Citrus Plant Propagation

Module 1:
Citrus Propagation Requirements

Learner Guide

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Citrus Growers' Association OF SOUTHERN AFRICA
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Contents

Introduction

Southern African citrus growers make a profit from producing quality fruit for the export market. It all begins with planting quality, true-to-type citrus trees, produced by certified citrus nurseries.

Citrus nurseries come in all sizes. The largest nurseries can in a year produce up to 800,000 trees of a wide range of cultivars that are sold all over the country. On the other end of the scale, small nurseries may focus on a few cultivars and produce trees only for citrus growers in their area.

The Citrus Improvement Scheme

When choosing a nursery, growers need to be sure that the nursery will be able to supply them with quality, disease-free, true-to-type trees. The term 'true-to-type' means that the tree will bear fruit of the variety and cultivar that the grower requires. On top of this, trees must be healthy, vigorous, and free of diseases. To assure growers that a nursery can comply with these standards, the nursery is certified through the Citrus Improvement Scheme.

The Citrus Improvement Scheme was put in place to ensure that growers are supplied with nursery trees of the highest possible quality, made from the best genetic material, and being free of diseases. A central component of the Citrus Improvement Scheme is the Citrus Foundation Block near Uitenhage in the Eastern Cape, which is where most of the budwood used in South African citrus nurseries is produced.

The Citrus Improvement Scheme certifies all citrus trees sold by nurseries in South Africa, and growers are strongly advised to only buy trees that have been certified through the scheme. In addition to tree certification, the Citrus Improvement Scheme also certifies nurseries according to a quality management system, on which they are audited twice a year.

Citrus Propagation Process

Before we look at the requirements for citrus propagation, we need to understand the process of making citrus trees.

As a first step, please make sure that you understand citrus types, cultivars and rootstock. If you need to learn more about this, please watch the Citrus Types and Cultivars module that is part of the Citrus Planting Management series.

The first step in the propagation process is to sow seeds in seedling trays. After a few days, the seeds germinate. The seedlings are left to grow until they have more than two differentiated leaves. The seedlings are now ready to be transplanted to seedling trays. Only seedlings that are vigorous and true-to-type are selected to be transplanted. If they are not, they are discarded.

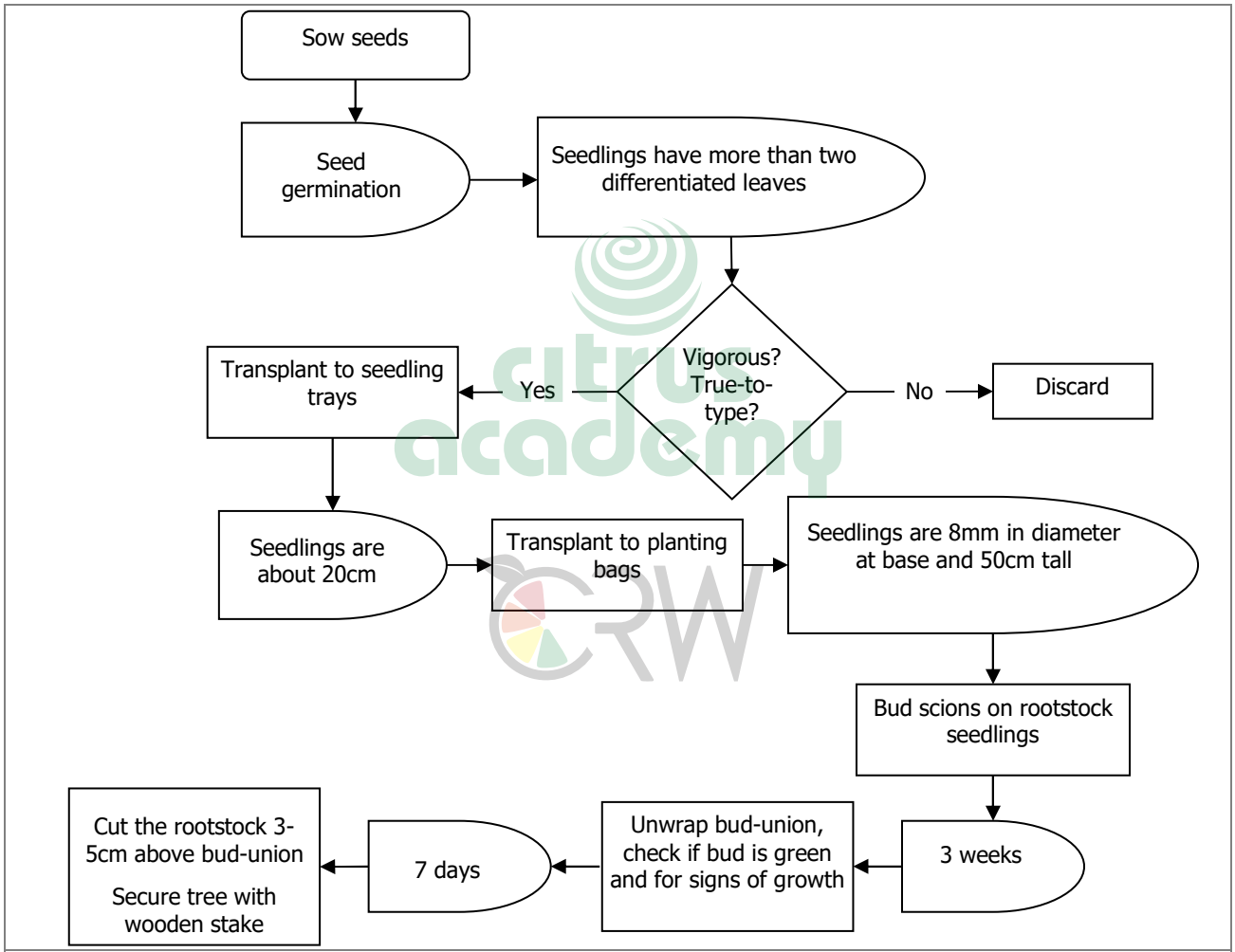
The selected seedlings are transplanted into individual cavities in seedling trays. Seedlings are left to grow until they are about 20cm long. They are then transplanted to planting bags, where they are left to grow until they are at least 50cm tall and the stems are at least 8mm in diameter at the base.

Once they have reached this size and are in active growth, scions of the correct cultivar of the fruit-bearing part of the tree are grafted, or budded, onto the seedlings and the bud-union is wrapped in tape.

The trees are now left to grow for three weeks after which the bud-union is unwrapped to check that the budding was successful; if it was the bud will be green and would have started to grow. If the bud is dead, the rootstock seedling is set aside for re-budding at a later stage. If the bud is green and growing, it is left for another seven days before the rootstock is cut back to 3cm to 5cm above the bud-union.

