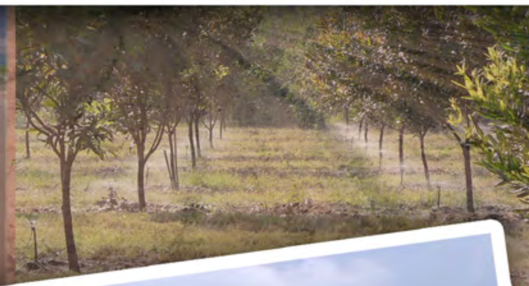
Training material for extension advisors in irrigation water management

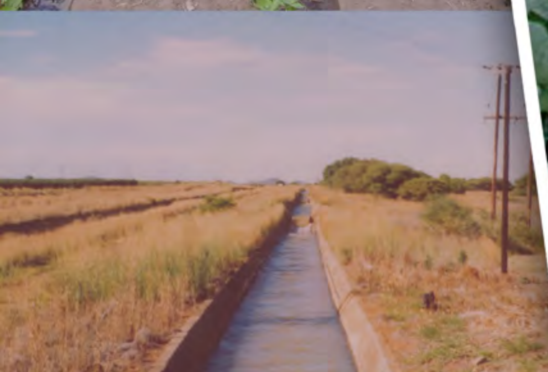
Volume 2: Technical Learner Guide
Part 8: Irrigated crop and fodder production

JB Stevens, PS van Heerden, P Reid, A Liebenberg, E Hagedorn & G de Kock










TT 540/8/12

WATER RESEARCH COMMISSION

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Report to the

Water Research Commission

NQF
Level 5

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This report forms part of the following set of reports:
Volume 1: Main report
Volume 2: Technical learner guide
Volume 3: Extension learner guide

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Before we start...............

Dear Learner ....this learner Guide contains information to acquire the basic knowledge and skills leading to the unit standard:

Title: Develop a propagation plan for any agricultural production systems

US No: 116427 **NQF Level: 5**

Title: Managing harvesting process of agricultural crops

US No: 116373 **NQF Level: 5**

Title: Demonstrate a basic understanding of physiology process in plant growth

US No: 116295 **NQF Level: 4**

Title: Propagate plant in a variety of situations

US No: 116321 **NQF Level: 4**

The full unit standards are available and can be cited on the SAQA website. Read the unit standards at your own time and if there are any questions or aspects that you do not understand, discuss it with your facilitator.

The unit standards are some of the building blocks in the qualification listed below:

Title	ID no	NQF Level	Credits
National Diploma: Plant Production	49010	5	120
National Certificate: Plant Production	49009	4	120

Assessment.........

You will be assessed during the course of the study (formative assessment) through the expected activities that you are expected to do during the course of the study. At the completion of the unit standard, you will be assessed again (summative assessment).

Assessment therefore takes place at different intervals of the learning process and includes various activities - some will be done before commencement of the program, others during the delivery of the program and others after completion of the program.

How to attend to the activities.......

The activities included in the module should be handed in from time to time on request of the facilitator for the following purposes:

- The activities that are included are designed to help gain the necessary skills, knowledge and attitudes that you as the learner needs in order to become competent in this learning module.
- It is important that you complete all the activities and worksheets, as directed in the learner guide and at the time indicated by the facilitator.
- It is important that you ask questions and participate as much as possible in order to be actively involved in the learning experience.
- When you have completed the activities and worksheets, hand it in so that the assessor can mark it and guide you in areas where additional learning might be required.
- Please do not move to the next activity or step in the assessment process until you have received feedback from the assessor.
- The facilitator will identify from time to time additional information to complete. Please complete these activities.
- Important is that all activities, tasks, worksheets which were assessed must be kept as it becomes part of your Portfolio of Evidence for final assessment.

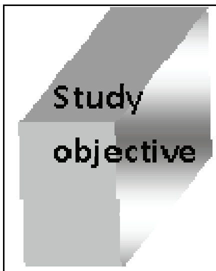
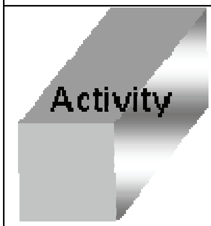
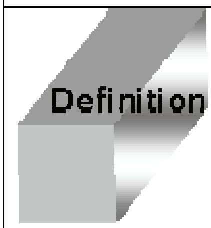
Check your progress.......

Use the following checklist to determine your competency regarding this specific learning module.

Confidence level	**I am sure**	**Still unsure**	**Do not understand and need help**	**Motivate your answer**
Can you identify problems and troubleshoot correctly?				
Are you able to work well in a team?				
Are you able to collect the correct and appropriate information required for decision making?				
Will you be able to perform the observation expected in an organised and systematic way while performing your task as an extensionist?				
Are you able to communicate the information and newly gained knowledge well to experts?				
Can you base your tasks and answers on scientific knowledge that you have learned?				
Are you able to show and perform the activities required in this learning module correctly				
Are you able to link the knowledge, skills and competencies you have learned in this module of learning to specific duties in your job?				

How to use this guide ………….

Throughout the learner Guide you will come across certain re-occurring notifications. These notifications each presents a certain aspect of the learning process, containing information, which would help you with the identification and understanding of these aspects. The following will be found in the learning material:

	What are the study objectives for a specific module? This provides an idea of the knowledge, skills and competencies that are envisaged to be
	You will be requested to complete activities, which could either be group or individual activities. Please remember that the completion of these activities is important for the facilitator to assess, as it will become part of your ***Portfolio of Evidence.***
	What does it mean? Each learning field is characterised by unique terminology and concepts. Definitions help to understand these terminology and concepts and to use it correctly. These terminology and concepts are highlighted throughout the learner guide in this manner.

My notes………………………………

You can use this box to jot down some questions or notes you might have, concepts or words you do not understand, explanations by facilitators or any other remark that will help you to understand the work better.

What are we going to learn?

For each of the learning modules included in this learning area specific learning outcomes were set, which you need to be able to demonstrate a basic knowledge and understanding of.

Contents

Module 1

Cropping systems: growth and development

Study objective

After completion of this module, the learner should be able to have a basic understanding of:

- The functions of the root system in the growth and development of the plant
- Functions of the stem in the growth and development of the plant
- Role of the leaf in the plant growth and development
- Role of the flower in the reproductive process of growth and development of the plant
- Difference between plant growth and development
- Different stem and root growth patterns of plants and the implications for the crop farmer
- Different types of bud dormancy and the affect on crop management
- Different factors affecting plant growth and development and the implications for crop management
- Photoperiodism and vernalisation
- Pollination and fertilisation
- Fruit set and fruit ripening

Table of contents

The growth and development of plants is a complex series of changes in plant cells, tissues and organs. The cycle begins with germination and progresses through a vegetative and reproductive phase. For annual crops the cycle ends with senescence and dying of the plant, while the cycle of vegetative and reproductive growth is repeated after a brief time of rest for perennials.

There are different types of plants namely herbaceous plants, where the stems are soft, and these plants usually die back every year. Herbaceous plants have usually green stems that contain little woody tissue. Woody plants are characterised by hard and rigid stems and usually do not die back to the ground during winter periods.

This module will focus on concepts and important characteristics of vegetative and reproductive growth of plants

1. Plant structure[5,6,7]

The main parts of the plant are:

- Roots
- Stems
- Leaves
- Flowers
- Fruit
- Seed

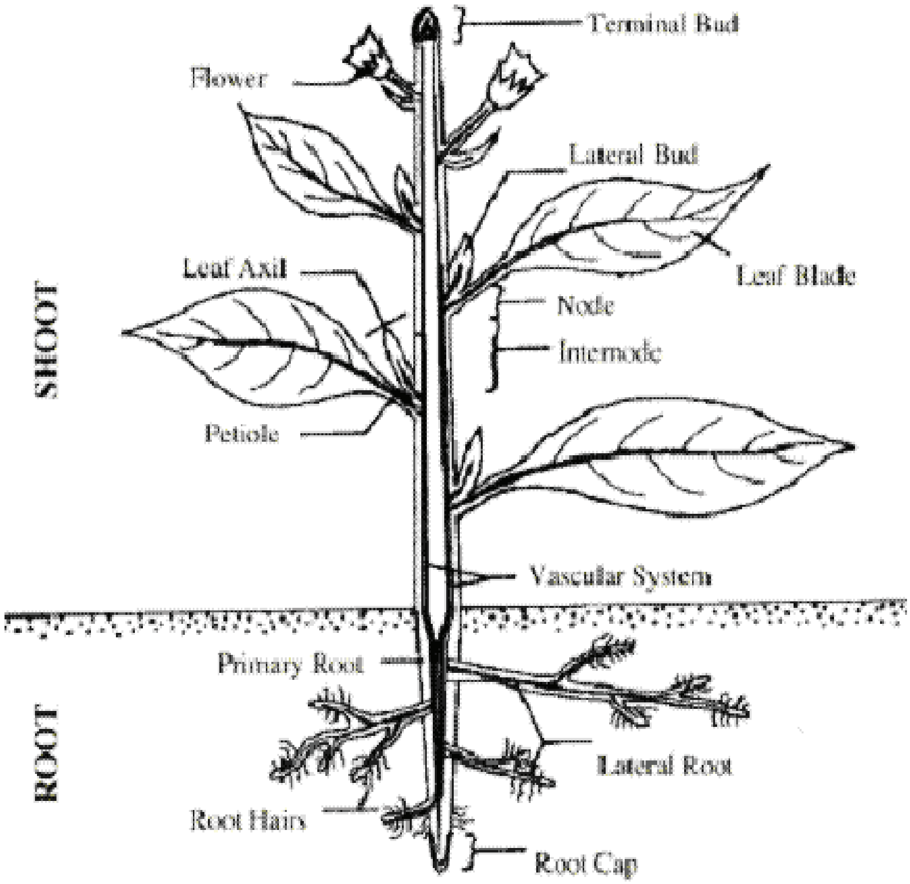


Figure 1. Plant structure

a. Root system of the plant

The root system is important for the plant because it:

- Takes up water and nutrients from the soil through a process called osmosis. During osmosis the water and nutrients in the soil, which are low in concentration, pass through the walls of the root, which represents an area with a high concentration.
- Carries water and nutrients to the stem of the plant
- Acts as a storage organ of water and food, which helps the plant to survive during dormant months and dry periods
- Anchors the plant so that it does not get blown away with the wind and washed a way with rain or irrigation

The root that grows out of the seed is known as the primary root, while the branches that come from it are called the secondary roots and those that emerge from the secondary roots are called tertiary roots.

