P.O. Box 461, Hillcrest, 3650
(031) 765-3410

Citrus Orchard Foreman Occupational Learning

Work Scenario Guide

A1:
New Enterprise Planning

Qualification:	110667 – Occupational Certificate: Orchard and Vineyard Foreman
Work Scenario:	**A1: New Enterprise Planning**
Learning Area:	A: Take part in the business management of the farming operation
Scenario Description:	You are working with management and the farm owner to plan the establishment of a new farm, or an extension to your current farm. To do this, you need to participate in planning for the financial and operational management of the new farm.

1st edition (06/2026)

Content originator:
Citrus Academy

Occupational alignment:
Ukudla Namanzi (Pty) Ltd

Contents

Alignment Information **7**
Qualification 7
Modules 7
Learning Outcomes 8

Chapter 1 The Farm Environment **11**
1. Introduction 11
2. Climatic and Environmental Requirements 11
3. Temperature 12
4. Sunlight 12
5. Rainfall 12
6. Soil 13
    6.1. Drainage 13
    6.2. Nutrient Levels 13
    6.3. pH 14
7. Topography 14
8. Grafting 15
9. Rootstock 15
10. Cultivar 15
11. Rootstock and Cultivar Combinations 16
12. Disease and Pest Resistance 16
13. Soil Adaptability 16
14. Climate Adaptation 17
15. Orchard Management 17
16. Canopy Management 17
17. Market Demand 18
18. Fruit Production Goals 18
19. Infrastructure Requirements 18
20. On-farm Infrastructure 19
    20.1. Irrigation Systems 19
    20.2. Nurseries 19
    20.3. Packhouses 19
    20.4. Cold Storage Facilities 19
    20.5. Worker Housing and Amenities 19
    20.6. Vehicles 20
    20.7. Security 20
    20.8. Environmental Compliance 20
21. Off-Site Infrastructure 20
    21.1. Packhouses 20
    21.2. Logistics 20
    21.3. Cold Chain Storage 21
    21.4. Seaports 21
    21.5. Research Institutions 21
22. Market Trends and Requirements 21
    22.1. Global Citrus Demand 22
    22.2. Sustainability and Certification 22
    22.3. Quality Standards 22
    22.4. Packaging and Labelling 23
23. Enterprise Integration 23

23.1. Labor Requirements 23
23.2. Production Practices 23
23.3. Risk Distribution 23

Chapter 2 Planning & Layout **26**
1. Introduction to Layout 26
2. Resource Requirements 26
3. Microclimates 27
4. Harvesting and Access 27
5. Pest and Disease Management 27
6. Roads 28
7. Natural Resources 28
8. Topography 28
9. Slope and Drainage 28
10. Topography and the Environment 28
11. Accessibility and Erosion Control 29
12. Wind 29
13. Windbreaks 29
14. Row Direction 29
15. Soil 29
16. Soil Drainage and Elevation 29
17. Soil Texture and Depth 30
18. Soil Testing and Management 30
19. Free-Standing Systems 30
20. Trellised Tree Systems 30
21. Protection 30
22. Spacing and Elevation 30
23. Support Structures 31
24. Drainage 31
25. Maintenance and Repairs 31
26. Pollination 31
27. Cross-pollination 31
28. Layout and Cross-pollination 32

Chapter 3 Soil Surveys **34**
1. Soil Surveys 34
2. Chemical vs. Physical Soil Surveys 34
3. Survey Timing 35
4. Profile Holes 35
5. Profile Hole Data 35
5.1. Soil Texture 35
5.2. Soil Horizons 36
5.3. Root Depth 37
5.4. Compaction 37
5.5. Drainage 37

Chapter 4 Irrigation Systems **39**
1. Irrigation Systems 39
2. Types of Irrigation Systems 39
2.1. Flood Irrigation 40
2.2. Mobile Irrigation Systems 40
2.3. Static Systems 40
3. Irrigation System Components 40
4. The Irrigation System 40
4.1. Pumps 41

4.2. Filters 42
4.3. Pipes 43
4.4. Valves 43
4.5. Emitters 44
5. Irrigation Installation 45
5.1. Orientation 45
5.2. Symbols 45
5.3. Pipe Notations 46
5.4. Irrigation Block Information 48
5.5. Bill of Quantities 49
6. Laying Out the Irrigation System 50
6.1. Marking the Corners of the Blocks 50
6.2. Marking the Rows 51
6.3. Marking the Plant Positions 52
7. Conveyance System Trenches 52
8. Installing Irrigation Equipment 52
8.1. Installing Pipes 54
8.2. Installing Filters and Valve Clusters 55
8.3. Installing Infield Fittings 55
9. Testing the Irrigation System 55
10. Irrigation System Maintenance. 56
11. Maintenance Planning 56
12. Evaluating the Functioning of Irrigation System 58
12.1. Coefficient of Uniformity (CU) Tests 58
12.2. Evaluation Irrigation System Performance 59
13. Water Supplementation 60
14. Water Quality Requirements 61
15. The Impact of Physical Water Quality 61
16. The Impact of Chemical Water Quality 62
17. The Impact of Microbiological and Biological Factors 65

Chapter 5 Farming Business Management 68

1. Farming Business Management 68
2. Production Systems 69
3. Income 70
3.1. Production Expenses 70
3.2. Fixed and Variable 71
3.3. Direct and Indirect Costs 72
4. Net Profit and Loss 72
5. Monitoring Labour Costs 73
6. Competitiveness 73
7. Sustainability 73
8. Export Agents 74
9. The Value Chain 74
10. The Cold Chain 75
11. Links in the Value Chain 75
11.1. Link 1 – Production 75
11.2. Link 2 – Picking 76
11.3. Link 3 – Packing 76
11.4. Link 4 – Transport 76
11.5. Link 5 – Harbour Handling 76
11.6. Link 6 – Shipping 77
11.7. Link 7 – Receiving and Transport 77
11.8. Link 8 – Sales 77

11.9. Other Costs 77
12. Value and Profit 77
13. Destroying Value 78
14. Budgeting 78
14.1. Monitoring Expenses against Budget 79
15. Strategic Plans, Goals, and Objectives 81
16. PERT Charts 82

Alignment Information

Qualification

The content of this learner guide is aligned to the following occupational qualification:

SAQA QUAL ID	**Qualification Title**
110667	Occupational Certificate: Orchard and Vineyard Foreman

Originator
Development Quality Partner – AgriSETA

Primary Or Delegated Quality Assurance Functionary	**NQF Sub-Framework**
-	OQSF - Occupational Qualifications Sub-Framework

QUALIFICATION TYPE	**FIELD**	**SUBFIELD**
Occupational Certificate	Field 01 - Agriculture and Nature Conservation	Primary Agriculture

Abet Band	**Minimum Credits**	**Pre-2009 NQF Level**	**NQF Level**	**Qual Class**
Undefined	147	Not Applicable	NQF Level 04	Regular-ELOAC

Modules

The content of this learner guide is aligned to the following modules of the occupational qualification above.

Module Code	Module Title	Level	Credits
Knowledge Modules			
611202-001-00-KM-01	Plant Structure and Physiology	4	5
611202-001-00-KM-02	Vineyard or Orchard Establishment	3	2
611202-001-00-KM-03	Vineyard or Orchard Manipulation Processes	3	8
611202-001-00-KM-04	Harvesting	3	4
611202-001-00-KM-05	Basic Principles of Plant Nutrition	4	4
611202-001-00-KM-06	Crop Protection	3	3
611202-001-00-KM-07	Assets in Horticultural Production	3	2
611202-001-00-KM-08	Farm Business Management and Farming Process Management	4	8
611202-001-00-KM-09	Human Resource Management and Processes	4	8
611202-001-00-KM-10	Overseeing Farming Resource Utilisation	4	8
Practical Skill Modules			
611202-001-00-PM-01	Organise, Allocate and Monitor Availability and Productive Use of Resources	4	5
611202-001-00-PM-2a	Set Team and Individual Performance Goals to Enhancing Team Performance	4	10
611202-001-00-PM-2b	Control Vineyard or Orchard Practices	4	10

611202-001-00-PM-03	Supply Accurate Daily Orchard or Vineyard and Production Information	4	10
Work Experience Modules			
611202-001-00-WM-01	Vineyard or Orchard Resource Optimisation	4	20
611202-001-00-WM-02	Skilled and Motivated Work Team Output	4	20
611202-001-00-WM-03	Daily Orchard or Vineyard and Production Information Availability	4	20

Learning Outcomes

The content of this learner guide is aligned to the following learning outcomes of the modules above.

Knowledge Topics	
Outcome Code	**Module Title**
KM-02-KT01	**Crop and cultivar selection**
IAC0101	The critical climatic and other requirements for the commercial production of the crop and cultivar/s are described
IAC0102	Reasons for suitable root stocks and cultivar combinations for specific situations are understood and explained
IAC0103	The infrastructure requirements for producing this crop is given in terms of the on-farm infrastructure and the infrastructure further down the value chain
IAC0104	Major market trends and requirements for the specific crop is described taking into account long-term future outcomes
IAC0105	The integration of the new enterprise with existing enterprises is outlined and explained with regards to labour requirement, production practices and risk distribution
KM-02-KT02	**Farm Lay-out**
IAC0201	Farm lay-out is described in terms of resource requirements and optimisation thereof
IAC0202	The effect of farm lay-out on natural resources is described in terms of the impact on the protection thereof
IAC0203	Agricultural infrastructure planning and layout principles are explained
IAC0204	The effect of topography on block lay-out and row direction is outlined
IAC0205	The impact of wind condition and direction on row direction and the need for protection of crop is described
IAC0206	The effect of physical soil limitations on block and row lay-out are reported
IAC0207	Free standing systems are compared to trellised systems in order to determine the impact on farm lay-out
IAC0208	Specific requirements regarding production under protection (i.e. hail netting) is discussed
IAC0209	Provision for sufficient cross pollination by the correct lay-out of the orchard is explained
KM-02-KT03	**Block establishment**
IAC0301	The difference between a chemical and physical soil survey as well as the need for both is explained
IAC0302	The need for and timing of a soil survey (chemical and physical) is described
IAC0303	The process of making a profile hole is outlined and the data which can be obtained is listed
KM-05-KT05	**Irrigation**
IAC0501	Different irrigation system plans and designs are compared in terms of advantages and disadvantages
IAC0502	Irrigation system components are given and the function of each is described

IAC0503	Installation and maintenances principles are outlined and motivated
IAC0504	The necessity of water supply (supplementation) through irrigation is explained
IAC0505	Water quality requirements for specific crops are given
KM-08-KT02	**Structure of the horticultural industry**
IAC0201	Various sectors in the horticultural industry are identified and discussed
IAC0202	Various production systems (such as organic foods) are listed and defined
IAC0203	The typical horticultural production value chain and process flow components are identified and explained
IAC0204	The concept of competitiveness is defined and the importance thereof is justified
KM-08-KT04	**General farming business management**
IAC0401	Basic financial principles related to viable business practices such as input costs, profit/loss and income are defined and explained as it pertains to horticultural production
IAC0402	The management concepts and basic principles of planning, organising, leading and controlling are defined within the horticultural farming context
IAC0403	The concepts and basic principles of decision making, problem solving, motivation, delegation are defined and evaluated as it pertains to horticultural production
IAC0404	The concepts and basic principles of planning and scheduling (PERT chart) are defined and evaluated as it pertains to horticultural production
IAC0407	Farm systems are defined and the component thereof is listed
IAC0408	The role of farm systems in effective management of the farm is explained
KM-09-KT03	**Overseeing horticultural farming operations**
IAC0301	A differentiation is made strategic plans, goals and objectives
IAC0302	The principles of setting goals and targets are outlined and explained
KM-10-KT01	**Finances**
IAC0101	Budgeting concepts are defined and the principles thereof are discussed
IAC0102	An understanding of concepts of profitability, sustainability and competitiveness is demonstrated
IAC0103	Principles of using operational budgets to prepare production plans are outlined
IAC0105	The concept of the cost value of labour is defined
Practical Skills	
PM-01-PS01	**Perform a practical exercise to compile a production plan for an orchard or vineyard for a full growth cycle based on case study information**
IAC0101	A set of information to construct a plan or schedule was analysed and applied
IAC0102	Requirements of the production elements were correctly identified
IAC0103	An applicable planning process taking into account the year and growth stages of the plant according to the seasonal cycle was applied
IAC0104	The correct agricultural calculations were applied
IAC0105	A set of written instructions is concise and clear
IAC0106	Information on the production cycle, production requirements and activities and crop requirements are accurately identified and used in the compilation of the production plan
PA0101	Obtain relevant production information from a production unit.
PA0102	Analyse and interpret production information.
PA0103	Set quality and quantity targets and standards for agricultural tasks such as planting, fertilising, pest and weed control, in accordance with the overall farm production targets for each growth stage of the crop.

PA0104	Schedule agricultural tasks such as planting, fertilising, pest and weed control, in accordance with the overall farm production targets for each growth stage of the crop.
PA0105	Compile work instructions which are clear and precise, and which will be clearly understood by the team.
PA0106	Identify the control mechanisms to ensure output and quality targets are met.
PA0107	Identify the steps for evaluation of the production process.
AK0101	Techniques and formats for the development of production plans
AK0102	Techniques for the interpretation of financial information such as budgets and cash flow
AK0103	Forecasting techniques
AK0104	Controlling and maintaining quality standards
AK0105	Techniques to exercise cost control
AK0106	Techniques for continuous improvement
AK0107	Techniques to analyse and summarise farm information
PM-01-PS07	**Describe the relationship between the farm and the environment in terms of resources**
PA0703	Research and describe the potential of the capacity of the farm or section of the farm
PM-01-PS10	**Calculate the establishment cost of a Vineyard or orchard**
IAC1001	The cost analysis for the establishment of a Vineyard or orchard is comprehensive and calculations are accurate
PA1001	Determine the input raw material quality and quantity
PA1002	Determine the work team input
PA1003	Determine other resource requirements
PA1004	Calculate the establishment cost of a Vineyard or orchard
PM-2b-PS04	**Define the operational management aspects of the farm**
IAC0401	A relevant and complete value and supply chain diagram is drawn
IAC0402	An accurate and complete flow diagram of the business is constructed
PA0401	Draw a diagram depicting the value and supply chain for the enterprise
PA0402	Draw up a diagram of the business processes which describes the business operations, sources of funding and the future growth of the business
PA0403	Give a description of the roles and responsibilities of the foreman paying special attention to the value added by the foreman

Chapter 1
The Farm Environment

learning outcomes

The content of this chapter is aimed at helping you to:

- The critical climatic and other requirements for the commercial production of the crop and cultivar/s are described.
- Reasons for suitable root stocks and cultivar combinations for specific situations are understood and explained.
- The infrastructure requirements for producing this crop is given in terms of the on-farm infrastructure and the infrastructure further down the value chain.
- Major market trends and requirements for the specific crop is described taking into account long-term future outcomes.
- The integration of the new enterprise with existing enterprises is outlined and explained with regards to labour requirement, production practices and risk distribution.

1. Introduction

The business of farming citrus is a complex one, combining many different jobs and tasks that require a wide base of knowledge. In this chapter, we will begin by discussing a few of the most basic things you, as a foreman, need to know to do your job well.

Firstly, we explore the climatic and environmental factors necessary for successful citrus production. You must be able to understand these requirements to be able to choose a good location for an orchard or farm, and to properly manage production practices.

Next, we will look at the process and importance of rootstock and cultivar selection, and why certain combinations are more suited for certain regions or climates than others. This will allow you to choose the trees best suited to your farm.

Thirdly, we will discuss the infrastructure requirements for citrus production, both on your farm and further down the value chain, in the rest of the country and world. Knowing what infrastructure is involved will help you ensure that you have everything you need on farm, as well as off it.

After this, we will briefly discuss major market trends and requirements shaping the citrus industry, with a focus on the long-term future. By keeping yourself up to date with these trends in consumer preferences and developments in the industry, you can change your production practices as the market demands.

Finally, we will look at how you go about integrating new citrus enterprises with existing ones, including how to manage the workers, combine the production practices, and distribute risk equally.

2. Climatic and Environmental Requirements

As you enter the world of commercial citrus farming, you will soon realise that understanding the climate and environment is very important for you to succeed. Commercial citrus production in South Africa relies on a combination of critical climatic and environmental factors. The climatic requirements include temperature, sunlight, and rainfall; and the environmental requirements include soil and topography. Let's take a look at each of these below:

3. Temperature

Temperature plays a big part in determining the suitability of a certain climate or area for citrus production. For example, citrus trees are particularly sensitive to frost, which can be damaging to both the fruit and the tree itself, meaning that very cold areas (such as in the Drakensberg mountains) are not suited to citrus production.

Some citrus varieties handle cold better than others, and some handle it worse. For example, naartjies are quite cold-sensitive, so tend to do best in areas with milder winters and sometimes need frost protection measures to safeguard them from very low temperatures. On the other hand, varieties like lemons are more cold-tolerant and can endure cooler temperatures without suffering significant damage or requiring extra protection.

You must understand these different temperature requirements, and especially those of the varieties your farm produces. This knowledge informs decisions related to selecting orchard location, establishing frost protection strategies, and selecting suitable citrus cultivars for the specific climate conditions of your location.

4. Sunlight

As you probably know, citrus trees need a lot of sunlight for their growth, fruit development, and overall health. This is part of the reason why South Africa, with its abundant sunlight, provides an ideal environment for citrus trees to thrive in.

In most plants, sunlight is essential for the process of photosynthesis. Sufficient sunlight also promotes robust foliage growth, which aids in the tree's ability to photosynthesize effectively.

definition

Photosynthesis

Photosynthesis is the process where citrus trees convert sunlight, water, and CO_2, into energy in the form of sugars, which are vital for fruit development and overall growth.

As an added bonus, citrus fruit exposed to abundant sunlight tend to have vibrant colours, a higher sugar content, and improved flavour, all of which make them more attractive to customers, while meeting market requirements. You need to keep sunlight in mind when you are laying out an orchard or managing the orchard and canopy, as you must always ensure that your trees receive the right amount of sunlight.

5. Rainfall

As you know, citrus trees require consistent and well-distributed rainfall to thrive and produce high-quality fruit. For you to do your job effectively, you need to understand the part that rainfall plays in commercial citrus production, and especially the rainfall requirements of your trees.

South Africa's climate is generally made up of wet and dry seasons, which can vary depending on the region. Rainfall patterns are different across the country, as coastal regions may receive more consistent rainfall, while inland areas (such as the Northern Cape) experience drier conditions.

Because of this, orchards in arid (dry) regions often rely heavily on irrigation. You will have to rely on effective water management systems and infrastructure, including advanced irrigation techniques, to deal with the impact of varying rainfall.

During the growing season, your trees require enough rainfall to support their growth and fruit development. Having enough moisture in the soil is essential for nutrient uptake and overall tree health. You must be careful though, as excessive, or poorly timed irrigation or flooding can lead to waterlogged soils, which can be very harmful to citrus trees, causing root damage and making them susceptible to diseases like root rot.

During the drier seasons in South Africa, new challenges for citrus production arise, due to the reduced rainfall. During this period, you need to manage irrigation carefully to ensure that the trees receive the necessary water.

6. Soil

Soil, as you well know, is the growth medium for all our citrus. Soil comes in various types, with various properties. South Africa's soil types and textures vary widely, and the type and texture of the soil available to you must be considered during the selection of suitable citrus varieties for specific regions.

Soil has several characteristics that must be assessed through regular soil testing or a more comprehensive soil survey, including drainage, nutrient levels, pH, structure, and moisture level, among others. The data collected during surveys or tests will assist you in creating and implementing effective fertilisation programs that meet the exact needs of your citrus trees, promoting their growth and fruit development. This data also assists in selecting the best location for the establishment of an orchard.

6.1. Drainage

As mentioned above, the first characteristic we will look at is drainage. As a general rule, citrus trees prefer soils that are well-draining. Soils that drain poorly can easily become waterlogged, which can lead to root rot and other diseases, stunting tree growth and impacting fruit quality.

For example, sandy soils offer good drainage, and as such there is less risk of waterlogging, however this means that citrus trees planted in these soils require more irrigation. On the other hand, clayey soils retain moisture better, so they require less frequent irrigation, but may be more prone to drainage-related issues such as waterlogging.

There are physical soil preparation techniques that you can use to improve drainage, such as ridging or the installation of subsurface drainage systems, especially in regions with heavy rainfall.

6.2. Nutrient Levels

Another characteristic mentioned above is that of nutrient levels. As you well know, citrus trees have specific nutrient needs, including macronutrients such as nitrogen (N), phosphorus (P), potassium (K), and micronutrients like iron (Fe), zinc (Zn), and manganese (Mn), among others.

Regular soil testing and analysis are essential to assess nutrient levels and guide the application of agrochemicals to ensure that your trees have access to the nutrients they require for healthy growth and fruit production.

6.3. pH

definition

pH

pH is a measurement of how acidic or basic something, is on a scale of 0 to 14. Things with a lower pH, like orange juice, are acidic, while things with a higher pH, like bleach, are basic (alkaline). In the middle is water, which usually has a neutral pH of 7.

In terms of soil pH, citrus trees generally thrive in slightly acidic to neutral soils with a pH range of 6 to 7. Soils outside of this range (i.e., Soils that have a pH lower than 6 or higher than 7) can hinder nutrient uptake and affect overall tree health. To manage soil pH, lime or other agrochemicals may be applied as needed to maintain the optimal pH range for citrus production.

7. Topography

definition

Topography

Topography refers to the physical features of a piece of land, such as its shape, slope, and elevation, which can affect the suitability of the land for various agricultural activities.

Topography is another important environmental condition in terms of citrus production, and must be considered carefully, particularly during the selection of a site for the establishment of a new orchard or planting.

The environmental topography of an orchard site impacts other factors we have already discussed, such as water drainage, wind and rainfall patterns, and temperature fluctuations. You must understand and be able to manage these topographical features to manage a farm effectively.

In terms of topography, one of our largest concerns is the slope of the land. Citrus orchards are best situated on gently sloping terrain, rather than steep slopes. These gentle slopes allow for water to drain naturally, but not too quickly, which aids in proper water distribution during irrigation. This reduces the risk of water runoff and soil erosion, both of which can be very harmful to a citrus enterprise and the longevity of an orchard.