The tree is also bound to a stake that is planted next to it to make sure that it grows upright. The trees are left to grow tall. After about sixteen to eighteen months, the trees will be ready for delivery.

This flow diagram shows how citrus trees are propagated.



Citrus propagation process

Nursery Requirements

What do we need in the nursery during the process of making citrus trees? In this module, we will look firstly at the tools and equipment we need, then at the propagation media that is used at each point in the process, thirdly at the propagation structures in the nursery, and we will finish with looking at the ideal environmental conditions for plants to grow in.

Tools & Equipment

Seed Germination Trays

The first equipment we need is seed germination trays. They are 5cm deep, with a square wooden frame and a gauze, or shade cloth, base for air root pruning and drainage. Germination trays are placed on special metal racks. Air root pruning is when seedling roots grow through the gauze in the base of the germination tray and die off when exposed to air. It ensures that roots don't grow too long, and is also why these trays must be put in racks and not on solid surfaces.

Every time after a batch of seedlings has been removed from germination trays, the trays must be sterilised. All the growth medium and bits of plant material are removed and the trays are dipped in a suitable sterilisation solution.

Seedling Trays

Seedlings are transplanted from germination trays into individual cavities in seedling trays, which are the next items we need. Cavities in seedling trays have a volume of 60ml.

There are two types of seedling trays. The one kind is solid polystyrene trays, and the other plastic trays with loose inserts. Plastic trays work better because the seedlings can be moved around with their inserts so that trays with uniform plants can be made up, but they are also more expensive than polystyrene trays. Both polystyrene and plastic trays can be used more than once.

Seedling trays must also be sterilised every time after they are used. Remove all the growth medium and plant material from the trays, wash them with clean water, and sterilise them, either with a sterilisation solution or with a steam steriliser.

Planting Bags

Next we need planting bags to transplant the seedlings into, and in which the young trees can stay for up to 24 months, until they are ready to be planted in the orchard. It is important that bags are good quality and strong, so that they will last. Nurseries use different planting bags, but they usually have a volume of 4l or 5l, and it is important that the bag must be tall but not too wide so that it will drain well. Bags also have holes low down on their sides for drainage.

Planting Tool

When you transplant seedlings to the seedling trays, you will need a planting tool to make a hole of the right size in the growth medium in the seedling tray. This planting tool is sometimes called a dibber.

You will also need a dibber when you transplant the seedlings from seedlings trays to planting bags. In this case it is easiest to use one of the loose inserts from the seedlings trays, attached to a stake, because it will make a hole of exactly the right size. Remember to sterilise the planting tool before you use it.

Budding Tools

When you bud scions onto rootstock seedlings you need a budding knife and tape. The budding knife is used to make an inverted T-cut on the stem of a seedling, and to cut the bud-eye from the budwood. A budding knife must always be razor sharp so that it won't bruise the plant tissue around the cut on the stem. Bruising can cause budding to fail.

Clear polyethylene tape is used to bind the bud to the stem after it is inserted in the T-cut, so that the bud is kept in place until the bud-union and the healing is complete. It also keeps the bud-union from drying out completely, and from too much water getting in and rotting the bud.

Plant Stakes

The last special items you need in the nursery are the stakes or cleats that trees are bound to. These cleats are usually about 1m long, and made of wood. The end of the cleats which are planted in the growth medium is treated with copper, which makes it green, so that it is sterile.

Other Equipment

In addition to this special nursery equipment, you will also need general items, such as pruning shears, spraying equipment, water sprayers and cans, herbicide sprayers, and so on.

Propagation Media

Next we take a look at the propagation media, or soil, used during the propagation process. Generally, three different kinds of growth media are used in the germination trays, seedlings trays and planting bags.

In germination trays we use a medium grade vermiculite or perlite, which is sterile and has a low risk of contamination. Most nurseries use pine bark, peat moss or coir in seedlings trays. This growth medium must hold water well, because the cavities are small. If the growth medium is too sandy, it can be difficult to remove the roots from the cavity and the plant can be damaged easily. Most nurseries have their own secret recipes for the growth medium used in planting bags. It is, however, important for it to have an air-filled-porosity of between fourteen and 20% and electrical conductivity lower than 60mS/m, and for it to be sterile, with a pH value of 6.5.

Propagation Structures

Now that we know what equipment, tools and media we need, let's look at the structures we will be working in. In most nurseries you will find germination rooms, greenhouses and shade houses. The most important job that structures must fulfil is to create and maintain the right environmental conditions for that stage of the propagation process.

Germination Rooms

During seed germination the temperature, humidity and light must be carefully controlled in the germination room. The ideal temperature is between 26°C and 28°C, and humidity must be higher than 80%.

For light, the quantity and the colour matter. It is important to have enough light in the germination room, otherwise the seedlings will not germinate properly or they will grow etiolated. Red light promotes germination and growth, and rooms should be equipped with sources of artificial red light.

Greenhouses

Greenhouses, also known as tunnels, are the next structures in which the citrus seedlings are housed. In greenhouses, plant growth and development are promoted and accelerated. Most nurseries will have greenhouses of different sizes, used to house plants at different growth stages.

The environmental conditions in greenhouses are still controlled to some extent, but not as closely as in germination rooms. Ideally the temperature should be kept between 26°C and 28°C and humidity should be between 40% and 65%. It is also important to ensure that there isn't a build-up of carbon dioxide (CO2) in the greenhouse, because this will limit plant growth. For this reason, greenhouses are equipped with extraction fans which are used to aerate the rooms at regular intervals.

Another important factor in greenhouses is light. Light is essential for photosynthesis and also increases the rate of transpiration, which makes more energy available for plant growth. In the greenhouses the plants are placed very close together, so light penetration can be a challenge. Trees in planting bags are arranged in the greenhouse in groups of the same size, but in most greenhouses groups of plants of different sizes and ages alternate to help with light interception and aeration, and there is usually pathways between the groups of trees.

If the greenhouse is kept cooler, the plants' respiration rate decreases meaning that less energy is used for respiration and more is available for plant growth. Remember transpiration is when a plant loses water through its surface, and respiration is when the plant takes up oxygen to be delivered to the different parts of the plant, and releases carbon dioxide and water.

Shade Houses

Shade houses are the last place the seedlings go to in the propagation process. Conditions in shade houses are determined mostly by ambient weather conditions. While the plants are protected from wind and direct sunlight, the temperature and humidity cannot be controlled to a great extent, and the light is controlled only by the percentage of shade cloth used. Ideally light intensity should be reduced, which in turn reduces the temperature and increases humidity.

Environmental Conditions

We briefly made mention before of the humidity, temperature and light conditions in the various structures. Let's look in more detail at these environmental conditions.