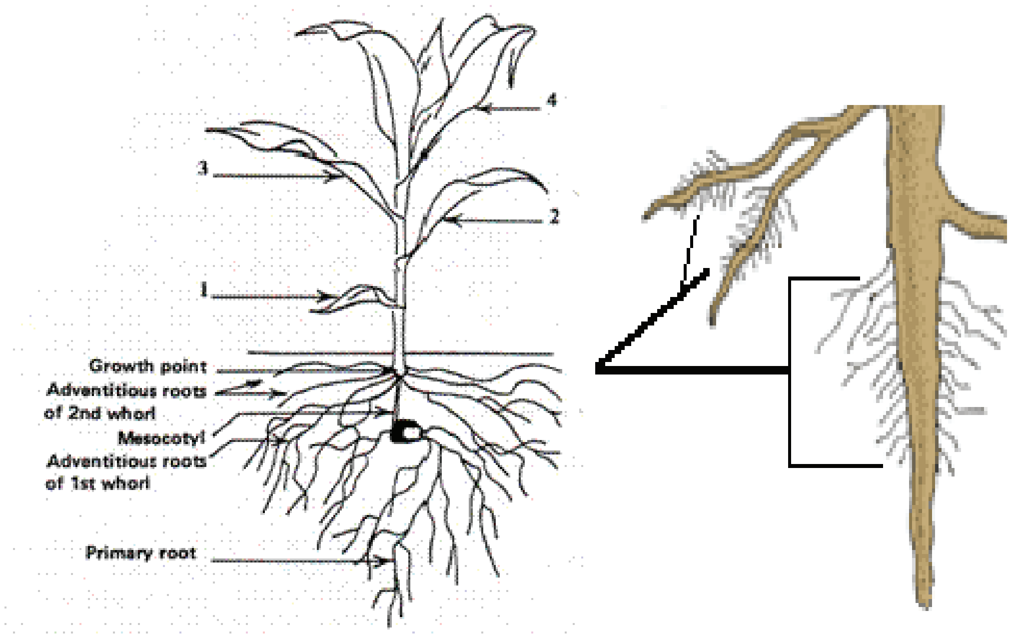


Figure 2. Basic structure of the root system of a maize plant

Types of root system

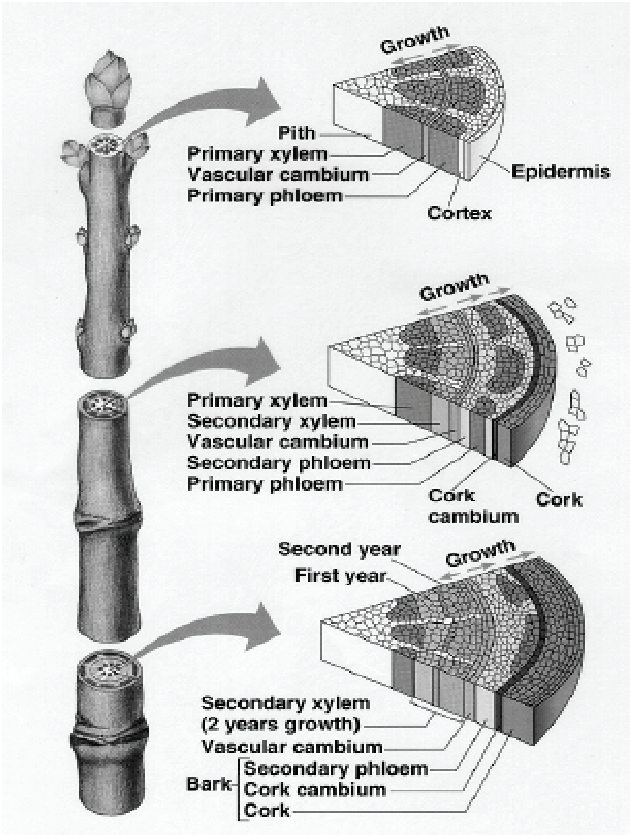
- Tap root system: have a single main root that grows deeply into the soil and is much thicker than the secondary roots that develop from it (a good example is the swollen taproot of the carrot).
- Fibrous root system: very common, and exists of many thin-branched roots, which grow into all directions in the soil.(a good exampleare many of the common weeds that we find in the irrigation field). Plants with a fibrous root system takes up water and nutrients from all around it in the soil and often explore the top soil better than tap root systems.
- Adventitious root systems: these roots can form on other parts of the plant, especially the stem and leaves. Examples of an adventious root system are onion, strawberry plants with roots that grow from the runners of the plant, “prop” roots that grow from the stems of maize and help to hold the plant straight.

Then some roots have been modified or adapted over time;

- Storage roots for example carrot and sweet potato
- Aerial roots for example like those on many orchids and on delicious monster plan
- Buttress roots: large roots at the base of tall trees that help hold them up straight
- Reproductive roots: roots that are able to send up new plants away from the main plant

b. Stems

Once the water and nutrients have been taken up by the root hairs, the water and nutrients are then carried to the stem of the plant. The plant's stem then carries the water and nutrients to other parts of the plant.



Internal Structure of the Stem	
Vascular Bundles	Inside the stem there are tube-like structures called the vascular bundles, these are long and tough and run from the roots through the stem to the leaves and flowers.
Xylem	Inside the vascular bundles are tubes through which the water and nutrients are taken up by the roots and transported. These are called Xylem.
Phloem	Inside the vascular bundles there are also tubes called phloem. These tubes transport the sugars and other foods manufactured by the leaves to all other parts of the plant, including the roots.

Figure 3. Internal structures of the plant stem and function of the various structures

The stem of a plant supports the plant by:

- Carrying water and nutrients from the roots of the plant to the leaves and other parts of the plant

- Transporting nutrients, produced by the leaves, to the root system and other parts of the plant
- Supporting the leaves of the plant and helping leaves to move in a position in which they can get the most sunlight, which helps the plant to produce food.
- Support the branches and flowers of the plant
- Acting as a storage organ.

c. Leaves

Leaves of plants come in various shapes and sizes and are important for transpiration and to produce food for the plant. Plants make their own food through the process called photosynthesis, which means “make food from light”. For photosynthesis to take place, a source of energy (sunlight), chlorophyll (green colour of the leaves), carbon dioxide and water are needed.

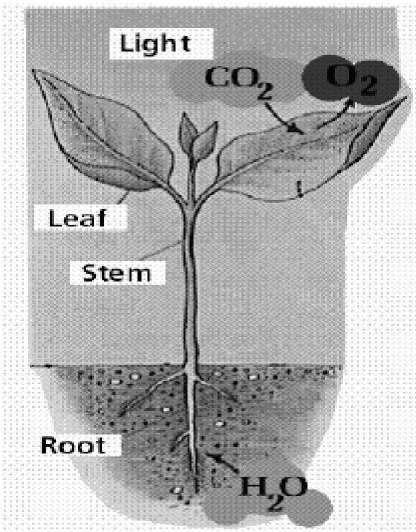


Figure 4. The role of leaves in photosynthesis[4)]

The process of photosynthesis is summarised as follow:

$$CO_2 + H_2O + sunlight \longrightarrow (CH_2O)_n + O_2$$

d. Flowers

Flowers represent the reproductive phase of plant growth and play an important role in pollination. The initiation and development of flowers are determined by the environment. More detail will follow in the discussion on the reproductive growth and development of the plant.

2. Vegetative growth and development of plants[1,2,4,5,6]

Growth is an irreversible increase in plant size, length, height, volume or dry matter. It also means the increase in the number of plant cells, even when actual size and dry weight stays the same.

Development is illustrated through initiation and differentiation. Growth is where a cell divides normally and the end product is two identical cells of the same type as the original. However, when a cell receives a stimulus or a message of some sort a (light, temperature) which makes the cell divide into something different, like a vegetative bud becoming a flower for instance, it is called initiation. Therefore *initiation* is a cell which produces tissue of a different kind when it divides, and the outcome of initiation is a visible change in the plant, called *differentiation*.

2.1 Flowering habits

Plants show different flowering habits namely:

- Determinate flowering habit: determinate growers will develop a period of vegetative growth, a flower or interflorenscence from the apical meristem on the apex of the stem. Growth effectively stops on that specific stem, and maize, sunflower and wheat are examples of determinate flowering habit. Vegetables like cabbage and onions also have a determinate growth habit.