Slopes that are either too steep or too shallow can lead to uneven moisture distribution and soil erosion, which can adversely affect citrus tree health and orchard sustainability. Therefore, it is essential that you select suitable land with a gentle slope for citrus cultivation.

Orientation refers to the direction of the orchard rows, and plays a role in optimising sunlight exposure for citrus trees. Rows are typically planted in a north-south orientation in the Southern Hemisphere (where we are) to ensure even sunlight distribution. This orientation helps prevent shading of trees by neighbouring rows, allowing for uniform fruit development, and ripening. A well-thought-out row orientation can enhance orchard productivity and fruit quality.

8. Grafting

definition

Grafting

Grafting is a production technique where plant parts from two different plant parts are combined so that they grow into one new plant that shares characteristics of both parents. Grafting in citrus is performed by combining the rootstock (bottom) of one tree with the cultivar, or scion (upper part) of another.

When it comes to selecting the right citrus tree to plant, you often have a situation where you want the qualities of one tree, such as being tough and resistant to disease, as well as the qualities of another tree, such as having tasty fruit.

To combine the characteristics of two different trees, we perform a practice called grafting. Grafting is very important in citrus farming and orchard management.

In this section we will discuss the way in which we select the plant parts to be grafted, and the effects that different combinations have on production practices and the characteristics of your trees and fruit.

9. Rootstock

definition

Rootstock

The rootstock is the lower portion of a grafted citrus tree, consisting of the root system and the lower stem; and serves as the foundation and support for the entire tree.

Your choice of rootstock is very important as it determines the tree's growth rate, size, and adaptability to soil conditions and pests. Different rootstocks can impart specific characteristics to the tree, such as drought resistance, cold tolerance, and resistance to diseases.

For example, in South Africa, where citrus greening is a concern, selecting rootstocks with resistance to this disease is vital for orchard success. You must be able to evaluate the soil type, climate, and potential pest and disease pressures in your orchard location to choose the most appropriate rootstock.

10. Cultivar

definition

Cultivar

A cultivar, short for "cultivated variety," represents the upper portion of the grafted citrus tree, including the branches, leaves, and the fruit-bearing scion or budwood.

Cultivars are selected based on the desired fruit characteristics, including taste, size, shape, colour, seed content, and overall quality. Because of these characteristics, cultivar selection is focused on considering the market demand and fruit quality desired to maximise profitability. As an export-focused industry, our citrus industry requires that we select cultivars that meet international market standards.

You, as foreman, must also be able to anticipate market trends and consumer preferences to make informed decisions on which cultivars to plant. Balancing rootstock and cultivar choices to optimise fruit yield, quality, and adaptability to environmental factors is a complex task that requires both knowledge and practical expertise.

11. Rootstock and Cultivar Combinations

The process of combining rootstock and cultivar involves attaching a scion, or budwood, from the chosen cultivar onto the selected rootstock. This process is known as "budding" or "grafting." The result is a single tree that has the desirable fruit-bearing cultivar (scion) growing on the robust and disease-resistant rootstock.

This combination combines the strengths of both parts to optimise the tree's performance, giving us as producers the “best of both worlds”. Properly selected combinations provide many benefits, such as improved disease resistance, better adaptation to local soil and climate conditions, and higher fruit quality. Below, we discuss the various characteristics affected by this selection in more detail:

12. Disease and Pest Resistance

Disease and pest resistance is a big part of the selection of suitable rootstock and cultivar combinations. Citrus trees are susceptible to numerous pests and diseases, and some of these can be devastating, causing the loss of entire orchards of trees if they get out of control. As such, you must understand the importance of resistance and how it influences your choice of combinations.

As an example, let us discuss Citrus Greening Disease. This disease, also known as Huanglongbing or HLB, among other names, is spread mainly through psyllids. It currently has no cure, spreads quickly, and is eventually fatal to trees. All of this should show you why this disease should be taken seriously, as entire orchards have been lost to the disease or culled in an effort to stop its spread.

It should now be clear why selecting rootstock that have a natural resistance or tolerance to Citrus Greening Disease or pests like the citrus psyllid is so important. These resistant rootstocks serve as the foundation upon which disease- or pest-susceptible cultivars can be grafted, allowing for the cultivation of desirable citrus varieties in regions where pests or disease would normally prevent it.

Cultivar selection also plays a significant role in disease and pest management, and as such you must carefully consider the prevalence of specific diseases in your region when selecting cultivars for planting. Doing this properly not only reduces the reliance on chemical control methods but also contributes to healthier orchards in South Africa.

13. Soil Adaptability

As discussed earlier, South Africa's diverse landscape includes a wide range of soil types, from sandy to clayey. Certain cultivars are better suited to different soils than others, and some are more able to adapt to different types of soil than others. During selection, you must carefully match cultivars with local soil conditions to maximize yields and fruit quality.

definition

Soil Adaptability

Soil adaptability refers to the ability of a specific rootstock to adapt to soil conditions outside of its ideal range, as well as the general tolerance for unsuitable or imperfect soil conditions.

Soil adaptability is an important consideration in the selection of suitable combinations. As different regions in our country have varying soil types and characteristics, you must consider these differences when choosing rootstocks and cultivars to ensure that they match the soil conditions prevalent in their specific location.

14. Climate Adaptation

Climate adaptation is another important aspect of selecting suitable rootstock and cultivar combinations. Our country has many diverse climate regions, from arid to subtropical, and this poses unique challenges and opportunities for citrus cultivation. Learning to understand how climate adaptation works will contribute directly to your success as a foreman.

Different citrus cultivars have different climate preferences, particularly regarding ideal temperature ranges and tolerance for heat or cold. For example, some cultivars are better suited for the warmer, frost-free regions of South Africa, while others can withstand cooler temperatures and occasional frosts.

Rootstock selection also plays a big role in climate adaptation. Certain rootstocks are more resistant to drought or waterlogging, which are common climate challenges in some South African regions. By choosing cultivars and rootstocks that align with the local climate conditions, you can optimise the growth of your trees, while minimising the risk of climate-related damage.

15. Orchard Management

Orchard management is also affected by your rootstock selection, as citrus trees grown on various rootstocks exhibit different growth habits, canopy sizes, and fruiting patterns. This means that orchard management tasks may need to be applied more often on trees grown from certain rootstocks to accommodate for their larger size or faster growth.

Because of this, the selection of rootstock and cultivar combinations should be guided by the planned orchard management practices. You must consider the selected combination when designing orchard layouts and spacing to maximize sunlight penetration, airflow, and ease of management.

16. Canopy Management

The selection of rootstock and cultivar combinations plays a crucial role in determining the overall structure and size of the citrus trees' canopies. Some rootstocks naturally lead to more tightly packed canopies, while others result in more sprawling growth. The choice of rootstock impacts how our trees need to be pruned and shaped to get the best sunlight exposure, airflow, and overall orchard management.

Canopy management practices, including pruning, hedging, and topping, are essential for shaping and maintaining the desired canopy structure. As a foreman you need to consider the compatibility of these management techniques with the selected rootstock-cultivar combinations.

17. Market Demand

The citrus market is diverse, with the various citrus varieties each having their own unique consumer base and preferences. Market demand changes based on factors like consumer taste trends, health considerations, and trade agreements. Because of this, you must always be aware of current and anticipated market demands.

The choice of cultivar is often driven by these market preferences for fruit size, quality, flavour, and appearance. To meet these market demands, specific cultivars are selected based on their suitability for a chosen rootstock. As citrus farming in South Africa is export-oriented, your cultivar selection must be in line with international market preferences to ensure that they sell well on the foreign market, otherwise South Africa will not remain competitive in the international market.

For instance, if there is a growing demand for sweeter, seedless citrus varieties in the market, you might choose a rootstock-cultivar combination that produces these types of fruits. Alternatively, if there's a preference for tart or acidic citrus, you may select different combinations.

Market demand in the modern day extends beyond fruit preferences to include aspects like organic production, sustainability, and ethical farming practices. Some consumers, especially those in wealthier countries, are willing to pay a high price for citrus fruits produced using environmentally friendly methods or under specific certifications.

You must consider these market trends when selecting suitable rootstock-cultivar combinations, as certain varieties may be better suited for organic or sustainable production, which can ultimately lead to higher returns.

18. Fruit Production Goals

Understanding fruit production goals is very important when selecting suitable rootstock and cultivar combinations. You must understand how these goals directly influence decision-making to ensure the orchard's success and profitability.

Fruit production goals include many different aspects, including yield quantity, fruit quality, harvesting efficiency, and resource optimisation. Your selection of rootstock and cultivar combinations should align with these objectives to achieve the best outcomes.

For instance, if your primary goal is to maximize yield quantity, you may choose rootstock-cultivar combinations known for high fruit production per tree. These combinations should have characteristics like prolific fruit-bearing, resistance to diseases, and adaptability to local environmental conditions.

On the other hand, if our emphasis is on fruit quality, you may prioritize combinations that yield fruits with desirable attributes such as superior flavour, colour, size, and juiciness.

Harvesting efficiency is another crucial consideration. You should select combinations to ensure that fruits ripen uniformly and can be harvested efficiently. This might involve choosing cultivars with synchronized maturation patterns to minimise multiple harvest rounds and reduce labour costs.

19. Infrastructure Requirements

Producing citrus crops in South Africa requires a well-planned and efficient infrastructure network, encompassing both on-farm infrastructure and infrastructure further down the value chain. Let’s take a look at some of the critical infrastructure requirements:

19.1. On-farm Infrastructure

The success of your farm relies on well-planned and efficiently managed on-farm infrastructure. You play a major role in ensuring that the necessary infrastructure is in place and properly maintained; and as such you must be familiar with the infrastructure in place on your farm. The infrastructure described below are examples of the infrastructure found on most farms, your farm may not have all of the mentioned pieces of infrastructure in place.

19.1.1. Irrigation Systems

Efficient, well-designed irrigation infrastructure is vital for citrus farms, especially given our country's varying climates and water availability. Irrigation systems come in different forms depending on the method of irrigation, and you must ensure that you are familiar with your farm's particular system.

You must also oversee the installation and maintenance of your irrigation systems, to ensure that they are being maintained effectively and consistently. These systems should also ideally be equipped with timers and moisture sensors to optimise water use and ensure consistent soil moisture levels for citrus trees.

19.1.2. Nurseries

Some citrus farms maintain on-farm nurseries for propagating rootstock and cultivars. These nurseries' infrastructure would include shade structures, misting systems, and well-drained soil beds to promote healthy seedling growth. If your farm has a nursery on-site, it is your responsibility to manage nursery operations, monitor seedling health, and plan for timely transplanting into the orchards.

19.1.3. Packhouses

Citrus packhouses are essential for producing fruit ready for the export market, and are therefore necessary for the success of any farm. Some farms have on-site packhouses, where others share a single packhouse with other farms in the area to split the costs if no single farm in the area could justify the expense of building its own packhouse.

These packhouses are equipped with lots of complex machinery and can be very large. Some of this machinery and equipment includes sorting and grading lines and tables, optic sizers, washing and waxing stations, and packing equipment, among others. If you pack your fruit on-farm, it is up to you to oversee packhouse operations.

19.1.4. Cold Storage Facilities

Proper cold storage infrastructure is vital for preserving fruit quality and extending shelf life, and serves as the beginning of the "cold chain". If your farm has one, you must be familiar with the workings of the cold storage facility, and must ensure that it is running at the proper temperature at all times, while being consistently maintained and available whenever needed.

19.1.5. Worker Housing and Amenities

Many farms, especially those in more remote areas, require housing for seasonal workers, such as those extra workers hired during harvest. A happy workforce is a productive workforce, and so you must provide suitable, comfortable accommodation and amenities to attract and keep a skilled, committed workforce.

These amenities and accommodation can include boarding houses, cafeterias, bathrooms, hand- and eye-washing stations, storage areas (such as lockers), and changing rooms, among others. You must oversee the maintenance and cleaning of these amenities or accommodation to ensure that labour regulation requirements are met and to keep your workers happy.

19.1.6. Vehicles

Farms rely on a range of and vehicles, including tractors, sprayers, and trailers. These vehicles require infrastructure such as storage areas, maintenance areas, garages, and workshops. You are responsible for ensuring that they are properly maintained, and that the areas and equipment used to maintain them are kept clean, neat, and in good condition.

19.1.7. Security

As our farms can have a lot of expensive equipment and machinery on them, we must ensure that they are safe against theft and vandalism, and for this we require security infrastructure. This infrastructure may include fencing, gates, and surveillance systems. You must be familiar with the systems in place on your farm, and any required maintenance or calibration.

19.1.8. Environmental Compliance

When running a farm, you must always be compliant with environmental regulations, and farms may need specific infrastructure to meet these requirements, such as waste management, erosion control, and pesticide storage facilities. You must ensure that the farm adheres to environmental laws by maintaining these facilities as required.

19.2. Off-Site Infrastructure

In addition to on-farm infrastructure, producing and exporting your fruit requires various off-farm infrastructure elements that lie further down the value chain. These pieces of infrastructure are needed to efficiently process, market, transport, and finally export your fruit. These processes are essential for ensuring that your fruit reaches international markets in the best condition possible.

19.2.1. Packhouses

As mentioned above, some farms pack their fruit off-site, at communal packhouses. These packhouses perform the same operations as an on-farm packhouse, but at a larger scale with more complexity. As a foreman, you must be acquainted with the management of these packhouses and have a good line of communication with them to ensure that you always know the status and condition of any fruit you send there.

19.2.2. Logistics

Efficient, well-managed transportation infrastructure is vital for transporting citrus from farms to markets. As an export-dependent industry, us farmers in South Africa rely on our fruit to be transported on a strict time schedule to ensure that they arrive overseas in the best condition possible.

To achieve this, we require a well-maintained network of roads, rail, and ships. This transport network is supported by other pieces of infrastructure such as loading docks, refrigerated trucks, cold storage, and railway hubs, among many others. You must be able to coordinate with transportation companies to ensure the timely and safe delivery of our fruit to their distribution points, both nationally and internationally.

19.2.3. Cold Chain Storage

As mentioned above, export citrus requires temperature-controlled storage facilities along the supply chain to maintain freshness and extend shelf life. Off-farm cold storage warehouses and distribution centres are critical for storing citrus before it reaches retailers or export destinations. It is vital that you ensure that the cold chain remains unbroken to preserve the quality of the fruit during transit and storage.

19.2.4. Seaports

As an industry which makes most of its revenue from export to international markets, high-quality export facilities such as seaports are essential to our continued success. These facilities aim to provide easy, streamlined access to global markets.

As with other logistical elements, you may need to coordinate with the management at these ports, possibly through an export agent. You must always ensure that all documentation and accreditation for export consignments is in order, so that you are compliant with international trade regulations.

19.2.5. Research Institutions

If you want to stay updated on the latest production techniques, pest and disease management strategies, and other innovations in the industry, it is essential that you collaborate with agricultural research and development institutions, such as the CRI. You can benefit hugely from the research of these institutions, by maximising productivity and efficiency while minimising cost or waste.

It is vital that you and your farm maintain a good relationship with these institutions, and that you sign up for any publications they release, as well as attending any conferences or other presentations that you can, to ensure you stay up to date on all developments.

20. Market Trends and Requirements

The South African export citrus industry is an ever-changing and highly competitive sector that plays a major role in our country's agricultural exports. To work effectively in this industry, you must understand the major market trends and requirements, both current and anticipated for the long-term future.

South African citrus exports have grown beyond traditional markets like the European Union and the United Kingdom. Emerging markets in Asia, including China and India, have shown a lot of growth, and you must be aware of these market shifts and their implications.

Below, we discuss some of the current and future trends and changes in market requirements and preferences in the international citrus market.

20.1. Global Citrus Demand

The global demand for citrus has shifted significantly in recent decades, as consumer preferences, dietary trends, and health considerations change. Traditionally, citrus fruits were primarily consumed for their refreshing taste and high vitamin C content.

However, in recent years, there has been a growing awareness of the health benefits associated with citrus consumption, including its role in immune system support, antioxidants, and potential disease prevention. As a result, the demand for citrus products, such as fresh fruit, juice, and processed goods, has been on the rise.

Moreover, the globalization of food markets and improved transportation infrastructure has made the international trade of citrus products easier and faster than ever before. South Africa, in particular, has become a major player in the global citrus market, exporting our high-quality fruits to various countries all over the world.

Citrus is expected to continue its upward growth in the markets. Consumers are increasingly seeking natural and healthy food options, which is good news for our citrus products. Additionally, advancements in technology and agricultural practices have improved citrus yield and quality, further supporting the industry's growth.

However, it's important to note that changing consumer preferences and international trade dynamics require us as South African citrus producers to be able to change to maintain our competitiveness and meet the changing demands of global markets.

20.2. Sustainability and Certification

Sustainability and environmental concerns are becoming increasingly important in international markets, particularly in wealthier countries. To meet these concerns, South African citrus producers are adopting sustainable farming practices and obtaining certifications like Global Good Agricultural Practices (GlobalG.A.P).

As a foreman, you must implement these sustainable agriculture methods, manage water resources responsibly, and reduce the environmental impact of your farming operations.

Integrated pest management and the practices involved in it tie into this, as they have become more and more important as customers demand sustainable pest control methods, including biological control, and minimal chemical usage. This trend is expected to continue.

20.3. Quality Standards

International markets, particularly the European Union, have very stringent quality standards for citrus. As farmers we must adhere to these standards, ensuring that the fruit meets size, colour, taste, and safety requirements, if we are to export to the EU.

Tying into this are various food safety regulations, including Maximum Residue Levels (MRLs) for pesticides. These requirements are non-negotiable, and you need to implement strict controls to ensure the safety of our citrus.

An important aspect of meeting quality requirements is the concept of "traceability", which refers to the ability to trace a particular consignment of fruit all the way back through the supply chain to the orchard where it was grown and harvested. This traceability throughout the supply chain is crucial for ensuring the origin and quality of citrus, and often forms a vital part of certification schemes and market requirements.

20.4. Packaging and Labelling

Many markets have strict regulations regarding the way in which our fruit is packaged and labelled, and improper packaging or labelling may (and has) led to entire consignments being rejected outright. Because of this, it is important that you are fully aware of the specific requirements regarding packaging and labelling for the market(s) that you are exporting to, and that you ensure that these requirements are being followed to the letter.

21. Enterprise Integration

In the dynamic landscape of citrus production, the integration of a new citrus enterprise with an existing one is a big move that, when done right, can yield many benefits. This process of integration is a complex one, and there are several critical aspects to be considered, including labour requirements, production practices, and risk distribution, all of which we discuss below.

21.1. Labor Requirements

Integrating a new citrus enterprise with an existing one involves several considerations, particularly in terms of labour requirements. During this integration, you have the opportunity to "fine-tune" your workforce.

Existing enterprises often have an established workforce, with years if not decades of experience in citrus production. By merging the workforces of the new and existing enterprises, you can allocate resources better, and the workers can share knowledge and skills they have developed. This, handled properly, can lead to increased productivity and cost-efficiency, as well as a more competent workforce overall

However, it's essential to handle this process with care, to ensure that there is no friction between the two workforces, and that they both see the benefits of the integration. The workforces must both have the common goal of making the transition as smooth as possible.

21.2. Production Practices

When integrating enterprises, it is crucial that production practices are combined and perfected. Both the new and existing enterprises may have distinct methods and techniques for citrus cultivation, based on differences in education, training, or experience.

It's essential to conduct a thorough review of these practices and identify which practices are preferred, and then to ensure that every single worker is aware of the preferred practice and commits to it.

During this review, it is important that workers feel "heard", and that the existing workforce in particular do not feel that they have become obsolete and are being "replaced". It is vital that the experience of these workers is respected and considered.

By making production practices standard across the integrated enterprise, there can be consistency in both practices and personnel, resulting in better quality fruit, reduced operational complexities, and streamlined decision-making.

21.3. Risk Distribution

Another key aspect of integrating enterprises is the distribution of risk. Citrus production is inherently susceptible to various risks, including weather-related events, pests, diseases, social or political change, and market fluctuations. By merging enterprises, risks can be diversified and thus shared more effectively.

This process can involve the development of risk mitigation strategies, such as crop insurance, diversification of citrus varieties, and geographical spread of orchards. Your goal must always be to minimise the impact of negative events on the overall enterprise. By carefully assessing risk and planning for it, you can ensure the sustainability and resilience of the integrated enterprise for decades to come.

summary

Chapter 1 – The Farm Environment

- Commercial citrus production in South Africa relies on a combination of critical climatic and environmental factors.
- The climatic requirements include temperature, sunlight, and rainfall.
- The environmental requirements include soil and topography.
- Citrus production requires a specific temperature range, which varies with different cultivars.
- In citrus trees, sunlight is essential for the process of photosynthesis, as well as for growth.
- Citrus trees require consistent and well-distributed rainfall to thrive and produce high-quality fruit.
- Soil comes in various types, with various properties, including drainage, nutrient levels, and pH.
- Topography refers to the physical features of a piece of land, such as its shape, slope, and elevation, which can affect the suitability of the land for various agricultural activities.
- Grafting is a production technique where plant parts from two different plant parts are combined so that they grow into one new plant that shares characteristics of both parents.
- The rootstock is the lower portion of a grafted citrus tree, consisting of the root system and the lower stem; and serves as the foundation and support for the entire tree.
- A cultivar, short for "cultivated variety," represents the upper portion of the grafted citrus tree, including the branches, leaves, and the fruit-bearing scion or budwood.
- Citrus trees are susceptible to numerous pests and diseases, and some of these can be devastating, causing the loss of entire orchards of trees if they get out of control.
- Different rootstocks are vulnerable to different diseases and pests, and you should consider this when selecting a rootstock.
- Different citrus cultivars are more adaptable to different climates and soil types.
- Orchard management is also affected by your rootstock selection, as citrus trees grown on various rootstocks exhibit different growth habits, canopy sizes, and fruiting patterns.
- Canopy management practices, including pruning, hedging, and topping, are essential for shaping and maintaining the desired canopy structure.
- Market demand changes based on factors like consumer taste trends, health considerations, and trade agreements.
- Fruit production goals include many different aspects, including yield quantity, fruit quality, harvesting efficiency, and resource optimisation.

