# Contents of Module 5

# The Role of Plant Nutrients

## Introduction

All plants need the following to grow and produce food, and to complete their lifecycles:

- Sunlight
- Water
- Air (containing oxygen and carbon dioxide)
- Nutrients (food), or mineral nutrient elements or **essential nutrient elements**

Different kinds of plants need the above in different quantities. For instance, in the garden there are some plants, such as ferns, that prefer to grow in the shade, while others prefer full sun. Some plants may need a lot of water, while others get along with very little. While all kinds of plants need the same nutrient elements, they need them in different quantities of specific nutrients.

Plants get nutrients from the growth medium and the irrigation water, and fertilisers must supply what these two cannot supply enough of naturally. If a citrus tree is provided with the correct essential nutrient elements in the correct chemical formula and quantities at the right time, it helps the plant to grow well. To do this, we need to know:

- Which nutrients does this plant need?
- How much of these nutrients does this plant need?
- What is the best way to supply these nutrients?

Growth mediums can be composed of almost any material and it may or may not contain the essential nutrient elements. Some growth mediums are pure quarts sand containing hardly any nutrient, while others may contain compost which will add almost all the nutrients.

## Essential Nutrient Elements for Citrus

Each essential nutrient element has a special role or roles in the functions of plants. These nutrients are called **essential** elements because without them a plant cannot complete its lifecycle from seed through the vegetative and reproductive stages to the seed stage. Essential nutrient elements are grouped in **macro** elements, of which the plant needs relatively large quantities, and **micro** elements, of which the plant needs relatively small quantities.

information

### Please Note

While you are not required to learn the chemical symbols of the nutrient elements, it will be useful because the elements are referred to by their symbols in the rest of the material.

| Name | Chemical symbol |
|---|---|
| **Macro nutrient elements** | |
| * Carbon | C |
| * Oxygen | O |
| * Hydrogen | H |
| Nitrogen | N |
| Phosphorus | P |
| Potassium | K |
| Calcium | Ca |
| Sulphur | S |
| Magnesium | Mg |
| **Micro nutrient elements** | |
| Sodium | Na |
| Copper | Cu |
| Iron | Fe |
| Manganese | Mn |
| Zinc | Zn |
| Boron | B |
| Molybdenum | Mo |
| Chloride | Cl |

The first three macro nutrient elements (*) are supplied to the plant by the air and water, and are not supplied through fertilisers. We therefore generally refer to fourteen essential nutrient elements.

# The Role of Essential Nutrient Elements

Before we look at the symptoms caused by nutrient deficiencies, we need to understand the role that each essential nutrient element plays in the physiological processes of a plant. The role of each element is complex and elements are involved in many physiological processes of which some are still not understood. In the table below, the roles of the essential nutrient elements are summarised.

| Essential nutrient element | Function |
|---|---|
| Nitrogen (N) | Nitrogen forms part of all protein and enzyme molecules and is therefore involved in almost every physiological process in plants. |
| Phosphorus (P) | Phosphorus is involved in all energy transfer reactions in the plant. It is also part of the nucleic acids in cells. |
| Potassium (K) | Potassium has many rolls, including cell-division and transport of photosynthetic products from the leaves to the roots and other parts. |
| Calcium (Ca) | Calcium forms a vital part of all cell-walls, keeping the cells together in the same way as cement in a brick wall. |

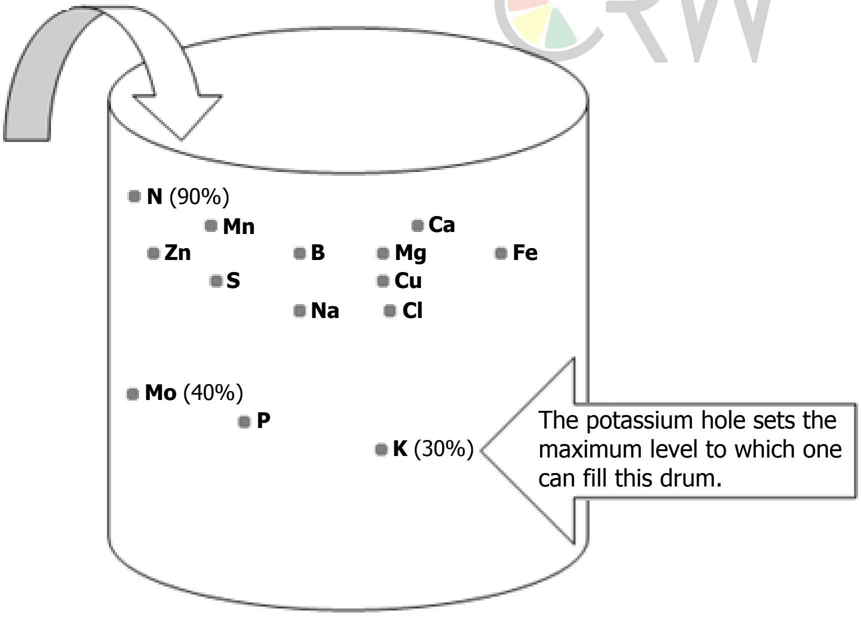
| Essential nutrient element | Function |
|---|---|
| Magnesium (Mg) | Magnesium forms the centre metal ion in the chlorophyll molecule, which is required for photosynthesis, apart from its role in other physiological processes. |
| Sulphur (S) | Sulphur is involved in the production of the sulphur-containing amino acids and in reproductive processes. A sulphur deficiency will reduce flowering and fruit set. |
| Sodium (Na) | Sodium can replace potassium to some extent in certain plants. |
| Chloride (Cl) | Chloride is a micro-nutrient, with plants requiring about 20mmg per litre in their nutrient solution. Chloride is involved in the reactions where water molecules are split during photosynthesis. |
| Other micro nutrient elements Cu, Fe, Mn, Zn, B and Mo | Are involved in many physiological reactions as catalysts. |