- Interdeterminate flowering habit: With interdeterminate growers the stem apex stays vegetative and will continue till the onset of senescence. Flowers and fruit are usually carried on lateral buds and an example of this is cotton.

- Some crops like green beans can exhibit either the one or the other flowering habit depending on the cultivar. Bush bean types, for instance, have a determinate flowering habit, while trailing pole bean cultivars exhibit an interdeterminate flowering habit.

Implications for crop production:

- Interdeterminate growers plant size usually tends to be larger √
- The ration between vegetative and reproductive growth larger with interdeterminate growers √
- The length of the growing season of interdeterminate growers is longer and therefore the harvesting season of these plants are later √

2.2 Stem growth patterns

Stem growth patterns differ between different plant types. Annuals, growing in optimal conditions, normally illustrate a sigmoid growth curve. Annuals in the beginning of the growth cycle, after emergence is showing a relative slow rate of growth. This increase and advances into a straight linear growth and the slow down towards the end of the growing season. After the seeds have matured, the plant usually dies.

Stem growth of perennials on the other hand, depend whether it is a tropical perennial crop or a deciduous perennial crop. The tropical perennial crops usually grow in a tropical climate, and their annual growth pattern corresponds to the growth pattern of annuals (any variation in the environment like sunlight, temperature, etc. will influence the growth pattern). Deciduous perennial crops show a growth pattern of recurring cycles, and the growing conditions experienced during the growing season determine the extent of growth that will occur. Therefore the growing pattern can vary tremendously over years; the growing pattern is mainly determined by internal plant factors (like plant growth regulators, etc.) and not by the external factors.

The following stem growth patterns occur with perennials:

- Continuous growth throughout the year, the growing apex never enters a resting phase like for instance bananas

- Recurrent flushes: after each growth flush the apex forms a dormant apical bud for a brief resting period, followed by the next flush. This is typical of subtropical perennials like citrus, which can have about three flushes per annum.

- A single flush of the terminal stem growth, which usually begins in spring and ends when the apical apex forms a dormant bud in autumn, followed by a dormant period during winter. This is typical of the growth patterns of deciduous trees like peaches and apricots.

2.3 Root growth patterns

Root growth patterns are mainly influenced by environmental factors like physical soil conditions, availability of soil water, nutrient reserves and soil temperature.

Root growth and root distribution depend on:

- the availability of soil water: roots usually follow the water that is available in the soil. Roots cannot however grow from one place to another through dry soil.

- changes in soil profile : roots do not grow across any abrupt physical change in soil, and therefore soil compaction (like a plough layer) or an abrupt change in clay content will have roots following the route of lest resistance.

- soil fertility: plants growing in a relative poor fertile soil will produce roots that are weak and thin versus those active growing roots, thick and vigorous, that grow in fertile soils.

Annual root growth: The initial growth of roots after emergence is very rapid and the vegetative stem growth initially lags behind but eventually catches up with the root growth. At the flowering stage, the root system of most crops will reach its potential root volume. After this stage very little expansion of root volume occurs.

Perennial root growth: Root growth usually begins prior to the bud break in spring and continues till leaf drop during autumn. The direction and speed of root development depend on availability of water, nutrients and soil temperature. Spring flush usually occurs during spring based on the nutrient reserves stored from the previous year, and after this flush growth usually decreases. Growth rate of roots usually increases during autumn due to the accumulation of nutrients through photosynthesis.

2.4 Bud dormancy

Dormancy is defined as a period of arrested growth. This may affect the whole plant or may be restricted to certain plant parts, especially seed and buds. Buds become dormant because the growth in the apical meristems is stopped and is a survival mechanism for plants enabling them to escape unfavourable environmental conditions. Two types of bud dormancy occur:

d.1 *Winter dormancy:* this winter rest of deciduous plants is brought about by internal plant factors like plant growth regulators. The plant stays dormant and is subjected to a certain amount of chilling temperatures before normal bud break will occur. The optimum temperature required for accumulation of the chilling units of deciduous plants lies between 4-7°C. Inadequate chilling of deciduous plant is called delayed foliation, where plants do not show profusion of bud break (flowers followed by leaves) expected under normal conditions.

Example

Peaches generally require about 600 hours of temperatures below 7°C for normal spring bud break. Therefore certain areas are not suitable for the production of peaches.

d.2 *Environmental dormancy:* this dormancy is the effect of unfavourable environmental conditions like a lack of water or temperature extremes.

FACTORS AFFECTING PLANT GROWTH AND DEVELOPMENT

- √ Genes
- √ Temperature
- √ Water
- √ Gases
- √ Sunlight

- *Genes*

The genetic code is exactly the same for all plant parts although the expression of that code is very diverse, e.g. leaves look and function totally differently to flowers. Diversity is achieved when some genes on the chromosomes are inactive at certain stages, and active on others for instance the genes that form flowers are already present, but inactive in cells during the vegetative growth stage. Suddenly, by some unknown process, the flower genes become active in a specific cell or couple of cells, during cell division. Therefore a plant cell has to receive a signal to trigger this reaction of initiation and differentiation. Enough evidence is available to believe that growth regulators (hormones), enzymes and metabolic products are such triggers.

- *Temperature*

The radiant energy from the sun provides visible light, but also produces heat (longer wavelengths). Different plants react differently to temperature, depending the amount of heat required for growth and development:

- ✓ *Length of growing season:* temperature determines the length of the growing season. For many plants the length of the growing season (number of days available for plant growth) is determined by the last day of frost in spring and the onset of frost during autumn. If the growing season is too short for a specific crop type, the planting will not be successful and the yield will be drastically reduced. The growing season in South Africa varies between 200 (colder areas) - 300 days (subtropical areas).

- ✓ *Cardinal temperature:* plants need a certain optimum temperature for maximum growth and development and there are minimum and maximum temperatures that determine the limits for plant growth. These temperatures are called cardinal temperatures, which determine the rate of respiration and photosynthesis.

- ✓ *Heat units:* is the number of temperature degrees above an established minimum growing temperature for a specific plant. So when we calculate the average temperature for a given day and subtract the base temperature for a specific crop, it gives us the heat units per day.

Heat units for a specific day= (max temp+min temp) – base temp
2

$$\text{Heat units for a specific day} = \frac{\text{max temp} + \text{min temp}}{2} - \text{base temp}$$

Normally: maximum temperatures above 30°C are taken as 30°C
minimum temperatures below 10°C are taken as 10°C

With this method, the flowering dates of male and female plants on a land are synchronised for the production of hybrid seed or for plant breeding (the male and female plants are planted at different dates to have them flower at the same time). It can also be used for the scheduling of an orderly pattern of harvesting.

Information required:

1. Base temperature for a specific crop i.e. cotton=16°C; maize=10°C and wheat and peas =4°C

2. Amount of accumulated heat units required for the growing season or part of the growing season. It is important to take that into consideration for different cultivars. Information is available from seed companies.
3. Temperature data: can be obtained from automatic weather station or own records of data.

- ✓ *Sunburn:* plants and plant parts can be injured by high temperatures, referred to as sunburn. Leaves have the capacity to cool themselves through transpiration. Other plant parts, which do not possess large amounts of stomata, do not have cooling mechanisms. Stems and fruit are often shaded by leaves, but can sometimes be exposed to direct sunlight.

- ✓ *Frost damage:* plants differ in their susceptibility to frost.
  - *Species differ in chilling susceptibility:* susceptibility of species to chilling can differ at different times of the year. An apple tree can withstand temperatures below -34°C in their dormant stage. During the growing season the same plant can be killed by temperatures only a few degrees below 0°C.
  - *Plant parts differ in their susceptibility to chilling:* For instance with peas, the older the stems and leaves the lower chilling temperatures it can withstand (-4°C), while young tender vegetative growth will be sensitive to temperatures of (-2°C). Temperatures below 0°C will kill most of the flowers and the young fruit on a pea plant.
  - *Growing conditions prior to chilling determines the susceptibility to chilling.* The better the growing conditions, the more sensitive plants are to chilling damage.
  - *Species differ:* For instance cabbage can withstand temperatures of approximately -6°C, tomatoes -1°C, while cucurbits (pumpkins) will suffer severe chilling damage at 0°C.

- *Water*

Water is required for the proper functioning of plants, and a crop like lucerne for instance requires approximately 900l of water to produce 1kg of dry matter. Very little of this water is used structurally, since most of it is lost through transpiration through the stomata. Usually when the transpiration demand of plants exceeds the absorption rate through the roots, the stomata close. This is called *"water stress",* and when severe, the plant will wilt. The reaction reduces the leaf area exposed to the sun. In the middle of the day, when temperatures are high, it is normal for herbaceous plants, like pumpkins to wilt. When the stomata close, the outflow of water is limited but the inflow of carbon dioxide to the mesophyll is also reduced at the same time and this decrease photosynthesis. The majority of plants can compensate for a brief period and experience mild water stress. However, if it occurs for extended periods of the day, a loss of production can be expected.

- *Nutrients*

Some 60 elements have been found in plants, of which 16 have been demonstrated to be essential elements. They are carbon, hydrogen, oxygen, nitrogen, phosphorous, sulphur, potassium, calcium, magnesium, iron, boron, zinc, manganese, copper, molybdenum, chlorine. The first three elements are normally provided by the soil water or from the oxygen and carbon dioxide from atmosphere. About 96% of the total dry matter in the plant consists of these three elements.

