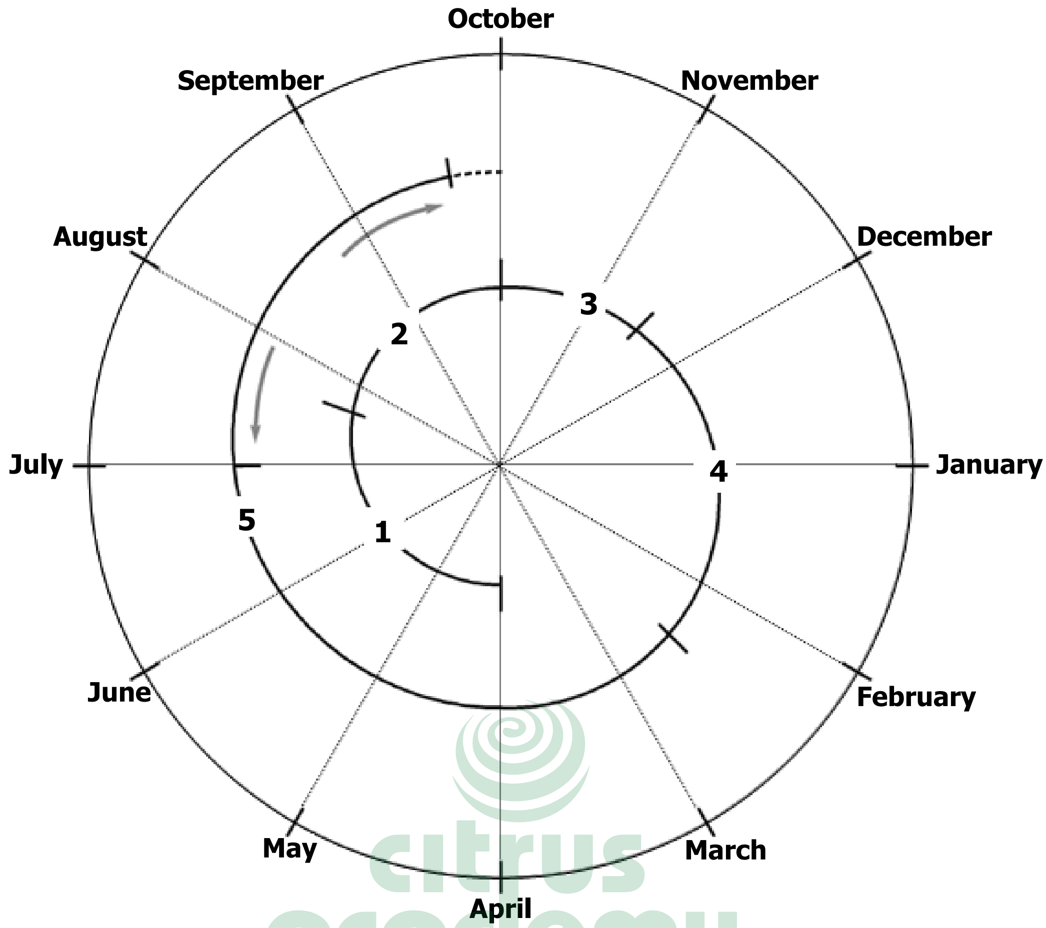
Phenology refers to regularly recurring biological phenomena and the environmental and climatic factors that influence them. In citrus, phenology refers to the annual cycle of the citrus tree.

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 table and figure 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. Phenology differs between cultivars.

It is important to note the term citrus season refers to the period from when flower initiation begins to th`e 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.

Stage		Description	Time period
1	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
2	Flowering	Flowering or 'bloom' is when blossoms appear on the tree.	August to Mid-September
3	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
4	Cell enlargement and fruit growth	Cell enlargement is the period during which cells making up the fruit increase in size, which results in the fruit growing and developing.	December to Mid-February
5	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
6	Harvest		July to September



summary

The Citrus Plant

- Most plants are made up of seeds, roots, stems and trunks, leaves, flowers, and fruit.
- The seed is the starting point of a plant. Every plant has a unique seed, meaning that the seed of every plant is different from those of other plants.
- Seeds are produced through sexual propagation and are made up of two parts, being a seed coat and a zygotic embryo.
- The principal functions of roots are to absorb nutrients and moisture, anchor the plant in the growth medium, furnish physical support for the stem, and serve as food storage organs.
- Stems are structures which support buds and leaves and serve as conduits for carrying water, minerals, and sugars.
- The principal function of leaves is to absorb sunlight for the manufacturing of plant sugars through a process called photosynthesis.
- Flowers are the reproductive parts of plants and are responsible for the production of sex cells.
- The fruit normally contains the seeds and its main purpose is to protect the seeds and help them to disperse.

- Phenology refers to regularly recurring biological phenomena and the environmental and climatic factors that influence them.
- Understanding the phenology of the citrus tree is essential to understanding the reasoning behind many of the practices and actions employed in citrus production.
- In a valencia citrus tree, the following stages occur during these time periods:
  - Flower induction and initiation – May to July
  - Flowering – August to Mid-September
  - Cell division and fruit set – Mid-September to November
  - Cell enlargement and fruit growth – December to Mid-February
  - Fruit maturation and further fruit growth – Mid-February to September
  - Harvest – July to September
- The citrus season refers to the period from when flower initiation begins to the harvest.

Citrus Propagation Media

Introduction

Growth media refer to the soil or other substances that are used to grow plants in. Various types of growth media are used in commercial citrus nurseries, including soil-less media, such as pine bark, commonly used for container-grown seedlings in South Africa. Most plants need some sort of growth medium to:

- **Stay upright** – Plants anchor in the growth medium with their roots. Their roots must be able to go deep into the medium.
- **Get nutrients** – Plants absorb food (nutrients) from the growth medium through their roots. Plants can also absorb nutrients through their leaves (foliage), but most often they use their roots.
- **Get water** – Most plants take up or absorb water through their roots from the growth medium.
- **Get oxygen and carbon dioxide (air)** – The roots of a plant, like the rest of the plant above the growth medium, also need to 'breathe', and the air that the roots need is taken up from the growth medium.