For a more detailed description of the roles of the essential nutrient elements, please refer to the classic publication of **Homer D Chapman: Mineral Nutrition of Citrus**.

# The Most Limiting Element

The ability of the plant to grow and produce food is determined by the level of most limiting nutrient element.

There is an optimum level for every nutrient element. The portion of that optimum level that is available to the plant determines the plants ability to complete the processes related to that element. The element of which the lowest portion is available is the most limiting element, because the plants ability to grow will be limited to this portion, or percentage.




This effect can be illustrated by trying to fill a drum or bottle that has holes at various levels in its side. Each hole represents the percentage of the optimal concentration of a nutrient element that is available to the plant. In the illustration, K is the most limiting element (the lowest hole). This means that no matter how much of all the other elements are available, the plant will only fulfil 30% of its growth potential because it only has 30% of the K that it needs.

To fill the drum (optimise plant growth), one first has to block the lowest hole, i.e. the element that is at the lowest percentage of its optimum concentration (K). Thereafter, you can fill the drum to the level where phosphorus (P) becomes the most limiting element. If you first block the nitrogen (N) hole before blocking the K hole you still will not be able to fill the drum to more than 30%.

Blocking a whole means bringing that element up to its optimum concentration, or to 100%. To fill the drum all nutrient elements must be present at their respective optimal concentrations, or 100% level. Getting the N level to 100% and not the K level will not enable the plant to produce at 100% capacity. Although molybdenum is required in very small quantities compared to nitrogen, the shortage of this element will still cause the plant to produce, in this example, at only 40% of its capacity.

Fertilisation of commercial citrus production is about keeping all holes blocked at the lowest cost.

# Nutrient Deficiency Symptoms

**definition**

### Nutrient Deficiency

A nutrient deficiency is when there is not a sufficient quantity of a specific nutrient element and the plant cannot complete a certain physiological process as a result.



The most important features of nutrient deficiency symptoms are:

- The leaf should display the same characteristics on the left- and right-hand side of the midrib. This is important in distinguishing between nutrient deficiencies and other leaf symptoms.
- Nutrient deficiency symptoms first appear on either new or old leaves. From there the symptom can spread to the entire plant.
- Certain nutrient deficiency symptoms appear first or more noticeably in the fruit.
- Nutrient deficiency starts with mild symptoms and develops into severe symptoms.
- Sometimes more than one deficiency symptom appears on the same leaf making identification difficult.
- Sometimes the nutrient deficiency symptom is blurred by a symptom caused by factors other than nutrient deficiencies.

| Nutrient element | First plant part to display symptoms | Mild expression | Severe expression |
|---|---|---|---|
| Nitrogen (N) | Old leaves | Yellowing of all old leaves, to a light yellow colour | Yellowing of all leaves just before or during new leaf flush resulting in leaf drop |
| Phosphorus (P) | Fruit | Open centre resembling over-matured fruit | Thick skins and puffy fruit with high acid levels |