- *Gases*

The two most important gases for plant growth are oxygen (O_2) and carbon dioxide (CO_2).

✓ *CO_2 (carbon dioxide)*

CO_2 is a building block of all organic compounds produced in the plant. Through photosynthesis sugars are constructed by linking CO_2 molecules. Photosynthesis can be promoted by the following:

- Allowing free entrance of CO_2 into the leaf through the stomata by keeping the stomata open. This can be done by avoiding water stress through adequate irrigation. Transpiration rate can also be retarded by: the use of anti-transpirants on young plants just after transplantation (lettuce transplants partially shading of plants (less sunlight required for photosynthesis) and cooling of plants by wetting the canopy with irrigation.

- Increasing of the amount of CO_2 in the mesophyll, by adding CO_2 to irrigation water. The cost effectiveness of this method has not yet been proven.

✓ *Oxygen (O_2)*

Oxygen is very important for living cells and the living processes. Therefore plants are both producers of O_2 as well as users of O_2 for their normal functioning. All living plant parts like roots, leaves and stems use oxygen for respiration, or to change sugars as produced through photosynthesis.

Very important is that roots also use oxygen for proper functioning. Poorly aerated and waterlogged soils (as discussed in Part 2) cannot provide enough oxygen for normal root development and functioning.

- *Sunlight*

Sunlight is the source of energy which drives the photosynthesis process, also called a photochemical process. The wavelengths of the radiant energy which fall within the visible spectrum of the human eye, determine growth and development of plants in different ways:

✓ *Photosynthesis*

The amount of photosynthesis will determine the extent of the plant growth, therefore production. The photosynthetic rate and total sum of photosynthesis is affected by:

- Light intensity: photosynthetic rate will increase up to a certain saturation point, after which photosynthesis will not increase. Leaves can compensate to certain degree for the light intensity, by becoming thinner and larger. The mesophyll cells also have more chloroplasts, implying that the photosynthetic centres are more abundant and easily accessible to the light. It is important to be able to differentiate between a"sun" and a "shade" leaf.

- Duration of exposure: more hours of exposure to sunlight means more photosynthesis.

- Light quality: photosynthesis requires light of certain wavelengths. The quality of light (the light spectrum) which strikes the leaf will determine the rate of photosynthesis.

✓ *Photo stimulus of the plant*

Sunlight also stimulates certain plant reaction and therefore the development of the plant. For these reactions the sunlight intensity is of great importance. The daylight length (photoperiod), wavelength of light (red and far-red spectrum) as well as the direction of the incidence of light are important.

Photo stimulus induces the following:

- Flower initiation: plants are classified as long, short and day neutral depending on how photoperiod controls flower development
- Onset of dormancy: usually because of shorter photoperiod
- Formation of storage organs for instance potato, which are initiated by a shorter photoperiod. Onion bulbs, on the other hand are stimulated by longer photoperiods.
- Direction of growth: stems and flowers tend to grow towards the light, depending on the direction of the incidence of light. This is called *phototropism.*
- Seed germination: light of certain wavelengths can stimulate some seed to germinate, and can inhibit others. For instance, seed of weeds brought into contact with light, causing the seeds to germinate.

Activity

Activity 1

You visit a crop farmer who intends to plant a maize cultivar that requires 900 Heat Units from planting till 50% pollination. He wants to know when to plant to avoid the effect of the mid summer (middle February) drought on his crop and to optimise the production yield. The Weather Bureau forwarded the following long term temperature data for the specific area.

	Average daily temperature °C	
Month	**Max temp (°C)**	**Min temp (°C)**
Aug	18	12
Sep	20	13
Oct	22	15
Nov	23	17
Dec	26	19
Jan	27	21
Feb	23	19

Calculate when the last planting day for this specific maize cultivar that he can plant to avoid these extreme conditions during pollination.

1. Calculate the heat units for the first 15 days of February
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2. Then work backwards from this point taking into account that some months may have 30 days and others 31 days
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3. Determine the latest planting date.

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3. Maturity of plants

The principle life phases of plants are embryonic growth, juvenility, maturity senescence and death. Plants look and function differently during each of these life phases and the crop water requirements are also different. Many plants like the citrus tree have a striking different appearance during the early stages of their life cycle. For instance young citrus seedlings are often very thorny but, as it becomes more mature, the new stems are less thorny. Juvenile plants also never flower, even if environmental conditions are favourable.

Senescence demonstrates the end of the normal life cycle and reflects an irreversible period of physical decline of the living plant, leading to the breakdown of tissues and ultimately death. Senescence occurs in individual plant parts like leaves and stems, and can be observed in annuals as well as perennials.

Activity

Activity 2

1. Explain the difference between growth and flowering habit and the possible consequences these aspects have on agriculture production.

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2. Distinguish between the different root systems that plants have.

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3. Distinguish between determinate and interdeterminate flowering habits and the consequences it has regarding agriculture practising.

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4. Explain what is meant with the cardinal temperature of crops. What relevance does this have for practical agriculture?

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5. Explain the concept "photo stimulus" and how it influences crop growth and development.

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4. Reproductive growth and development of plants[1,2,4,5,7,6]

The aim of any crop producer is to optimise the productivity of his crop. This is done by manipulating the vegetative and reproductive phases of the life cycle of the crop. Manipulating through farm management refers to how the farmer or producer changes the environment with different cultivation practices, planting time, spraying, fertilising, irrigation, etc. It is however important that the producer understand the structure and morphology of the specific crop and how it will respond to manipulation; as well as to know what to do to effectively manipulate the crop.

Fruit and seed production involves the following:

- Initiation and differentiation of flowers
- Pollination, fertilisation and fruit set
- Fruit growth
- Ripening or maturing of fruit

4.1 Initiation and differentiation

The time between germination and maturity can take a couple of weeks with some annuals, or many years in the case of perennials. At maturity the plant becomes sensitive to environmental stimuli and this leads to the onset of flowering.

Definition

Photoperiodism (or in layman's terminology "daylength") refers to the response of plants to the relative length of light and dark periods.

We get three categories of plants namely:

- Short day plants: require a dark period exceeding a critical length in order to flower with the following examples; tobacco, cotton, soybean, sunflower, green beans and many of the crops that flower during autumn
- Long day plants: require a dark period shorter than the critical length in order to flower with examples of wheat, potatoes, carrots and other plants that flower readily during summer
- Day neutral plants: flower irrespective of length of dark period with examples like tomatoes, maize, cucurbits and many tropical crops flowering all year round.

Photoperiod reactions of plants have significant implications for the farmer. Irrespective of when sunflowers are early or late planted it will flower approximately on the same date, since they are short day plants. Early plantings will have the advantage of a longer growing period resulting in a higher crop yield.

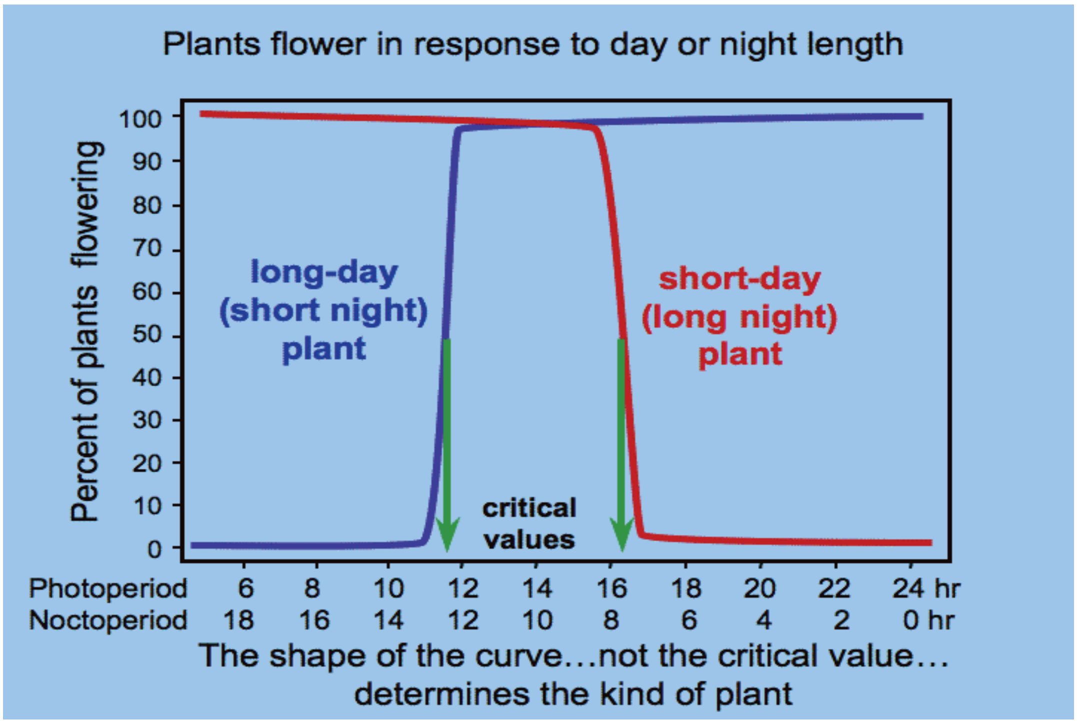

Figure 5. Plants flowering patterns in response to day length

Definition

Vernalisation is the process where flower initiation is promoted by exposing plants to low temperatures for a certain length of time.