Plants naturally regulate their level of metabolic activity according to environmental conditions. In extreme temperatures and humidity plants stop growing altogether, and they may even die if the conditions persist. Even in conditions that are reasonable but not ideal plant growth will slow down, which can have a significant impact on the efficiency in the

nursery and its ability to produce quality trees in the shortest possible time. Effectively regulating these factors is an important part of nursery management.

The most important environmental conditions are humidity, aeration, light quality and quantity, and temperature. 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 the most influential factor in this interaction. Light changes the temperature, which in turn affects the humidity level.

Humidity

Humidity levels are particularly important in allowing the plant to carry on with its metabolic processes. The ideal relative humidity for citrus propagation ranges between 80% and 90% for seed germination, and in the region of 50% for budding. In warm and dry areas, the humidity level often falls below 50% on hot summer days, making budding more delicate and requiring close monitoring.

Aeration

By aeration we mean the balance of the gasses in the structure where the plants are kept, of which the most important gasses for our purposes are oxygen and carbon dioxide. Plants grow best in a balanced environment, where both gasses are sufficient, as the processes of respiration and photosynthesis make use of both oxygen and carbon dioxide to sustain and develop the plant. In the open and under shade cloth the ambient air movement is good enough to aerate plants. In structures such as tunnels, ventilation becomes important. Ventilation extracts 'old' air which may have excess oxygen or carbon dioxide, produced by plants during the day or night respectively.

Light

All plants require light to grow. Light is essential for photosynthesis, while light quality, which is determined by the wavelength of the light, influences germination. In greenhouses and shade houses there has to be 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 will display symptoms of retarded growth.

In germination rooms, red light with a wavelength of 160nm (nanometre) is used to stimulate seed germination. Fluorescent tubes are commonly used as an artificial source for red light. These lights are used extensively and kept on for as long as possible – it is not unusual to have lights on 24 hours a day, week-round. This is also why seeds must not be too deep in the growth medium, because light needs to penetrate to the seed.

Some red light sources also increase the temperature in the room, otherwise additional heating units are used. Humidity can be increased by using a humidifier, or by wetting the floor. It is essential to have accurate, dependable monitoring equipment installed in the room, and to keep record of the temperature and humidity.

Temperature

The ideal temperature for propagation and plant growth is between 26°C and 28°C, and it must be monitored closely. If the temperature rises above 30°C the stomata on the leaves close and no further respiration takes place. This means that plants will start drying out and wilt.

Conclusion

Now that we have all our equipment ready and the conditions in our buildings are ideal, the next step is to start the propagation process. In the next module we look at this processes in detail.

Citrus Plant Propagation

Module 2:
Citrus Propagation Methods

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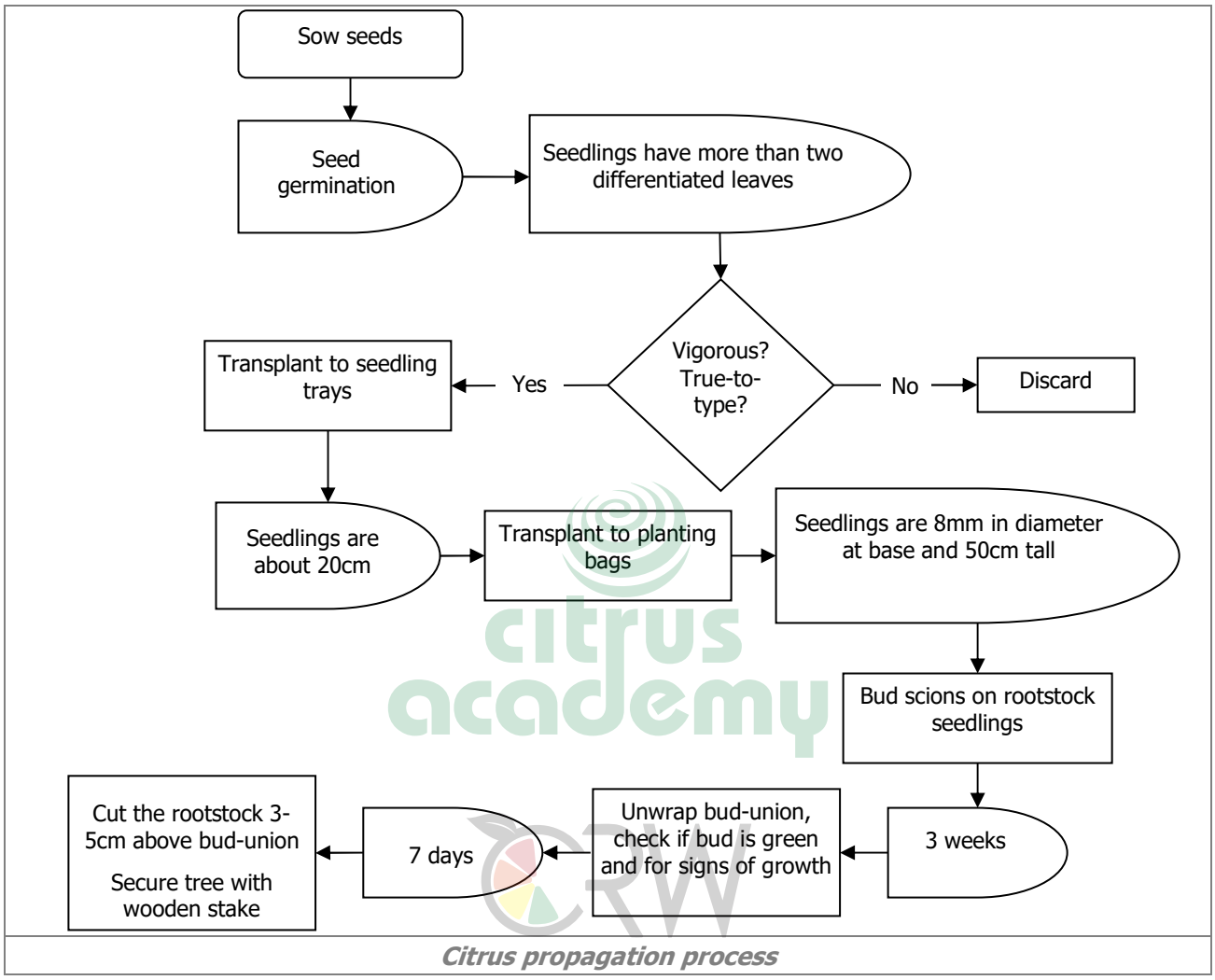
Contents

Introduction

In this module we take a detailed look at the process of growing a new citrus tree. You will be familiar with this diagram from the first module.