| Nutrient element | First plant part to display symptoms | Mild expression | Severe expression |
|---|---|---|---|
| Potassium (K) | Fruit | Small fruit | Small fruit with thin skins combined with a low yield; on young trees the leaves may turn bronze |
| Calcium (Ca) | Fruit | Increase creasing incidence (physiological disorder); not yet confirmed | Chlorosis (yellowing) of very young leaves and dieback of growth tips |
| Magnesium (Mg) | Old leaves | Chlorosis of front of leaf from tip and sides; inverted green V with open end of V at petiole side appears as symptom develops | Leaf drop and decrease in fruit set |
| Sulphur (S) | New leaves | Yellowing to butter-colour of new leaves on green twig | Extremely reduced fruit set |
| Copper (Cu) | New leaves | Extra large leaves on strong new growth | Gum pockets in albedo (white part of the peel) of fruit; fruit is small, thin-skinned and hard |
| Iron (Fe) | New leaves | Yellowing of lamina (leaf blade) of young leaves leaving well-defined network of small veins | Reduced fruit set |
| Manganese (Mn) | New leaves | Inter-veinal yellowing of normal-sized leaf, almost over entire leaf Broad green areas around veins and chlorotic areas between veins are most obvious symptoms | Increase in number of leaves affected |
| Zinc (Zn) | New leaves | Interveinal yellowing of small-sized leaf, starting at tip of leaf Resembles manganese deficiency, but appears on small leaves and chlorosis starts at tip of the leaf | Increase in number of leaves affected and reduction in fruit size |
| Boron (B) | New leaves | Corking of midrib vein on underside of leaf Resembles symptoms of cold damage on leaves | Gum pockets around centre of the fruit Fruit size reduced |

# Rectifying Nutrient Deficiencies

The first response to detecting nutrient deficiency symptoms is to report to the supervisor or manager. Citrus nurseries should have reporting procedures in place that allow the relevant information to reach the persons responsible for taking corrective action as soon as possible.

The presence of nutrient deficiency symptoms is a sign of an unsuccessful fertilisation program. Deficiency symptoms appear after the shortage has an impact on the plant. The fertilisation program should provide for methods to identify and correct short supplies of any essential nutrient element before it impacts on the tree.

Rectifying nutrient deficiencies are seldom a simple matter of applying the nutrient. Very often the deficiency is the result of factors other than an absolute short supply. Inducing a deficiency means that these factors convert the nutrient into an unavailable form or a form which is physiologically less active. To improve the supply of the specific nutrient, one needs to determine why its supply is not optimal and try to correct that. However, in nurseries the deficiency is more often the result of a too low concentration of the available specie of the nutrient.

Once nutrients have been applied to the plant, there is unfortunately no guarantee that the active form will last long enough to result in the required physiological reactions. To maintain optimal concentrations of the nutrient elements in the trees, enough of the nutrient in the available form must be present to be utilised by the plant. Unlike plants in open ground, plants in containers have a much smaller volume of growth medium to exploit and need frequent applications of small masses of fertilisers.

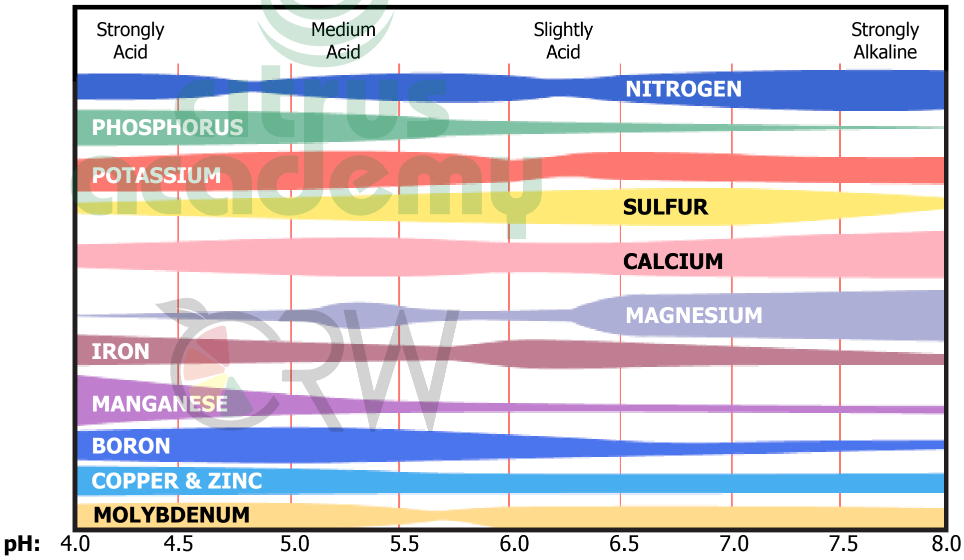
The table below lists that most common causes of and factors associated with nutrient deficiencies, and the corrective measure that can be taken.