Biennials require a period of vernalisation before they will flower. Onions, cabbage, carrots are examples of biennials. These plants produce a storage organ like a bulb or head during the first phase of the growing period and follow that with the production of flowers during the second phase of the growing period. If these plants are exposed to below optimum temperatures for a certain critical period (optimum temperature for vernalisation for these plants lies between 0-10°C for about a 6 week period) – they start to flower without producing a storage organ. This is called bolting. Bolting is a common problem that occurs with winter plantings of biennial corps and influences the crop yield negatively. In annual crops, like cereals (wheat, rye, oats, barley), the chilling period is required to advance the reproductive stage, and therefore promotes production.

Figure 6. Vernalisation as illustrated in a cauliflower plant

4.2. Pollination and fruit set

Pollination is a crucial event during growth and the development of fruit and seed. Pollination is the transfer of pollen from an anther to a stigma (Figure 7). *Self pollination* is the process where the anther and the stigma are in the same flower, in separate flowers of the same plant, or between plants of the same cultivar. *Cross pollination* occurs where pollen comes from different flowers of from plants of different cultivars. When the pollen is mature, the anther ruptures and pollen is released. Pollen is usually transferred to receptive stigma via wind, insects (honey bees) and occurs during the flowering stage of a plant. After pollination fertilisation takes place and in many crops it, takes about 24-48 hours from pollination to fertilisation.

After fertilisation the ovule will develop into a seed and the ovary around it into a fruit. Flower drop and fruit drop usually occur when the growth regulator (auxin) reaches a low or when imbalances of growth substances occur. Fruit set means that the flower has been pollinated and fertilised, and the fruit tissue will be able to grow into a fruit.

Fruit set are influenced by:

- Imbalanced fertilisation practices
- Temperatures below 15°C combined with overcast weather, reduces bee activity,
- Low light intensity

- Strong winds
- Insect activity
- Diseases
- Sprays for insect control

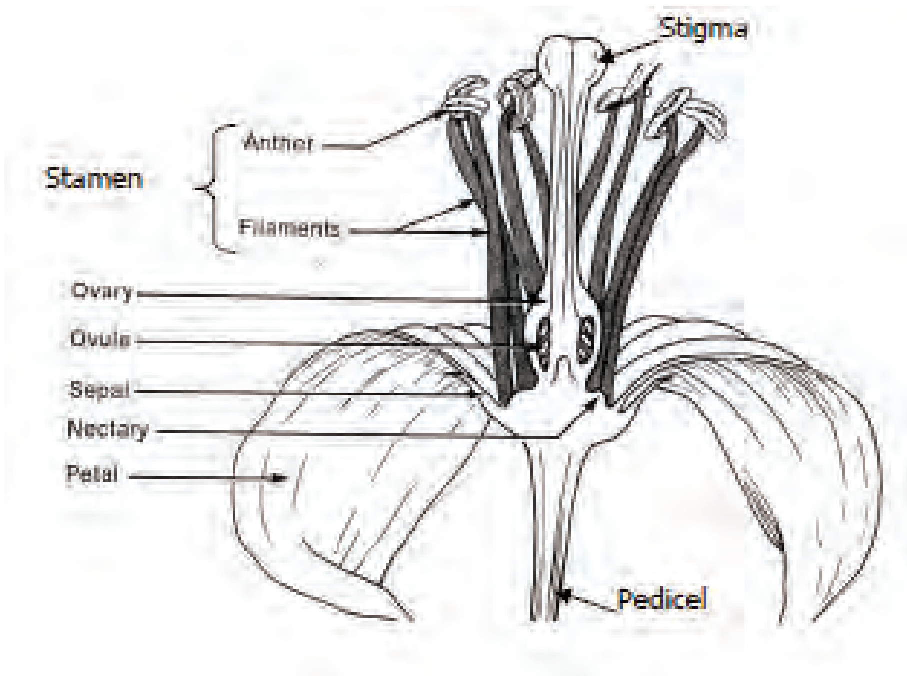

Figure 7. Diagram of a longitudinal section of a citrus flower[4)]

4.3 Fruit growth

Fruit growth results from three processes namely cell division, cell enlargement and the enlargement of the spaces between the cells (intercellular spaces). The first few weeks after flowering cell division dominates and this is followed by the enlargement of the cells and the intercellular spaces predominate until the fruit matures. The length of cell division varies between fruit crops, i.e. with apples it is approximately 4 weeks, while it is 6-8 weeks in the case of citrus. Fruit growth and development is controlled by auxins, gibberrelins and other growth regulators. Growth regulators can be sprayed on fruit to promote fruit size like farmers are doing with the production of seedless table grapes.

Fruit exhibits one of two growth curves when cumulative increases in volume, weight or diameter is plotted against time.
a) Sigmoid curve for crops like tomatoes, avocados, citrus, cucurbits
b) Double sigmoid curve for crops like apricots, peaches, cherries, grapes and figs. The double sigmoid curve is often divided into three growth stages namely: stages I and III are separated by growth stage II, a time where very little fruit growth takes place.

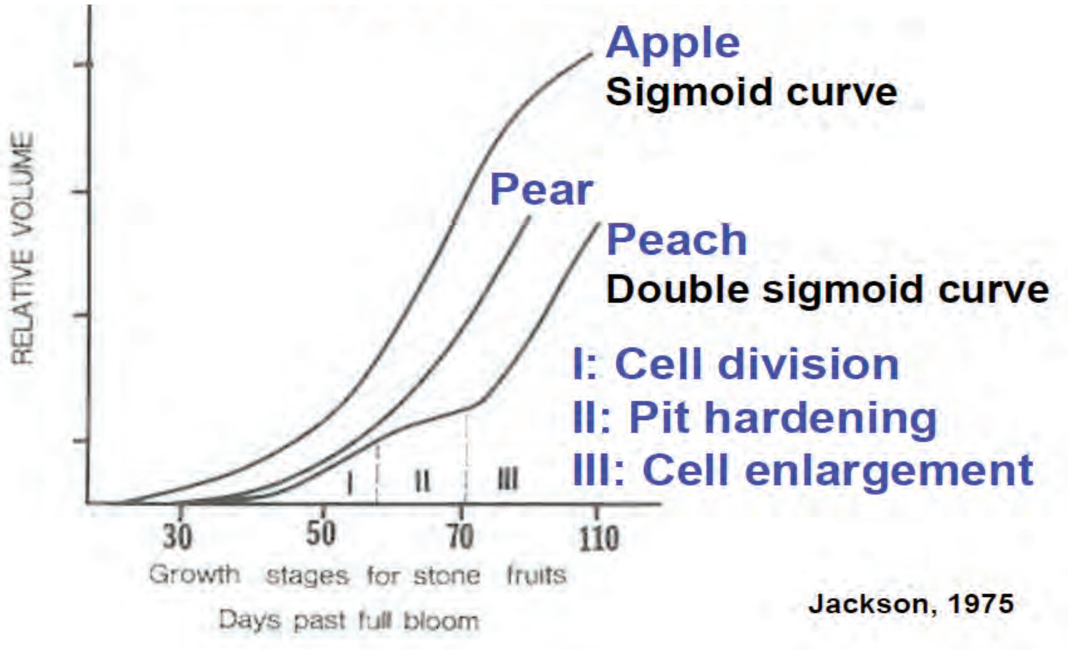

Figure 8. Fruit growth cuves[5]

4.4. Fruit ripening or maturing

When fruit ripen, it becomes palatable, sweet, colour changes and other substances accumulate to give it a distinctive flavour and aroma. Fruit ripeness can be determined by measuring the sugars (sugar: acid ratio), colour, hardening of the skin (skin set), size of the fruit, and with grain the percentage moisture is declining.

Activity

Activity 3

1. Explain the difference between a short and long day plant.

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2. What is meant with the terminology "vernalisation" and how does this influence the production of biennials?

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3. What are the external factors that cause poor fruit set and how can the crop farmer plan to prevent this from impacting on the crop production?

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4. Some fruits grow rapidly after fertilisation, and then growth is retarded for a while before it starts to grow rapidly again until the fruit reaches its ultimate size. What is this fruit growth pattern called and how does it differs from other crops?

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My notes............

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Module 2

Water uptake in the plant

Study objective

After completion of this module, the learner should be able to have a basic understanding of:

- Functions of water in the plant
- Transpiration
- Water potential
- Water potential gradient
- Route that a water drop is following from the soil to the leaf
- Effect of water stress on the various growth and development stages of the plant

Table of contents

This module will focus on water uptake of herbaceous crop plants. Water content varies between 70-90%, depending on age, species, particular tissue, an environment. Under field conditions, the roots permeate relatively moist soils while the stems and leaves grow into relatively dry atmosphere. This causes a continuous flow of water from the soil through the plant to the atmosphere along a gradient of decreasing energy potential. On a daily basis, this flow amounts to 1-10 times the amount of water held in the tissues, 10-100 times the amount used in expansion of cells, and 100-1000 times the amount used for photosynthesis. The primary movement of water is therefore from the soil to the leaf to replace transpiration loss. Because of the high demand for water, a plant requires a consistent water source for growth and development.

1. Function of water in the plant

About 80-90% of the fresh weight of herbaceous living plants consists of water, with the following important functions in the plant:

- Provides mechanical stability, especially to plant parts like leaves and young stems which have thin walled stems. The role of the water is to keep the cells firm or turgid.
- Water is an essential reagent in many of the chemical reactions and processes in the plants, for instance photosynthesis
- Water is a solvent of compounds in plants and also acts as a medium for chemical reactions.
- All compounds are transported as solutes through the plant. Mineral elements like N, P, K, Mg, etc. as well as compounds produced through metabolism like protein, carbohydrates, can only be absorbed and transported as solutes to the various destinations in the plant.
- Water plays an important role in the stabilising of plant temperature, and therefore the plant temperature will change more gradually than that of the environment.