Citrus propagation process

In short, seed is sown in germination trays. Once they have germinated the seedlings are transplanted to seedling trays, from where they are transplanted to planting bags as soon as they are big enough. A bud of the required fruit variety is budded or grafted onto the rootstock seedlings. The rootstock plant is cut back and the bud grows out to form the fruit-bearing part of the tree. Around eighteen months later, the tree is ready to be delivered to the farm for planting. Let's look at each of these steps in detail.

But before we do that, please make sure that you have a thorough understanding of citrus rootstocks, cultivars and varieties. To refresh your memory, please watch the Citrus Types and Cultivars module that is part of the Citrus Planting Management series.

Rootstock Sowing

We start by sowing seeds in germination trays and placing them in a germination room. Seeds must be from a reputable supplier, where they are sterilised, treated with fungicides and dried before being packed and sent to the nursery. Here they must be stored in a refrigerator at about 10°C until they are used.

In preparation for sowing, put the seeds in water in a bucket for about 30 minutes. This allows the seed to imbibe water and for the seed coat to swell, which kick starts germination. In the meantime, fill the germination trays about halfway with vermiculite, level it out and stamp it down. When the seeds are ready, pour them in an even layer over the vermiculite, covering the entire tray. Stamp the layer of seeds down evenly. Fill the trays with vermiculite, even it out and stamp it down. Water the trays well before moving them into the germination rooms and placing them on the metal racks.

In the first module we described the ideal environmental conditions for seed germination. It is important that the temperature, humidity levels and light in the rooms must be controlled and monitored. The seeds must also be watered regularly and treated with fungicides – remember that the hot and humid conditions in these rooms are ideal for fungal growth. Seeds are kept in the germination room until they have developed at least two differentiated leaves.

Transplanting Seedlings to Seedling Trays

The next step is to transplant seedlings into seedlings trays. Not all seedlings are transplanted, and seedling selection at this point is very important. Remember that growing each plant from here on becomes increasingly expensive, so the sooner we can remove and eliminate trees that are not true-to-type or that will not grow healthy and strong, the more we will save. On the other hand, we don't want to discard seedlings that are true-to-type and viable, because then we will lose the effort that we already put into the germination process.

Citrus seeds occasionally produce more than one seedling per seed, and one of those will not be true-to-type. This is a characteristic that is rarely found in the plant kingdom. To understand how it works, please watch the section on citrus seeds in the Citrus Plant Structures and Functions audio-visual series.

It means, however, that you will find a number of off-type seedlings, and it is important that they are discarded at this point. They are fairly easy to spot – their leaves are usually different from those of true-to-type seedlings, and they tend to be either a lot bigger or a lot smaller than true-to-type seedlings. You also need to look out for and discard seedlings that have bent roots and that are etiolated. They will never grow well and are best discarded at this point.

In preparation for planting, empty and wash the seedling trays if they still contain plant rests and soil. Sterilise the seedling trays, either by using a sterilisation solution or by using a steam steriliser, which is preferable. Sterilise the medium in a steam steriliser, a process that usually takes about twelve to 24 hours, depending on the system you have installed. Fill the individual cavities in the seedling trays with sterilised medium. Make a hole in the growth medium and push the seedling in slightly deeper than necessary. Pull the seedling out slightly to make sure that its roots are straight. Water the transplanted seedlings well.

While they are in the seedlings trays, the seedlings will need to be watered, fertilised, and kept free of pests, diseases and weeds. Generally fertigation is used in the nursery to apply fertiliser, because applications can be controlled accurately. The seedlings are irrigated either with hand sprayers or through an overhead irrigation system, depending on the size of the plants. From time to time individual seedlings in their cavities are moved between trays, to make up trays of seedlings that are uniform in size. Trays with seedlings of similar size are also placed together in the greenhouse, so that it is easy to see which seedlings are due to be transplanted next. At the same time, seedlings that are off-type and weak are discarded. You can spot off-type seedlings by their leaves.

Transplanting Seedlings to Planting Bags

When the seedlings reach a height of about 20cm they are transplanted to planting bags, where they will stay until they go to the orchard.

The first step is to prepare the planting bags. Depending on the type of propagation medium you use, you need to prepare and sterilise it as indicated. Planting bags are filled to the top with the medium. Don't stamp it down; it is important that the medium must stay aerated and loose so that the roots can penetrate it as they grow. The filled bags are packed into crates, which are moved into the greenhouse or shade house. Line up the crates with the filled planting bags, and water them well with a hand sprayer. It is important that the medium must be wet through before the seedling is planted in it. Make a dibber by using a cavity from a seedling tray and attaching it to a stick. This is a good way to make sure that the holes are exactly the right size.

A tray of uniform seedlings that are all true-to-type and vigorous should be easy to identify for transplanting, if seedling selection and grouping have been done regularly in the greenhouse. Make sure that the growth medium around the roots is moist. Carefully remove the seedling from the cavity with the growth medium still around the roots. If the seedling sticks in the cavity, tap the cavity on the outside.

Put the seedling into the cavity in the planting bag. Don't plant the seedling too deep, the seedling's growth medium must still be visible on the surface of the growth medium in the bag after it has been planted. The seedlings are kept in greenhouses, but they can be moved to shade houses when they are a little bigger. They must also be kept irrigated, fertilised and free of pests, diseases and weeds.

Budding

When the rootstock seedling is about 50cm in height and about 8mm in diameter at its base, a scion of the cultivar that we want the fruit to be is grafted onto the rootstock seedling. This involves taking a bud-eye from a stick of bud-wood and inserting the bud-eye under the bark on the stem of the rootstock seedling. The bud-eye is also called the scion.

It is important to understand why we need to use grafting in citrus propagation. Essentially, it is because after many years of research we have a very good understanding of what sort of citrus trees grow best in particular soils and climatic conditions. We also have a good idea of what sort of fruit is the best to eat. The challenge is that these are rarely the same plants. In order to benefit from the strong growth characteristics of some types of plants, and the excellent fruit quality of others, we use grafting – or budding – to combine two different plants. In this regard, it is also important to know that not all rootstocks are compatible with all fruit varieties. It is important to make sure that you understand and know what rootstock to combine with your desired fruit variety.

At the Citrus Foundation Block near Uitenhage in the Eastern Cape trees of every citrus variety are grown. Bud-wood is cut from these trees and shipped to nurseries all over the country. This is a central part of the Citrus Improvement Scheme. In some cases, however, the Citrus Improvement Scheme may authorise nurseries to cut bud-wood for their own use if they have their own variety blocks. This may, however, only be done with authorisation and under strictly controlled circumstances.

In preparation for budding, get your budding knife, tape and bud-wood ready. Sterilise the budding knife in a sterilisation solution. People normally work in teams of two for budding, with one person doing the budding and one person applying the tape to wrap the bud-union.