| **Nutrient element** | **Causes of deficiency and factors that can induce a deficiency** | **Corrective actions** |
|---|---|---|
| Nitrogen (N) | Too little applied | Increase the application |
| | Too much lost due to leaching | Split application and control irrigation |
| | Phytophthora (root rot) (limits ability of plant to take up nitrogen from growth medium) | Remove tree from nursery and discard |
| Phosphorus (P) | Too little applied | Increase the application |
| | Growth medium pH too high | Not much can be done |
| | Growth medium pH too low | Apply lime to growth medium or change the ammonium : nitrate ratio |
| Potassium (K) | Too little applied | Increase the application |
| | Mg supply too high | Apply K through foliar sprays |
| | Nematodes | Treat the pest |
| Calcium (Ca) | Too little applied | Increase the application |
| | Climatic conditions | Increase application during critical periods |
| | Growth medium pH too low | Apply lime to growth medium |
| Magnesium (Mg) | Too little applied | Increase the application |
| | K supply too high | Apply Mg through foliar sprays |
| | Growth medium pH too low | Apply lime to growth medium |
| Sulphur (S) | Too little applied | Increase the application |
| Copper (Cu) | Too little applied | Increase the application |
| | Growth medium pH too high | Apply Cu though foliar sprays |

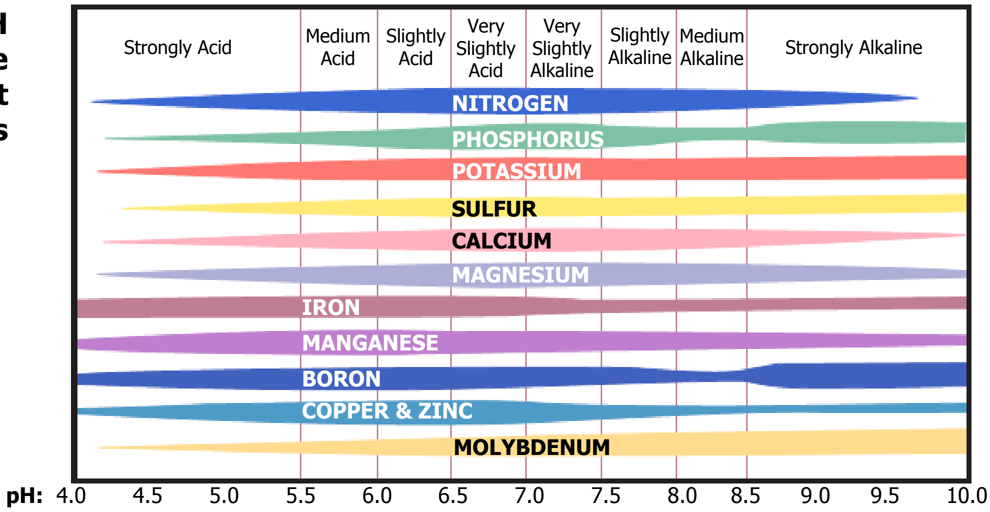
| Nutrient element | Causes of deficiency and factors that can induce a deficiency | Corrective actions |
|---|---|---|
| Iron (Fe) | Too little applied | Increase the application |
| | Growth medium pH too high | Apply chelate stable at high pH |
| | Over-irrigation | Reschedule the irrigation |
| Manganese (Mn) | Too little applied | Increase the application |
| | Growth medium pH too high | Apply Mn through foliar sprays |
| | Recent application of lime | Apply Mn through foliar sprays |
| Zinc (Zn) | Too little applied | Increase the application |
| | Growth medium pH too high | Apply Zn through foliar sprays |
| | Too much P applied | Apply Zn through foliar sprays |
| Boron (B) | Too little applied | Increase the application |
| | Growth medium pH too low | Apply lime to growth medium |

As can be seen from the above table, the pH of the growth medium affects the availability of nutrients for uptake by plant roots. In the graphics below, the effect of soil pH on nutrient uptake is shown.

**The Effect of the pH of Soilless Media on the Availability of Plant Nutrients**




**The Effect of the pH of Soil on the Availability of Plant Nutrients**




**Courtesy of Ocean Agriculture (Pty) Ltd**

## summary

### The Role of Plant Nutrients

- Plants need sunlight, water, air (oxygen and carbon dioxide) and nutrients in varying quantities to grow well and produce food.
- Nutrients are also called essential nutrient elements.
- Essential nutrient elements are divided into macro- and micro nutrient elements.
- Essential nutrient elements play various roles in the physiological processes in plants, some of which are still not understood.
- The plant's ability to complete its physiological process, grow and produce food depends on the concentration of the most limiting element.
- Each nutrient element has a very specific role and function in the metabolism or life of a plant.
- The most limiting element is the nutrient element present at the lowest percentage of its optimum concentration. Even if only one nutrient element is not at optimum concentration, the plant will be limited in its ability to grow.
- Nutrient deficiency symptoms are specific to the nutrient that is not at the optimum level, but can be blurred by a combination of deficiency symptoms or symptoms of other factors.
- The fertilisation program should provide for keeping nutrient elements at optimum levels.
- The cause of the deficiency has to be identified in order to deal with it effectively.