Plants can lose up to 98% of the water absorbed by the roots by means of transpiration, and plant types differ in the amount of water lost while growing and accumulating dry mass. Plants also have the ability to maintain relatively constant internal water content even with big fluctuations in available soil moisture. This stabilising effect is of utmost importance, as huge fluctuations in the moisture content of plant cells will influence the functioning of the plant.

2. Forces that influence behaviour of water and water movement[1,2)]

2.1 Water potential (Ψ)

The system that describes the behaviour of water and water movement in the plant and soils is based on a potential energy relationship. Water movement in plants occur because of a difference in the energy levels of water between two points, it will move from an area of high potential energy to an area of low potential energy, over an energy gradient. In the plant and soil, potential energy of water is called the water potential (Ψ), expressed as a force unit of area and measured in bar of kPa. Water moves from soil, through the plant into the atmosphere due to the Ψ between two points[2)].

Ψ therefore measures the tendency of water to be:

- Absorbed from the soil

- Transported through the plant
- Transpired into the atmosphere

2.2 Components of water potential

This concept of water potential supersedes the old concepts of suction, and has the advantage that the energy levels in the plant can be described in the following equation[2)]:

$$\Psi = \Psi_m + \Psi_g + \Psi_p + \Psi_\pi$$

Ψ_m= matrix potential: represents the contribution of the insoluble matter with which water comes into contact. . Pure water has a water potential equal to 0 bar. The water in plants and soils because it is not chemically pure (solutes) is usually less than 0bar, which means it has a negative value.

Ψ_g= gravitational potential, which is always present but usually insignificant in short plants, compared with other three potentials. It can however be significant in tall trees.

Ψ_p= pressure potential: presents the force caused by hydrostatic pressure on the solution. The Ψ_p of water at normal atmospheric pressure is zero. When the pressure increases, the Ψ_p increases simultaneously. The Ψ_p can be either positive or negative in plants.

Ψ_π = osmotic potential: represents the contribution of solutes in the water. Solutes lower the potential energy of water and result in a solution with a negative Ψ_π.

In the soil-plant-atmosphere continuum, each of these components of Ψ can be measured and is used in the research on water relationships of plants. All forces in the system can be determined, and the direction of water movement as well as the reaction on the system to these forces, can be predicted.

3. Route of water transport[2)]

3.1 Absorption

Plants absorb water through their roots, and therefore the majority of plants have an extensive root system. Water enters the root from the soil through the epidermis cells in the vicinity of the root apex. This specific area is enlarged by the special *epidermis cells*, the root hairs (Figure 1). The soil water does not move towards the roots since the diffusion of water through the soil is very slow. The root growth is very important for effective utilisation of soil water, and the growing root apex makes contact with the soil water in the soil pores. The root hairs are short lived being constantly replaced as new growth takes place. After soil water has entered the root through the epidermis (osmosis), it moves through the cortex and endodermis by means of diffusion and osmosis and is then deposited in the xylem. The gradient of water concentration that exists across the cortex creates a pushing force called the “root pressure” , eg. a pressure that pushes the water across.

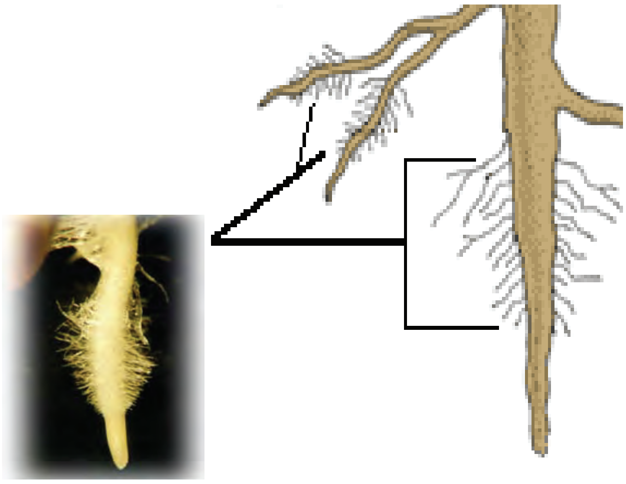

Figure 1. Basic structure of the root system and roothair

Activity

Activity 1

Cut a stem of any plant of your choice at soil level, and observe what happen.

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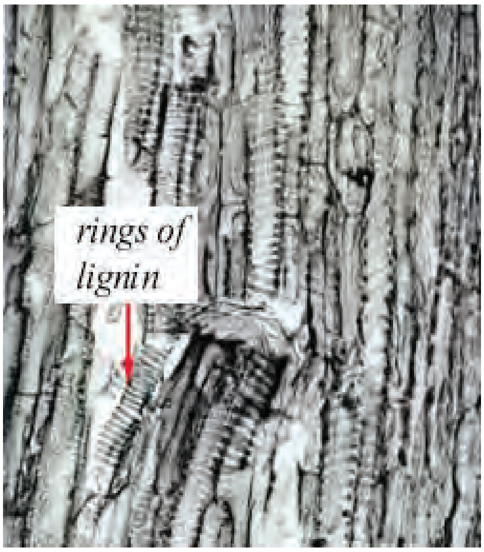
3.2 Water transport and loss

The xylem (vascular tissue) consists of lengthened dead plant cells with bands of lignin which are linked by perforated ends, forming capillary tubes in which the water is transported through the plant (Figure 2). The lignified cell walls (wood) are therefore capable of giving the stability to counteract the large differences in pressure when water is transported to the top of large trees. The movement of water in the xylem is due to bulk flow, much like in a water pipe. The xylem (a continuous capillary tube system) begins in the root apex and ends in the leaf veins. The xylem vessels are narrow which increase the capillary forces. However this only makes a small contribution to water's upward movement[2)].



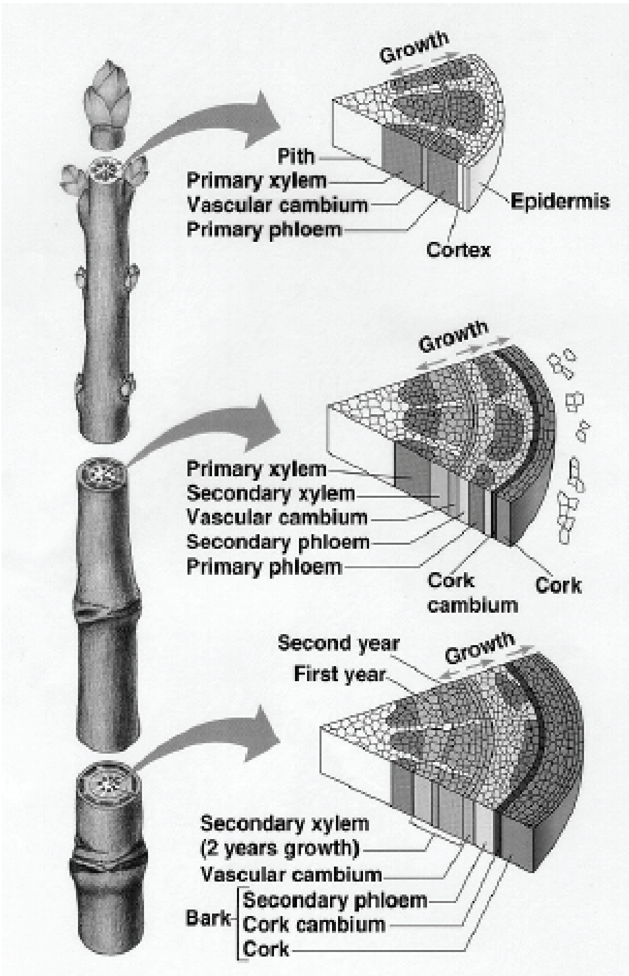


Figure 2. Internal structures of the plant stem and function of the various structures[2)]

Looking at the leaf structure provides clues to what is the main force involved in maintaining a continuous flow of water from the root to the leaf through the xylem.

3.3 Water loss as vapour

The water transported by the xylem into the leaf blade and leaf veins evaporates from the mesophyll cell walls through the stomata into the atmosphere. In broad leaved plants, the leaves are large, thin, flat structures. Large, in order to trap lots of energy, and thin so that carbon dioxide can diffuse into the leaf from surrounding air. Closer examination of the leaf reveals that small pores or stomata occur in the leaf's surface. Each stoma is controlled by two guard cells which open and close the pore. If the plant is to obtain sufficient carbon dioxide for photosynthesis, it is necessary that the stomata are open. However, in being open, water can also be lost through these stomata by evaporation(called transpiration).It is this force, transpiration that is the driving force behind the pulling of water through the plant system. Air usually has extremely low water potential, compared with plants and soils. Since a living leaf usually has a water potential greater than -15 bars, there is a steep energy gradient and continual movement of water as vapour from the leaf to the air takes place. Effectively, water can only escape the plant through the root apex and the stomata.