Growth media are made up of minerals, air spaces, water and organic material. The physical and chemical properties of growth media are determined by the concentration, form and ratios of these components. The ability of roots to grow, take up nutrients and water, and 'breathe' is influenced by the properties of the growth medium.

It is very important that one develop a thorough understanding of growth medium properties and so that one can work out what kind of growth medium will:

- Allow citrus plants to take up nutrients and air most effectively
- Best allow the roots of citrus plants to penetrate to an optimal depth
- Best allow ample aeration for the roots
- Absorb enough water that the roots can access without much effort
- Allow the ample draining of excess water most efficiently

Physical Growth Medium Properties

Generally, physical soil properties refer to the texture, structure, depth, stratification and aeration. In citrus production, soil depth and stratification are also of importance, but these factors are controlled in the nursery and are therefore not discussed here. Physical growth medium properties that are of importance in the nursery environment are as follows:

- Texture
- Structure
- Aeration
- Air-filled porosity

Texture

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
- Enough solid particles to anchor the roots

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 growth medium less permeable and therefore impeding the movement of roots and water.

Growth media 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.

definition

Water Holding Capacity

The water holding capacity of a growth medium is the volume of water retained just after is has been saturated with water and allowed to drain freely.

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.

Therefore, if the water holding capacity of a growth medium is too high, the root respiration can be impaired and leaching is made more difficult, because larger volumes of irrigation water are required. If the water holding capacity is too low, it is necessary to irrigated more frequently to keep roots from drying out.

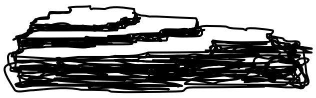
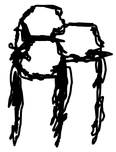
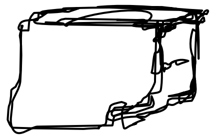
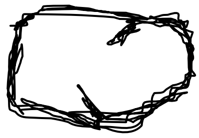
definition

Respiration

Respiration is an energy-producing oxidation process in cells, the complete chemical and physical process in which oxygen is delivered to plant cells and carbon dioxide and water are given off. The plant takes up oxygen (O_2) and releases carbon dioxide (CO_2).

Structure

The structure of the growth medium refers to the manner in which the particles that make up the growth medium, including organic material, are arranged to form structural units. The structural units are named according to their physical appearance, as described in the following table.

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

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

Aeration

Oxygen is essential to healthy root activity, and it is important that it is available in sufficient volumes. Plant roots 'breathe' (respirate), which means using oxygen and excreting carbon dioxide, and a constant replenishment of the air in the growth medium is required. The rate at which air moves through growth medium depends on factors such as pore-size, which in turn depends on the texture and structure of the growth medium.

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

definition

Field Water Capacity (FWC)

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

Air-Filled Porosity (AFP)

definition

Air-Filled Porosity

The air-filled porosity of a growth medium is the percentage of its volume that contains air after it has been saturated with water and allowed to drain. It is a measure of how much air is available to the roots and is therefore an excellent measure of determining the suitability of the physical properties of a growth medium.

After a growth medium is saturated with water and drainage has ceased, there is a portion of the pore-space occupied by air. This is referred to as the air-filled porosity (AFP).

In field growth media and sand seedbeds, AFP values of 5% or more are usually considered favourable. In container media, AFP values of 15% to 25% are desirable, while citrus is propagated best in media with porosity ranging from 14% to 20%. If the AFP of a growth media is correct, all other physical properties should be acceptable.

Chemical Growth Medium Properties

Chemical growth medium 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. The most relevant chemical properties of growth media are:

- pH
- Resistance or electrical conductivity
- Salinity
- Fertility level
- Cation exchange capacity
- Organic matter

pH

definition

pH

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

Growth medium pH is essential since it affects the availability of nutrients for uptake by plant roots. 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.

Electrical Conductivity and Resistance

definition

Electrical Conductivity

Electrical conductivity refers to the ability of any substance, such as water or growth medium paste, to conduct an electrical current. It can be expressed in various units, with the international standard unit being Siemen.

Resistance

Resistance is the opposite of electrical conductivity and refers to the resistance of a substance, such as water or growth medium paste, to conducting an electrical current. Resistance is expressed in ohms.

Salts

Salts not only refer to table salt (sodium chloride), but any compound of acids and bases, such as calcium sulphate, potassium nitrate, magnesium chloride, etc. In these salts, the calcium, potassium and magnesium are **bases**, and the salts are formed when **acids** like sulphuric acid, nitric acid and hydrochloric acid are added.

The resistance of growth medium is important because it is an indication of the total dissolved salts (TDS) in the growth medium solution. Measuring resistance is a quick method of measuring the electrical conductivity (EC) of the growth medium.

Salinity

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 growth medium alkaline.

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

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.

Fertility Level

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

Not having enough plant nutrients in the growth medium is less of a problem in commercial agriculture than having too much. It is quite easy and fairly cheap to add nutrient elements to the growth medium. It is however seldom easy and cheap, if possible at all, to remove excess nutrients or to correct huge imbalances.

Cation Exchange Capacity (CEC)

information

Cation Exchange Capacity (CEC)

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

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

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

Organic Matter

Organic matter in growth media ranges from dead plant and animal material, organic debris, microbial debris and all stages of humus.

Humus is processed and condensed organic matter and it takes thousands of years to reach a stable form. Humus contributes to the activity in growth media and consists of humus acid (or humates, the salts of humic acids), fulvic acid (or fulvates, the salts of fulvic acid) and humins (a very stable form).

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 state.

Types of Citrus Growth Media

The success or failure of a propagation activity can be influenced by the medium used and how this medium is handled. The quality of the materials used to formulate growth media is very important. The growth medium must:

- Be consistent in quality
- Be free from all pathogens
- Provide an appropriate balance between air and water in the medium

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

Different media are available for citrus propagation, ranging from natural coarse river sand to exfoliated vermiculite, which are available in fine, medium and coarse grade. The choice of the growth medium is determined by the propagation method and the economics of the particular media.