# Fertiliser Application

## Introduction

To grow citrus successfully, we need to know:

- Which nutrients are required
- The quantities of nutrients required
- The right time to apply them
- The best way to apply them

In this section we look at the different methods used to apply fertilisers.

## Nutrient Applications

Nutrients that are applied to plants are commonly referred to as **fertilisers**. Fertilisers are supplied to citrus trees in the nursery in one or in a combination of the following ways:

- **Pre-plant applications**, which is when the fertiliser is applied to the growth medium prior to potting, by using one of the following:
    - **Slow release fertilisers** that last 6, 9 or 12 months
    - **Fairly insoluble fertilisers**, such as lime, gypsum, single supers, supported by maintenance applications and foliar sprays
- **Maintenance applications**, through:
    - **Manual applications**, which is the application of granular and powdered forms of fertiliser to the surface of the growth medium by hand or by applicator
    - **Fertigation**, meaning the applications of solutions of water-soluble powdered fertiliser by means of the irrigation water
- **Foliar applications**, which is when the fertiliser is dissolved in water and sprayed onto the leaves of the plant

In citrus nurseries, the most commonly used means of nutrient application is fertigation. Nutrients are applied to the trees on an ongoing basis in low quantities through the irrigation system. Another method is the infrequent applications of slow release fertilisers.

## Commercially Available Fertilisers

Fertilisers can be from organic (natural and synthetic) or inorganic (chemical) sources. Mixtures of the two are also available in South Africa. The most common essential nutrient elements contained in fertilisers are nitrogen, phosphorus and potassium. They are available in compounds containing one, two or all three of these nutrient elements. Nitrogen is available in organic form and inorganic form, or mixtures of the forms.

Fairly complete mixtures to prepare nutrient solutions are commercially available, but the formulations are based on the average requirement and do not take into account the composition of the irrigation water.

Compost is a form of organic fertiliser, and is normally made by allowing plant material to decompose under specific conditions. Compost is however not recommended for use in commercial citrus nurseries, because it is difficult to determine and control the nutrient element content of and release from the compost, and to ensure that compost remains pathogen free. Other examples of organic fertilisers are chicken and cattle manure. Because organic fertilisers are not recommended for use in nurseries, only commercially available fertilisers are discussed in this programme.

Plants require nutrients in specific chemical forms, which are present in a number of commercially available fertilisers. Even when organic fertilisers are used, the nutrients must first be converted to these forms before they can be absorbed by plants. Fertilisers are found in the following forms:

- **Granular** – rough granules which are used in growth medium applications as pre-plant or maintenance applications
- **Powdered** – fine powder that are either used as pre-plant or maintenance applications or mixed with water for foliar applications or fertigation
- **Liquid** – liquid fertilisers that are mixed with water for foliar applications or fertigation

In the table below is a list of the fertilisers suitable for nurseries, commonly available in Southern Africa, showing the nutrient element that each fertiliser provides to a plant.

| Fertiliser | Nutrient elements | Nutrient content |
|---|---|---|
| Potassium sulphate | K and S | 40-45% K*, 19% S* |
| Potassium nitrate | K and N | 38% K, 13% N |
| Mono potassium phosphate (MKP) | K and P | 29% K, 24% P |
| Mono ammonium phosphate (MAP) | N and P | 11-12% N and 22-26% P |
| Calcitic lime | Ca | minimum 35% Ca |
| Dolomitic lime | Mg | maximum 10% Ca and minimum 4.3% Mg |
| Gypsum | Ca and S | 23% Ca, 19% S |
| Calcium nitrate | Ca and N | 17% Ca, 12% N |
| Magnesium nitrate | Mg and N | 10% Mg 10% N |
| Magnesium sulphate | Mg and S | 10% Mg, 13% S |
| Limestone ammonium nitrate (LAN) | N | 28% N |
| Urea | N | 46% N |
| Ammonium sulphate | N | 21% N, 23% S |
| Ammonium nitrate | N | 19-34% N |
| Ammonium sulphate nitrate | N | 27% N, 12% S |
| Single super phosphate | P, Ca and S | 10% P, 10% S, 10% Ca |

# The Fertilisation Program

We have seen that citrus plants require a range of nutrients in different quantities to grow well. A fertilisation program for a nursery is developed by a specialist, taking into account specific conditions in the nursery, of which the most important are the water quality and the properties of the growth medium.

Water and growth medium analyses are therefore done before the fertilisation program is compiled. Once the fertilisation program has been developed, preparations can be made to apply the fertilisers.