Budding is done as follows:

- Make an inverted T-cut into the bark of the stem of the rootstock.
- Cut a bud-eye evenly and smoothly from the bud-wood stick.
- Slide the upper end of the bud-eye underneath the bark flaps at the bottom of the inverted T-cut.
- Wrap the bud-union with tape to hold the bud in place and to give the wound a chance to heal.

The tape also prevents water from entering the wound and protects it against infection. The tape is applied from below the incision in overlapping turns around the stem until the entire bud and incision are covered. Tie the ends of the tape to keep it in place.

Remember to sterilise the budding knife often, especially when you change the fruit variety that you are budding.

Post-Budding Process

After three weeks the tape is cut on the opposite side of the stem from the bud-union, and removed. If the bud is green and growing, the budding has been successful. If the bud is brown and dead-looking, the budding was not successful, in which case the seedling is set aside for re-budding.

After another seven days the scion should be growing actively. At this time the rootstock seedling is cut off 3cm to 5cm above the bud-union, so that growth energy is directed into the bud. This is done with pruning shears, which have been sterilised with a sterilisation solution. As soon as the first flush has grown and hardened off on the bud, the 3cm to 5cm stub is cut off just above the bud-union.

Side shoots are also removed from the rootstock part of the plant, so that growth energy is not wasted.

Staking

Once the stub has been cut off just above the bud-union the tree is staked. A wooden stake or cleat is planted next to it, to which it is tied. The cleats must be treated with copper at the end that is planted in the soil, to ensure that it is free of soil-borne diseases and to slow down the rotting of the part of the cleat that is in the soil.

Topping

When the plant reaches pencil-thickness at the top of the stake, it is topped to encourage the main stem to thicken and the fruit-bearing part to grow side branches. The timing of this varies between cultivars, and can be anything from twelve to fourteen months.

Nursery Practices

Irrigation

Nurseries make use of a variety of irrigation methods and systems, depending on the size of the plants and the nature of the structure in which the plants are kept.

Small seedlings are mostly watered by hand, with hand-held hoses. In greenhouses, smaller seedlings can also be watered with overhead irrigation system, which are sometimes called rain-replacement systems. Once the seedlings are in planting bags there is enough space to install drip irrigation, which allows for a much greater level of control in the amount of water that is delivered to each plant. Drip irrigation is used until the plants are ready to be shipped.

Fertilisation

Plants are fertilised mostly through using fertigation. Automated fertigation systems can be expensive, but they are worth the investment because it allows the manager to accurately control the amount of fertiliser that is applied to each plant. Fertilisation mixes and application rates are normally based on recommendations by plant nutrition experts.

Pest and Disease Control

It is important to scout regularly in the nursery for pests that attack citrus plants and for disease symptoms, by manually inspecting plants and by using pest traps. A preventative spray programme is also usually implemented. Plant protection products can be applied with knapsack sprayers or with spray machines in shade houses that are big enough to accommodate them.

Weed Control

All plants that compete with citrus trees for food and water in the nursery are weeds, and they have to be eliminated. Weed control products are normally applied with knapsack sprayers.

Recordkeeping

Recordkeeping is an important part of nursery management. It is also essential for certification under the Citrus Improvement Scheme. In a large nursery there can be hundreds of thousands of trees in the nursery at a given time, of all ages and at different points in the propagation cycle. The nursery must have a system in place that carefully keeps track of all the trees in the nursery.

It is a good idea to keep trees of the same age and in the same stage together in groups of a certain size, for instance 1,000. Each group can then be given some unique name, which will allow you to keep track of the groups. If all groups have the same number of trees in them – in our example 1,000 – it is also easier to count the trees in a particular place. It is important to have some form of signage attached to each group and even to the individual trees, which shows the unique name of that group, along with important information about the propagation of the trees, such as the type and cultivar of the rootstock and the scion, and the dates of sowing, transplanting, budding, and so on. Your recordkeeping system can be designed to keep track of each group, in terms of where it is located in the nursery at a given time, and where in the production cycle it is.

Citrus Plant Propagation

Module 3:
Citrus Rootstocks

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Introduction

Rootstocks are used in citrus production to take advantage of the useful traits of different citrus types and cultivars. The rough lemon cultivar, for instance, has a strong root system that makes for vigorous, large trees that produce high yields, but its fruit is not what consumers want. On the other hand, the Eureka lemon cultivar has wonderful fruit that is very popular, but its root system is not as strong as that of rough lemon. By combining a Eureka lemon scion with a rough lemon rootstock, we can take advantage of the best characteristics of both cultivars.

For this module, we visited citrus orchards with various scion and rootstock combinations, and the Citrus Foundation Block where citrus rootstock trees are cultivated for seed. Under the Citrus Improvement Scheme, nurseries can also get permission to harvest their own seed for rootstock production, for which they need to have full-grown trees of rootstock varieties. Most seeds used in nurseries are however sourced from the Citrus Foundation Block.

You will not see these rootstock trees on a commercial citrus farm, of course, because the fruit is not marketable. It is however useful to look at fully grown rootstock trees, as they show most clearly those traits that make them desirable as rootstocks. It is also useful to study the characteristics of their leaves and trunks so that we are able to identify the rootstocks used in existing plantings where there are no accurate records.

Rootstock Selection

How do we go about selecting the right rootstock for the fruit-bearing cultivar and for the conditions on our farm? There are three factors we need to keep in mind when selecting the rootstock.

First and foremost, the rootstock must be compatible with the fruit-bearing variety. Much research is done on rootstock and scion compatibility, and it is important to review the most recent findings before taking a final decision. We will say more about the signs and impact of incompatibility a little later.

Secondly, a rootstock must be selected with the eye on minimising the effect of limitations that there might be at the site, such as the soil type, the quality of the irrigation water, and the prevalence of pests and diseases. Lastly, the right rootstock can enhance the tree vigour, and the yield, fruit size and fruit quality.

Rootstock-Scion Compatibility

During propagation two plants with different genetic makeups are combined to make a citrus tree, one being the rootstock and one the fruit-bearing scion. For the trees to grow well, the two plants have to be genetically compatible, and have to be able to integrate well enough to ensure that metabolic processes in the plant and the transportation of water and nutrients through the plant is optimal.

The affinity or compatibility between the rootstock and the scion is fundamentally important. If the tree continues to grow without difficulty, it is considered a compatible union. But not all citrus species are compatible with each other. Research into rootstock and scion compatibility, mostly in the form of field trials, is continually conducted in various climatic and growing conditions.

In most cases, incompatibility is evident at a young age, with trees showing bud-union deformity or low growth rates from the outset. There are however cases where incompatibility only becomes evident when the trees are already mature, and then goes into decline.