- Producing citrus crops in South Africa requires a well-planned and efficient infrastructure network, encompassing both on-farm infrastructure and infrastructure further down the value chain.
- On-farm infrastructure includes irrigation systems, nurseries, packhouses, cold storage facilities, worker housing and amenities, vehicles, security and environmental structures.
- Off-site infrastructure includes packhouses, logistics, cold chain storage, seaports, and research institutions.
- The integration of a new citrus enterprise with an existing one is a big move that, when done right, can yield many benefits.
- When integrating two enterprises, you should consider labour requirements, production practices, and risk distribution.

assessment activities

- ✓ **Activity P1**: Complete this activity to test your knowledge of the entire chapter.

Chapter 2
Planning and Layout

learning outcomes

The content of this chapter is aimed at helping you to:

- Farm layout is described in terms of resource requirements and optimisation thereof.
- Agricultural infrastructure planning and layout principles are explained.
- The effect of farm layout on natural resources is described in terms of the impact on the protection thereof.
- The effect of topography on block layout and row direction is outlined.
- The impact of wind condition and direction on row direction and the need for protection of crop is described.
- The effect of physical soil limitations on block and row layout are reported.
- Free standing systems are compared to trellised systems in order to determine the impact on farm layout.
- Specific requirements regarding production under protection (i.e. hail netting) is discussed.
- Provision for sufficient cross-pollination by the correct layout of the orchard is explained.

1. Introduction to Layout

The layout of your farm has a big impact on your success at citrus farming. Efficiently organizing the various parts of your citrus farm, from orchard placement to infrastructure placement, is important to ensure a productive and sustainable operation.

Farm layout plays a big role in determining the allocation of resources, including natural resources and labour resources. For example, by considering factors like the distance between tree rows, the organization of work zones, and access to tools and equipment during the design of the layout; you can allocate workers in a way that maximises their efficiency while minimising unnecessary labour costs and time.

In this chapter, we will explore the key considerations and strategies for designing an effective citrus farm layout, ultimately contributing to the success of your farm.

2. Resource Requirements

The first important resource in citrus farming is the land itself. Citrus orchards need ample space for tree growth and proper spacing between tree rows. The layout of the farm will be determined by the land available, as any decisions on where to place anything on the farm must account for the size and shape of the available land.

When designing an orchard, for example, you must ensure that your planned layout accommodates the desired number of trees per hectare while allowing for easy access and manoeuvrability.

The next important resource is sunlight. Our trees require ample sunlight for photosynthesis and fruit development. The layout you design should maximize sunlight exposure to all trees by considering the orientation and spacing of tree rows, as well as the topography of the area surrounding the orchard. A properly laid out orchard ensures that each tree receives their required share of sunlight, contributing to optimal fruit production.

3. Microclimates

An important aspect to consider during layout planning is that of microclimates. In a citrus orchard, microclimates refer to small-scale variations in climate conditions within the larger orchard area. Imagine a full-sized orchard, with dozens if not hundreds of trees. Because of the size of this orchard, different parts of it will experience localized differences in temperature, sunlight, wind, and other factors. This is referred to as the "microclimate" of that part of the orchard.

One of the primary factors influencing microclimates is sunlight. Certain areas of the orchard may receive more direct sunlight throughout the day, while others might be shaded by taller trees or structures. Consequently, spots with more sunlight tend to be warmer compared to their shaded counterparts.

Wind patterns also shape microclimates within the orchard. Wind can cool down certain areas, and its intensity can vary throughout the orchard. Some regions might be more sheltered from the wind by windbreaks, natural or otherwise, creating pockets of still, warmer air.

The orchard's topography also plays a role in microclimate variations. If the orchard is situated on a slope or hill, the higher elevations typically experience cooler temperatures, as warm air rises and cool air sinks.

Additionally, the presence of water bodies, such as streams, rivers, dams, or ponds, can influence microclimates. Areas of the orchard near water sources may be more humid and cooler due to the evaporative cooling effect and increased moisture in the air.

Lastly, the types and arrangement of vegetation within the orchard can generate microclimates. For example, a row of tall trees might create shade and act as a natural windbreak, resulting in a cooler and more sheltered environment compared to more open areas.

4. Harvesting and Access

Efficient harvesting is essential for your farm's success. The layout you design should provide easy access for harvesting crews and machinery into the orchard. Properly designed access roads and pathways enable quick and hassle-free harvesting, reducing labour costs and harvest time.

An important aspect of farm layout in terms of harvesting is the arrangement of orchard blocks and tree spacing. Trees should be planted with adequate space between rows and within rows to allow for efficient harvesting operations.

This spacing not only provides access for workers and vehicles but also ensures that workers can reach the fruit without damaging the trees or fruit, or injuring themselves. Rows should be aligned to enable straightforward access for harvesters and equipment, minimising the time and effort required to harvest the entire orchard.

5. Pest and Disease Management

As you well know, farmers need to manage pests and diseases effectively to be successful. When designing a layout, you must consider the placement of pest monitoring stations, beneficial insect habitats, and traps. You must also consider separating different citrus varieties to prevent the spread of diseases between them. This thoughtful arrangement can reduce the need for extensive pesticide use and promote natural pest control methods.

6. Roads

While designing your farm's layout, the way that you arrange the roads is an important consideration for smooth operations. Your roads serve many different purposes and need careful planning to make the farm work well.

The main roads connect the farm to roads off the farm, such as public roads. They should be wide and well-kept so that large vehicles, like tractors and fruit trucks, can move freely. Other smaller roads branch off from these main ones, leading to different parts of the farm. These smaller roads help workers and vehicles get to the orchards, storage areas, packhouses as quickly and efficiently as possible.

Inside the citrus orchards, there are many roads or paths. These allow workers, vehicles (such as tractors or trailers) and machinery (such as sprayers) to move around easily and safely. They should be placed in such a way that workers can reach all the rows of trees easily. These roads and paths are necessary for production practices such as pruning, agrochemical applications, monitoring, and harvesting. Well-thought-out road layouts make work faster and safer for everyone on the farm, and thus the layout of roads is an important part of a successful farm.

7. Natural Resources

The layout of a farm isn't merely a matter of convenience and efficiency, but also a way to ensure that we can protect and conserve our natural resources. This planning goes beyond the arrangement of trees and roads; and becomes about ensuring that the farm works well within its environment while safeguarding valuable resources such as soil, water, and biodiversity.

8. Topography

Topography, or the natural features and contours of the land, has a significant impact on the layout and row direction of citrus orchards. South African citrus farms often span diverse landscapes, from flat plains to hilly terrains, and understanding how topography influences orchard design is important for optimal productivity and resource management.

9. Slope and Drainage

The slope of the land is a big consideration when planning orchard block layout. In areas with significant slopes, orchard rows are typically aligned across the contour lines rather than up and down the slope. This contour planting minimizes soil erosion and allows for more efficient water drainage. It also prevents runoff and soil loss during heavy rainfall, promoting soil conservation.

10. Topography and the Environment

Topography also affects sunlight exposure. Orchards located on north-facing slopes in the Southern Hemisphere (where we are) receive more direct sunlight throughout the day. In contrast, south-facing slopes receive less direct sunlight. You must consider these factors when determining the row direction to optimize sunlight exposure and promote even fruit ripening.

Topography can impact soil characteristics, including soil depth, composition, and drainage capacity. These factors influence tree root development and nutrient uptake. In hilly terrains, areas with shallow or rocky soils may be less suitable for citrus cultivation. The orchard block layout should account for variations in soil quality to optimize tree growth and fruit production.

11. Accessibility and Erosion Control

Steep slopes can present challenges in terms of accessibility and erosion control. Orchard rows must be designed with safe access for machinery, vehicles, and workers in mind. Additionally, erosion control measures may be necessary to prevent soil erosion on steep slopes. Your layout should prioritize safety and minimize soil loss.

12. Wind

In some citrus-producing regions, there are strong winds, and these strong winds pose a considerable threat to our citrus crops, by potentially causing fruit drop, branch breakage, and leaf damage. In addition to direct physical damage, wind can create microclimate variations within the orchard. These variations affect temperature, humidity, and evaporation rates, directly impacting fruit quality and yield.

13. Windbreaks

To safeguard our trees against damage and unsuitable microclimate variations, you must put measures for wind protection in place. The most common form is that of windbreaks. Windbreaks in citrus orchards usually come in the form of trees, planted in rows next to or in the orchard, which act as a "buffer" against wind.

These windbreaks serve to intercept and diffuse the wind. By doing so, they create a more favourable microclimate within the orchard, making our trees happier, healthier, and more productive.

The selection and placement of windbreaks is an important consideration. When choosing windbreak species and their placement, you must consider factors such as wind direction, tree height, and spacing. This ensures that the windbreaks effectively protect our trees without casting excessive shade or competing for vital resources.

The choice of tree species for windbreaks is critical, as they should be hardy, drought-tolerant, and compatible with the overall orchard ecosystem.

14. Row Direction

To lower the risks associated with strong winds, citrus orchards are typically designed with rows perpendicular (at a right angle) to the wind direction. This layout minimizes wind exposure to the tree canopy, reducing the pressure on trees and minimizing wind-related damage.

15. Soil

The physical characteristics of the soil play a big part in determining the layout of orchards. Different soil types have different properties that can heavily impact the growth and health of citrus trees. You must lay out orchard blocks and rows properly to optimise production while managing soil limitations effectively.

16. Soil Drainage and Elevation

One of the major considerations when planning orchard layout is soil drainage. In areas with poor natural drainage, excessive soil moisture can lead to root rot, reduced oxygen availability to roots, and poor overall tree health. Because of this, you may need to design orchard blocks with a slight elevation to promote better drainage.

The way orchard rows are generally oriented allows excess water to flow away from the root zone. This practice ensures that our trees are not subjected to waterlogged soil conditions, which can be harmful to them.

17. Soil Texture and Depth

Soil texture and depth also influence orchard layout. Citrus trees thrive in well-draining soils with good root penetration capabilities. In areas with shallow or rocky soils, you must adapt the arrangement of orchard blocks and rows.

You may choose to plant trees closer together to maximize root access to available soil, or you may select alternative rootstocks with improved soil tolerance to overcome soil limitations. Additionally, the use of techniques such as ridging can help create a suitable root zone for citrus trees in challenging soil conditions.

18. Soil Testing and Management

To address soil limitations effectively, soil testing is an important part of orchard planning. It allows for the precise assessment of soil properties and nutrient levels, so that you can make sure that you plant your trees in the best positions possible.

19. Free-Standing Systems

Free-standing tree systems are characterized by citrus trees that are not physically supported by structures like trellises. Instead, they grow naturally, with branches spreading out in various directions. This system allows for more space between individual trees, which can impact farm layout in several ways.

Free-standing trees typically require more space between them to accommodate their natural canopy growth. This wider spacing can affect the overall layout of the orchard, potentially requiring more land area to achieve the same tree density compared to trellised systems.

In South Africa, almost all citrus is grown in free-standing systems, apart from staking performed with very young trees.

20. Trellised Tree Systems

In contrast, trellised tree systems involve the use of support structures, such as trellises or wire frames, to train citrus trees into a specific growth pattern. Trellised systems can offer several advantages that impact farm layout, though they are only usually used on young trees in the citrus industry.

Trellised systems allow for closer spacing between trees, resulting in a higher tree density per unit of land. This can lead to a more efficient use of space, potentially maximizing yield within a limited area.

The controlled growth of trees in trellised systems can also lead to a more uniform and orderly orchard layout. Rows and tree spacing are often consistent, contributing to easier farm management and mechanization.

21. Protection

When designing the layout of a citrus farm, especially in regions prone to hailstorms, you may need to construct hail netting or other protective structures. Hail netting is designed to shield citrus trees from the damaging effects of hail, ensuring the protection of both the crop and the long-term health of the trees.

22. Spacing and Elevation

Hail netting structures need to be properly spaced to cover the entire citrus orchard. The spacing and elevation of the netting should allow for enough airflow and sunlight penetration, as these are essential for our trees to grow healthily. The spacing between individual netting structures should be carefully planned to avoid shading and overcrowding.

23. Support Structures

Hail netting requires sturdy support structures to withstand hail impacts and adverse weather conditions. These support structures may consist of steel or wooden posts or frames that need to be anchored securely into the ground. The layout you design should ensure that these structures are evenly spaced and positioned to provide optimal support for the netting. The choice of materials and construction methods will depend on the specific hail netting design and local weather patterns.

24. Drainage

Proper drainage is an important consideration when using hail netting. Excess water accumulation on the netting during heavy rainfall can lead to structural damage or even collapse. You should incorporate appropriate drainage systems, such as sloped surfaces or gutters, to channel rainwater away from the netting and prevent water-related issues.

25. Maintenance and Repairs

You should layout the orchard so that regular maintenance and potential repairs can be made on the hail netting where necessary. Access points and pathways for maintenance personnel should be clearly marked. Additionally, you should create a plan for inspecting and addressing any damage to the netting or support structures as part of the orchard management strategy.

26. Pollination

On your citrus trees, you will find flowers. In each of these flowers, there is pollen, a powdery substance that plays an important role in fruit formation. Each flower possesses both male and female reproductive parts, but for fruit to develop, this pollen must travel from the male part to the female part.

For this journey to happen, you need the help of pollinators. Pollinators are animals, usually bees and other insects, that make this journey possible. For example, as a bee flies around an orchard looking for nectar (also found in your flowers), they will land on your citrus blossoms. While searching for this nectar, they climb into the flower.

While in the flower, pollen gets stuck to the bees, and then, as they travel from one flower to another, this pollen that came from one flower gets carried and left on the other parts of the same flower, or other flowers on the same tree, which initiates fertilisation and fruit formation.

27. Cross-pollination

Cross-pollination is a little different, in that it refers to the transfer of pollen from one flower to another flower on a different tree of the same species. In the citrus farming business, cross-pollination usually involves the transfer of pollen between citrus trees of compatible varieties. Most types and varieties of citrus trees are self-pollinating, but cross-pollination can enhance the fruit set and yield significantly.

To encourage cross-pollination in your orchard, you must first select and plant appropriate citrus varieties that can cross-pollinate each other. You should select and place varieties with compatible bloom times and flowering habits within your orchard.

Another way to encourage cross-pollination is planting different citrus varieties throughout the orchard. By mixing varieties in the orchard, the chance of pollinators (such as bees) visiting blossoms of multiple citrus types increases.

As mentioned above, pollinators such as bees are vital for cross-pollination. By setting up bee hives in our orchards, or ensuring that we maintain the natural biodiversity and insect life in the area, we can ensure that cross-pollination occurs.

Finally, as with any production practice, regular monitoring is an important part of encouraging cross-pollination. By monitoring pollinator populations and activity, as well as fruit set, you can judge the effectiveness of your cross-pollination efforts.

28. Layout and Cross-pollination

Where possible, you should orientate your orchard rows in a way that promotes the movement of pollinators, primarily bees, between the trees. Typically, arranging rows in a north-south orientation is good, as it allows for better sunlight exposure and airflow, which encourage this pollinator activity. Good spacing between rows also facilitates bee movement.

Another possibility is the planting of hedgerows or windbreaks at the edge of the orchard, as this will create a protected environment that can attract pollinators and provide them with suitable resting places; or ideally, encourage the establishment of hives.

summary

Chapter 2 – Planning & Layout

- Farm layout plays a big role in determining the allocation of resources, including natural resources and labour resources.
- Citrus orchards need ample space for tree growth and proper spacing between tree rows, and orchard layout will be determined by the land available.
- Orchard layout should maximise tree density without overcrowding, and maximize sunlight exposure to all trees.
- In a citrus orchard, microclimates refer to small-scale variations in climate conditions within the larger orchard area.
- Microclimates are shaped by sunlight, wind patterns, topography, natural vegetation and the presence of water bodies.
- The layout you design should provide easy access for harvesting crews and machinery into the orchard.
- When designing a layout, you must consider the placement of pest monitoring stations, beneficial insect habitats, and traps.
- There are many types of roads and paths on farms, with various uses, and you should arrange them to ensure smooth operations.
- Steep slopes can present challenges in terms of accessibility and erosion control.
- In some citrus-producing regions, there are strong winds, and these strong winds pose a considerable threat to our citrus crops, by potentially causing fruit drop, branch breakage, and leaf damage.
- To safeguard our trees against damage and unsuitable microclimate variations, you must put measures for wind protection in place, usually windbreaks.

- The physical characteristics of the soil play a big part in determining the layout of orchards, including drainage, elevation, texture, and depth.
- Free-standing tree systems are characterized by citrus trees that are not physically supported by structures like trellises.
- Trellised tree systems involve the use of support structures, such as trellises or wire frames, to train citrus trees into a specific growth pattern.
- Cross-pollination and pollination are both important parts of growing citrus and the orchard should be designed to support these processes.

assessment activities

- ✓ **Activity P2**: Complete this activity to test your knowledge of the entire chapter.

Chapter 3
Soil Surveys

learning outcomes

The content of this chapter is aimed at helping you to:

- The difference between a chemical and physical soil survey as well as the need for both is explained.
- The need for and timing of a soil survey (chemical and physical) is described.
- The process of making a profile hole is outlined and the data which can be obtained is listed.

1. Soil Surveys

Soil surveys are very important when establishing a new orchard block. The process of doing a soil survey involves the analysis of soil in a specific area to understand that soil's unique characteristics.

These surveys are usually done before a new planting to determine the readiness of the soil for planting, and if any additional soil preparation is needed. By conducting soil surveys, you can discover useful information about the soil's composition, nutrients, and physical properties.

This knowledge helps you make informed decisions about crop choices, irrigation practices, and fertilisation methods, ultimately ensuring the best conditions for successful farming and orchard establishment.

2. Chemical vs. Physical Soil Surveys

When we discuss soil surveys, there are two types we generally talk about, namely chemical and physical soil surveys.

A chemical soil survey involves testing the soil to understand its chemical composition, such as the levels of essential nutrients and minerals in the soil. These chemical surveys tell you if the soil has enough of the right nutrients that your trees need to grow and produce healthy fruit. Chemical soil surveys also identify any potentially harmful elements like excessive salts or toxic compounds that might affect plant growth.

A physical soil survey, on the other hand, focuses on the soil's physical properties. Physical soil surveys help us understand the soil's texture, structure, and moisture-holding capacity.

Soil texture, whether it's sandy, loamy, or clayey, affects how well the soil retains water and nutrients. Soil structure refers to how soil particles are arranged, which influences root growth and water infiltration. As you know, monitoring moisture levels is important for proper irrigation, which creates optimal growing conditions.

Both chemical and physical soil surveys are essential because they provide different pieces of the same puzzle. The chemical survey tells you what nutrients are available in the soil, guiding your fertilisation practices. Conversely, the physical survey helps you understand how water moves through the soil, ensuring efficient irrigation. Combining these surveys lets you create the best possible environment for your citrus trees to thrive.

3. Survey Timing

You need to know when exactly to conduct soil surveys when planning the establishment of an orchard block. Surveys should ideally be done well in advance, during the planning stages, to ensure that any preparation of the land that is required is completed as early as possible.

Chemical soil surveys should be carried out at least a year before planting. This early timing allows ample time for soil amendments and adjustments, such as adding lime to correct pH levels or incorporating organic matter to enhance nutrient content.

Physical soil surveys are typically conducted a little closer to the actual planting date, usually several months before planting. This timing allows for fine-tuning soil preparations, such as ridging the land to optimize drainage and minimize erosion risks.

4. Profile Holes

Profile holes are the holes that you dig in the orchard that allow you to examine soil properties at various depths. Profile holes are an important part of soil surveys, both chemical and physical, as they are necessary to access the soil beyond the surface level.

Beyond the surface layer of your soil, there are multiple layers, each of which have their own distinct properties that impact root development, water retention, and nutrient availability. Profile holes unveil these layers, which form the basis of the soil profile.

5. Profile Hole Data

The data obtained from profile holes will let you make informed decisions regarding soil preparation and management practices. This data generally includes information about the soil texture, soil horizons, root depth, compaction, and drainage of the soil. Let’s discuss each of these factors in a more detail:

5.1. Soil Texture

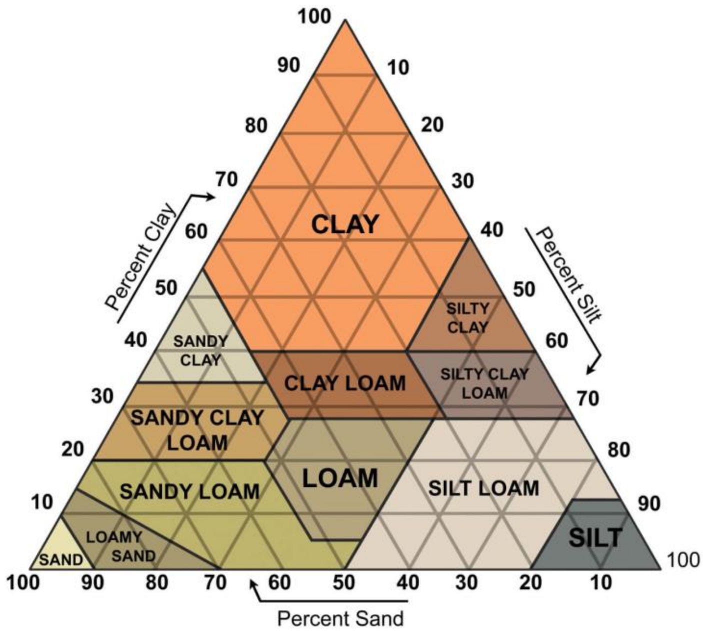
Soil texture refers to the relative proportions of sand, silt, and clay particles present in our soil. It is a fundamental characteristic of soil that plays a major role in determining the soil's physical properties, water-holding capacity, drainage, aeration, and suitability for farming.

Different citrus cultivars may perform better in soils with specific textures, so assessing and classifying soil texture is an important step in determining the suitability of a site for establishment.

The three primary soil particles that make up soil texture are:

- **Sand** – Sand particles are the largest among the three types, and they feel gritty when rubbed between fingers. Sandy soils have larger pore spaces between particles, which allows for good drainage but may result in lower water and nutrient retention.
- **Silt** – Silt particles are smaller than sand but larger than clay particles. Silty soils have moderate water-holding capacity and moderate drainage. They feel smooth and powdery when dry and slippery when wet.
- **Clay** – Clay particles are the smallest and finest of the three. Clay soils have high water-holding capacity but may drain poorly. They feel sticky and can form a dense, compacted structure when wet.