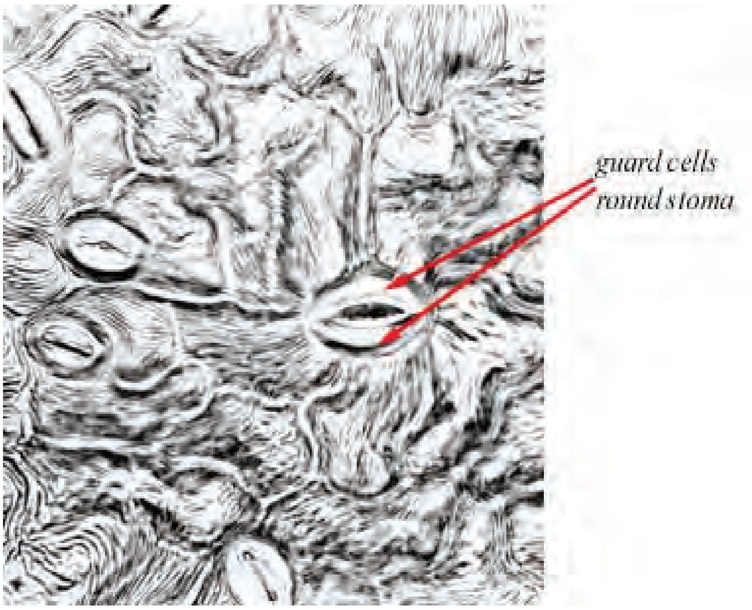


Figure 3. Guard cells controlling open and close of stomata

3.4 Transpiration

Transpiration is the evaporation of water from the plant through the stomata into the atmosphere. Little transpiration occurs when the stomata are closed. Some stomata are present in green plant parts like green fruit and stems, but the vast majority of stomata are situated on the leaves. Therefore transpiration is mainly perceived as a leaf function. Stomata are small pores found in large numbers, mainly on the bottom side of the leaves. For example, about 18 000 stomata /cm^2 can be found on the bottom side of cotton leaves. 98% of the water taken up by roots is transpired from the leaves' surfaces.

As stomata open wider, more water is lost, but the loss increase is less for each unit increase in stomatal width. Many factors influence the stomatal opening and closure under field conditions, with the major ones being light and moisture level. In most plants light causes stomata to open. Low moisture levels in the leaf (low Ψ_{leaf}) causes guard cells to lose turgor, resulting in closure of stomatal.

The soil-plant-atmosphere continuum is driven by successive pulling forces starting in the atmosphere, through the stomata, leaf tissue, stem, root and ending in the soil. This water potential gradient of the soil-plant – atmosphere continuum for a small tree is illustrated in Table 1.

Table 1. Estimated values of water potential in a soil-plant-atmosphere continuum for a small tree on well-watered soil, with an air humidity of 50% and atmospheric temperature of 22°C[2)]

	Ψ (kPa)	Ψ difference(kPa)
Soil water	-50	150
Root	-200	300
Stem	-500	1 000
Leaf	-1500	9 500
Atmosphere	-10 000	

4. Evapotranspiration

Although this concept is discussed in much detail in Part 3: Agro climatology, it is important to look once again at the plant and environment factors that determine water loss to the atmosphere:

Solar radiation: of solar radiation absorbed by the leaf, 1-5% is used for photosynthesis, 75-85% is used to heat the leaf and for transpiration.

Temperature: increasing the temperature increases the capacity of atmosphere to hold water, which means greater atmospheric demand.

Relative humidity: greater water content of the atmosphere, the higher $\Psi_{air,}$ which means the atmospheric demand decreases with relative humidity.

Wind: transpiration occurs when water diffuses through the stomata. A diffusion gradient barrier builds up around the stomata when the air is still. This means that water that is diffusing from the wet leaf interiors is almost matched by water build up outside the leaf, which reduces transpiration. When wind (turbulence) removes the moisture next to the leaf, the difference inside and immediately outside the stomatal opening increase and wet water diffusion or transpiration increases.

5. Plants sensitivity to water stress[3)]

Water often limits growth and development of plants, and the plant's response to water stress is relative to its metabolic activity, morphology, stage of growth and yield potential.

- *Cellular growth:* the effect of water stress during the vegetative stage is the development of smaller leaves, which usually reduce the leaf area index (LAI) at maturity and results in less light interception by the crop and reduced leaf photosynthesis.
- *Chlorophyll synthesis is inhibited at greater water deficits*
- *Enzymes show reduced activity:* nitrate reductase level reduction, protein synthesis reduction
- *Plant hormones also change in concentration:* abscisic acid (ABA) increases in leaves and fruits, and this accumulation of ABA induce stomatal closure, which result in reduced CO_2 assimilation.
- *Amino acid proline increases in concentration:* proline seems to aid drought tolerance and at extreme levels of water stress (greater than -15bars) respiration, CO_2 assimilation, xylem transport rapidly diminishes to lower levels while hydrolytic enzymes activity increases.
- *Water stress during floral initiation, pollination and seed development:* greatly reduce the number of seed developed.
- *Water stress during grain filling:* potential seed yield may be below potential photosynthate production.

Activity

Activity 2
Individual activity

1. Describe the route that a drop of water follows from the soil, through the plant into the atmosphere. Name the tissues and cell parts it comes into contact with.

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2. Discuss the following equation and its effect on the movement of large quantities of water through the plant. $\Psi = \Psi_m + \Psi_g + \Psi_p + \Psi_\pi$

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3. Which factors cause the stomata to close

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4. Give and explain the functions of water in the plant

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5. Discuss the effect of water stress on the various growth and development stages of the plant.

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My notes............

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Authenticator:

- Dr P Reid

Technical Learner Guide

Irrigated Crop and Fodder Production

Level 5

Module 3

Sustainable crop production

Study objective

After completion of this module, the learner should be able to have a basic understanding of:

- What is sustainability
- Sustainable agricultural approaches
- Agrobiodiversity
- Conservation agriculture
- Recognise different methods of multi cropping
- How can different crops grow together and be productive
- Crop rotation
- Integrated Weed Management System

Table of contents

Regardless of the type of farming, there is always tension between the farm being able to produce enough to provide a livelihood for farmers, be productive enough to meet the world's food needs - while at the same time having to be careful about using the natural resource base, under increasingly unpredictable climate conditions. So the question is how can the crop farmer be more sustainable?

1. Unpacking the concept sustainability[4,7,9)]

What exactly do we mean when we talk sustainability? This is a term that is often used loosely by the general public, and it becomes especially difficult to grasp because it seems to mean quite different things to different people. A definition that we will use for further discussion is the following:

Definition

Sustainability is the combination of resilience (being able to buffer shock stress) and continuity (being able to continue over long periods)[5)]

- **Resilience**

Resilience has to do with the ability to adapt to change. It does not necessarily mean that all things go back to how they were before a change. Resilience is described in terms the ability to be able to buffer shocks and stresses. For the agricultural system it means there have to be mechanisms - or buffers- for farmers to be able to withstand different challenges that occur. Examples of buffers on the farm is for instance the use of a variety of crops, with different harvesting dates that can withstand the varying climate conditions and also ensure cash flow on the farm. It is important to consider the opportunities offered and the constraints imposed by the wider farm context. It is important for the farmer to strengthen these buffers not only on the farm, but around it as well. These buffers are important for the farmer to be able to adapt his/her practices to the new conditions.

- **Continuity**

For a farm to be able to continue to be productive over a long period, the natural resource base should be handled carefully. Practices should not deplete the ecological environment - or go beyond its "carrying capacity". For instance, it is important that cultivation practices need to protect the soil from erosion and nutrition depletion, and to conserve as much water as possible. It also means that policies are in place to support farmers to continue farming, and to adopt practices that are not harmful to the environment or to fellow farmers and the public.

Activity

Activity 1
Small group exercise

Objective : To assist in explaining about the concept of sustainability

Start by asking the learners to discuss the two drawings illustrated below:

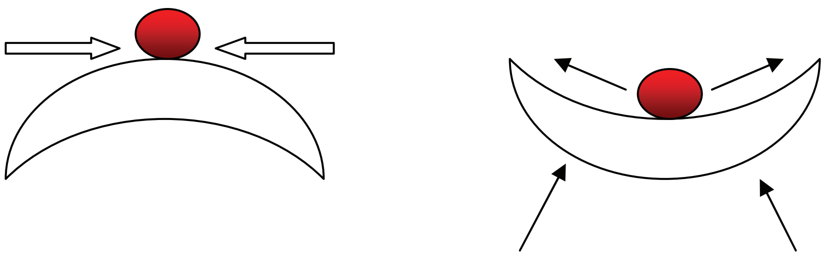


Figure adapted from: Napel T, Biancji F & Bestman M, 2006. Utilising intrinsic robustness in agricultural production systems)

If the red dot is representing a ball lying on a hard surface (one which is concave and the other with a convex form) that you are holding onto, how can you keep the ball from falling off?

Example of responses: the ball on the convex form is always in danger of rolling away, and therefore a lot of effort needs to be made to keep it firmly in place. In the concave form, the ball can shift from side to side without any worry of falling off, and it will tend due to its own energy, go back to the centre of the concave form.

What have we learnt from this small exercise regarding the managing approaches in farming? We have two models here: the "control" model which represents the conventional approach and the "adaptive" model which represents a more sustainable approach.