Such sudden tree decline can be due to a number of other factors as well, including suboptimal plant nutrition, water shortage, disease infection or pest infestation, but incompatibility must be investigated as one of the possible causes. Remove a strip of bark from the bud union of the tree. If there is a brown line between the rootstock and scion, it is a sign of incompatibility.

Bud union deformity is also seen to be a sign of incompatibility. Rootstock overgrowth, or benching, is a common deformity, and occurs with rootstocks of trifoliate orange parenting. Benching may reduce the lifespan of the tree because it causes compression girdling. In most instances, though, it does not seem to have a serious effect.

Identifying Rootstocks

On most farms excellent records are kept of the plantings on the farm, including details about the rootstock used in every orchard. Where records are however no longer available, it will be necessary to identify the rootstock used in an established orchard.

Rootstocks have distinguishing characteristics by which they can be identified, such as its colour, the smoothness of its bark, the bud union, and its leaf shape. To identify it by the leaves, you will need to find a tree that has water shoots bearing leaves growing out of the rootstock.

Correctly identifying the rootstock can be challenging, and it is best to consult a specialist in this regard.

Common Rootstocks

Let's now look at the most common rootstocks used in South Africa, and their characteristics.

Rough Lemon

Rough lemon is probably the best-known citrus rootstock and is still widely used. It is presumed to be indigenous to north-east India, where it still grows wild. This is a mature rough lemon tree, from which you can see the exceptional tree vigour. This is what the leaves and trunk of a rough lemon tree look like.

Rough lemon is known as one of the most vigorous rootstocks, developing large tree size, and producing medium to large fruit with a good crop load.

Rough lemon tree

Tree Characteristics

Trees on rough lemon rank at or near the top in terms of growth vigour and tree size in comparison with trees on other rootstocks, provided that soils are disease-free, specifically of nematodes and *Phytophthora*. Trees are more sensitive to cold and frost damage, but young trees that have been damaged by cold recover more rapidly than trees on less vigorous rootstocks.

Fruit Characteristics

Trees on rough lemon produce excellent crops with generally large fruit size. The internal quality of the fruit is moderate with lower sugar, juice and acid levels than is the case with quality-inducing rootstocks. The fruit also tend to have a relatively thick rind, and juice quantity and quality is among the poorest compared to other rootstocks. Fruit from trees on rough lemon does not hang as well as on some other rootstocks, with the flesh tending to dry out and to become granulated.

Planting Conditions

Rough lemon can be planted in a wide range of soils, but it is particularly well adapted to deep, coarse sands on which some other rootstocks do not perform well. Rough lemon is not tolerant of root rot and should not to be used on wet, poorly-drained soils, even though it is more tolerant of flooding than most rootstocks. Rough lemon tolerates calcareous soils with a pH above 7.5, but is sensitive to very saline soil conditions. Rough lemon is regarded as a poor replant rootstock, but there are treatments available with which it can possibly perform adequately, provided that irrigation is carefully controlled.

Pest and Disease Tolerance

Trees on rough lemon are tolerant of Citrus tristeza virus and exocortis. They are susceptible to citrus nematodes and are severely affected by *Phytophthora* root rot. High susceptibility to citrus blight is another major weakness of rough lemon and this has affected the extent of its use in South Africa.

Cultivar Options

Eureka lemon in combination with rough lemon performs very well and still remains the primary choice, except on replant and heavy soil types. Rough lemon is also an excellent rootstock for oranges. Some Valencia cultivars have an inherently high juice quality and propagating them on rough lemon does not greatly reduce their quality. These cultivars usually yield best on rough lemon, though Brix will be lower.

Rough lemon is however not a good rootstock for mandarins because the fruit tend to granulate, reducing the already short harvest season of most mandarin cultivars. The alternate bearing tendency of mandarin cultivars may also be enhanced if rough lemon is used as rootstock.

Volckameriana

Volckameriana tree

The Volckameriana rootstock is of Italian origin and is thought to be a natural hybrid of lemon and sour orange. It resembles rough lemon in many respects, but in areas where it is used widely it is not considered an improvement on rough lemon.

This is a mature Volckameriana tree, and this is what the leaves and trunk look like.

Tree Characteristics

As is the case with rough lemon, Volckameriana gives rise to vigorous, large trees. Trees are however less affected by cold than those on rough lemon.

Fruit Characteristics

As with rough lemon, trees on Volckameriana produce a good crop of large fruit, but the internal quality is below average in terms of sugar, juice and acid levels. Fruit also tend to have thicker rinds, and they are prone to granulation if left hanging on the tree.

Planting Conditions

Similar to rough lemon, Volckameriana is adapted to a fairly wide range of soil conditions, and is less susceptible to *Phytophthora* root rot than rough lemon.

Pest and Disease Tolerance

Volckameriana is not susceptible to exocortis, but is damaged by citrus nematodes and sensitive to the Citrus tristeza virus. Trees on Volckameriana are affected by citrus blight and seem to be as susceptible as those on rough lemon.

Cultivar Options

In South Africa the performance of Volckameriana as a rootstock for lemons has been excellent. It has also performed well in combination with grapefruit, Valencia and navel types, but its use in combination with these cultivars is no longer recommended due to its sensitivity to Citrus tristeza virus.

Cleopatra Mandarin

The Cleopatra mandarin originated in India and was introduced into Florida from Jamaica in the mid-nineteenth century. It has been distributed and tested around the world. As is the case with rough lemon and sour orange, its performance as a rootstock has been studied over many years.

Cleopatra has had limited use as a rootstock, but it remains a good option, considering the importance of tolerance to Citrus tristeza virus, blight and salinity, which outweighs the disadvantages of yield and fruit size. This is a mature Cleopatra mandarin tree, and this is what its leaves and trunk look like.

Tree Characteristics

The growth of trees on Cleopatra is good, producing trees of an average to large size. It is, however, a "lazy" rootstock in that while the trees grow well, they fruit relatively poorly until they are eight to ten years old.

Fruit Characteristics

Trees on Cleopatra produce fruit of good quality, similar to the citranges, but the fruit tend to be on the small side, especially in combination with Valencia types.

Planting Conditions

Trees on Cleopatra are tolerant of cold conditions. Cleopatra has a relatively deep root system, and is quite well-adapted to dry conditions, which makes it somewhat drought tolerant. Cleopatra has the highest salinity tolerance of all commercial rootstocks. It does well on deep, loamy, well-drained soils, but is adversely affected by soils with high water tables.

Pest and Disease Tolerance

Trees on Cleopatra are unaffected by Citrus tristeza virus and exocortis, and fairly tolerant of *Phytophthora* root rot. Cleopatra is susceptible to citrus nematodes.