The relative proportions of these three particle types in a soil sample determine its specific texture. Soil textures are often classified into various categories, such as sandy loam, silty clay, or clay loam, depending on the main particle type present.



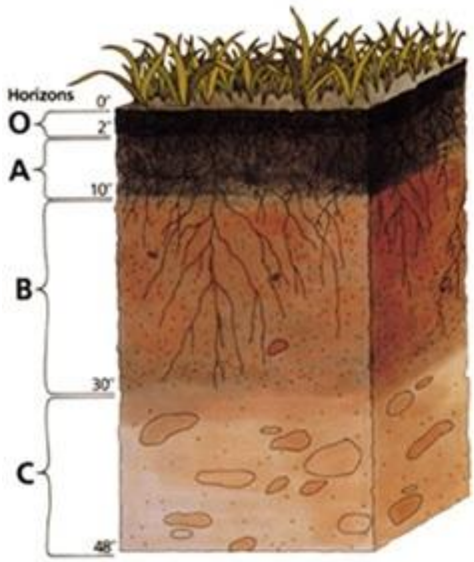
Various Soil Textures

5.2. Soil Horizons

Soil consists of several distinct layers, which we call horizons. Each of these horizons has unique physical, chemical, and biological characteristics, which differ from the horizons above and below.

There are many different types of soil, with varying amounts and types of horizons; however, most soils have three major horizons (A, B, C) and some have an organic horizon (O). These horizons are:

- **O (Organic or Humus)** – Mostly organic matter such as decomposing leaves. The O horizon is thin in some soils, thick in others, and not present at all in others.
- **A (Topsoil)** – Mostly minerals from the parent material with organic matter incorporated. A good material for our trees and other organisms to live and grow in.
- **B (Subsoil)** – Rich in minerals that leached (moved down) from the higher horizons and accumulated here.
- **C (Parent Material)** – This layer is the geologic material (such as bedrock) from which soil horizons form.



Soil Horizons

5.3. Root Depth

Root depth refers to the depth within the soil profile at which your trees' roots typically extend and grow. It is an important factor for you to consider when assessing soil conditions before a planting. The root depth of different trees and varieties can vary depending on factors such as soil type, cultivar, and environmental conditions.

5.4. Compaction

Soil compaction is a condition which occurs when soil particles are pressed together, reducing pore space between them. This compression results in increased soil density, reduced soil porosity, and limited air and water movement within the soil profile. These factors can have significant implications for farmers, as they can adversely affect root growth, water infiltration, and overall soil health.

When performing a survey, assessing soil compaction involves evaluating the soil's bulk density, penetration resistance, and visual characteristics. Soil compaction maps can be created to identify areas with compaction issues.

5.5. Drainage

Soil drainage is a natural process by which water moves through soil because of the force of gravity. Proper drainage is a crucial factor in agriculture as it directly impacts soil moisture levels, root health, and overall crop productivity.

Adequate drainage in your orchards is essential to prevent waterlogging, which can have detrimental effects on our trees. Drainage is closely linked to compaction, as a more compacted soil will have worse drainage.

Drainage is also influenced by factors such as soil texture, water table depth, and the topography of the orchard, all of which come into play during soil surveys.

summary

Chapter 3 – Soil Surveys

- The process of doing a soil survey involves the analysis of soil in a specific area to understand that soil's unique characteristics.
- Soil surveys are usually done before a new planting to determine the readiness of the soil for planting, and if any additional soil preparation is needed.
- There are two types of soil survey, namely chemical and physical soil surveys.
- A chemical soil survey involves testing the soil to understand its chemical composition.
- A physical soil survey involves testing the soil to understand its physical properties.
- Surveys should ideally be done well in advance, during the planning stages, to ensure that any preparation of the land that is required is completed as early as possible.
- Chemical soil surveys should be carried out at least a year before planting.
- Physical soil surveys are typically conducted a little closer to the actual planting date, usually several months before planting.
- Profile holes are the holes that you dig in the orchard that allow you to examine soil properties at various depths.
- The data obtained from profile holes will include soil texture, soil horizons, root depth, compaction, and drainage.
- Soil texture refers to the relative proportions of sand, silt, and clay particles present in our soil.
- Soil textures are often classified into various categories, such as sandy loam, silty clay, or clay loam, depending on the main particle type present.
- Soil consists of several distinct layers, which we call soil horizons, each of which have unique physical, chemical, and biological characteristics.
- Most soils have three major horizons (A, B, C) and some have an organic horizon (O).
- Root depth refers to the depth within the soil profile at which your trees' roots typically extend and grow.
- Soil compaction is a condition which occurs when soil particles are pressed together, reducing pore space between them, increasing soil density and limiting air and water movement.
- Adequate drainage in your orchards is essential to prevent waterlogging, which can have detrimental effects on our trees.

assessment activities

- ✓ **Activity P3**: Complete this activity to test your knowledge of the entire chapter.

Chapter 4
Irrigation Systems

learning outcomes

The content of this chapter is aimed at helping you to:

- Different irrigation system plans and designs are compared in terms of advantages and disadvantages.
- Irrigation system components are given and the function of each is described.
- Installation and maintenances principles are outlined and motivated.
- The necessity of water supply (supplementation) through irrigation is explained.
- Water quality requirements for specific crops are given.

1. Irrigation Systems

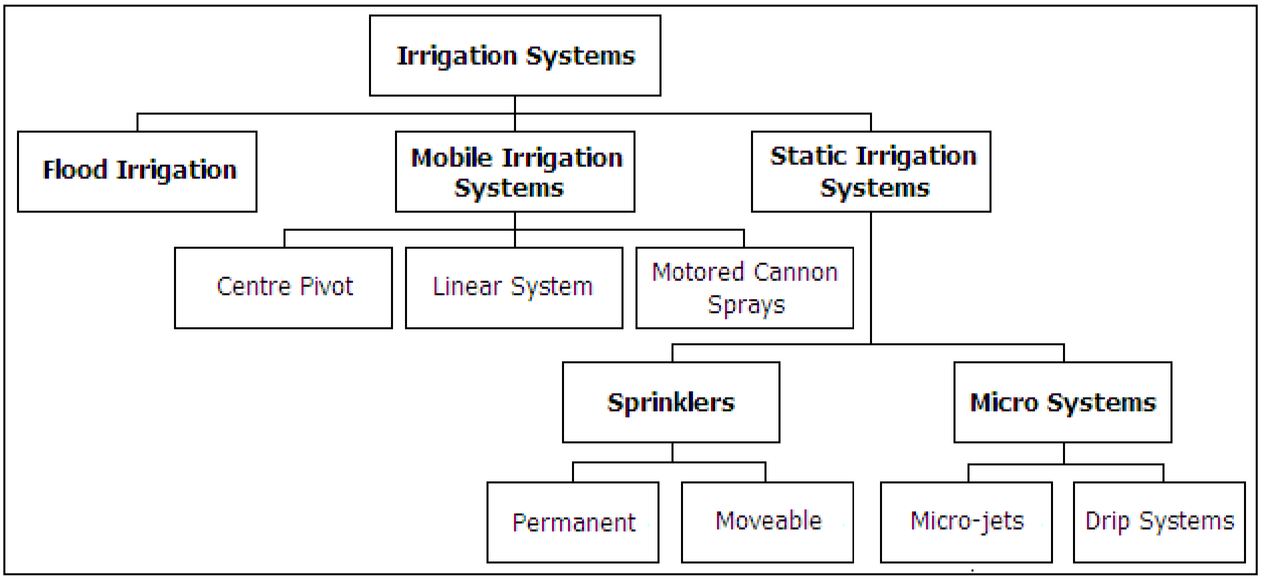
Irrigation systems come in many shapes and sizes, and not all of them are suitable for citrus production. In this chapter, we'll take a brief look at the different types of systems, then discuss the factors that play an important role in the decision on the type and specifications of irrigation system to be installed, namely:

- Water availability
- Water quality
- Crop type
- Soil water holding capacity
- Cost
- Management
- Maintenance

A SABI (South African Irrigation Institute) accredited irrigation designer will help you with selecting the correct irrigation system for a specific situation. They are also available to assist with the evaluation of irrigation systems.

2. Types of Irrigation Systems

Irrigation systems can be classified as follows:



Basic Irrigation System Classification

2.1. Flood Irrigation

In flood irrigation, water is channelled to the crop by furrows in the ground. This means that the area that is irrigated must have a constant slope that is not too steep. In some situations, basins that can be filled with water are made around the crop plants.

2.2. Mobile Irrigation Systems

Mobile, or moving, irrigation systems irrigate while the system is moving and includes systems such as centre pivots, linear systems, and motored cannon sprays.

The centre pivot consists of sections that are supported by wheels and rotate around a fixed point called a tower. The linear system is similar to the centre pivot in the sense that it is also made of steel sections supported on wheels, except that the linear system moves in a straight motion across a field.

Motored cannon sprays are water cannons, or large sprinklers, mounted on trailers. A mechanism is provided, usually a water powered winch, which propels the trailer through the field.

2.3. Static Systems

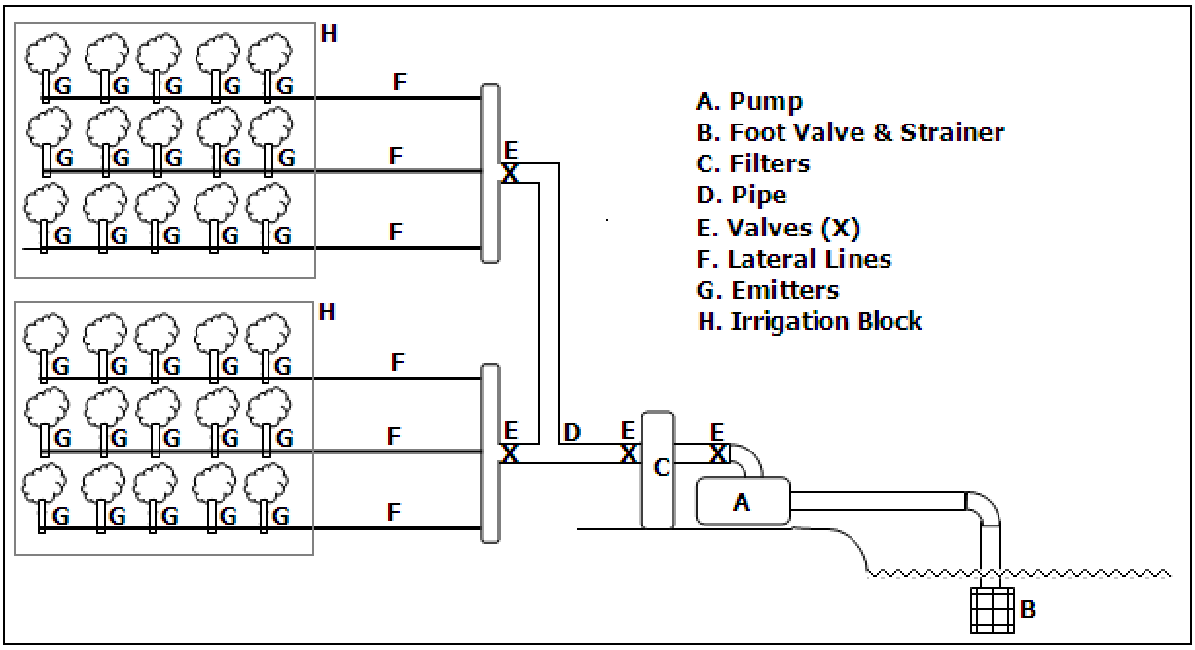
Static systems are systems that stand still, or are static, while they irrigate. These include systems such as permanent and non-permanent sprinkler systems and micro-jet and drip systems.

3. Irrigation System Components

In citrus production, farmers depend on irrigation, along with rainfall, to meet the water requirements of the tree crop. Proper operation and maintenance are necessary to make sure that an irrigation system works properly.

4. The Irrigation System

A basic irrigation system consists of the following components:



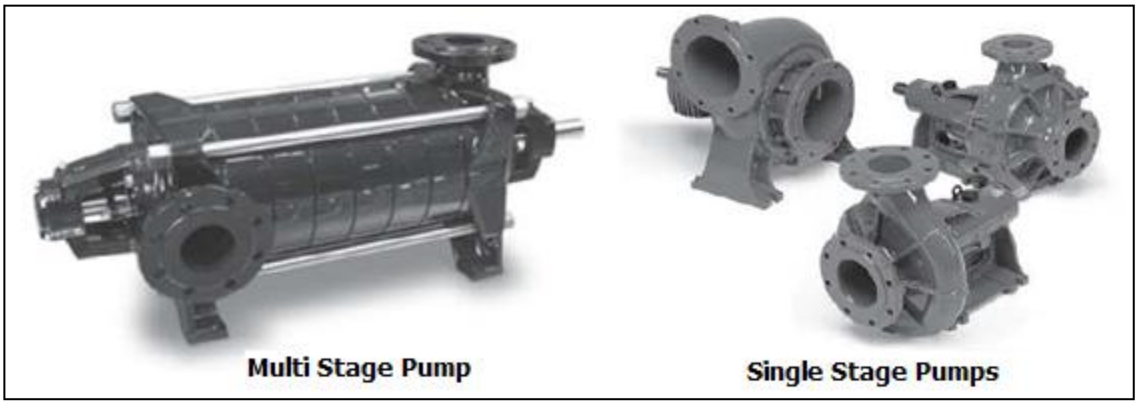
Basic Components of an Irrigation System

4.1. Pumps

Almost all irrigation systems, except gravity feed systems, rely on pumps to move water to the orchards and supply pressure to the emitters to work properly. The pump moves, or displaces, water by sucking water from the source, such as a river, dam, reservoir, etc., and propelling in through the irrigation system.

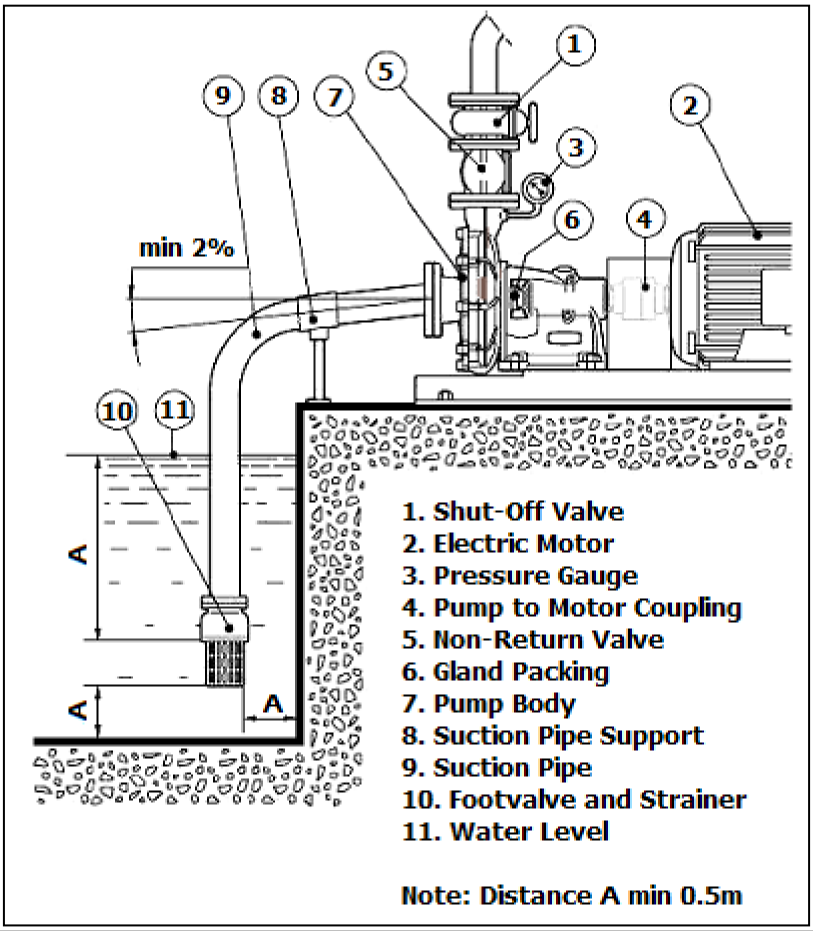
Pumps come in a wide range of shapes, sizes, and types, such as centrifugal, submersible, and positive displacement pumps. They are driven by either diesel engines or electrical motors. The most commonly used pumps are single and multistage centrifugal pumps driven by electrical motors.

Single stage pumps have only one stage containing a single impeller, while multistage pumps have two or more stages and deliver higher pressures where required.



Single and Multi-Stage Pumps

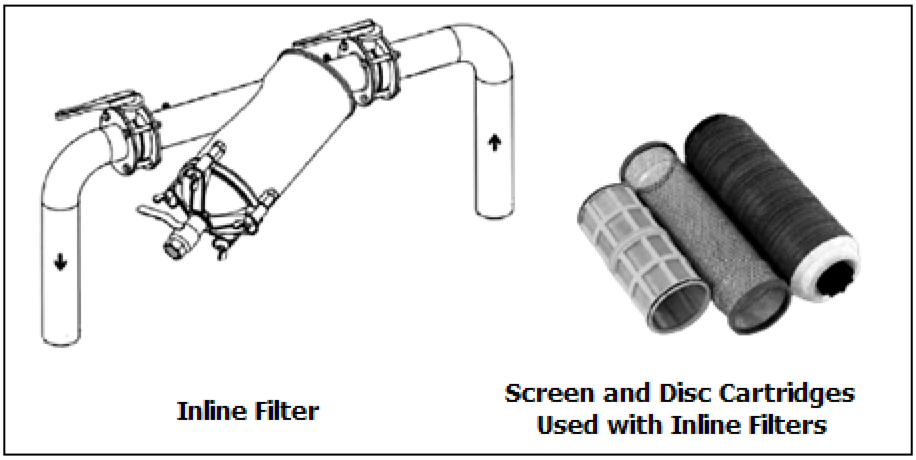
Pumps consist of various components, including the motor that drives the pump, the suction and delivery pipes, and various valves. The figure below shows the various components of a standard pump system.



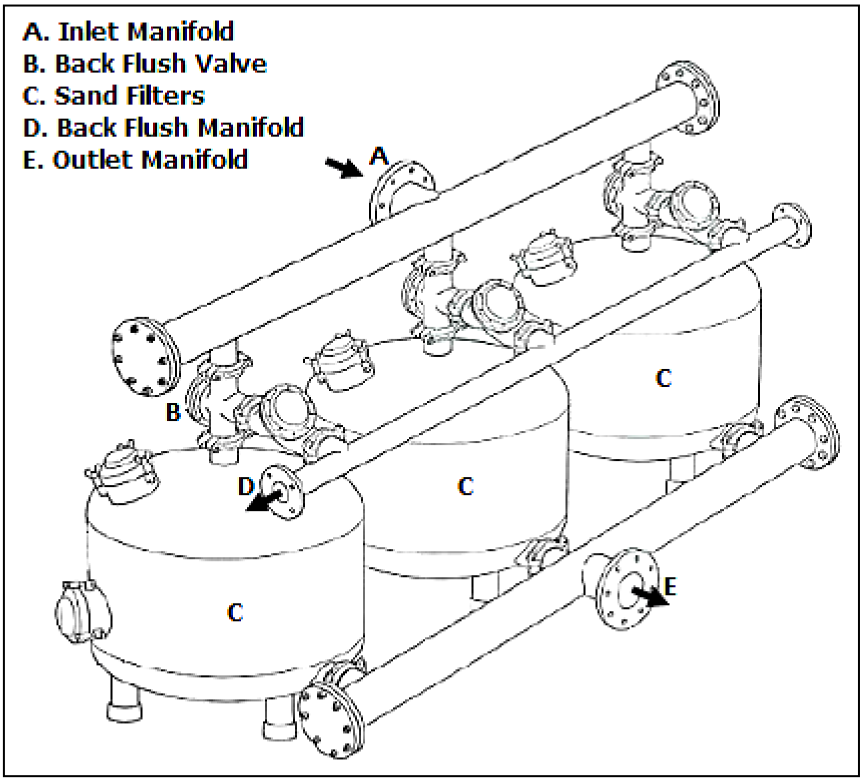
Basic Components of a Pump System

4.2. Filters

Filters 'clean' your irrigation water by trapping and removing suspended material that can block emitters. Suspended material consists of clay, silt, sand, and organic debris from plant and animal origin that do not dissolve in water. Filters cannot remove materials that are dissolved in water. Various types of filters are used, most commonly sand, disc and screen filters.