The most commonly used media in the South African citrus industry is composted pine bark, followed by coarse river sand. While seeds are germinated in medium grade vermiculite, most of the roots are developed in pine bark.

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, 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.

Other media is also used either on its own or mixed in proportions that allow optimum root development. One can consider using sawdust, peanut shell, river sand, composted organic material, shredded coconut fibre, peat moss, sedge peat, composted sawdust, perlite, rockwool, and ash. However, it is crucial that the chemical and physical properties of the growth medium are determined and that the medium is free from harmful pathogens.

Propagators of citrus trees in different parts of the world make use of mixtures to form the final growth medium for the plants to be raised in. In Australia for instance propagators frequently use mixtures of peat and sand constituents for raising trees, such as 3 parts peat and 1 part sand or 1 part peat and 1 part sand. In Egypt mixes of 1 part sand, 1 part sawdust and 1 part peat have been used successfully.

Growth Media Treatments

The best and most economic way of sterilising growth media is through steam sterilisation. The bark is treated with hot steam, produced by boiling water. Chemical fumigation, using for instance methyl bromide, is also still used in some nurseries, but it is not the recommended method of sterilisation.

practical

Activity 1.7 – Workplace Research

Find a small sample of the growth medium (or samples of media if more than one is used), in your nursery. Put it in a plastic bag, and paste it in your workbook. Give it a rating out of 3 (1=poor, 2=average and 3=good) for each of the following properties. Explain the reason for your rating.

- ✓ Texture
- ✓ Structure
- ✓ Aeration
- ✓ Air-filled porosity

Activity 1.8 – Interview an Expert

Ask a workplace expert or mentor / coach to explain the different types of growth media used for citrus and other types of plants that might be propagated at your nursery. Write keynotes on their answer.

Activity 1.9 – Experiential Learning

Observe how the different growth media in your nursery is treated before use and report on it briefly by writing your findings in your workbook.

summary

Citrus Growth Media

- Plants need growth medium to stay upright and to get nutrients, water and air (oxygen and carbon dioxide).
- It is important to understand chemical and physical growth medium properties to understand their influence on the ability of plants to grow.
- Physical growth medium properties relevant to plant propagation are texture, structure, aeration and air-filled porosity.
- Texture concerns the balance between water, air and solid particles in the growth medium.
- Texture impacts on the water holding capacity of the growth medium.
- Growth medium structure refers to the manner in which all the growth medium particles, including organic material, are arranged to form structural units.
- Aeration refers to ability of the growth medium to supply air to the roots.
- Poorly drained growth medium becomes water-logged and anaerobic, which can cause roots to die.

- The air-filled porosity of a growth medium is the percentage of its volume that contains air after it has been saturated with water and allowed to drain.
- If the AFP of a growth media is correct, all other physical properties can be assumed to be acceptable.
- Chemical growth medium properties include pH, resistance and electrical conductivity, salinity, fertility level, cation exchange capacity, and organic matter.
- pH indicates the acidity of growth medium.
- Growth medium pH is essential since it affects the availability of nutrients for uptake by plant roots.
- Electrical conductivity and resistance indicate the salinity of the growth medium.
- Growth medium salinity affects growth medium fertility and physical growth medium properties.
- Growth medium fertility indicates the ability of growth medium to sustain plant growth.
- The cation exchange capacity of growth medium determines the ability of growth medium particles to bind with nutrients and keep them available to plants.
- Organic matter in growth medium consists of dead plant and animal material, organic and microbial debris, and humus. Humus contributes to the activity in growth medium.
- Different media are available for citrus propagation, while the most commonly used media in the South African citrus industry is composted pine bark, followed by coarse river sand.
- The ideal growth medium for citrus propagation has between 14% and 20% air-filled porosity, with a particle sizes ranging between 10mm and 14mm in the case of pine bark.
- Propagators of citrus trees in different parts of the world make use of various mixtures to form the final growth medium for the plants to be raised in.
- The main treatment applied to growth media is steam sterilisation.

Citrus Propagation Structures

Introduction

The propagation of citrus can be seen as a natural process that is undertaken in modified, controlled environments in order to enhance the natural process. These modified environments take into account the immediate surroundings and the requirements for citrus propagation. Structures are established to create environments that can be modified and controlled.

For citrus propagation in South Africa, the Citrus Improvement Scheme (CIS) guidelines promote propagation in containers. Container propagation makes use of various structures before the tree is finally planted in the orchard, being:

- Germination rooms
- Greenhouses (tunnels)
- Shade houses

Germination Rooms

Seed trays that have been sown with citrus seeds for the production of rootstocks are placed in germination rooms, where they stay until the seedlings have developed and are ready to be transplanted into individual cavities.

Germination rooms are permanent buildings with raised walls that are plastered and painted. The standard size for a germination room is 3m x 2m with a ceiling height of 2.5m. A germination room is laid out to retain heat, to allow very little air circulation, and to easily build up and maintain humidity. Germination rooms are equipped with fluorescent lights as a source of red light, which promote germination.

Greenhouses

Greenhouses, also referred to as tunnels, are the next structure which the citrus seedlings are taken to in the propagation line. Greenhouses are built in such a way that plant growth and development are promoted and accelerated.

Materials are chosen to build the greenhouse taking into account the environment in which the structure will be built, and the environmental requirements of the plants. If the greenhouse is to be built in a location that is known to be windy, provision must be made to strengthen the structure to withstand wind. If the structure is to be built in conditions that are generally humid, special corrosion-resistant material must be used. At the same time, the design and material used in the greenhouse must contribute to creating the ideal environmental conditions that promote plant growth.

A greenhouse has a metal framework that is built from steel or aluminium that is rust and corrosion resistant. The framework is covered with ultraviolet (UV) resistant polyethylene sheeting. Initially glass was used for covering the metal framework, but now several different plastic materials can be used. The best results in terms of lifespan and light penetration have been achieved with 100 micron UV resistant cross-woven polyethylene.