Cleopatra ranks as one of the most tolerant rootstocks to citrus blight. Trees only become affected at an advanced age, which makes Cleopatra a good option for inter-planting in orchards affected by blight.

Cultivar Options

Because of the smaller fruit size, Cleopatra is not considered ideal for use with Valencia types. It has been used with success in combination with navels, where smaller fruit size is less of a disadvantage. Cleopatra also performs well with grapefruit, Eureka lemon and mandarin cultivars with large fruit.

Carrizo and Troyer Citrange

Hybrids of sweet orange and trifoliate orange are known as citranges. Carrizo and Troyer are hybrids of Washington Navel orange and *Poncirus* trifoliata. Carrizo and Troyer citranges are visually indistinguishable.

The main difference between the two is that Carrizo is resistant to the burrowing nematode, a nematode not present in southern Africa. In the past, Troyer was widely used in South Africa, but Carrizo has now become more popular.

These are mature citrange trees. Note the trifoliate leaf formation. This is what the trunk of a citrange rootstock look like.

Carrizo Citrange tree

Tree Characteristics

Trees on Carrizo and Troyer tend to be large, but smaller than those on Swingle citrumelo. Characteristic of these rootstocks is the excellent performance of young trees, both in terms of vigorous growth and producing excellent crops of high quality fruit.

Fruit Characteristics

Fruit size is usually medium to large and internal fruit quality is excellent. A major disadvantage is the tendency to induce a higher incidence of creasing when used in combination with sensitive cultivars.

Carrizo and Troyer also induce higher acid levels than rough lemon, which may be a problem in the cooler production areas, but can be an advantage in hotter areas. Colour development of fruit is usually five to ten days ahead of that on Swingle or rough lemon.

Planting Conditions

Carrizo performs far better in replant orchards than rough lemon. Carrizo and Troyer are sensitive to alkaline-induced chlorosis and in some cases trees have severely declined as a result of iron and other trace element deficiencies on saline, calcareous and especially high pH soils.

Carrizo and Troyer have a less-developed feeder root system than rough lemon and are therefore not as tolerant of low soil moisture levels. Irrigation regimes must be adjusted to take this into account.

Pest and Disease Tolerance

Carrizo and Troyer inherited their susceptibility to citrus viroids from the trifoliate orange parentage. Carrizo and Troyer are ranked as tolerant of *Phytophthora* root rot, Citrus tristeza virus and citrus nematodes.

Trees on Carrizo and Troyer appear somewhat susceptible to Fusarium dry rot decline, and are affected by citrus blight.

Cultivar Options

Carrizo and Troyer are excellent rootstocks for sweet orange and grapefruit cultivars, and for most mandarin hybrids, with midknight Valencia in combination with Carrizo citrange considered a particularly good combination. It is not compatible with Eureka lemon.

Swingle Citrumelo

Swingle Citrumelo tree

Hybrids of grapefruit and trifoliate orange are known as citrumelos. There are many named and unnamed citrumelos, but Swingle citrumelo has been the most widely planted.

In South Africa, Swingle became popular during the 1990s, but its popularity has decreased since due to preferences shown for Carrizo citrange.

This is a mature Swingle tree. Note that it also has a trifoliate leaf. This is what the trunk looks like.

Tree Characteristics

Swingle produces large, vigorous and productive trees. In their first five years, trees on Swingle have similar growth to trees on Carrizo, regardless of scion. The Swingle tree itself is very cold tolerant and trees on Swingle perform better than those on Carrizo citrange or rough lemon in this respect.

Swingle tends to overgrow the scion at the bud union, also referred to as benching. This can cause compression girdling and affect tree performance. Overgrowth has been seen in combination with mandarin types, and with most orange cultivars. It seems to be linked to tree vigour and stem diameter, which means that where tree size is being managed the problem is less prevalent. A higher bud union also reduces the problem.

Fruit Characteristics

Trees on Swingle citrumelo produce high yields of large-sized fruit with excellent internal quality, but fruit size tends to be smaller where crop load is excessive. Rind colour development and late fruit maturity may be delayed due to higher acidity, with acid levels being higher in fruit in cooler production areas. Swingle is prone to cause creasing in scion fruit.

Planting Conditions

Swingle citrumelo is a suitable rootstock for most soils except heavy clay, with a clay content greater than twenty-five to thirty percent possibly restricting root growth. Trees on Swingle are more sensitive to calcareous conditions and subject to lime-induced chlorosis, for which iron chelates can be added to the soil.

pH adjustment to between 5.8 and 6.2 through regular fertigation applications can overcome iron chlorosis on heavy, calcareous soils. Trees on Swingle are more salt tolerant than other trifoliate hybrids. The trees are also moderately drought tolerant, and resistant to cold damage.

Pest and Disease Tolerance

Swingle is classified as resistant to *Phytophthora* root rot, and is tolerant of the citrus nematode and Citrus tristeza virus. Swingle is sensitive to citrus exocortis viroid and to Armillaria, a fungal disease which affects the rootstock just beneath the soil surface.

Cultivar Options

Swingle is a superior grapefruit and Minneola tangelo rootstock, although problems with higher fruit acidity levels occur in the cooler areas. It also works well with Valencia and navel scions. Limited information is available on this rootstock in combination with mandarins, although certain tangors and clementines have performed well. Swingle is incompatible with Eureka lemons, with Tomango and Shamouti midseason cultivars, and with Murcott mandarin.

C35 Citrange

C35 citrange was developed in California and is a cross between Ruby sweet orange and *Poncirus* trifoliate orange. Trees on C35 citrange are very productive, producing good-sized fruit with high internal quality. As a result, C35 has become very popular amongst Californian growers and is now one of their leading rootstocks. This is a mature C35 tree. Note the shape of the leaves. This is the trunk of the C35 rootstock.

Swingle Citrumelo tree

Tree Characteristics

Trees on C35 grow at the same rate as those on Carrizo and Troyer citranges up to about six years of age, at which stage growth slows down with the eventual mature tree size being fifteen to twenty-five percent smaller. Ten years after planting, the tree will be a third smaller in size compared to a tree on Swingle citrumelo. Trees on C35 is less cold resistant than those on Swingle and Carrizo.

C35 has a lower percentage of nucellus seedlings than other citranges. Because of its popularity, demand for seed long outstripped supply. The seed shortage, combined with a high demand for seedlings, led to a situation where seedling culling in the nurseries was insufficient. This resulted in off-type or zygotic seedlings being included in new plantings, resulting in incompatibilities and dieback, as well as poor uniformity in orchards. To produce good quality trees, selection of C35 seedlings in the nursery is therefore very important, where up to thirty percent or higher seedling culling might be necessary.