**example**

## Typical Nursery Fertigation Program

**Please note:** The fertilisation program below was developed for a nursery with a low EC and pH. The fertilisers are mixed in 600l concentrates and added to irrigation water when it is applied in a ratio of 1:100, fertiliser concentrate to irrigation water. The time that it takes to apply one tank of concentrate depends on how often one irrigates.

| FERTIGATION PROGRAM – CITRUS NURSERY | |
|---|---|
| **Fertiliser** | **Quantity** |
| **Tank 1 – 600 litre concentrate** | |
| Potassium nitrate | 18.432kg |
| Calcium nitrate | 38.376kg |
| **Tank 2 – 600 litre concentrate** | |
| Micro Fe600 | 0.250kg |
| Boric acid | 0.096kg |
| Manganese sulphate | 0.056kg |
| Zinc sulphate | 0.009kg |
| Copper sulphate | 0.0018kg |
| Sodium molybdate | 0.0009kg |
| Magnesium sulphate | 22.500kg |
| Mono ammonium phosphate (MAP) | 8.172kg |
| **Remarks:** Supply both concentrates at the same time in irrigation water at 100-125 mS/m | |



**information**

## Fertigation Nutrient Solutions

The table below contains general guidelines for the concentration of nutrients in the total nutrient solution (TNS) that is applied to citrus nursery trees.

| Element | Symbol | Ppm (1ppm = 1mg/l) |
|---|---|---|
| Nitrogen | N | 150-250 |
| Phosphorus | P | 50 |
| Potassium | K | 100-200 |
| Calcium | Ca | >50 |
| Magnesium | Mg | 50 |
| Sulphur | S | >50 |
| Iron | Fe | 2.5-5.0 |
| Copper | Cu | 0.025-0.05 |
| Manganese | Mn | 0.25-0.5 |
| Zinc | Zn | 0.5-1.5 |
| Boron | B | 0.25-0.5 |
| Molybdenum | Mo | 0.01-0.1 |

As in the example above, the TNS is applied to trees with every irrigation application. If the trace elements are not supplied by fertigation, they may be supplemented on a four to six week basis by foliar applications. Note that the optimum ratio for N:P:K is 5:1:3 to 6:1:4.

When preparing the nutrient stock solution or concentrated solution, it is always important to consider the solubility of the various fertilisers. In the table below, the solubility of some fertilisers suitable for fertigation is indicated.

| Product | Formula | Solubility (gram per litre) |
|---|---|---|
| Ammonium nitrate (34% N) | $NH_4NO_3$ | 180 |
| Ammonium sulphate (21% N) | $(NH_4)_2SO_4$ | 705 |
| Calcium nitrate (% Ca, 12% N) | $Ca(NO_3)_2$ | 1,210 |
| Urea (46% N) | $NH_2CONH_2$ | 1,000 |
| Mono-ammonium phosphate (12% N, 26% P) | $NH_4H_2PO_4$ | 227 |
| Potassium nitrate (13% N, 38% K) | $KNO_3$ | 130 |
| Potassium sulphate (45% K, 23% S) | $K_2SO_4$ | 120 |
| Mono potassium phosphate (24% P, 28%K) | $KH_2PO_4$ | 330 |

Another important factor is the compatibility of the various chemicals. In principle never mix sulphates and calcium in a concentrated solution. When in doubt conduct the bottle test, as follows:

Consider the bottle as a replica of the mixing tank. Use a 5 litre clear plastic bottle. Fill it to 75% capacity with clean water. Add the chemicals one at a time in the same ratio of mass / volume to water and ensure that the first one is completely dissolved before the next one is added. Leave the mix for 24 hours and observe any precipitation at the bottom. If no sediment is present and the solution is clear, then the two chemicals are compatible in that ratio and dilution.

# Fertigation Applications

The manner in which a nutrient solution is applied through fertigation depends on the fertigation system that is used in the nursery, and the form in which the fertiliser is supplied. Nutrient solutions can be bought ready-mixed from suppliers and either added directly to the irrigation water or introduced into the irrigation system at the prescribed rates.

Nutrient solutions can also be mixed at the nursery, according to the directions on the fertigation program. It is extremely important to use only forms of fertiliser that are entirely soluble in water, so that there is no residue in the irrigation system. When the nutrient solution is mixed, it is important that the prescribed volume or mass of each fertiliser is measured or weighed very carefully and accurately, and that the solution is mixed very well, preferably with a mechanical stirrer.

Apart from the volume water required to re-wet the growth medium to container capacity, an additional volume of water, called the leaching requirement, should be added to get rid of the salts accumulated from the previous fertigation. The leaching requirement depends on the EC of the water or nutrient solution. In the table below, the relationship between the EC of the water or nutrient solution and the leaching requirement (LR) for 100 and 90% production, is shown.

| **EC of water ($mSm^{-1}$)** | **LR for 100% production** | **LR for 90% production** |
|---|---|---|
| 50 | 7 | 5 |
| 75 | 10 | 7 |
| 100 | 14 | 10 |
| 125 | 18 | 12 |
| 150 | 22 | 15 |
| 175 | 26 | 18 |



**information**

## Leaching Requirement

These values are calculated from the following formulas:

LR for 100% production = EC of the water ÷ 850-EC of the water
LR for 90% production = EC of the water ÷ 1165-EC of the water

# Applying Foliar Applications

Foliar applications are prepared by mixing the prescribed nutrient carrier after measuring or weighing the prescribed volume or mass of fertiliser very carefully. Mix the solution well, preferably with a mechanical stirrer.