Inline Filter and Filter Cartridges



Sand Filter Bank

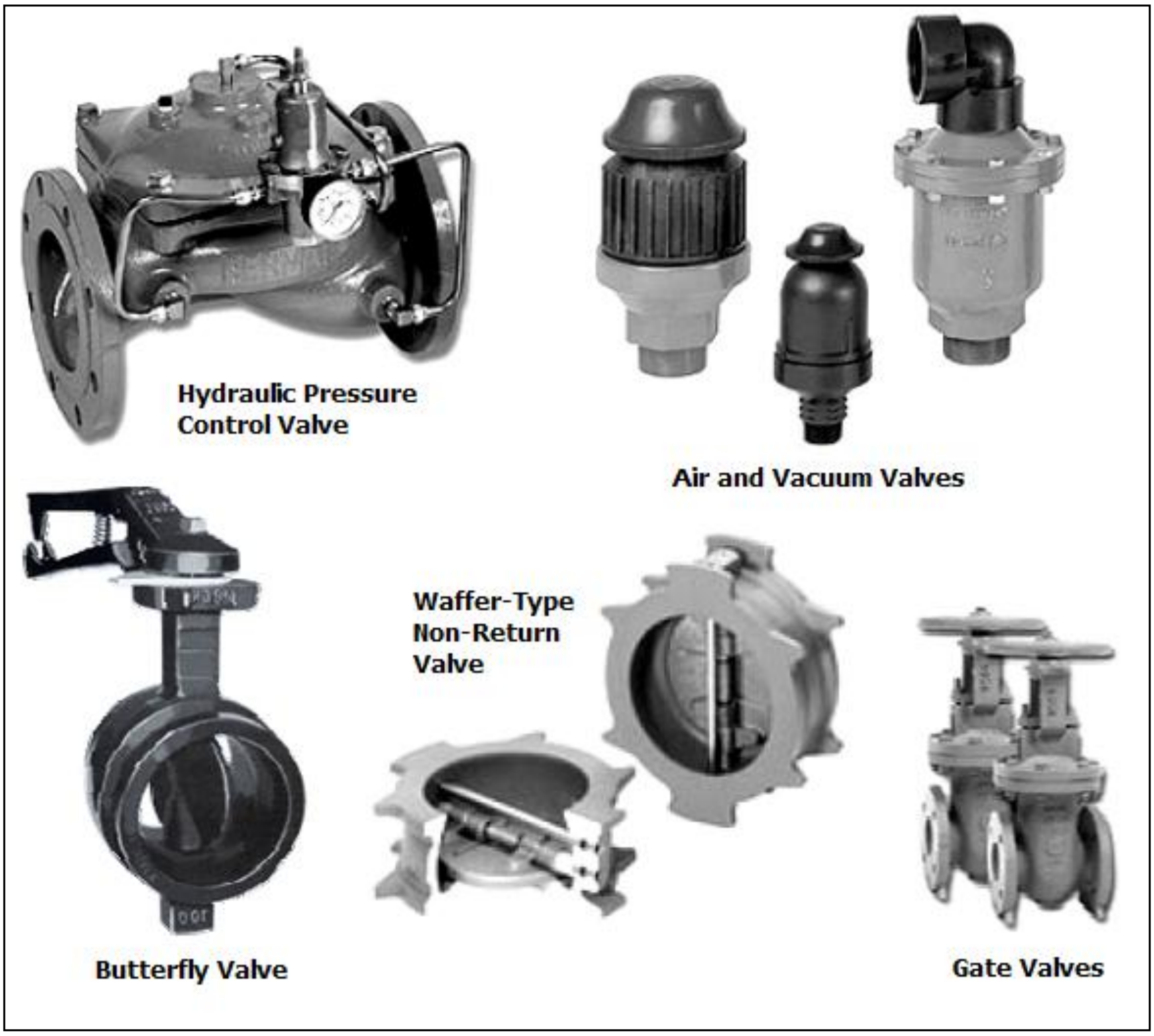
4.3. Pipes

Pipes channel water between points, such as from the water-source to the pump, from the pump to the main lines and from the mainlines to the trees. A wide range of pipes are available and used on citrus farms. For main and sub-main lines, PVC, steel and fibreglass pipes are used. In some older installations, asbestos or cement pipes are still in use. These pipes are unsuitable where acid is introduced into the irrigation water for fertigation purposes. Poly-pipe is used for lateral lines, which are a specific type of pipeline that moves water into the orchards.

4.4. Valves

Valves control the flow of water by opening or closing, thereby allowing water through, or cutting it off. Various types of valves are used.

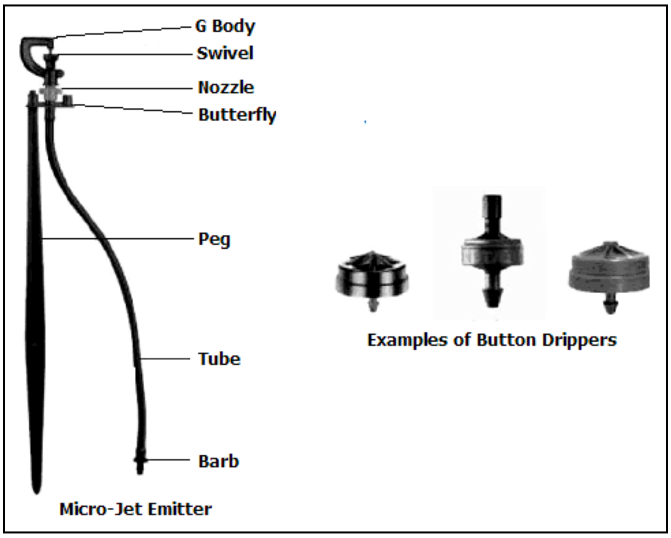
Gate and butterfly valves are used to open or close a pipeline. Pressure control valves are used to regulate pressure and flow rate. Non-return valves are used to prevent the reverse flow of water when the pump is switched off. Air and vacuum valves are used to expel air in the pipeline and to prevent a vacuum from forming after a line is closed or the pump is switched off.



Examples of Various Types of Valves

4.5. Emitters

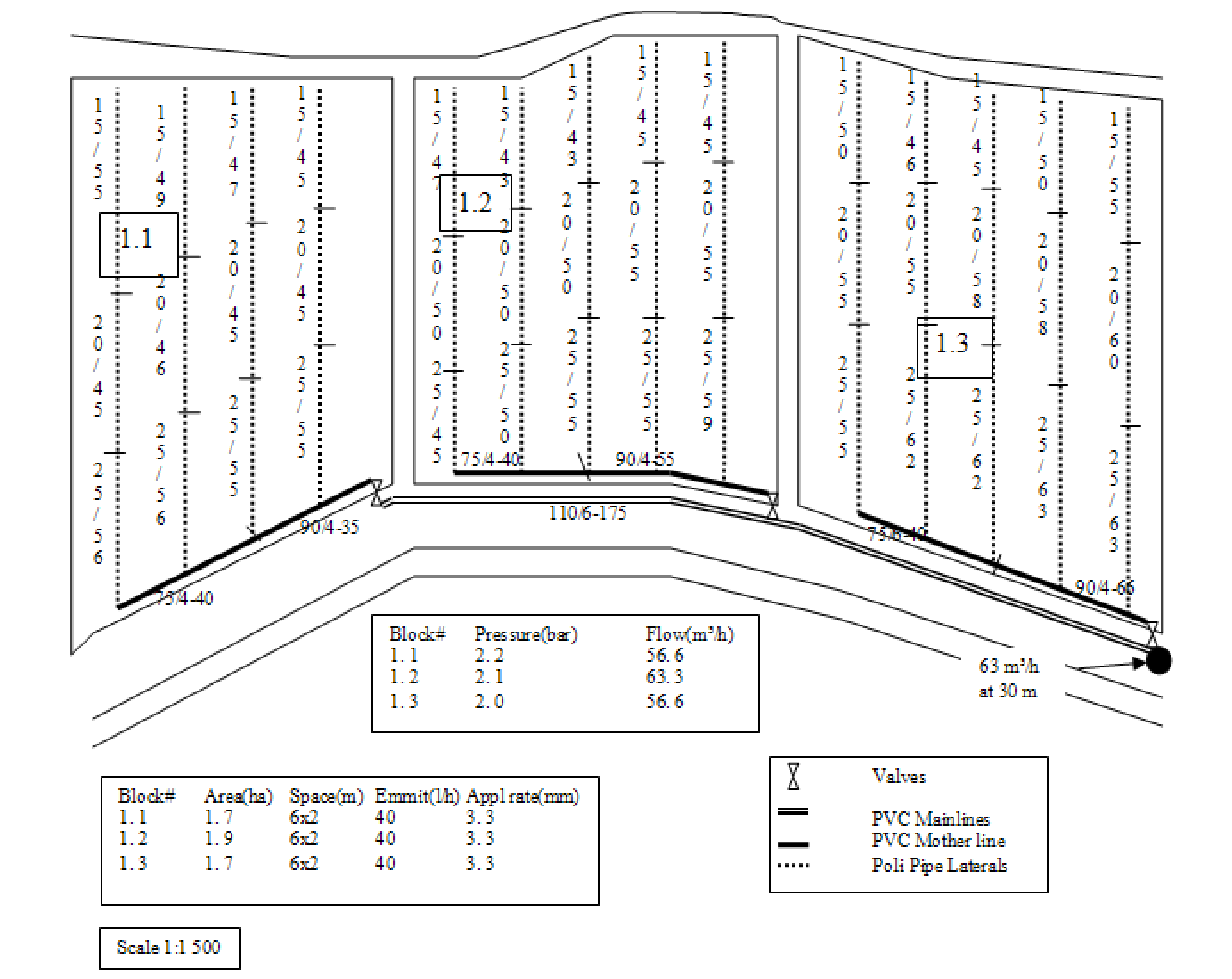
Emitters are placed in lateral lines and apply water to individual trees in a uniform and efficient manner. Examples of emitters are micro-jets, drippers, and sprinklers.



Micro-Jets and Drippers

5. Irrigation Installation

Installing your irrigation system in the right way is the first step in having reliable irrigation. To do this, you need to have enough data on the crop, soil and root system, and use this data when designing the system. The irrigation system is usually designed by a qualified irrigation consultant. Below is an example of an irrigation design plan for three adjacent blocks.



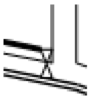
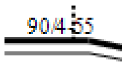
Irrigation Design Plan

5.1. Orientation

When reading an irrigation design plan, the first step is to get the orientation right. The plan must be turned so that landmarks on the plan agree with the actual landmarks, such as dams, canals, koppies, or any other distinguishable feature shown on the map. After orienting the plan to fit with the orchard landscape, familiarise yourself with the block and pipe layout on the plan and compare it with the actual block and pipe layout.

5.2. Symbols

On an irrigation design plan, symbols or different colours are used to depict the various pipes, valves, and other features. Usually, a key is provided with the symbols and their meaning. In table 1.1, the symbols and keys that are used on the irrigation design plan above are explained.

Symbol	*Description*	*Example of Use*	*Details*
●	Pump		The best place to start on an irrigation plan is at the pump station or the beginning of the mainline. The pump station is marked on the plan with a dot and the pump duty point is noted (63m^3/h at 30m in this case).
═	Mainline		The mainline can be traced from the pump station. On some plans there may also be sub-mainlines, which are pipes that branch off the mainline to take water to blocks that are further off the mainline.
⧗	Valve		On the mainline and sub-mainlines are the valves for the blocks. Valves feed directly into the mother lines.
━	Mother Line		There is a mother line for each block. The lateral lines branch off from the mother lines.
·····	Lateral line		Lateral lines run from the mother line along the tree rows. The emitters are located on the laterals.

Symbols and Keys Used on Irrigation Design Plan

5.3. Pipe Notations

The notations next to the different sections of pipes indicate the pipe size and class for that particular section of pipe, and the length of the pipe.

For example, in the table above, the mainline has the notation of 110/6-175 written under it. The 110/6 indicates the pipe size and class, meaning the pipe will have a nominal diameter of 110mm and will be PVC class 6 pipe. The second part of the notation indicates the length of the pipe in meters, meaning that this pipe will be 175m long. Note this is the total length and includes the bends in the pipe.

Pipe sections are indicated by a short line (/ or -). In the example above, the different sections of the lateral lines are marked in this way. The first lateral for block 1.3 has the numbers 25-63, 20-60 and 15-55. This means that in the first section, 25mm poly-pipe is laid for 63m. In the second section, 60m of 20mm poly-pipe is laid, and 15mm poly-pipe is laid for 55m in the third section.

Classes are usually not specified for the laterals, because class 3 poly-pipe is used as a rule. If drippers are used, the drip line would be specified.

The class of the pipe indicates, for plastic, PVC and poly-pipe, how much pressure in Bar the pipe can withstand. The class notations for asbestos and cement pipes are more complicated and have to be verified with the supplier.

On the following page is information on the commonly used pipe sizes and classes.

information

Popular Pipe Sizes and Classes for Irrigation Pipes

Pipe	*Number*	*Nominal Diameter (mm)*	*Class*	*Working Pressure (bar)*
Poly-pipe	15/3	15	3	3
Poly-pipe	20/3	20	3	3
Poly-pipe	25/3	25	3	3
Poly-pipe	32/3	32	3	3
Poly-pipe	40/3	40	3	3
Poly-pipe	50/3	50	3	3
Poly-pipe	32/6	32	6	6
Poly-pipe	40/6	40	6	6
Poly-pipe	50/6	50	6	6
Poly-pipe is available in sizes 65mm, 80mm, 100mm and in classes 3, 6, 9. Note that this for LDPE (low density pipe).				
PVC	50/4	50	4	4
PVC	50/6	50	6	6
PVC	63/4	63	4	4
PVC	63/6	63	6	6
PVC	75/4	75	4	4
PVC	75/6	75	6	6
PVC	90/4	90	4	4
PVC	90/6	90	6	6
PVC	110/4	110	4	4
PVC	110/6	110	6	6
PVC	140/4	140	4	4
PVC	140/6	140	6	6
PVC	160/4	160	4	4
PVC	160/6	160	6	6
PVC	200/4	200	4	4
PVC	200/6	200	6	6
PVC pipe is available in sizes up to 500mm and up to class 20.				
Asbestos Cement	150/6	150	6	3
Asbestos Cement	150/12	150	12	6
Asbestos Cement	150/18	150	18	9
Asbestos Cement	200/6	200	6	3

Asbestos Cement	200/12	200	12	6
Asbestos Cement	200/18	200	18	9
Asbestos Cement	250/6	250	6	3
Asbestos Cement	250/12	250	12	6
Asbestos Cement	250/18	250	18	9

5.4. Irrigation Block Information

On the irrigation design plan information with regard to each block is given in a table that shows the block number, area, spacing, emitter delivery and application rate.

Block#	Area(ha)	Space(m)	Emmit(l/h)	Appl rate(mm)
1.1	1.7	6x2	40	3.3
1.2	1.9	6x2	40	3.3
1.3	1.7	6x2	40	3.3

Block Information on Irrigation Design Plan

The area of each block is indicated in hectares (ha). In the Space column, the plant spacing is indicated. In the example the spacing is 6m x 2m, meaning that the plant rows are 6m apart and the trees are planted 2m apart in the rows. Remember that plant spacing varies according to the cultivar and the production area.

The plant spacing is used to calculate the number of plants per hectare, and therefore the number of emitters that is required. The plant spacing is multiplied to calculate the area per plant, and area in hectare is divided by the area per plant, which will give the plant population per hectare. Remember that 1 hectare equals 10,000m2.

example

Calculating Plant Population per Hectare

Plant spacing: 6m x 2m

Calculating Area per Plant

6m x 2m

=12m2 per plant

Calculating Plant Population per Hectare

Area of a hectare / Area per plant

10,000m2 / 12m2

=833 plants per hectare

Calculating Plants per Block

Plants per hectare x Block Area

833 plants x 1.7ha

=1,416 plants in block number 1.1

This is useful when plants are ordered or when the plants are allocated per block.

The emitter delivery in the table is used to calculate the precipitation and to check the emitters. The precipitation is used in the scheduling of the irrigation. The irrigation design plan also contains a table with the pressure and flow per block. This information is used in the irrigation scheduling.

5.5. Bill of Quantities

When a system is designed from scratch or if new blocks are designed, a bill of quantities is supplied along with the irrigation design plan.

If the company that designed the system is delivering the materials as well, the bill of quantities is used to check and verify all the materials that are delivered. If the designer is not delivering the materials, the bill of quantities is used to obtain quotations for the materials and for budgeting.

example

Bill of Quantities

Item	*Unit*	*Quantity*
Poly-pipe 15/3	m	1,200
Poly-pipe 20/3	m	1,300
Poly-pipe 25/3	m	900
25 mm nylon couplings	Each	90
20 mm nylon couplings	Each	130
15 mm nylon couplings	Each	120
Reducer 25x20 mm	Each	80
Reducer 20x15	Each	85
Grommet fitting and rubber	Each	85
Micro 40 l/h, spreader, peg, tube, barb	Each	8,250
PVC 50/4	m	300
PVC 63/4	m	200
PVC 75/4	m	180
PVC 90/4	m	150
Reducer boseng 63x50	Each	6
Reducer boseng 75x63	Each	6
Reducer boseng 90x75	Each	5
RO bend 80x90	Each	6

Valve cluster 80mm hydraulic valve, pilot	Each	6
Saddle 110x50	Each	6
Reducing socket 50x80	Each	6
Nipple 50 mm nylon	Each	6
Glue on bend 50mm	Each	12
Glue on ball valve	Each	6
End cap 110	Each	1
Air valves 25 mm	Each	6
Risermatic short 25 mm	Each	6
Bend boseng 110mm	Each	2
PVC 110/6	m	800
Pipet	Each	1
Pressure gauge 0 – 4 bar	Each	1
Pipe punch	Each	2
Hole saw	Each	1
Pipe lubricant	Bucket	1

6. Laying Out the Irrigation System

Now that we have developed an understanding of the irrigation design plan, the blocks can be pegged out in the field. The assumption is made that the land has been cleared and soil preparation has been done, and that other infrastructure items, such as roads and waterways, has already been marked.

Care must be taken when laying out the irrigation blocks that it is done correctly and precisely. It may take a day or two longer to get it right but remember that the result will be visible for the lifespan of the orchard.

The following tools and equipment are required for pegging out the blocks:

- Pegs (one per tree in the block)
- Hammer
- Dumpy level or other surveying instrument
- Measuring tape
- Wire or rope

Blocks are laid out as follows:

- Marking the corners of the blocks
- Marking the rows
- Marking the plant positions

6.1. Marking the Corners of the Blocks

The corners of the blocks are first pegged out roughly to see the relation of the blocks to one another. The lengths of the sides of the blocks are now measured on the irrigation design plan, and the scale of the plan is used to calculate the actual length.

The scale is a ratio that shows the relation between the measurement on the plan and the actual distance on the ground. The scale of the plan in the example is 1:1500, meaning that for every centimetre on the plan, the distance on the ground would be 1,500cm or 15m. If the side of a block measures 10cm on the plan, it equals a distance of 15,000cm or 150m on the ground.

The corners of the blocks can now be marked precisely. Make sure the corners are in the right spot and that the pegs are hammered in well. These corners will be the markers used to lay out the rest of the block, so if they are wrong, the rest of the layout will also be wrong.

6.2. Marking the Rows

Start by measuring the rows on the side of the block with the mother line, using a measuring tape. Remember that poor-quality measuring tapes can stretch and expand. Use a good quality measuring tape made of fibre.

If the plant spacing on the irrigation design plan is for example 6x2, it means that there must be a 6m space between rows, and a 2m space between the plants in the rows. The row spacing is the bigger number.

Set the dumpy level up at one of the corners of the block. To set up the dumpy, the legs of the tripod is extended and secured. The base of the dumpy is fastened to the tripod by means of the attachment screw on the base the tripod.

On the dumpy is a spirit level, located on the eyepiece or the base of the dumpy. By moving one leg of the tripod at a time in or out, adjust the level of the dumpy until it is almost in the middle. On each of the three corners of the base of the dumpy is an adjusting screw.

Adjust these screws until the spirit level shows dead centre. In the case of the spirit level being located on the eyepiece, the dumpy has to be turned to face the leg that is being adjusted. Rotate the dumpy trough all three legs after it is levelled to check the levelling.

When you look into the dumpy level you will note crosshairs on the inside. Turn the dumpy towards the other corner of the block. If the other corner is out of sight due to elevation, have an assistant hold a long pole or staff at the other corner. Plant pegs between the corners at about 20m to 30m intervals.

Make sure the pegs are in the vertical crosshair and therefore in line with the other corner. These preliminary pegs give a straight line along the side of the block for the measuring of the rows.

Use a tape measure to mark the end of each row with a peg. Make sure the straight line is followed. Check the pegs with the dumpy. They should all be in one straight line from the dumpy to the other corner. Move the pegs perfectly into line, and check the row spacing again with the measuring tape.

Keep the dumpy at the corner it is and swivel it to mark a line perpendicular to the one on which the rows have been marked. Apply the same method as above and put down two marking pegs at about 50m to 100m intervals on this line. Move the dumpy to the first peg and level as set out above.

Turn the dumpy back to the first corner and zero the degree scale, by adjusting the degree plate on the dumpy so that 0 degrees shows to the first corner. Now swivel the dumpy trough 90° and lock.

Peg out a line to the opposite end of the block and use the same method as above to mark the rows at six-meter intervals on this line as well. Repeat the procedure for the remaining pegs that run parallel to the rows. When the rows are marked the pegs in the rows must be checked to see that they are in line.

Citrus orchards are sometimes ridged, meaning that the ground is cropped up into the row to improve the soil depth and drainage. Once the rows are marked, the ridges must be made. Once the rows have been ridged, the rest of the land can be pegged.

After ridging the row markers must be checked again as the grader could have moved the pegs. Check the rows by using the same method that was used to lay them out.

6.3. Marking the Plant Positions

Set up the dumpy at the end of a row and look at the other end. Use the tape measure to measure the inter-plant spaces. If the plant spacing is 6x2m, this would be 2m. Plant pegs at every spot where a tree must be planted.

Check the pegs visually to see that they are in line. Check them also at an angle, meaning from one corner to the corner diagonally opposite, to see if they are aligned.

7. Conveyance System Trenches

Conveyance system trenches are the trenches into which the pipelines are buried. Before the trenches are dug, they must first be pegged out. The centre of the trench can be pegged with pegs about 50m to 100m apart. Tie a wire or a rope to the pegs to mark out line between them and use ordinary lime to mark out the line of the trench. When the trenches are dug, the chalk line must be in the centre of the trench.

Trenches are dug about 400mm to 600mm wide, depending on the size of the pipe. Trenches are usually about 600mm deep. Trenches for pipes that go through lands and roads, such as mainlines and sub-mainlines, should be 1,000mm deep. Trenches for mother lines can be a bit shallower, at about 400mm. Trenches must be free of protruding rocks on the bed since these rocks can break the pipes.

Trenches can be dug by either using manual labour or a back-end loader, also called an excavator. Manual labour may be cheaper, but will take longer, while using a back-end loader will be faster but more expensive. Keep in mind that back-end loaders are also more suited for rocky terrain. The choice will depend on the budget.