Greenhouses provide a more favourable environment than the outdoors. The propagator is not at the mercy of nature's extremes in as far as temperature is concerned, and propagation and plant production can take place year-round. With the use of control systems, temperature is controlled to allow normal respiration, even when photosynthesis is reduced, commonly in cloudy weather.

Plants are grown closer together in greenhouses resulting in an increased density per surface area. If water-supply is not a limiting factor, light becomes the most important factor as it relates to photosynthesis.

With increased light intensity, coupled with increased relative humidity (rh), comes a reduction in the rate of transpiration as CO_2 diffuses rapidly into the leaves increasing the rate of photosynthesis. In a cooler environment the respiration rate is reduced, resulting in less carbohydrates being used up for respiration and more being available for plant growth.

definition

Transpiration

Transpiration means to lose water through the surface of a plant, particularly through the stomata.

Greenhouses can also be equipped to humidify the air when required. Air movement helps to avoid high temperatures and high levels of CO_2. The propagator must constantly check the balance between heat build-up and the availability of CO_2 for plant growth.

The following equipment is used to control environmental conditions in greenhouses:

- A wet-wall on one side of the greenhouse made up of a honeycombed cellulose pad, perforated PVC pipes that run water through the wall, a pump, and a shallow tank.
- A set of extractor fans on the other end of the tunnel, that pull air from outside the greenhouse through the wet-wall, which cools and humidifies the incoming air and at the same time removes the 'old' warm air out of the tunnel.
- An irrigation system and tables or beds where plants are to be placed.
- Temperature, aeration, and light intensity are controlled either manually by opening and closing louvers or doors, or by modern automated systems that use ceiling curtains.

Shade Houses

Shade houses are where young citrus trees are kept before being sent to farmers to be planted in orchards. Shade houses have frameworks built from wooden or metal poles and are covered with shade cloth on the top and the sides. They generally have flat tops.

Shade cloth is available in different colours and shading percentages. The most commonly used in the South African citrus industry are black and white nets. Depending on the area, the percentage of shading varies between 30% and 50%.

Plants under shade cloth are reasonably protected from harsh environmental conditions and light is filtered before reaching the plants. Aeration is passive as the wind speed is reduced. The main concern is the transpiration rate. At high light-intensity, the temperature in the shade house increases and the relative humidity decreases. Keeping the cells of the plant turgid becomes the main goal. The choice of shading percentage is influenced by this goal. The ideal environment is where light-intensity is reduced, which in turn reduces the temperature and increases humidity.

definition

Humidity

Humidity, also referred to as relative humidity (rh), is the percentage water vapour in the air at a given temperature. This means that at 20% relative humidity, 20% of any given volume of air will consist of suspended water molecules.

The selection of the wrong covering material for a shade house can result in poor light intensity during a specific time of the year. The location and season are important factors that determine the quantity of light received. From October to March the light intensity is high, with the peak reached in January. From April to September, the intensity is classified as moderate with the lowest intensity recorded in June. Higher shading percentage might be good for the high intensity months, but may result in insufficient light during the low intensity period. In areas such as Letsitele, the propagator has to ensure that there is sufficient light during the month of August for growth as the plants come out of the winter.

All shade houses are equipped for irrigation and fertiliser application, and have access points for pest control systems.

Potential Problems with Structures

Structures are used to provide an environment that is and remains easily controllable. Should any structure lose this property, it becomes less useful to the propagator and economic losses may occur. Potential faults may occur with the control devices, such as probe malfunction, or as a result of the wrong interpretation of information that has been relayed by a machine, or with the structure frame itself.

Propagation structures are generally held together with links and joints, and these can come loose. The links and joints and the generally stability of the structure must be checked regularly.

Tears or cuts in the covering material, whether it is the polyethylene sheeting of greenhouses or the shade-cloth of shade houses, results in unwanted changes of the environmental conditions in the structure. Plants are exposed to harsher conditions with increased probability of damage to the plant.

Greenhouses are at greater risk. Fans and wet-wall malfunctions spell disasters of bigger proportions. Temperatures can quickly reach levels where plants cannot continue normal metabolic processes, resulting in severely wilted plants which are the result of low photosynthesis rate. Poor aeration can also lead to a drop in the CO_2 level, limiting photosynthesis. High respiration rates are required, with a constant supply of O_2 and CO_2. A backup power supply, such as a generator, is a necessity for a greenhouse, especially if it makes use of a wet wall and an extractor fan.

practical

Activity 1.10 – Worksheet

Answer the following questions:

- ✓ What are all the structures that are found in and around the nursery where you work?
- ✓ What is the purpose of each structure?
- ✓ How does each structure contribute to successful citrus propagation?
- ✓ What risks does each structure pose to successful citrus propagation?

summary

Citrus Propagation Structures

- The propagation of citrus can be seen as a natural process that is undertaken in modified, controlled environments in order to enhance the natural process.
- Container propagation makes use of various structures before the tree is finally planted in the land, being germination rooms, greenhouses, and shade houses.
- Seed trays that have been sown with citrus seeds for the production of rootstocks are placed in germination rooms.
- Greenhouses are built so that plant growth and development are promoted and accelerated.
- Shade houses are where young trees are kept before being sent to the farmer to be planted in the orchard.
- Structures are used to provide an environment that is and remains easily controllable. Potential faults may occur with the control devices or as a result of the wrong interpretation of information that has been relayed by a machine, or with the frame or equipment of the structure itself.

Environmental Conditions

Introduction

Plants have the natural ability to regulate their 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.

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

Humidity

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 propagation though 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.

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.

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 excess of O_2 or CO_2 produced by plants during the day and night respectively, thereby maintaining a balanced environment.

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 deep into the growth medium.

With no or inadequate light, weak seedlings of poor quality are produced. These seedlings tend to be tall, spindly and pale, a condition known as **etiolation**.

definition

Etiolation

Etiolation is a condition caused by a lack of light, which results in the plant being deficient in the green pigment chlorophyll, causing the plant to be unusually tall, spindly and pale.

Temperature

If heat and light that 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. If the temperature rise above 33°C the stomata on the leaves close and no further photosynthesis takes place, resulting in wilting.