Foliar sprays are applied with manual or motorised knapsack sprayers as a medium cover spray.

practical

## Activity 5.1 – Workplace Procedures

Find examples of at least one granular and one liquid fertiliser in the nursery. Write down step-by-step procedures on how each of fertiliser is applied.

## Activity 5.2 – Logbook

Hand in a logbook proving that you have successfully done the following:

- ✓ Collected fertiliser from storage
- ✓ Measured / weighed fertiliser accurately according to instructions
- ✓ Prepared fertiliser according to the correct procedures
- ✓ Applied fertiliser correctly to citrus plants

Make sure that you attach all the relevant instructions to your workbook and that your supervisor signs off that you have completed these tasks successfully.

summary


## Fertiliser Application

- To grow citrus successfully, we need to know which nutrients are required, the quantities of nutrients required, the right time to apply them, and the best way to apply them.
- Nutrients, or fertilisers, can be applied through growth medium applications (manual or mechanical), foliar applications, and fertigation. In nurseries, fertigation and foliar applications are commonly used.
- Fertilisers can be from organic (natural or synthetic) or inorganic (chemical) sources. In commercial citrus nurseries inorganic, commercial fertilisers are mostly used.
- Compost and manure are forms of organic fertilisers that are produced by allowing organic material to decompose.
- Commercial fertilisers are available in granular, powdered and liquid form.
- A fertilisation program for a nursery is developed by a specialist, taking into account specific conditions in the nursery, of which the most important are the water quality and the properties of the growth medium.
- The manner in which a nutrient solution is applied through fertigation depends on the fertigation system that is used in the nursery, and the form in which the fertiliser is supplied.
- Foliar applications are prepared by mixing the prescribed nutrient solution after measuring or weighing the prescribed volume or mass of fertiliser very carefully.
- Foliar sprays are applied with motorised knapsack sprayers with a medium cover spray.

# Sampling

## Introduction

In nurseries, the preferred practise is to keep all growing conditions as close to optimal as possible because managing by symptoms is not an option. Symptoms, whether of deficiency or excess, is an indication of negative impact on growth long before they become apparent.

The recommended practice is to monitor the nutrient status of the tree through:

- Start correctly and maintaining optimal conditions
- Taking regular samples of incoming growth mediums
- Regularly measuring the pH and EC of the nutrient solution (or water)
- Regularly measuring the pH and EC of leachate at the bottom of container after irrigation
- Taking leaf samples and having them analysed in a laboratory – a special set of optimum values for citrus nursery trees have been developed
- Taking growth medium samples from time to time to monitor the changes in pH, electrical conductivity and other properties of the growth medium

## Growth Medium Sampling

Growth medium is sampled only to monitor the pH and electrical conductivity of the medium in-house or to send the sample to a laboratory for a comprehensive analyses.

Growth medium samples are taken from representative trees. At least 15 small sub-samples are collected from the designated containers and mixed together in a clean plastic bucket. From this mix a composite sample is taken for analysis. For in-house analyses, a sample of 50 to 100ml will suffice, but for a laboratory analyses a sample of 500ml for chemical and 2,000ml for physical or biological analyses is required.

skills

Please see the instructions on **Growth Medium Sampling** in the Skills module.

## Growth Medium Testing

The electrical conductivity of the growth medium can now be tested.

skills

Please see the instructions on **Measuring Electrical Conductivity of Growth Medium** in the Skills module.

If the electrical conductivity is above 200mS/m, the growth medium must be leached. This is done by applying more irrigation water than usual so that the build up of salts is washed out, until the water drains from the bottom of the bag has an EC equal to that of the nutrient solution. A garden hose can also be used to leach out the excess salts but only as an emergency measure. The irrigation scheduling should cater for leaching.

When a sample is sent to the laboratory a more comprehensive analyses can be requested.