8. Installing Irrigation Equipment

In the table below, various items of irrigation equipment are discussed in greater detail.

information

Irrigation Equipment

Pipes	
Asbestos Cement (AC) Pipes	Asbestos cement pipes are not manufactured any longer due to health concerns regarding the manufacturing process. It is however not uncommon for these pipes to be used second-hand. Many older systems also use these pipes for mainlines and sub-mainlines. AC pipes are hard but very brittle, so care must be taken when they are handled and transported. The trench must be free of protruding stones and the pipe must be laid on a bed of clean sand. AC pipes are joined by collars. Triplex couplings are made out of asbestos cement and have three seal rings. The pipe slides into this socketed joint. The other method of joining AC pipes is with the short collar, which is a coupling with two iron rings that are tightened around an iron collar. Each ring contains a rubber ring that is compressed around the pipe when the collar is tightened, preventing the collar from leaking. AC pipes come in COD (constant outside diameter) and CID (constant inside diameter).
PVC Pipes	This is the most commonly used pipe for irrigation. PVC is a plastic material and these pipes are more flexible and tolerant to movement. The one end of the pipe is chamfered, and the other end is socketed. The chamfered end slides into the socketed end. Trenches must free of stones, but do not need to be lined with sand for smaller pipe sizes of 200mm and smaller. Fittings are either steel or PVC and are also socketed. Inside the sockets are lip-seals that seal the pipe.
Steel Pipes	Steel pipe is very expensive but very reliable and durable. Steel pipes are used more often for suction pipes, delivery pipes, risers, and filter manifolds, where the line must go through or over unsuitable terrain. Steel pipes can be threaded at the end (up to 150mm) or flanged (from 50mm and bigger). Threaded pipes are connected using screwed sockets. Flanged pipes are bolted together with a packing in the middle. Steel pipes rust, so they must be coated with a rust-proof coating such as paint, coupon, galvanizing or powder coating.
Poly-pipe	Poly-pipe is used for the lateral lines. Class 3 LDPE pipe (low density pipe) is used most often, but HDPE (high density pipe) is also available. HDPE pipe is used more often in boreholes and shade houses.
General Fittings	
Reducers	A reducer is used to connect pipes of different sizes.
Bend	A bend is used to allow a pipe to change direction. Bends are available in 90° and 45°.
End Cap	An end cap is used to plug the end of a pipe.
Air Valve	An air valve expels air from the system, preventing air locks. Some air valves have a vacuum function (see below).
Vacuum Valve	A vacuum valve prevents the formation of a vacuum when the pump system is switched off.

Non-return Valve	A non-return valve prevents the backflow of water.
Gate and Butterfly Valve	Gate and butterfly valves open and close the pipeline, thereby decreasing and increasing the water flow. They are used to regulate the water pressure in a block manually.
Hydraulic Valves	Hydraulic valves are also used to decrease or increase the water-flow, thereby regulating the water pressure in a block.
Infield Fittings	
Grommets	A grommet is a fitting that is used to connect lateral lines to the mother line.
Nylon Couplings	Nylon couplings and reducers are used to connect poly-pipe.
Micro-jets and Drippers	Micro-jets and drippers are the emitters that supply water to each individual tree. They are installed on the lateral lines.

8.1. Installing Pipes

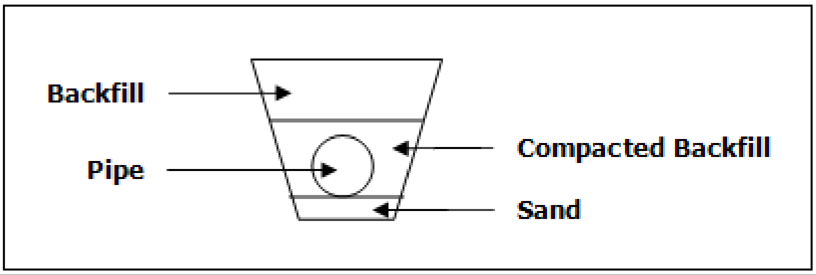
Pipes are installed in trenches as follows:

- Before installing pipes in trenches, ensure that the trenches are free of stones and sharp edges.
- Asbestos cement pipes and large PVC pipes must be laid down on a bed of sand.
- Place the first pipe into the trench and secure it by backfilling the trench near the ends of the pipe.
- Place a collar over the end of the pipe. Make sure the collar and the end of the next pipe is clean.
- Lubricate the inside of the collar and the end of the next pipe with pipe lubricant or soap water. Do not use oil because this will cause the rubbers to perish.
- Insert the end of the second pipe into the collar.
- Place a wooden block over the other end of the second pipe and tap the block with a hammer to force the pipe into the collar. The force that is required depends on the size of the pipe.
- Drive the pipe in up to the depth marked on the pipe. Take care not to pinch the rubbers.
- If the pipe refuses to go into the collar, remove the pipe and inspect the collar, as the rubbers may have shifted.
- Ensure that there are no foreign objects inside the pipes that can cause blockages in the irrigation system.
- As the pipes are laid, they can be backfilled near the edges. Joints must be left open to check for leaks.

Where bends or end caps are fitted there is always the possibility that the joints can kick out, except in the case of steel joints. Bends and end caps must be anchored either by driving Y-standards in and tying them down, or by casting trust blocks. Trust blocks can be 600x600x300 and cast in ordinary concrete.

It is good practice to flush the pipes as the work continues. First flush the mainline before the valves are fitted. Then flush the mother lines before the laterals are fitted. Next, the laterals can be flushed before emitters are fitted.

After the system has been tested (see section 9) the trenches can be backfilled. The backfilling around and above the pipe for about 100mm must be stone free and compacted. The rest of the backfill does not need to be compacted.



Cross Section of a Backfilled Trench

8.2. Installing Filters and Valve Clusters

Pump and filter bank installation is a specialised job that should be carried out by a competent contractor. Inline filters, on the other hand, can be installed very easily. The filter is attached to risers so that it is above ground. At the bottom end of the risers are riser outlet bends, which are spigoted to slide over the pipe. At the back of each riser leg, a Y-standard is hammered in and tied down to the riser to keep the leg from popping out. The valve clusters are installed in the same way.

8.3. Installing Infield Fittings

Grommets are installed by sawing a hole in the mother line and inserting a rubber ring into the hole. The ring has a groove that fits into the sides of the pipe. The coupling is inserted into the lateral and then pushed into the rubber ring. There is also another type of grommet that is pushed into the hole and the retaining nut on the grommet is tightened.

Nylon couplings and reducers are pushed into the poly-pipe. No clamps are needed as long as the working pressure is within limits. Micros have a tube that is fitted with a barb and drippers have the barb moulded onto them. A hole is punched into the poly-pipe and the barb inserted into the hole.

9. Testing the Irrigation System

The various components of the irrigation system are tested as they are installed, and the performance of the entire system is tested once the installation is complete.

As the pipes are laid and flushed, joints are inspected for leaks. Once the pipes are partially backfilled with the joints exposed, the system is brought up to working pressure. The blocks that are grouped in operations are opened.

Pressure readings are taken before and after the valves, and these are compared with the values noted on the irrigation design plan in the Pressure and Flow at Nodes table. If the readings are not correct, it may be an indication of wrong pipe size, incorrect hydraulic valve settings, or pump or filter malfunction.

Hydraulic valves are calibrated at this time. The pressure gauge is inserted downstream after the valve and the valve is opened. Note the pressure reading. Once the block is filled, the valve is switched to automatic.

If the pressure reading drops, the screw on the pilot is turned slowly in a clockwise direction. If the pressure rises, the screw on the pilot is turned anticlockwise. The process is repeated by adjusting the pilot, checking the pressure again after a while, and adjusting the pilot again if necessary.

Once the hydraulic valves have been calibrated, the pressures in the lateral lines can be checked. Check the pressure at the end of each lateral, which should be close to the pressure that the valve is set at. Alternatively, each lateral can be assessed visually, and the pressure of the laterals measured that appears to have a different distribution pattern than the other lines.

Emitter delivery can also be checked to see if it corresponds with the irrigation plan. Place the emitter in a suitable container. After 15 or 30 minutes, remove the container and measure the volume of water. Multiply the volume of water by four for 15 minutes and two for 30 minutes to calculate the emitter delivery per hour. When this test is done with a representative sample for the whole block, it is called a CU (Coefficient of Uniformity) test.

After this test is done and the system has been operating for a couple of days, inspect joints for leaks. If no leaks are found, the trenches can be backfilled completely.

10. Irrigation System Maintenance.

Irrigation systems that have been installed correctly and that are operated within the set parameters should never require major maintenance under normal circumstances. A sound preventative maintenance plan ensures that minor problems do not turn into major problems, and constant evaluation and monitoring of the system ensures that the system operates within the required parameters, and that problems are picked up and dealt with when they occur.

11. Maintenance Planning

Below is an example of a comprehensive maintenance plan, which also includes essential monitoring actions.

example

Irrigation Maintenance Plan

Frequency	*Item*	*Task and Action*
Daily	Block pressures	Check that block pressures are within prescribed limits.
	Emitter operation	Check for clogged, broken, or misplaced emitters. Repair, replace, unclog, or reposition emitters.
	Leaks	Check for leaks in pipes and other equipment and other water wastage, and repair if found.
	Primary filter	Flush primary filters as prescribed.
	Fertigation application	Check that fertigation applications are within specifications.
Weekly	Lateral lines	Flush lateral lines as prescribed.
	Secondary filters	Flush secondary filters as prescribed
	System pressure and flow	Check that system pressure and flow are as per irrigation design plan.

	Pump operation	Check that pump operation is within prescribed parameters.
	Block pressures for automated valves	Check that block pressures are as prescribed where automated valves are used.
	Pump oil levels	Check pump oil levels as prescribed.
	Fertigation plant	Inspect fertigation plant.
Monthly	Valves, water meters, and gauges	Visually check valves, water meters and gauges and look for damage and / or vandalism.
	Filters	Open and inspect filters as prescribed.
	Pump pipe work	Check for leaks at pump pipe work through which water is lost and for leaks through which the pump can suck air.
	Pump motor	Grease pump motor as prescribed.
	Coefficient of Uniformity (CU) tests	Perform CU tests
Annually	Valves	Service valves and physically check correct operation.
	Filters	Thoroughly clean filters. Replace sand in sand filters.
	Pump	Change oil in pump.
	Water sampling	Take a water sample at the end of lateral lines and send it for analysis.
2-10 years	Pump	Replace bearings and other wearing parts, such as bearings, on pump and motor every five years.
	Hydraulic valves	Replace diaphragms on hydraulic valves every three years.
	Poly-pipe and emitters	Replace poly-pipe and emitters every seven to ten years.

Citrus has a continuous irrigation cycle, and therefore has no pre- or post-season period for irrigation. However, the peak water demand is lower during the winter, and this is the ideal time to perform maintenance and repair operations that require a system shut down for a few days.

It is with this in mind that a continuous preventative maintenance plan is implemented and carried out. A good maintenance plan focuses on daily, weekly, monthly, and yearly actions.

Water quality is a very important factor in planning preventative maintenance. Water quality differs widely from farm to farm, and it is essential to keep records of lateral flushing, filter flushing and water quality. This data is used to determine whether flushing should be done more often or whether water treatments are required.

In general terms, physical water quality is worse during the summer than in winter. In summer rainfall areas, the higher rainfall during the summer means that water sources carry more suspended solids, usually clay, silt, and sand.

Algae are also more prevalent during the warmer months, which increases the biomass that has to be filtered out of the water. However, the soluble salt content, which is a chemical water quality factor, is usually lower during the rainy season.

Pump hours are also increased during summer, resulting in filters having a bigger filtering load. The higher pump hours also cause the levels of the water source to drop. Water quality usually suffers because of the lower water level, as pumps tend to suck more dirt and there is little time for the silt and sand to settle out of the water. When water quality is poor, filters must be flushed more often.

Note that the physical water quality, which relates to the suspended solids in the water, plays a role in how frequently filters are flushed and cleaned.

The above plan is merely an indication of the tasks that have to be performed. The objective should be to use this plan and decide how the intervals should be changed in each individual case. Use the following as a guideline:

- If the physical water quality is poor, increase the frequency of flushing and cleaning for laterals, mother lines, filters, and filter rings.
- CU test can be performed less often in a well-designed system.
- The frequency of the inspection for air leaks can be decreased on new suction pipe work.
- Replace bearings and wearing parts as soon as the pump cannot deliver the original duty.
- Replace diaphragms when valves do not close properly.
- Replace poly-pipe when the pipes become brittle and burst easily.
- Replace emitters as soon as CU tests show a deviation from the design specifications and the flow rate per block increase.

12. Evaluating the Functioning of Irrigation System

It is very important that you evaluate the functioning of the irrigation system to make sure that the system operates within the set parameters, which protects the components of the system. It is also essential to make sure that the correct volume of water is delivered to your trees.

All the data required to monitor and evaluate the operation of the irrigation system is provided on the irrigation design plan, including the list of operations, a table with pressures and flows at valves and at nodes, and a table with the plant spacing and precipitation for each block.

12.1. Coefficient of Uniformity (CU) Tests

The coefficient of uniformity (CU) test is used to determine the variance in the performance of equipment, for instance the uniformity in delivery rate of the emitters across an irrigation block.

To perform a CU test on the delivery rate of emitters, select five evenly spaced lateral lines in the block. For example, you can use the 1st, 5th, 9th, 13th, and 17th lines in the block. Select five evenly spaced emitters on each lateral line. For example, you can use the emitter at the beginning of the line, an emitter about one quarter of the way along the line, one about half-way along the line, one about three-quarters of the way along, and the one on the end.

The delivery of each sample emitter is measured by allowing the emitter to drip or spray into a measuring tube for 5 minutes. The volume of water expelled by the emitter is noted on a data table. The delivery of each emitter in litres per hour is calculated from the data that has been gathered.

The average delivery is calculated and the difference between the highest and the lowest emitter delivery is expressed as a percentage of the average. This tolerance level for the variance is 10%. If it is more than 10%, the block must be examined, and the fault repaired.

example

CU Test Data Table

Emitter Delivery in l/5min					
Lateral	**Position on Lateral**				
	Beginning	***¼***	***½***	***¾***	***End***
1	3.30	3.30	3.16	3.16	3.16
5	3.30	3.30	3.30	3.25	3.30
9	3.40	3.30	3.30	3.30	3.30
13	3.30	3.25	3.25	3.25	3.16
17	3.30	3.30	3.30	3.25	3.25

Emitter Delivery in l/h					
Lateral	**Position on Lateral**				
	Beginning	***¼***	***½***	***¾***	***End***
1	39.6	39.6	37.9	37.9	37.9
5	39.6	39.6	39.6	39.0	39.6
9	40.8	39.6	39.6	39.6	39.6
13	39.6	39.0	39.0	39.0	37.9
17	39.6	39.6	39.6	39.0	39.0

The average emitter delivery is 39.48l/h. The emitter with the largest delivery is 40.8l/h and the emitter with lowest delivery is 37.9l/h. This is a deviation of 7.5% and, with the tolerance level being 10%, the system can be considered to be in order.

Note that the same procedure of the coefficient of uniformity (CU) test can be used to determine the uniformity of the pressure at the emitters.

12.2. Evaluation Irrigation System Performance

The irrigation system is evaluated as follows:

- Open the blocks as per the list of operations
- Check and correct, if necessary, the block pressures
- Note the pump operating parameters
- Note the pressures at nodes
- Perform a CU test
- Repeat the procedure for all the operations
- Evaluate the data

The following is indicative of the system flow being higher than specified:

- Pump: Amp reading is higher than expected
- Pump: Pressure reading is the same or lower than expected

- Pump: Flow meter reading higher than expected
- Pressure at Nodes: Lower than expected
- Pressure at Blocks: Lower than expected
- CU Test: CU might be good, but the flow per emitter can be higher

The most probable cause is worn nozzles on the emitters, especially if the water has a high silt and sand content. The system pressure is lower due to the higher flow in each block. The pump is trying to compensate by pumping more, which is why the amp reading will be higher. The CU should be acceptable since wear will occur on all the nozzles.

The following is indicative of the system flow being lower than specified:

- Pump: Amp reading is lower or higher than expected
- Pump: Pressure reading is higher or lower than expected
- Pump: Flow meter reading is lower than expected
- Pressure at Nodes: Higher or lower than expected
- Pressure at Blocks: Lower or higher than expected
- CU Test: Poor CU with low emitter delivery

Lower flow can be caused by a worn pump or by blockages. When the pump is worn, the symptoms will be low pressure and flow but a high amp meter reading. In this case, the pump must be serviced and repaired, or replaced. Blockage can occur at various places with differing symptoms.

The pressure reading before the blockage will be abnormally high, but pressure readings after the blockage will be very low. Amp meter readings will also be lower. Consider the following examples:

- Blocked Impeller: Low pressure reading at pump and in the rest of the system
- Blocked Filter: High pressure at pump, but low pressure after filter bank
- Blocked Pipeline: High pressure up to the filter and some nodes, but at other nodes the pressure is low

13. Water Supplementation

When it comes to producing citrus, especially in a country with a diverse climate like South Africa, it is vital that you can consistently supply enough good quality water to keep your trees healthy and happy for years, if not decades. Unfortunately, in most places, rainfall is not consistent or plentiful enough to meet all the water needs for your trees.

In these situations, irrigation becomes an essential part of orchard management and citrus production as a whole. Irrigation is incredibly important in supporting the growth, health, and productivity of your citrus trees.

As you know, water plays a major role in plant physiology. Water is needed for photosynthesis, as well as being the medium through which nutrients are dissolved and transported within the trees. Without sufficient water, your trees can easily develop nutrient deficiencies, even in soils that are nutrient rich.

The climate in South Africa can be challenging for farming, as certain areas have periods of inconsistent rainfall and prolonged dry spells. These conditions make the use of natural water sources (such as rainfall) unreliable for citrus trees, which require consistent water for optimal growth. Irrigation mitigates this by providing a controlled and regular water supply.

Consistent water supply through irrigation supports the overall health and longevity of your trees. Water stress can weaken trees, making them more susceptible to diseases and pests. A well-irrigated orchard is likely to have healthier trees with a longer productive lifespan, contributing to the long-term sustainability and profitability of the citrus operation.

14. Water Quality Requirements

The quality of water used in irrigation can have a large impact on the irrigation system, soil productivity and crop production. Water quality factors are classified as either physical, chemical or biological.

The impact of water quality factors on the effectiveness of the irrigation system, soil productivity, and crop production varies. In the table below, the hazard according to the Department of Water Affairs of various physical, chemical and biological water quality factors on the irrigation system in terms of the clogging of emitters are shown.

information

Water Quality Hazards for the Irrigation System

Factor	*Unit*	*Low Hazard*	*High Hazard*
Physical Water Quality			
Suspend solids	mg per litre	<50	>100
Chemical Water Quality			
pH		<6	>8
Bicarbonates	me per litre	<1.64	>3.28
	mg per litre	<100	>200
Calcium	me per litre	<0.50	>2.50
	mg per litre	<10	>50
Manganese	mg per litre	<0.10	>1.50
Iron	mg per litre	<0.20	>1.50
Sulphide	mg per litre	<0.20	>2.00
Total dissolved solids (TDS)	mg per litre	<500	>2,000
EC	mS per m-1	<75	>300
Biological Water Quality			
Total bacteria	Numbers per ml	<10,000	>50,000

15. The Impact of Physical Water Quality

The main impact of physical water quality is blocking or clogging of emitters. The standard set by the Department of Water Affairs and Forestry (DWAF, 1996) for the clogging hazard of water is as follows:

example

DWAF Standards for Suspended Solids

Rating	*Suspended Solids per Litre Water (mg)*
Minor hazard	less than 50mg
Moderate hazard	50mg to 100mg
Severe hazard	more than 100mg

The effects of clogged emitters are so devastating on production that even water classified as having a Low Clogging Hazard according to the tables above still needs treatment, because some of these factors have a cumulative effect on the irrigation system.

Filtration is used as a standard treatment for improving physical water quality by removing suspended solids from water. Apart from the initial analysis of the water, continuous monitoring of the suspended solids in the piping and emitters, and of the effectiveness of the filter system, is essential. The classification in the table above needs adjustment based on the hazard that can be caused by the accumulation in the pipes. Such an assessment is done as in the example below:

example

Assessing Clogging Hazards

Suspended Solids	Assessment	Actions	Comments
<50mg per litre and 50-100mg per litre	Minor clogging hazard but can accumulate, requires action.	Filtration	Suspended solids will accumulate in the piping and will eventually cause emitters to clog*.
>100mg per litre	Needs action	Sedimentation, cyclones, filtration	Techniques and level of physics and engineering fall outside the scope of this material. Seeks specialised advice.

* The rate of accumulation of suspended solids and the agglomerating effect of the bacteria depends on a number of factors, including temperature and the flow rate in the pipes. The requirement should be included in the specifications for the filtration system. This forms part of irrigation system design and a filtration system with the capacity to handle the load of solids for the specific water should be installed.

16. The Impact of Chemical Water Quality

It can be a lot more complicated dealing with data relating to the chemical water quality and determining the best course for corrective action than for physical water quality data.

It is too expensive to improve certain chemical factors, so the water quality manager can only take steps to limit or correct the impact on production and the environment. The type of irrigation system used, being micro-jets or drippers, also has an influence on the actions that can be taken to correct and / or minimise the impact.