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 also increases humidity in the chambers if trays are drenched or floors are dampened.

Moisture

Moisture is essential for germination and healthy plant growth. Over-irrigating seedlings is as dangerous as under-irrigation. 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 of between 55% and 60%, and the ability to make water available to the plants and allow lateral water movement.

With germination the seed and seedling has to be kept in media wetted to field water capacity. 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.

Monitoring Environmental Conditions

Environmental factors are critical during citrus propagation and they must be monitored and manipulated to maximise the success rate. Atmospheric conditions especially can change very quickly and must be monitored and controlled carefully wherever possible. A wide range of electronic and manual control systems can be used to monitor environmental factors.

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.

External probes that are plugged into a light-meter can also be used. The internal detector of the light-meter is automatically disconnected and the reading displays the quantity and the units measured with the probe.

Humidity and Temperature

Humidity is monitored using a battery operated hydro-thermograph meter, such as a Thies CLIMA, which measures and records both rh and temperature. 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, can also be 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.

Water

Citrus seedlings are grown in containers in a citrus nursery and containers do not provide enough depth for long and thick devices such as irrometers. Hand-held probes can be used in some cases, although they are not very reliable.

Growth medium water levels are therefore generally monitored through observation of the plant and growth medium, and experienced nursery managers determine the right time to irrigate. It is however essential to water plants before they wilt, as plant growth stops as soon as the plant wilts.

Aeration

The control 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.

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 can be controlled only 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.

Adjusting Environmental Conditions

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

Under shade-cloth, quick adjustments are not possible. Ventilation is passive and relies on wind movement. Significant adjustments the propagator can make relate to the percentage of shade-cloth to control light intensity and temperature.

Recordkeeping

Recordkeeping is a management 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 well-structured systems detailing all operations undertaken, to computer software systems.

Information 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 *Phytophthora* and other pathogens
- Records of environmental conditions
- Pest and disease scouting records
- Information of chemicals that were used, target pests or diseases, and the concentrations
- Water quality and growth medium test results
- Type and amount of fertiliser used
- Electronic conductivity and pH of water before and after fertiliser is added

practical

Activity 1.11 – Flashcards

Design a set of flash cards that can be used to educate casual or temporary nursery workers. Insert your set of flashcards in your learner workbook.

- ✓ Write one environmental requirement for successful citrus propagation on each flashcards.
- ✓ For each of the 'environmental requirements' flashcards, make a new flash card on which you briefly describe why and how this is of importance in citrus propagation.

Activity 1.12 – Workplace Interview

Interview the nursery manager where you work, and ask him / her the following questions. Record your answers in your learner workbook:

- ✓ How is the nursery environment managed to ensure the best chances for successful citrus propagation?
- ✓ What can go wrong in terms of environmental conditions and how is this prevented?
- ✓ How are environmental conditions monitored in the nursery?
- ✓ What records are kept of environmental conditions?

summary

Environmental Conditions

- ➢ Environmental conditions play an important role in the ability of a plant to grow and in general plant health.
- ➢ Environmental conditions that must be controlled during plant propagation are humidity, aeration, light quality and quantity, temperature and moisture.

- Humidity (relative humidity) is the percentage water vapour in the air at a given temperature. 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 to take place.
- Light is essential for photosynthesis, while light quality, which is determined by the wavelength of the light, influences germination. Red light is used to stimulate seed germination.
- The temperature during propagation must be maintained at about 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-irrigation.
- Atmospheric conditions can change in a short space of time and must be monitored closely.
- Light is not generally monitored in citrus nurseries, but can be measured with a light-meter.
- Humidity and temperature is monitored using a battery operated hydro-thermograph meter or high-tech devices, such as Hanna Instruments HI91610. Electronic control systems that can be linked to a computer are also available for this purpose.
- Growth medium moisture is monitored through physical observation, and these observations are used to determine the timing of irrigation.
- The control and monitoring of aeration is referred to as ventilation.
- Unforeseen changes in atmospheric conditions are mostly due to changes in weather conditions and having access to dependable weather forecasts helps the propagator to prepare and plan.
- Records are kept of atmospheric conditions and of all practices undertaken in the nursery.

The Citrus Nursery Industry

Introduction

The main goal of citrus growers in Southern Africa is to produce export citrus fruit. The success of the industry depends on a secure supply of good quality, true-to-type plant material. Citrus nurseries are therefore the foundation of a successful citrus industry.

Citrus nurseries come in all sizes, from large operation that produce up to 800,000 trees a year of a wide variety of cultivars that are sold all over the country, to small operations that produce trees of a limited variety for the local citrus growers.

There are a number of structures in place that support the local citrus nursery industry, such as the South African Citrus Nurserymen's Association and the Citrus Improvement Scheme.

The South African Nurserymen's Association

The South African Citrus Nurserymen's Association (SACNA) is a voluntary body of people involved in the citrus nursery industry. The purpose of SACNA is to:

- Encourage healthy citrus nursery practices
- Protect its members from any unfair measures that may affect them prejudicially
- Arrange a bi-annual general meeting of members to discuss matters of common interest
- Promote the training of technical staff
- Represent the citrus nurseries on various industry bodies
- Make recommendations on joint action to the citrus industry
- Provide feedback and information to members

The Citrus Improvement Scheme

For the long term profitability and growth of the Southern African citrus industry it is important that citrus nursery trees of the highest quality are made available by nurseries to the growers. The first step in growing high quality citrus is to have certified nursery trees that meet certain requirements.

The Citrus Improvement Scheme (CIS) is aimed at ensuring the quality of citrus nurseries trees. The CIS sets standards for trees sold by nurseries in South Africa and ensures that certified nurseries produce trees that comply with these standards. Trees that do not meet these requirements are considered substandard.

The Citrus Foundation Block (CFB) near Uitenhage in the Eastern Cape is the single site at which all budwood for the South African nursery industry is produced, from where it is supplied to accredited citrus nurseries around the country. Any movement of plant material outside of this is illegal and is regulated by the National Department of Agriculture (NDA).