**information**

## Optimal Nutrient Concentrations for Growth Medium

**Please note:** The optimal concentrations of the nutrient elements also depend on the water holding capacity (WHC) and the moisture content of the sample. The table below shows the optimal concentration range of the nutrient elements in a 1:1.5 water extract, at three different water holding capacities.

| Element | WHC 10-20% (mmol/l) | WHC 21-40% (mmol/l) | WHC 41-60% (mmol/l) | WHC 10-20% (mg/l) | WHC 21-40% (mg/l) | WHC 41-60% (mg/l) |
|---|---|---|---|---|---|---|
| $HPO_4^{=}$ | 0.10-0.30 | 0.25-0.45 | 0.40-0.60 | 10-29 | 24-44 | 39-58 |
| $NO_3^{-}+NH_4^{+}$ | 0.90-2.00 | 1.75-3.90 | 3.50-5.75 | 32-70 | 61-137 | 122-200 |
| $SO_4^{=}$ | 0.21-0.50 | 0.40-0.85 | 0.65-1.25 | 20-48 | 38-82 | 62-120 |
| $Cl^{-}$ | <0.50 | <1.00 | <1.50 | <18 | <35 | <53 |
| $K^{+}$ | 0.35-0.75 | 0.65-1.40 | 1.25-2.00 | 14-29 | 25-55 | 49-78 |
| $Ca^{++}$ | 0.35-0.75 | 0.65-1.40 | 1.20-1.75 | 14-30 | 26-56 | 48-70 |
| $Mg^{++}$ | 0.15-0.35 | 0.30-0.60 | 0.55-0.80 | 4-8 | 7-14 | 13-19 |
| $Na^{+}$ | <0.50 | <0.75 | <1.00 | <11 | <17 | <23 |
| $Cu^{++}$ | 0.10-0.20 | 0.16-0.47 | 0.40-0.65 | 0.006-0.013 | 0.010-0.030 | 0.025-0.041 |
| $Fe^{++}$ | 6-12 | 10-25 | 20-36 | 0.35-0.67 | 0.56-1.40 | 1.12-2.01 |
| $Mn^{++}$ | 2.50-5.00 | 4-10 | 9-15 | 0.14-0.27 | 0.22-0.55 | 0.49-0.82 |
| $Zn^{++}$ | 0.50-1.10 | 0.90-2.00 | 1.75-3.00 | 0.033-0.072 | 0.06-0.131 | 0.115-0.200 |
| $BO_3^{---}$ | 23-46 | 37-56 | 46-69 | 0.25-0.50 | 0.40-0.60 | 0.50-0.75 |
| EC mS/m | 30-60 | 50-85 | 75-100 | 30-60 | 50-85 | 75-100 |

# Leaf Sampling

Leaf samples can be taken from non-bearing trees planted in the orchard and from nursery stock, whether it is rootstock or scion material. Ten to fifteen leaves are collected per sample and put in a clean plastic bag. A label is attached to the sampling bag, with full details of the nursery on the label.

**skills**

Please see the instructions on **Leaf Sampling** in the Skills module.

information

## Optimal Nutrient Concentrations for Leaf Samples

The following optimal range of the concentration of the nutrient elements for leaf samples from nursery and non-bearing trees can be applied.

| Element | Minimum to maximum |
|---|---|
| N % | 3.00 to 4.50 |
| P % | 0.25 to 0.35 |
| K % | 2.25 to 3.00 |
| Ca % | 1.50 to 3.00 |
| Mg % | 0.25 to 0.50 |
| S % | 0.25 to 0.50 |
| Cu mg/kg | 8 to 20 |
| Fe mg/kg | >30 if the pH <7.0 |
| Mn mg/kg | 30 to 200 |
| Zn mg/kg | 20 to 100 |
| B mg/kg | 25 to 100 |

The electrical conductivity (EC) of an extract of leaves from nursery trees will also give an indication of the total amount of salt absorbed. This measurement is handy when dealing with fluctuating EC in the nutrient solution. One gram dried leaf material is extracted with 25ml demineralised water for one hour. The optimal EC of the extract is 150 to 200 $mSm^{-1}$.

practical

## Activity 5.3 – Draw a Poster

Create a poster to explain to new and temporary nursery workers how to take leaf samples. Be sure to specifically note things that can go wrong. Include the poster in your workbook.

summary

## Sampling

- In nurseries, the preferred practise is to keep all growing conditions as close to optimal as possible because managing by symptoms is not an option.
- Growth medium sampling is done from time to time to monitor the pH and electrical conductivity, and to evaluate the medium and for quality control purposes.
- Small sub-samples of growth medium are collected from representative containers and mixed

together to make the composite sample.

- Salts can build up in the growth medium if the salinity of the water is high, over-fertilisation happens, and / or the leaching requirement is not met.
- If the electrical conductivity is above 200mS/m, the growth medium must be leached by applying more irrigation water than usual, until the EC of the water drains from the bottom of the bag equals that of the nutrient solution.
- Leaf samples can be taken of nursery trees, for which a set of optimum values have been developed.
- Leaf samples can be taken from rootstock or scion material, with ten to fifteen leaves collected per sample.