The corrective actions in the table below include those aimed at improving chemical water quality and those aimed at reducing its impact on the environment and on crop production.

example

Assessment of Chemical Water Quality and Corrective Actions

Value	*Comments*	*Assessment*	*Actions*
pH			
<6.00	Half-life of pesticides depends on the pH of the spray solution. Buffer solutions available for various pH levels. Consult supplier.	Suitable for most pesticide and nutrient sprays and needs no treatment.	None
		Some pesticides and nutrient sprays need higher pH.	Buffer the pH at the desired level
	Low pH in combination with low salt increases corrosion potential. The Corrosivity Index (CI) is used to evaluate this.	The corrosion potential of the water is high. Treatments are required.	This is a specialised action. Seeks expert advice.
	Nutrient solutions can be formulated without addition of acids, provided added chemicals do not increase the pH.	No need to use acids in drip irrigation systems.	None
6.00-7.00	Half-life of pesticides depends on pH of spray solution. Buffer solutions available for various pH levels. Consult supplier.	Solutions of some pesticides and nutrient sprays need to be acidified.	Identify the pesticides and nutrients and select the appropriate acid.
	Water usually contains Ca, Mg and S which should be incorporated in the formulation of the nutrient solutions.	Acidification of irrigation water used in drip systems is an option. Reduce the pH while adding nutrients and utilise the nutrients already in the water.	Select the most suitable acid or buffer solution.
	Half-life of pesticides depends on pH of spray solution. Buffer solutions available for various pH levels. Consult supplier.	Solutions of most pesticides and nutrient sprays need to be acidified.	Select the most suitable acid or buffer solution.
7.00-8.00	In combination with high Ca levels, scale forming and clogging are possible. Langelier Index is an indicator of the potential for scale formation. Acidification is undertaken when needed to clean the system. Water applied through micro-jets is seldom acidified due to the cost of the acids and the lack of proof of benefits. Using nitric and / or phosphoric acid reduce the pH	Scale is causing clogging of emitters.	Acidify continuously for drippers and as needed for micro-jets. Acidification of water used in micro-jet systems can possibly be justified during July to November. Acidification of irrigation water used in drip systems is a must to reduce pH,

	and add nitrogen and / or phosphorus without much change in EC.		add nutrients and utilise the nutrients already in the water.
> 8.00	The volume of acids required to reduce the pH might be so much that N and P are over-supplied. Other acids are required. Consult a specialist.	In conjunction with high Ca concentrations scale forming and clogging are a real threat.	Acidify
Electrical Conductivity (EC)			
<75	A leaching requirement (LR) of up to 10% is necessary.	Low salt content. Requires no special attention.	Monitor metal and cement components for signs of corrosion.
75-125	When the LR of between 10% and 15% is added to the volume of water applied, the salts will not accumulate in the root-zone.	Suitable for most soils and crops.	Apply the LR during each irrigation cycle.
126-200	When the EC of the water is greater than $150mSm^{-1}$ plants need energy to utilise the water and production will suffer.	Not suitable for irrigation of citrus with conventional systems.	Consult a specialist.
>200	Plants need large amounts of energy to utilise the water and production will suffer greatly.	Not suitable for irrigation unless specialised equipment and techniques are implemented.	Consult a specialist.
Sodium Adsorption Ratio (SAR)			
<1.00	No sodium hazard	No sodium hazard	None
1.00-3.00	Crusting slows infiltration rate and free water accumulates on surface. The first sign of detrimental effect of too high sodium content.	Crusting is possible	Monitor the infiltration of water into the soil. If runoff occurs, consider the application of gypsum.
>3.00	Excessive crusting	The sodium hazard needs attention.	Consult a specialist.
Calcium (Ca)			
>50mg/litre	In combination with a high pH, high carbonate or bicarbonate concentration will cause clogging.	Clogging of emitters	Consult a specialist.
Magnesium (Mg)			
>50mg/litre	Magnesium and potassium act mutually antagonistic, meaning they oppose each other's uptake and functioning.	Continuous use of the water will induce a potassium deficiency in plants.	Monitor the potassium level in the soil and leaves and act accordingly.
Chlorine (Cl)			
>50mg/litre	The leaves accumulate the absorbed chlorine until toxic levels are reached. The edges of the leaves can become scorched and leaf drop will occur.	High chloride concentrations in water promote soil salinity in the root-zone and can cause scorching of leaves	Monitor the chloride levels in the leaves and soil and avoid wetting leaves with the water during irrigation.

		when the water is used for spraying.	
Boron (B)			
>1.0mg/litre	Symptoms of an excess of boron include yellowing of the leaf-tips, development of chlorotic blotches and premature leaf drop.	Boron toxicity may develop.	Monitor boron concentration in leaves. Consult a specialist.
Nitrogen (N)			
>20mg/litre	For proper development of the orange colour of the fruit, little or no nitrogen must be applied during January to June.	Using this water during January to June may result in poor fruit colour.	Monitor the N concentration in the leaves as well as the colour development of the fruit.

definition

Buffer Solution

Buffer solutions have the ability to absorb or release protons (hydrogen or acid ions) in a solution in order to keep the pH constant. Buffers have a limited pH range and different buffers must be used to buffer the pH at various levels.

Chlorosis

Chlorosis is the yellowing of local areas on a leaf. This is usually the first sign of a problem with nutrition or irrigation in or on the leaf. The cells are not dead and sometimes the reaction can be reversed.

Necrosis

Necrosis is the step following chlorosis when the cell dies, and brown areas or spots appears on and in the leaf. Necrosis is irreversible.

Apart from the salts in the water that can cause clogging, salts added as fertilisers can aggravate the clogging hazard. This however forms part of the course on soil management and plant nutrition, where fertigation, compatibilities, and order of mixing are discussed.

17. The Impact of Microbiological and Biological Factors

In citrus production, the impact of microbiological and biological water quality factors is limited to those that promote the growth of bacteria and slimes in the piping after filtration. The bacterial and slime growth act as "agglomerating agents", meaning that they bind other suspended material into lumps that block the emitters.

The growth is aggravated by the addition of nitrogen, phosphorus and organic carbon, such as molasses, organic acids or buffers. Applying nutrient solutions through the irrigation system stimulates the growth of the microbes.

Treatment is applied before, during or after filtration. The best results are however obtained when the complete system (including filters, supply lines, lateral lines, and emitters) is disinfected. Drip irrigations systems need continuous disinfection. This decision should be based on historical data and current analyses, including those of the deposits in the piping and emitters.

Although DWAF indicates that less than 10,000 organisms per ml poses a low clogging hazard, the bacteria multiply in the pipes and any number will eventually clog the emitters. The bacteria population in the system must be monitored continuously and action must be taken accordingly. The most effective method to determine the presence of the different microbes is to evaluate the deposits in the pipes when flushing the system.

summary

Chapter 4 – Irrigation Systems

- In citrus production, farmers depend on irrigation, along with rainfall, to meet the water requirements of the tree crop.
- Irrigation systems come in many shapes and sizes, and not all of them are suitable for citrus production.
- A SABI (South African Irrigation Institute) accredited irrigation designer will help you with selecting the correct irrigation system for a specific situation.
- Irrigation systems can be classified as flood, mobile, and static.
- In flood irrigation, water is channelled to the crop by furrows in the ground.
- Mobile, or moving, irrigation systems irrigate while the system is moving and includes systems such as centre pivots, linear systems, and motored cannon sprays.
- Static systems are systems that stand still, or are static, while they irrigate, and include systems such as permanent and non-permanent sprinkler systems and micro-jet and drip systems.
- A basic irrigation system consists of a pump, a foot valve and strainer, filters, pipes, valves, lateral lines, emitters, and the irrigation block.
- Almost all irrigation systems, except gravity feed systems, rely on pumps to move water to the orchards and supply pressure to the emitters to work properly.
- The most commonly used pumps are single and multistage centrifugal pumps driven by electrical motors.
- Pumps consist of various components, including the motor that drives the pump, the suction and delivery pipes, and various valves.
- Filters 'clean' your irrigation water by trapping and removing suspended material that can block emitters.
- Suspended material consists of clay, silt, sand, and organic debris from plant and animal origin that do not dissolve in water.
- Pipes channel water between points, such as from the water-source to the pump, from the pump to the main lines and from the mainlines to the trees.
- Valves control the flow of water by opening or closing, thereby allowing water through, or cutting it off.
- Emitters are placed in lateral lines and apply water to individual trees in a uniform and efficient manner.
- Properly installing an irrigation system requires good data on the crop, soil and root system.
- When reading an irrigation design plan, the first step is to get the orientation right so that landmarks on the plan agree with the actual landmarks.

- On an irrigation design plan, symbols or different colours are used to depict the various pipes, valves, and other features.
- The notations next to the different sections of pipes indicate the pipe size and class for that particular section of pipe, and the length of the pipe.
- On the irrigation design plan information with regard to each block is given in a table that shows the block number, area, spacing, emitter delivery and application rate.
- When a system is designed from scratch or if new blocks are designed, a bill of quantities is supplied along with the irrigation design plan.
- After the plan has been interpreted, you can peg out the irrigation blocks, by marking the corners of the blocks, the rows, and the plant positions
- Conveyance system trenches are the trenches into which the pipelines are buried, and can be dug by either using manual labour or a back-end loader, also called an excavator.
- The various components of the irrigation system are tested as they are installed, and the performance of the entire system is tested once the installation is complete.
- Irrigation systems that have been installed correctly and that are operated within the set parameters should never require major maintenance under normal circumstances.
- Maintenance should be scheduled if water quality is poor, delivery is inconsistent or insufficient, or if there are visible signs of damage.
- The coefficient of uniformity (CU) test is used to determine the variance in the performance of equipment, for instance the uniformity in delivery rate of the emitters across an irrigation block.
- The quality of water used in irrigation can have a large impact on the irrigation system, soil productivity and crop production.
- Water quality factors are classified as either physical, chemical or biological.
- It is too expensive to improve certain chemical factors, so the water quality manager can only take steps to limit or correct the impact on production and the environment.
- In citrus production, the impact of microbiological and biological water quality factors is limited to those that promote the growth of bacteria and slimes in the piping after filtration.
- The bacterial and slime growth act as "agglomerating agents", meaning that they bind other suspended material into lumps that block the emitters.

assessment activities

✓ **Activity P4**: Complete this activity to test your knowledge of the entire chapter.

Chapter 5
Farming Business Management

learning outcomes

The content of this chapter is aimed at helping you to:

- Various sectors in the horticultural industry are identified and discussed.
- Various production systems (such as organic foods) are listed and defined.
- The typical horticultural production value chain and process flow components are identified and explained.
- The concept of competitiveness is defined and the importance thereof is justified.
- Basic financial principles related to viable business practices such as input costs, profit/loss and income are defined and explained as it pertains to horticultural production.
- The management concepts and basic principles of planning, organising, leading and controlling are defined within the horticultural farming context.
- The concepts and basic principles of decision making, problem solving, motivation, delegation are defined and evaluated as it pertains to horticultural production.
- The concepts and basic principles of planning and scheduling (PERT chart) are defined and evaluated as it pertains to horticultural production.
- Farm systems are defined and the component thereof is listed.
- The role of farm systems in effective management of the farm is explained.
- A differentiation is made between strategic plans, goals and objectives.
- The principles of setting goals and targets are outlined and explained.
- Budgeting concepts are defined and the principles thereof are discussed.
- An understanding of concepts of profitability, sustainability and competitiveness is demonstrated.
- Principles of using operational budgets to prepare production plans are outlined.
- The concept of the cost value of labour is defined.

1. Farming Business Management

Just like every other businessman, a citrus grower runs his business to make a profit. How do you make a profit from farming with citrus? With very few exceptions, citrus farming is profitable only when most of the fruit produced on the farm is sold on the overseas market, where you can sell citrus for more money than on the local market.

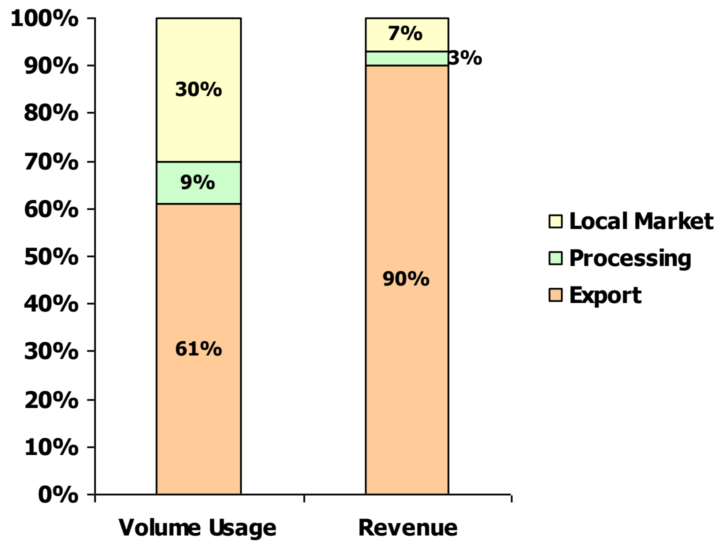
We are lucky in South Africa to have land, water, and the right climate to produce a wide range of citrus fruit for a big part of the year. The fact that we are in the southern hemisphere also means that our citrus is ready for the market at a different time of the year from northern hemisphere countries.

Because of these favourable conditions, we can produce good quality citrus fruit and supply it to people living in countries where they either don't produce citrus – because they don't have the land, water and right climate – or during a time of year when their fruit is not ready for the market.

information

Citrus Usage and Income

Of the commercially grown citrus in South Africa, about 61% is exported as fresh fruit. Of the balance, about 30% is sold on the local market and 9% is sent for processing. Yet over 90% of total revenue is generated from exports.



2. Production Systems

There are a few different ways you can produce fruit, depending on your goals and target markets. Fruit production can be categorised according to the type of production system, which are listed and defined below:

- Subsistence – Farming or a system of farming that provides all or almost all the goods required by the farm family, usually without any significant surplus for sale. This form of fruit production is very low as subsistence farming is largely limited to vegetables and maize.
- Semi-intensive and mixed produce farming – A system of mixing fruit production with other cash crops to provide a more sustaining cashflow. Smaller fruit producers commonly use this system.
- Intensive and highly industrialised – This is the mainstay of the large fruit export growers of South Africa, using sophisticated production methods, and dependent on a sophisticated supply chain infrastructure to market.
- Organic – Organic farming is a method of agricultural production that excludes the use of synthetic substances, such as pesticides, synthetic medicines or fertilisers, and genetically modified organisms. Fruit production for export is hardly ever organic given the stringent phytosanitary controls.

3. Income

Income refers to all the money the farm receives. This money is usually recorded in an income statement, which usually also includes any money that the farm spends (known as expenditure).

When we talk about income, you will hear the term "gross income" or "gross margin". Gross margin refers to the part of the farm's income that is left over after direct costs, such as labour and raw materials, are subtracted. Gross margin is one of the most important indicators of your farm's financial performance.

The gross margin percentage is the difference between revenue and cost of goods sold, divided by revenue. Gross margin is expressed as a percentage. A gross margin percentage can be calculated for each production unit and this allows you to compare the profitability of various production units.

Another term you will hear is "gross value of production". The gross value of production for the citrus farming business is calculated by adding export income, local sales, and juice income, and is calculated by adding together your gross sales (including all advance, interim and deferred payments), insurance received for crop losses, and household and labour expenditure (including charitable donations).

Farms can derive income of various sources. Income consists of:

- Current income (income from selling fruit)
- Capital income (income from selling machinery, land, etc.)
- Sundry income (interest received, rent income, profit on sale of fixed assets, grant income, etc.)

Sundry farm income comes from other sources than sales of produce, such as rental income, interest received, etc. Gross farm income is the sum of the gross value of production and sundry farm income. Capital income is irregular, and it is not shown in the income statement. If a fixed asset is sold at a profit, the profit amount will be reflected as sundry income.

3.1. Production Expenses

Farming requires inputs, equipment, infrastructure, and a market for the final product. All of these are used as part of the production process, which is shown in the example below using the example of making a sandwich.

example

Production Process

Input	 **Bread**	 **Jam**	 **Butter**	 **Our skills, work and ideas**
Equipment	 **Knife**	 **Bread Board**	 **Cloth**	
Infrastructure	 **Table**			
Process	 **Slice the bread**	 **Spread the butter**	 **Open the jam**	 **Spread the Jam**
Final Product	 **Sandwich**			

We can see that making the sandwich involves a process by which we use equipment and infrastructure to convert inputs into a final product. Inputs, equipment, and infrastructure cost money. Costs in a farming enterprise can be categorised in two ways. The first way to look at it is to differentiate between variable and fixed costs, and the second way is to differentiate between direct and indirect (overhead) costs.

3.2. Fixed and Variable

Fixed costs are those costs that are constant and have to be paid regularly, although their value may change over time, for example, rent, electricity, salaries, etc. Variable costs are those that change depending on the time of year and what is happening on the farm, for example, fertiliser, diesel, agrochemicals, etc.

Some costs are a little more difficult to classify. For instance, although salaries are a fixed cost, wages paid to seasonal workers are seen as a variable cost. Electricity is another one that is a little difficult to classify because the amount paid for electricity can vary quite a lot from month to month, but it is still seen as a fixed cost because it must be paid every month.

Because variable costs depend on the farming activities and therefore depend on the production plans, you can control them in the short term through good planning. Variable costs can also usually be allocated to particular production units on the farm. For citrus farms these may include plant material, fertiliser, herbicides and pesticides, specific contract work, casual labour, marketing costs, hired transport, crop insurance, packing material, etc.

3.3. Direct and Indirect Costs

Indirect, or overhead, costs are those which are not direct operational costs linked to a specific production unit. Examples of overhead costs are rent, building maintenance, insurance, administration and management salaries, stationery, levies, accounting fees, bank charges, etc.

Indirect or overhead costs must be paid, no matter how much of the product is being produced or how much income is being generated from crop sales. For example, salaries for management and administration staff must still be paid, whether the farm has a large crop that will generate a lot of income, or whether there has been a crop failure and very little income.

Direct costs are direct operational costs of a production unit. This includes costs such as production salaries, agrochemicals, protective clothing, tools and equipment, packing costs, fuel, etc. Direct costs can vary depending on the size of the crop. If we use the example above, packing costs and picking labour costs will depend on the size of the crop, and will be lower when the crop is smaller. Equipment (not production tools) and infrastructure are not seen as either direct or indirect costs but is called capital expenditure, but their maintenance is allocated either to a specific operating unit (direct) or to overheads (indirect).

4. Net Profit and Loss

Net profit, also referred to as net income, means the amount of money that the farm made as a profit for a given period if it earned more income than the amount it spent on costs. Net loss, on the other hand, is the amount of money that the farm lost in a given period, if it spent more money than it earned in income. A net profit or loss is not enough to know whether the farm is successful or not.

For example, let’s say a farm is showing a net profit for a specific year, but if you carefully look at the information, you find that they received significant grant income during that year without which it would have made a loss. This means that the farm itself is not actually profitable, despite making a net profit in that particular year.

Conversely, consider an example of a farm that recently planted new orchards. The orchards are not yet in full production, but the trees already need the same level of production inputs as grown trees, meaning that while the farm is not yet getting the income from the trees that it will when the trees are grown, the farm already spends money on production costs for the trees.

Finally, consider a situation where the farm shows a profit (net income) based on confirmed sales, but some clients have not paid yet (debtors), i.e., the income shows in the accounts, but the cash isn’t in the bank. A profitable business with a debtors problem can easily fail – cash is king.

5. Monitoring Labour Costs

You, as the farm foreman, need to keep a close eye on labour costs. Farming is a labour-intensive business, and the costs of labour can become out of control if you don't monitor them closely. Some labour costs are fixed, and do not require much monitoring, but even in these cases, you need to keep a keen eye on the following:

- Absenteeism
- Late coming
- Poor performance (slow, or poor quality, or in the worst case rework)
- Overall productivity and efficiency. How much of the working day are people Walking, Waiting, or Working? Maximise Working!

However, there are also variable labour costs which require special attention. These include:

- Seasonal labour
- Contracted expertise
- Overtime
- Performance related bonuses or incentives

As important as the labour cost is in terms of money, the performance of the people and teams on the farm is just as important. If you accept mediocre or even poor performance, the labour cost for each fruit sold will be higher than necessary and the profit margin will be lower.

6. Competitiveness

definition

Competitiveness

In the farming business, competitiveness is a farm's ability to get more sales than other farms.

To be successful as a farmer, you need to be able to sell your product in a huge, global market, filled with thousands of other competitors. To compete in this market, you have to focus on offering the best product you can, at the best price possible (for both you and customers), and to do this you need to understand the requirements of the market. The ways you can market your fruit are discussed in the work scenario focused on Marketing, so we will not go into further detail here.

7. Sustainability

definition

Sustainability

In the farming business, sustainability is the ability of the farm to minimise the negative environmental and social impacts caused by their farming operations.

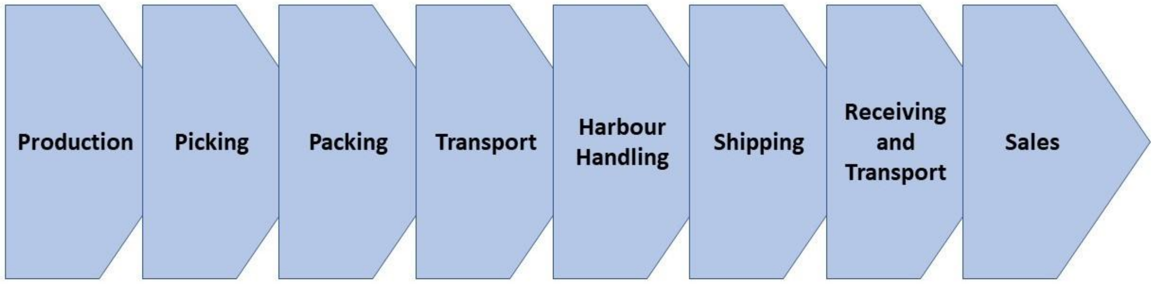
In the modern world, far more people than ever before want their food to be as environmentally friendly as possible. There is a wide range of practices and accreditation schemes that form part of farming in a sustainable way. The ways in which compliance with sustainability practices affects farming are discussed in the work scenario focused on Sustainability & Environmental Management, so we will not go into further detail here.

8. Export Agents

Many growers use an agent to help them with their fruit exports. An export agent's job is first and foremost to know the market, and to advise the grower on where to send how much of his fruit. The export agent also plans and manages the shipping and sale of the fruit and tells the grower and packhouse what the specific market requirements are for the fruit. The export agent then receives the money for the fruit from the buyer, pays costs, fees and levies to service providers, keeps an amount as commission, and pays the rest to the grower.

9. The Value Chain

A value chain is a concept describing the full chain of your farm business's activities in the creation and sale of your fruit. This chain goes from production (growing the fruit) all the way to the final sale in a supermarket, sometime on the other side of the world, and everything in between. Every stage in the value chain is created by an activity that adds to the product getting to market in a manner that the market is prepared to pay for.



The Value Chain

We call it a value chain because getting the fruit to the market is not enough – we must make sure that the fruit sold to the market is what the consumer wants in terms of how it looks, what it tastes like, and how it was produced, packed, and delivered.

definition

Value

The benefit that you can expect for something, normally measured in money.

Before we look at the links of the value chain, we need to understand the meaning of the term 'value'. People judge the value of a thing differently, mostly depending on how much they need the product, how unique the product is, and how much the product meets their own expectations and requirements. Value is not determined only by the cost of producing it – it is also determined by the market buying the product or service, and if the market does not think it is worth spending money on, the product has very little market value.