Responsibility and Authority

The Citrus Growers Association of Southern Africa (CGA) is responsible for the Citrus Improvement Scheme and has mandated Citrus Research International (CRI) to manage and operate it.

Certification Criteria

For a nursery to be certified, the nursery must be audited twice a year. Nurseries are assessed for the following:

- Nursery registration
- Access control
- Drainage and rain water control
- Growth media pathogen status and drainage
- Water pathogen status
- Greening
- Citrus blackspot (CBS)
- Elevation of trees from the ground
- Nursery sanitation
- Quality management systems (QMS)
- Tree status and control
- Propagation from non-certified budwood
- Administration
- Tree sales register

Nursery Registration

The nursery must be registered with the Citrus Improvement Scheme and the National Department of Agriculture.

Access Control

Access to the nursery must be limited to authorised people only. This can be done by means of fencing, hedges or any other suitable means.

Drainage and Rain Water Control

The nursery must be positioned so that no rain water from adjacent land can enter it. There must also be good drainage of excess water in the nursery.

Growth Media Pathogen Status and Drainage

All growth media used in the nursery must be well drained and tested to be free of pathogens before being used.

Water Pathogen Status

The water used in all parts of the nursery must be tested to be free of pathogens before use. A spore trap must be run every three months to check that the water source of the nursery is pathogen-free.

Greening

The nursery must produce seedlings and trees that are free from greening disease. There must be no psylla pock marks on any tree. Trees must either be produced in psylla-proof structures as approved by the authority, or be under a preventative chemical control programme.

Citrus Blackspot (CBS)

All nurseries in CBS infected areas must be on a recommended CBS control programme. This programme should preferably consist of contact fungicides, such as Copper or Mancozeb sprays, and not systemic chemicals such as Benzimidazoles or the Strobulirenes, to prevent the development of resistance to these chemicals.

Elevation of Trees from the Ground

Trees must be suitably raised from the ground to allow free drainage of water from the bottom of the bag and to prevent the roots from growing into the soil. Suitable structures include bricks, wire mesh, cinder beds, concrete lintels, and so on. A minimum height of 100mm high is required.

Nursery Sanitation

Proper sanitation control shall be exercised in the nursery at all times.

Quality Management Systems (QMS)

The nursery must use quality management principles. The following processes in the nursery must be included in a proper QMS:

- Water treatment and testing every three months
- Media treatment and testing with each new batch
- Media and root pathogen testing every three months
- Pest monitoring and control

The QMS must document the manner in which each process is controlled, how often it was done and what records were kept. The QMS must be able to produce reliable records to prove that the water, media and trees are *Phytophthora* free and that pests have been controlled.

Tree Status and Control

Trees must conform to the rules set for certification, meaning that they must:

- Be propagated from certified propagation material, which implies that the tree is true-to-type
- Have been tested for *Phytophthora* every three months
- Be visually healthy and without signs of deficiencies
- Be free of insect pests
- Be budded 200mm or higher above the growth medium
- Have no root bench within 150mm from the collar of the tree
- Have straight stems
- Be not older than 21 months from budding
- Be not older than 30 months from seed germination

Propagation from Non-Certified Budwood

Trees propagated from non-certified budwood must be kept isolated from the rest of the nursery with controlled access. Strict control must also be exercised over the use of a separate set of tools for this part of the nursery only.

Administration

An adequate administration system must be in place to be able to trace the budwood code from receipt of the budwood to sale of the tree and be able to produce all the needed information for certification.

Tree Sales Register

A register must be kept of all trees sold. Tree certification must be applied for when the trees are ready to be supplied to the grower.

Nursery Auditing

Below is an example of the sheet used during nursery audits.

information

Nursery Audit Sheet

Nursery:	**Date:**					
Criteria	**Ratings**					
	Poor			**Good**		
	0	**1**	**2**	**3**	**4**	**5**
1. Registered with authority						
2. Greening – area and structures						
3. Access control						
4. Drainage and rain water control						
5. Media pathogen status and drainage						
6. Raising containers						
7. Water pathogen status						
8. Citrus blackspot control						
9. Nursery sanitation						
10. Quality management systems						
11. Tree status and condition						
12. Non Certified Budwood						
13. Administration						
14. Sales register						
Certification:	**Full certification**					
	Conditional approval					
	Conditional approval - new nursery					
The nursery must be re-audited by:	**Date:**					

NURSERY CERTIFICATION AUDIT SHEET

Audit Report:

Audited by:______________________ Report received by:_____________________

Rating

Each point on the audit sheet is rated using the guidelines. A cross is made under the rating for each point on the audit sheet.

Determining Certification Status by Using Audit Form

For a nursery to be granted full certification it must have ratings of 3 or higher for each point. No certification will be granted if one or more points rate 1 or 0. Conditional approval can be granted for a period not exceeding three months if specific ratings are a 2, being for points 3, 4, 6, 8, 9, 10 and 12. The nursery must improve the non-conforming areas to fully meet the criteria within a three month period or it will loose its conditional approval.

New Nurseries

A certification audit will only be done in a new nursery once seedlings have been planted into large containers. The new nursery must be re-audited six months after being certified to ensure it is under good management.

Audit Frequencies

All nurseries will be audited a minimum of twice a year. If the nursery is new or has temporary certification a re-audit must be called for by the nursery. The re-audit must take place on or before the lapse date on the audit form. If the nursery does not comply with the accreditation criteria it will only be re-audited on written request from the nursery. The authority may audit more frequently if necessary.

Audit Report

If the nursery does not meet the certification criteria a short written explanation must be given on the audit sheet. This can be followed up by a formal letter if necessary.