Fruit Characteristics

Trees on C35 produce very good quality fruit with high internal quality early in the season. Larger fruit size and high yields remain some of the better qualities of this rootstock. As an example, Star Ruby trees on C35 have been recorded as peaking at a hundred kilograms per tree from year seven onwards.

Planting Conditions

As with Carrizo and Troyer, C35 does not adapt well to saline and high pH soils. C35 also performs below average when planted on soil that is very sandy or has a high clay content, and its performance on replant soils is average.

Pest and Disease Tolerance

C35 is tolerant of citrus nematodes and Citrus tristeza virus, and has intermediate resistance to *Phytophthora* root rot. It is sensitive to citrus exocortis viroid and has been found to be sensitive to citrus blight during trials.

Cultivar Options

C35 has performed well in trials in combination with grapefruit, navels, most Valencia and mandarin types, but has shown incompatibility with Turkey Valencias, Nules Clementine and Fukumoto Navel. In general, there appears to be more incompatibility problems with C35 than with the other rootstocks.

Benton Citrange

Benton citrange is a promising new rootstock that was bred in Australia, in an attempt to produce rootstocks compatible with Eureka lemon. It is a hybrid of Ruby Blood orange and trifoliate.

Benton has been used for commercial Eureka plantings in Australia since 1990, where it proved to be both Citrus tristeza virus and *Phytophthora* tolerant. Benton has been tested in South Africa as a rootstock for Eureka lemon.

This is a mature Benton tree, and this is what the leaves and trunk look like.

Swingle Citrumelo tree

Tree Characteristics

Trees on Benton are more compact than trees on rough lemon, Swingle and Carrizo, resulting in more manageable trees, closer spacing and higher production per hectare. Trees grow less vigorously than those on Swingle citrumelo. In the nursery, the rootstock tree has a bushy growth habit with a shrub-like appearance. Trees on Benton also show a good tolerance to drought and cold conditions.

Fruit Characteristics

For Valencia types, Benton produces very good quality fruit with high internal quality early in the season. Medium to larger fruit size remains one of the more favourable traits of this rootstock. A trial of Midknight Valencia on Benton in the Letsitele area produced an average crop of over eighty kilograms per tree.

Planting Conditions

Benton is sensitive to saline and calcareous soils. It outperforms most other rootstocks on replant soil.

Pest and Disease Tolerance

Benton shows intermediate resistance to *Phytophthora* root rot, nematodes and Citrus tristeza virus.

Cultivar Options

Benton is compatible with Eureka lemon and this combination has shown good crop production and fruit size. It is also showing promise in combination with grapefruit, Valencia, Navel and mandarin types. In a rootstock trial in Letsitele it was found to be the best rootstock option in combination with Midknight Valencia in terms of yield, fruit size, internal quality and external colour development.

X639 Hybrid

The X639 rootstock arose from a cross between Cleopatra mandarin and *Poncirus* trifoliate and was bred in South Africa. This is a mature X639 tree. This is what the leaves and trunk look like.

Tree Characteristics

Trees on X639 are less vigorous than those on Swingle citrumelo, and more similar to Carrizo citrange, with a fairly smooth bud-union between the scion and rootstock. X639 develops a medium-sized tree in combination with most scion cultivars. Trees on X639 show good cold hardiness.

Fruit Characteristics

X639 is capable of inducing good internal fruit quality and of producing fair yields of good-sized fruit. High levels of creasing of fruit on this rootstock are occasionally reported, and it is best to scion cultivars that are not susceptible to creasing.

Planting Conditions

X639 performs well on higher pH soils and is suitable for most soils except in extremely calcareous conditions. It performs particularly well on loamy soils and where fruit with a high internal quality is required.

Pest and Disease Tolerance

X639 is tolerant of *Phytophthora* root rot and Citrus tristeza virus, but highly susceptible to citrus viroids. Trees on X639 are susceptible to citrus blight, but take about twelve years to show decline.

Cultivar Options

X639 is compatible with Eureka lemons. This combination has performed very well on replant soils. X639 is a rootstock with promise for other cultivars as well, seemingly well-suited to grapefruit and with no apparent problems in combination with Valencias, navels and mandarins. It is considered a very good option for Midknight Valencia.

Minneola x Trifoliate Hybrid (MxT)

MxT is a hybrid of minneola tangelo, itself a cross between a grapefruit and a tangerine, and a trifoliate orange. This is a mature MxT tree. Note the trifoliate shape of the leaf. This is what the trunk of an MxT rootstock tree looks like.

Tree Characteristics

MxT is a vigorous rootstock plant in the nursery, but once budded, it controls the size of the scion. Mature trees on MxT are slightly smaller than those on Swingle and Carrizo.

Fruit Characteristics

Trees on MxT have excellent yield per tree, and the internal fruit quality is high.

Planting Conditions

The adaptability of MxT to various soil conditions is not well-known, but it seems as if it does not adapt well to soils with a high pH. It is suitable for replant soils.

Pest and Disease Tolerance

MxT is sensitive to exocortis, but tolerant of Citrus tristeza virus, *Phytophthora* root rot and citrus nematodes.

Cultivar Options

MxT is compatible with most scion varieties, and performs well with Eureka lemons. It is incompatible with Kumquat cultivars.

US-812 (Sunki x Benecke)

The Sunki Benecke rootstock is a hybrid of Sunki mandarin and Benecke trifoliate orange, and was developed in the USA. It has been commercially available since 2001. Sunki Benecke is still relatively new in South Africa and has not been extensively tested with different cultivars under different growing conditions. This is a mature Sunki Benecke tree. This is what the leaf and trunk of the Sunki Benecke looks like.

Tree Characteristics

The average size of trees on Sunki Benecke is medium to large, except for Star Ruby which has a compact tree size.

Fruit Characteristics

Trees on Sunki Benecke produce high yields from a young tree age. The fruit is medium in size with good to excellent internal quality. Trials with Delta and Midknight Valencia have produced an average crop of over a hundred kilograms per tree.

Planting Conditions

Sunki Benecke was selected as a rootstock option because of its tolerance to high pH and calcareous soils and generally performs well in most replant conditions.

Pest and Disease Tolerance

Sunki Benecke is resistant to *Phytophthora* root rot and tolerant of nematodes, Citrus tristeza virus and blight, but is expected to be sensitive to citrus exocortis.

Cultivar Options

Sunki Benecke is compatible with Eureka lemons, and is a promising new rootstock which can be used on a semi-commercial scale in combination with grapefruit, Valencia, Navel and mandarin types.

Conclusion

The choice of the right rootstock can be critical to the ultimate success of the citrus farm. It is therefore important that you make your decision after careful consideration and obtaining the advice from cultivar experts and the citrus nursery. Citrus Research International and the Citrus Improvement Scheme are excellent sources of information on rootstocks, and can advise on the latest research findings.