The terms "value chain" and "supply chain" are often used to mean the same thing, but there is a difference in the precise meaning of each. The main difference between a value chain and a supply chain is that the supply chain deals with building/creating the product and getting it to the consumer (process and steps), while the value chain looks for ways to enhance the product's value as it moves along that supply chain.

Therefore, you can analyse your supply chain (all the steps and processes) and identify those areas in the chain where value is added (or could be enhanced) and where value could be lost. For example, fruit production is a step in the supply chain, but the yield and level of quality produced determines the value added in that step.

10. The Cold Chain

Fresh products (like your fruit) need to be transported under controlled temperature and humidity conditions to maintain quality and increase shelf-life. This is particularly important when exporting fruit because the time in transit is significant. Recently, some markets, notably the EU, have introduced mandatory cold treatment of fruit that is being shipped, meaning that, for example, you have to ship your fruit at a given temperature for a specific time period.

The cold chain refers to the process of keeping this required cold temperature constant for your packed and loaded fruit as it travels along the supply chain and to the customer. If the cold chain is broken, and the temperature is allowed to get too high, your fruit quality is compromised, and your fruit may be rejected by the receiving market.

Having the infrastructure, equipment, and ability to comply with cold chain requirements is important for maintaining fruit quality and shelf-life, and maintaining competitiveness and access to premium markets which may also pay premium prices.

The process of monitoring and maintaining a cold chain is costly and time-consuming, but non-compliance, especially if it leads to a rejection of a shipment and wasted fruit, is far, far more expensive.

11. Links in the Value Chain

Let’s now take a look at the parts of a value chain. Before we start, note that in this module, we use a simple example of a value chain to explain to you how it works. We have used industry averages for the percentage cost that every link in the chain adds to the final cost of export fruit. In real life, cost structures of different operations and value chains are different for many different reasons, so your value chain and cost structure might look quite different to the example we use.

Your value chain may also include steps that we have not included here, such as fruit being repacked overseas before being sold. But it is important that you understand these principles, so that you can analyse your own costs, and above all, that you understand how easily the value of your fruit can be lost.

11.1. Link 1 – Production

The first step in the value chain is the production of your citrus fruit. Production includes every step up to the point where fruit is hanging on the tree, including:

- Choosing the right variety and cultivar.
- Planting the orchard.
- Taking care of plant nutrition and irrigation.
- Pruning the trees when necessary.
- Protecting them from pests, diseases, and competition from weeds.

All these activities are aimed at producing the best possible quality fruit, that the consumer wants and will spend money on. All of these activities also cost money. The grower pays the capital costs of establishing the orchard, including the land and land preparation, the irrigation system, the trees and so on, and he must buy the machinery and equipment that he will need. After that, he must pay all the input costs for producing good quality fruit, including salaries, water, fertiliser, plant protection products and fuel.

Production is driven by two factors: quality and volume. The grower must produce fruit in volumes that justify the money he spent on capital and input costs. Volume is normally expressed in tonnage per hectare. The quality of the product is essential in creating value, meaning something that the consumer will pay money for. If the grower fails in either of these two respects, his farm will not be profitable.

If the grower and his workers do all their production tasks well, they will come to the harvesting season with a good volume of superior quality fruit hanging on the tree. We have already said that there has been considerable cost involved in getting the fruit to this point but let us consider what the value of the fruit is.

It is obvious that it must have some value, and that good quality fruit of a superior cultivar will have more value, but what exactly is the value? In terms of realising the value that we aim for – the money that an overseas consumer pays for the fruit – it is not much at all.

To realise this value, the fruit has only taken the first step on a long journey. We need to add more value, which means that we must spend more money. Up to this point, we have only spent about 11.5% of what it will eventually cost us to get the fruit to the consumer.

11.2. Link 2 – Picking

The next step is to harvest the fruit and send it to the packhouse. This adds more costs, because pickers and supervisors must be paid for their work, and equipment is required for harvesting. This cost is included in the 11.5% above.

11.3. Link 3 – Packing

Once the fruit reaches the packhouse, it is de-greened, washed, treated, waxed, sorted, graded, sometimes wrapped and labelled, and then packed into cartons, which are then stacked on pallets and inspected to make sure it is fit for export. In some cases, fruit will be pre-cooled at the packhouse before being transported. The cost that is added in this process can be significant and depends on the type of citrus and the market for which it is meant. But on average, packing accounts for about 13% of your total cost.

11.4. Link 4 – Transport

The next link in the chain is moving the fruit from the packhouse to the port from where it is shipped to an overseas market. Pallets can be loaded onto flatbed, tautliner or refrigerated trucks, depending on the cultivar and the market. Refrigerated trucks are used to transport fruit that has been pre-cooled at the packhouse.

The fruit can also be packed into containers at the packhouse, with the packed container then transported on a truck. Another option that is gaining popularity in South Africa is transporting containers or loose pallets by rail. The distance and method of transport determines how much it will cost you, but on average, transport makes up about 1.5% of the eventual cost.

11.5. Link 5 – Harbour Handling

Before the fruit is loaded onto a ship, it may have to be stored at the harbour terminal for a period, where it is either cooled in pre-cooled facilities, or kept in holding rooms that maintain the temperature of fruit that has already been pre-cooled. This also costs money, and together with the handling fee that the fruit terminal charges, it accounts for a further 3.5% to your total cost to market.

11.6. Link 6 – Shipping

The fruit is now loaded onto ships, either in containers, or as loose pallets. On the ship fruit must be kept at the temperature to which it has been pre-cooled and is sometimes also exposed to cold sterilisation treatment. Shipping of fruit, including insurance, makes up about 18.5% of your total cost.

11.7. Link 7 – Receiving and Transport

When the fruit arrives in the overseas market, it is again handled in the harbour, sometimes stored, and transported to the point where it is sold to the consumer. The grower also carries these logistics costs, which is about 13% of the total cost.

11.8. Link 8 – Sales

The fruit is now eventually sold to the consumer. The retailer adds on his profit margin, which is normally around 30% of the final costs, and the consumer buys the product.

11.9. Other Costs

The last cost item that we must add is the commission of the export agent and the importer, and the various levies and inspection fees that is paid on export fruit. This adds the final 9% to the cost, leading to a final cost breakdown as follows:

example

Final Value Chain Cost Breakdown

1&2 – Production and Picking	11.5%
3 – Packing	13%
4 – Transport	1.5%
5 – Harbour Handling	3.5%
6 – Shipping	18.5%
7 – Receiving and Transport	13%
8 – Sales	30%
Other Costs	9%
Total	**100%**

12. Value and Profit

The big question is now: how much does the consumer pay for the fruit? If the consumer looks at the product and thinks that it is good value for money, they will pay enough to cover all the costs that we have listed above, plus an adequate margin for the grower to make a profit.

The value is therefore more than the costs of producing, packing and shipping the fruit. This is generally the case – there are enough growers in South Africa that are able to make a decent living from producing citrus to prove that it can be a profitable business.

13. Destroying Value

Chains, including the value, supply, and cold chains, can all be broken. If these chains are broken, the value of our fruits can be destroyed at any point of the chain. There are a great many examples of how things can go wrong in this chain of events. If these chains are allowed to be broken, you run the risk of the whole farm going out of business and many people losing their livelihoods.

14. Budgeting

Budgeting is an essential financial management tool. Without a budget it will be very difficult for a farmer to know how much money can be spent on particular items, and whether it is necessary to cut costs, or find other sources of income.

A business will do a budget every year, setting out their expected (budgeted) income and expenses. For a long-term crop such as citrus, projections will be done for as long as 10 years. These projections are based on assumption, such as the rate at which costs and income will increase over time due to inflation, how production volumes will change over time due to orchards maturing, at which point new vehicles and equipment will be needed, etc.

Budgets are only worthwhile if they are used in the day-to-day management of the business. Annual budgets are too vague to be used as a day-to-day management tool, so monthly budgets are much more useful for this purpose. Income and direct expenditure on a farm are seasonal by nature. Even though an annual budget can show a positive picture, some months might show expenses exceeding income. The farmer needs to be aware of this, so that these months can be planned for.

There are many different ways to budget, but let's start with the two main ways:

- Delta Based Budgeting – Delta refers to a difference between two numbers or sets of numbers. Therefore, in budgeting terms, you take the one year's budget as a base for the next year's budget and make the changes you believe are required for the next year, e.g., salaries will go up by 7% (the delta). Usually, this method is used as it is quicker and relies on using the previous budgets to inform a new budget.
- Zero-Based Budgeting – In this approach one makes a budget from scratch (zero), and does not just accept the assumptions and the base of the previous budget. This is much more time consuming, but the advantage of doing a zero-based budget from time to time is that one tests all the assumptions and takes a fresh look at the business.

Using either the zero-based or delta approach, you can then simply base a budget on the income statement, showing expected revenue and expenses for the next 12 months of the financial year. You can also project what the balance sheet will look like at the end of each year as well as predict the effect of non-cash items such as depreciation on your profits. Lastly, income statement budgets allow you to project the amounts that will have to be paid for income tax.

For more effective day-to-day financial management, a cash flow budget is much more useful. A cash flow budget is based on the cash flow statement, and is used to project:

- When you should expect income and when you will incur expenses, based on the seasonality of your enterprise.
- Whether the business will have enough cash to meet its commitments every month, or whether a loan or an overdraft facility may be necessary to carry it through. It may also be necessary to negotiate payment terms with creditors.

- The capital requirements of the business. It may be necessary to postpone buying expensive new equipment or spending money on infrastructure. Alternatively, the farmer can decide to rather lease capital items such as vehicles.
- The cash flow budget may also indicate that an alternative income source is needed that provides more regular income. This may prompt the farmer to change his crop mix, such as adding a cash crop. The cash flow budget will also help to forecast the costs of such an operation. Cash flow budgets prevent spending money impulsively on items that are not necessary or that the farm cannot afford at a particular time.

It is essential that a cash flow budget be used as a management tool. Once the monthly cash flow budget for a new year has been drawn up, the actual expenditure must be recorded and compared with the budget on a monthly basis. The monthly projections for the remainder of the year should be adjusted to be the most accurate estimate of what can be expected.

The budget will guide you on the following key decisions in which you will be involved:

- What can I plan for?
- What item or activity can/must I spend on?
- How much can I spend?
- When can/should I spend?
- How much am I spending? It may be below or above budget, and is that a good or a bad thing? For example, you may save on plant nutrition costs with good intentions but reduce yield and quality.
- Identifying waste or loss. For example, you might be spending above budget on fuel and realise that it is due to poor tractor maintenance.
- Identifying and justifying changes. For example, you might be spending more on irrigation (power and water) than for the same period last year because of hotter, dryer weather. This is discussed with the farm management and the budget and/or the irrigation plan is revised.

14.1. Monitoring Expenses against Budget

It is very important that you report actual spending against the budget, so that, if any problems arise, you notice and solve them immediately. A monthly budget review may not be enough in a farming operation because operational decisions are made daily and plans change all the time.

You must ensure that you receive reports of key expenses on a regular basis, ideally every week. Some of those key expenses include:

- Fuel
- Unexpected maintenance costs
- Chemical use
- Workforce attendance records, both absenteeism and late coming
- Overtime

You should investigate deviations from budgets and respond to them in an appropriate manner. Firstly, you should set a “range”, or “comfort zone”, of tolerable spending vs budget. For example, you can set a range of 5%, meaning that spending coming in 5% more or less than budget will require no action.

If expenditure ends up outside of the range, you need to ask why this is happening, and whether it is "good" or "bad", since it might be good if you are spending less than budgets due to being efficient, or it might mean that you are not performing certain tasks properly.

Next, you need to ask yourself if this over- or under-budget expenditure is a once-off exception or if it is likely to happen again. If this is a once off situation, then you probably don't need to adjust the budget to account for it, but if it is a systematic problem that will likely cause the same under- or over-spending in future, you need to work with other managers to adjust the budget accordingly.

An example of a budget is shown below:

example

Cash Flow Budget

ABC Citrus Farm			
Cash Flow Projection for 2018			
	March 2017	**April 2017**	**May 2017**
Opening cash balance	45 751	(131 945)	(324 045)
Cash Inflow			
Income			
Fruit sales	25 000	45 000	235 000
Grant funding			
Interest received	200	200	200
Rent received	1 500	1 500	1 500
Other cash inflow			
Increase in Land Bank loan			
Increase in creditors	50 000	65 000	125 000
Repayments from debtors	17 044	25 000	22 500
Total cash inflow	**93 744**	**136 700**	**384 200**
Cash Outflow			
Expenses			
Production cost			
Electricity	18 000	18 000	20 000
Fertilisation			
Fuel	4 000	4 500	4 500
Harvesting labour	1 000	2 000	3 000
Packing costs	9 000	15 000	75 000
Pest control	10 000	10 000	10 000
Plant manipulation			

Production salaries	85 000	85 000	85 000
Repairs and maintenance	1 750	1 750	1 750
Tools and equipment	2 000	2 000	2 000
Weed control	2 000	2 000	2 000
Overhead expenses			
Accounting and audit fees		7 000	
Bank charges	250	250	250
Computer expenses	300	300	300
Consulting fees	1 000	1 000	1 000
Insurance	1 500	1 500	1 500
Legal fees	500	500	500
Printing and stationery	500	500	500
Salaries – Admin	50 000	50 000	50 000
Staff training	5 000	15 000	
Telephone, postage, and fax	1 000	1 000	1 000
Travel and accommodation	1 500	1 500	1 500
Other cash outflow			
Improvements to fixed property			
Acquiring movable assets			
Increase in debtors	25 000	45 000	235 000
Repayment of Land Bank loan	35 000	35 000	35 000
Increase / (repayment) of corporate card			
Repayment of creditors	6 324	30 000	30 000
Repayment of VAT	10 816		(3 500)
Total expenditure	**271 440**	**328 800**	**556 300**
Closing cash balance	**(131 945)**	**(324 045)**	**(496 145)**

15. Strategic Plans, Goals, and Objectives

Finally, let's briefly discuss the process of thinking forward in business management. There are a few different tools we can use to do this, namely creating strategic plans, goals, and objectives. Although these terms are similar; there are slight differences.

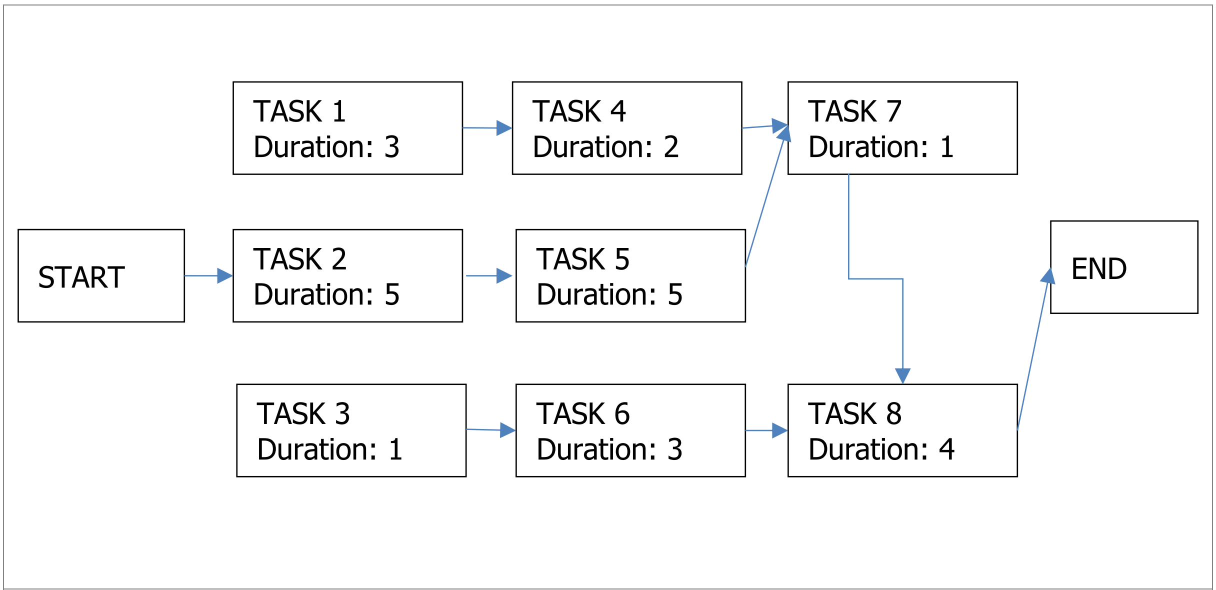
- Strategic Plans - Strategic plans describe the long-term plan of the farm. These give you a multi-year map of the direction the farm is heading, and are made by carefully analysing your strengths, weaknesses, opportunities, risks, and the market.
- Goals - Goals are statements of what you aim to achieve over a specific period. You can derive goals from your strategic plan and use them to make decisions and allocate resources.

- Objectives – Objectives are often made using the SMART criteria, meaning that they should be Specific, Measurable, Achievable, Relevant, and Time-bound. Objectives are the small, more detailed targets that you break down goals into, and allow you to track your progress towards the goal.

As an example of all three, when you develop your strategic plan, you may realise that you have the potential to increase production in the next few years. Your goal would be to improve production, and your objectives would be detailed, specific actions, such as adopting new agro-chemicals or changing production practices, that specifically help you achieve that goal.

16. PERT Charts

A common system used for planning and project management is called a PERT chart. PERT stands for Program Evaluation and Review Technique chart. The PERT chart is a diagram used to plan, organize, and represent the necessary tasks within a project. It is a handy way to visualise a project and create an effective timeframe for the project. In agriculture, these charts can be used when planning a new development (such as a new orchard) or a repeated operation (like the yearly harvest). Below is an example of a PERT chart:



PERT Chart

summary

Chapter 5 – Farming Business Management

- With very few exceptions, citrus farming is profitable only when most of the fruit produced on the farm is sold on the overseas market, where you can sell citrus for more money than on the local market.
- South Africa has favourable conditions which let us produce good quality citrus fruit and supply it to people living in countries where they either don't produce citrus or during a time of year when their fruit is not ready for the market.
- Of the commercially grown citrus in South Africa, about 61% is exported as fresh fruit, 30% is sold on the local market and 9% is sent for processing.
- Fruit production can be categorised according to the type of production system.

- Fruit production systems include subsistence, semi-intensive and mixed produce farming, intensive and highly industrialised, and organic.
- Income refers to all the money the farm receives, and is usually recorded in an income statement, which also includes any money that the farm spends (known as expenditure).
- Gross margin refers to the part of the farm's income that is left over after direct costs, such as labour and raw materials, are subtracted.
- The gross margin percentage is the difference between revenue and cost of goods sold, divided by revenue.
- Income consists of current income (from selling fruit), capital income (from selling machinery, land, etc.), and sundry income (interest received, rent income, profit on sale of fixed assets, grant income, etc.).
- Farming requires inputs, equipment, infrastructure, and a market for the final product, all of which are part of the production process.
- Fixed costs are those costs that are constant and have to be paid regularly, although their value may change over time.
- Variable costs are those that change depending on the time of year and what is happening on the farm, for example, fertiliser, diesel, agrochemicals, etc.
- Indirect, or overhead, costs are those which are not direct operational costs linked to a specific production unit.
- Indirect or overhead costs must be paid, no matter how much of the product is being produced or how much income is being generated from crop sales.
- Direct costs are direct operational costs of a production unit.
- Net profit, also referred to as net income, means the amount of money that the farm made as a profit for a given period if it earned more income than the amount it spent on costs.
- Net loss is the amount of money that the farm lost in a given period, if it spent more money than it earned in income.
- A net profit or loss is not enough to know whether the farm is successful or not, as they may not represent the full picture of the farm's historical financial performance.
- Labour costs can be unnecessarily high (wasted) if you are not careful about absenteeism, late coming, poor performance, and low overall productivity and efficiency.
- Variable labour costs include seasonal labour, contracted expertise, overtime, and performance related bonuses or incentives.
- In the farming business, competitiveness is a farm's ability to get more sales than other farms.
- In the farming business, sustainability is the ability of the farm to minimise the negative environmental and social impacts caused by their farming operations.
- Many growers use an agent to help them with their fruit exports, whose job is to know the market, and to advise the grower on where to send how much of his fruit.
- The export agent also plans and manages the shipping and sale of the fruit and tells the grower and packhouse what the specific market requirements are for the fruit.
- A value chain is a concept describing the full chain of your farm business's activities in the creation and sale of your fruit.

- We call it a value chain because getting the fruit to the market is not enough – we must make sure that the fruit sold to the market is what the consumer wants.
- Fresh products (like your fruit) need to be transported under controlled temperature and humidity conditions to maintain quality and increase shelf-life.
- This is particularly important when exporting fruit because the time in transit is significant, and some markets have introduced mandatory cold treatment of fruit that is being shipped.
- The cold chain refers to the process of keeping this required cold temperature constant for your packed and loaded fruit as it travels along the supply chain and to the customer.
- The links of the value chain include production, picking, packing, transport, harbour handling, shipping, receiving and transport, sales, and other costs.
- A business will do a budget every year, setting out their expected (budgeted) income and expenses, and for a long-term crop such as citrus, projections will be done for as long as 10 years.
- Budgets are only worthwhile if they are used in the day-to-day management of the business.
- Delta based budgeting involves taking one year's budget as a base for the next year's budget and making the changes you believe are required for the next year (the delta).
- Zero-Based Budgeting involves making a budget from scratch (zero), without accepting the assumptions and the base of the previous budget.
- For more effective day-to-day financial management, a cash flow budget is much more useful.
- It is very important that you report actual spending against the budget, so that, if any problems arise, you notice and solve them immediately.
- A monthly budget review may not be enough in a farming operation because operational decisions are made daily and plans change all the time.
- Strategic plans describe the long-term plan of the farm.
- Goals are statements of what you aim to achieve over a specific period.
- Objectives are the small, more detailed targets that you break down goals into, and allow you to track your progress towards the goal.
- Objectives are often made using the SMART criteria, meaning that they should be Specific, Measurable, Achievable, Relevant, and Time-bound.
- PERT stands for Program Evaluation and Review Technique chart, and PERT charts are a diagram used to plan, organize, and represent the necessary tasks within a project.

assessment activities

- ✓ **Activity P5**: Complete this activity to test your knowledge of the entire chapter.
- ✓ **Activity F1**: Complete this activity to test your knowledge of the entire module.