Certified Nursery List

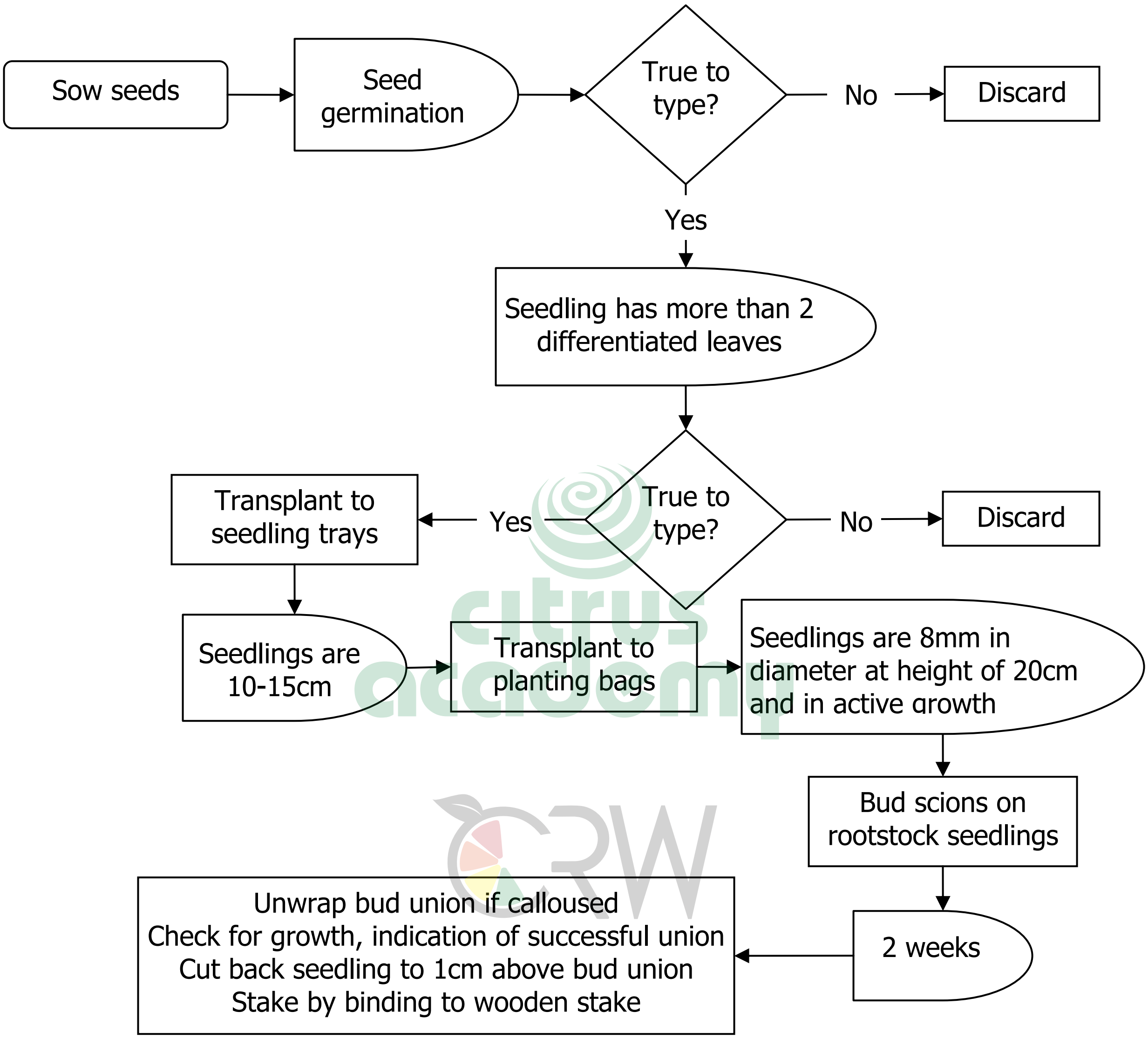
An up to date list of certified nurseries is maintained by the authority and copies made available on request and published annually in the SA Fruit Journal.

Tree Certification

Every batch of trees that are sold to a citrus grower has to be certified as meeting the requirements set out under tree status and control. Only certified nurseries can apply for tree certification and a certificate will only be issued if the trees meet the standards.

The Citrus Propagation Cycle

Below is a flow diagram of the citrus propagation process from seed to seedling in planting bag:



The nursery trees are now kept in shade houses until they are ready to be sold to the grower. During this time, the young trees are continually tied to their stakes to ensure that they grow upright. Pest and disease monitoring and control, fertilisation, irrigation and weed control are important production practices during this time.

Nursery Work Program

The work program of a nursery is determined by the propagation cycle. Below is an approximate work program that takes into account the propagation cycle, and the growth stage of the tree.

Task	Timing
Sow rootstock seed in seed germination trays	Begin in August, can be done through summer
Fill seedling trays with germinated seed	15-20 days after sowing, when seedlings have 2 to 4 leafs
Fumigation or steam sterilisation of growth medium as required	
Fill planting bags, pack in shade house / tunnels	1 month before replanting
Replanting of 20cm seedlings in planting bags	± 3 months after sowing
Budding	± 6 months after sowing; budding can be done throughout the summer while the plant is actively growing
Unwrapping	± 14 days after budding
Topping	± 5 days after unwrapping
Pest control – scouting and spraying	Weekly in summer; monthly in winter
Irrigation as and when required as per schedule	Every second / third day, more often in summer than in winter
Weed control and cleaning of planting bags and paths	Weekly
Take water and growth medium samples for analysis	Every 3 months
Selection of trees for sale	± 18 months after sowing, 12 months after budding (September to February)
Application for tree certification at sale of trees	As soon as trees leave the nursery
Routine work – maintenance of infrastructure, shade houses, tunnels, greenhouses, irrigation system, fumigation/sterilisation equipment	As required with regular inspection
Recordkeeping of every process	Daily as required

practical

Activity 1.13 – Report Writing

Write a report about the nursery where you work. Draw a diagram in which you show the management structures of the nursery, i.e. show where you are as nursery employee, if there are employees that report to you, who you report to, who that person reports to, etc. Also explain the following:

- ✓ What does your immediate supervisor do?
- ✓ Who does your immediate supervisor report to?
- ✓ Why do you not report to the person to whom your superior reports?

Activity 1.14 – Group Discussion

Discuss the following with your co-workers and make notes on your conclusions:

- ✓ Why are there management structures in the nursery?
- ✓ What would happen if the nursery didn't have management structures?

summary

The Citrus Nursery Industry

- Citrus nurseries are the foundation of a successful citrus industry.
- Structures that are in place to support the local citrus nursery industry are the South African Nurserymen's Association (SACNA) and the Citrus Improvement Scheme (CIS).
- SACNA is a voluntary body and its purpose is to look after interests of its members, promote good nursery practices, and represent nursery owners on industry bodies.
- The Citrus Improvement Scheme (CIS) is aimed at ensuring the quality of citrus nurseries trees.
- The Citrus Foundation Block (CFB) near Uitenhage in the Eastern Cape is the single site at which propagation material (budwood) for the South African nursery industry may be produced.
- Certified nurseries are audited twice a year and assessed for nursery registration, access control, drainage and rain water control, media pathogen status and drainage, water pathogen status, greening, citrus blackspot (CBS), elevation of trees from the ground, nursery sanitation, quality management systems (QMS), tree status and control, propagation from non-certified budwood, administration, and tree sales register.
- An audit sheet is completed, and if the nursery has the required ratings, a certificate is issued. Provision certification may be granted.
- If the nursery does not meet the criteria, it may be re-audited at its own request.
- An up to date list of certified nurseries is maintained by the authority.
- Every batch of trees that are sold to a citrus grower has to be certified as meeting the requirements set out under tree status and control.
- The work program for a nursery is determined by the propagation cycle.

Health and Safety Legislation

Introduction

The health and safety of nursery workers and of the environment in which the nursery is located must be taken into account during the planning and execution of all nursery activities. It is important to understand that there are legislation that regulates the protection of workers and the environment.

The laws concerned with personal and environmental safety are:

- The Occupational Health and Safety Act
- The Environmental Management Act

Occupational Health and Safety Act

The Occupational Health and Safety Act (OHSA) aims to ensure the safety and health of employees in the work place. The employer has the responsibility of providing and maintaining, as far as is reasonably practicable, a working environment that is safe and without risk to the health of his employees. Employees on the other hand must comply with the regulations and procedures prescribed by the act and by the employer.

The act also states that no person shall intentionally or recklessly interfere with, damage, or misuse anything which is provided in the interest of health and safety.

The complete act can be found on the website of the Department of Labour at www.labour.gov.za.

Responsibilities of the Employer

The responsibilities of the employer includes in particular:

- The provision and maintenance of systems of work, plant and machinery that are safe and without risks to health.
- Taking such steps as may be reasonably practicable to eliminate or mitigate any hazard or potential hazard to the safety or health of employees, before resorting to personal protective equipment.
- Making arrangements for ensuring the safety and absence of risks to health in connection with the production, processing, use, handling, storage or transport of articles or substances.
- Establishing what hazards to the health or safety of persons are attached to any work which is performed, any article or substance which is produced, processed, used, handled, stored or transported, and any plant or machinery which is used, establishing what precautionary measures should be taken in order to protect the health and safety of persons, and providing the necessary means to apply such precautionary measures.

- Providing such information, instructions, training and supervision as may be necessary to ensure the health and safety at work of his employees.
- Not permitting any employee to do any work or to produce, process, use, handle, store or transport any article or substance or to operate any plant or machinery, unless the necessary precautionary measures have been taken.
- Taking all necessary measures to ensure that the requirements of the act are complied with by every employee and all other persons on premises.
- Enforcing such measures as may be necessary in the interest of health and safety.
- Ensuring that work is performed and that plant or machinery is used under the general supervision of a person trained to understand the hazards associated with it and who have the authority to ensure that precautionary measures taken by the employer are implemented.

Responsibilities of the Employee

Employees have the obligation to:

- Take reasonable care for their own health and safety and that of other persons who may be affected by their acts or omissions.
- Cooperate with the employer to enable him to comply with his responsibilities under the Act.
- Carry out any lawful order given to him, and obey the health and safety rules and procedures laid down by his employer or by anyone authorised to do so by his employer, in the interest of health or safety.
- If any situation which is unsafe or unhealthy comes to his attention, as soon as practical report such situation to his employer or to the health and safety representative for his workplace or section, who shall report it to the employer.
- If he is involved in any incident which may affect his health or which has caused an injury to himself, report such incident to his employer or to anyone authorised for this purpose by the employer, or to his health and safety representative, as soon as possible, but not later than the end of the particular shift during which the incident occurred, unless the circumstances were such that the reporting of the incident was not possible, in which case he shall report the incident as soon as practical thereafter.

Environmental Management Act

The Environmental Management Act aims to protect, maintain and improve the environment and to ensure the right to a safe and healthy environment. It also regulates the relationships between government, communities and agriculture.

All institutions that are undertaking activities that have an impact on the environment are required to do an environmental impact assessment and to develop an environmental management plan. The act also stipulates that specific action must be taken to protect and preserve resources such as soil and water. This act can be found on the website of the Department of Environmental Affairs at www.environment.gov.za.

information

Safe Handling of Chemicals

The safe handling, storage and discarding of chemicals is a aspect that requires specific attention in terms of health and safety. It is essential that chemicals used in and around the nursery, are handled, stored and discarded correctly to prevent damage nursery workers, plants and the environment. For guidelines to the safe use and storage of chemicals, please consult the relevant section in module 6 (Nursery Practices: Pest and Disease Control) of this learning program.

summary

Health and Safety Legislation

- The health and safety of nursery workers and of the environment in which the nursery is located must be taken into account during the planning and execution of all nursery activities.
- The laws concerned with personal and environmental safety are the Occupational Health and Safety Act and the Environmental Management Act.
- The Occupational Health and Safety Act (OHSA) aims to ensure the safety and health of employees in the work place.
- The employer has the responsibility of providing and maintaining, as far as is reasonably practicable, a working environment that is safe and without risk to the health of his employees.
- Employees on the other hand must comply with the regulations and procedures prescribed by the act and by the employer.
- The Environmental Management Act aims to protect, maintain and improve the environment and to ensure the right to a safe and healthy environment.