"Control" model	"Adaptive" model
• Focus on the problem • Negate variation • Constantly monitor • Step in instantly • Seek static balance	• Focus on the system • Make use of variation and seek ways of buffering • Stimulate self regulation • Indirectly steer • Seek dynamic balance, resilience

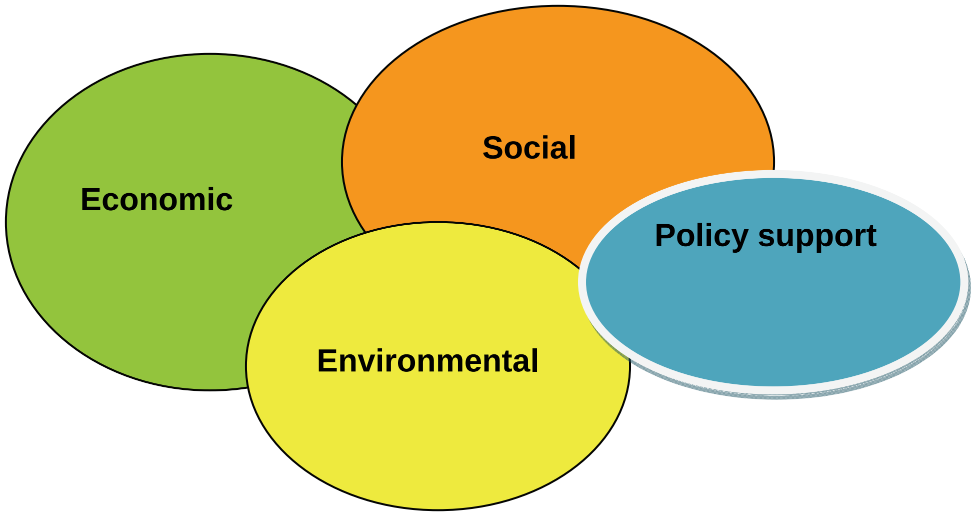
Carefully run through these characteristics and ask learners to think about what it means if you relate this to crop farming. Give examples, comparing technological fix approaches versus the build up of buffers.

- **Sustainability is dynamic process – not an endpoint[4,5)]**

A farmer can never stand up and say "my farm is sustainable". Farms are dynamic-there is always something moving on them and in the surrounds as well. Since farms are dynamic systems - it is impossible to think that it could be sustainable as in being static or at an endpoint. As changes are coming up, so farmers need to learn how to respond and adapt their strategies to the change. Basic changes relate to variability in weather patterns to which farmers need to adapt their crop selection, water use, etc. In other case market opportunities could change – new demands, infrastructure developments or market mechanisms. Clearly managing a farm, especially being able to get sustainable livelihood from it while maintaining and nurturing the resource base is a dynamic process.

2. Dimensions of sustainability[4)]

Sustainable agriculture depends on a whole system approach whose overall goal is continuing health of the land and people. Therefore it concentrates on long-term solutions to the problem instead of short-term treatment of symptoms. Strategies for the enhancing of sustainable agriculture development should include the following four dimensions:



2.1 Ecological aspects of sustainability

Sustainable agriculture can be viewed as ecosystem management of complex interactions among soil, water, plants, animals, climate and people. The goal is to integrate all these factors into a production system that is appropriate for the environment, the people and economic condition. Taking the sustainable approach therefore means that practices need to strengthen buffers that allow the farmer to be resilient! Some examples of a sustainable approach to ecological aspects are:

- Integrate crops that offer favourable interactions, e.g. crops that repel pest or are efficient users of nutrients
- Prevent soil degradation and build soil structures and fertility
- Protect water quality on and beyond the farm
- Manage pest ecologically
- Farm landscape through maximizing of biodiversity on the farm

Activity

Activity 2

Small group activity

Can you think of more examples of *ecological aspects* or resilience relating to your specific area?

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2.2 Economic aspects of sustainability

The economic dimension of a farm includes markets, processing opportunities, prices and consumer demand for the farm product, as well as conditions for transactions such as credit and interest rates. For a sustainable approach to economic aspects of farming strategies should oriented toward the building up of buffers that allow farmers to adapt to changes in market demand and price swings. The following are examples of a sustainable approach to economic aspects:

- Know your markets
- Protect your profits
- Add value to your products
- Diversify enterprises
- Market outside the commodity supply chains and corporate vertical integrators
- Add value through on farm processing

Activity

Activity 3

Small group activity

Can you think of more examples of *economical aspects* relating to your specific area?

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2.3 Socio-cultural aspects of sustainability

The socio-cultural dimensions that are important for the farm include norms and values of the wider society, gender relations and participation in social networks. For farmers to be able to adapt to changes, social-cultural norms and rules need to be flexible enough to allow adoption. For instance if farmers are to be convinced to adopt more of a sustainable approach, changed practices should build on the farmers' priorities, skills and knowledge.

- Strengthen farmer knowledge and skills, building on local practices and knowledge
- The farm supports other businesses and families in the community
- Strengthen social networks for farmers towards greater resilience
- Young people take over their parents' farm and continue farming

Activity

Activity 4

Small group activity

Can you think of more examples of socio-cultural aspects relating to your specific area?

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2.4 Political support for sustainable farming practices

"Governance" has to do with the process of decision making and the process by which decisions are implemented (or not implemented). It refers to all those involved in decision making and implementing decisions. Governance affects all dimensions of sustainability and plays out at different levels - national, local and even household level. For sustainable farming practices and farming to thrive, governance mechanisms are required that give a voice to farmers when decisions that affect their farms or practices are made. It also needs policies that support sustainability, and these policies need to be safeguard and enforced. Some examples of policies in support of farming sustainability:

- Allow farmer organisations to thrive in providing services, and to speak and negotiate on behalf of member farmers
- Strengthen access to information (radio, open media)
- Support farmer access to services (for example, equitable rights to resource, specific extension and research services, fair credit conditions, subsidies that reward sustainable practices).

Activity 5

Small group activity

Discuss whether policies that stimulate sustainability are seen as the prerogative of government or are farmers' voices heard in policy and legislation that affects farming sustainability.

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3. Brief overview of selected sustainable agriculture approaches

In Table 1 a simple overview is given of some selected large scale movements that have gone so far as to formalise the ideas of farmers how to improve sustainability farming into a set of principles for certification.

Table 1. Brief overview of selected sustainable agriculture approaches[11, 12)]

Name of approach	Origins and when formally described	Distinguishing Characteristics
Agroecology	Latin America late 1970s	The term agro-ecologia originates from Latin America and refers to the holistic study of agro-ecosystems, including environmental and human elements. Its goal is to integrate components so that biological efficiency is improved, biodiversity is preserved and the agro-ecosystem productivity and its self-regulating capacity are maintained. This term is used in Latin America for what the rest of the world refers to as organic agriculture – in Latin America; "organic agriculture" is specifically linked to a particular system of certification. (For more information and literature links, see the Agro-ecology in Action website at: *www.agroeco.org*.)
Agroforestry	Based on traditional systems	This basically refers to "trees on farm". It is the collective name for land-management systems that optimise the economic and ecological benefits created when trees and/or shrubs are integrated with crops and/or livestock. (For more information and links to resources, see the website for the World Agroforestry Centre, at: www.worldagtoforestry.org.)
Biodynamic (BD) agriculture	Austria/Germany 1924	This approach to agriculture relates the ecology of the earth-organism to that of the entire cosmos. The farm is seen as a "living organism" and an important core concept is the necessity to take care of the living soil. Biodynamic products have official certification. (For more information and linked resources, see the website of the Biodynamic Farming and Gardening Association in North America, at: *www.biodynamics.com*.)

Name of approach	Origins and when formally described	Distinguishing Characteristics
Bio-intensive agriculture	United States – inspired by methods in France 1972	A sustainable 8-step food-raising method known as "Grow Biointensive" which focuses on maximum yields from a minimum area of land, while simultaneously improving the soil. This method was developed by Jeavons and includes double dug raised beds, intensive planting, composting and companion planting. (For more information and links to resources, see Ecology Action website, at *www.growbiointensive.org.)*
Conservation agriculture OR Conservation farming OR Conservation tillage	United States 1940s	This is a concept for resource-saving agricultural production that strives to achieve acceptable profits together with high and sustained production levels while conserving the environment. It is based on enhancing natural biological processes above and below ground. It centres around three principles: 1. Continuous minimum mechanical soil disturbance; 2.Permanent organic soil cover; and 3.Diversified crop rotations in the case of annual crops or plant associations in case of perennial crops. The movement originates from large-scale farming in North and South America, New Zealand and Australia – but has been widely adapted from small-scale farms around the world, including in Africa. For further information, see *www.fao.org/ag/ca/la.html)*
Eco-agriculture	Europe 2000	Eco-agriculture was a concept coined by Scherr and McNeely in a report that includes three pillars: 1. Enhance rural livelihoods; 2. Conserve or enhance biodiversity and ecosystem services; and 3. Develop more sustainable and productive agricultural systems. It calls for agriculture to be looked at from the Landscape scale rather than at individual farm level, in order to become sustainable. (For more information and links to resources, see the Eco-agriculture website at: *www.ecoagriculture.org.)*
Fair Trade	Netherlands and Mexico 1970s	This movement emerged in the 1970s when the first fair trade label was established for coffee producers in Mexico, to guarantee a fair price to small-scale producers. Since then, the fair trade movement has grown to become a trading partnership that promotes standards that seek greater equity and transparency in international trade. In practice, fair trade producers can sell their products at predefined and guaranteed prices, while receiving an additional premium over and above this price. The premium is paid to the group of producers and can be used for community development purposes. (For more information, see the website for FLO International, at *www.fairtrade.net.*).

Name of approach	Origins and when formally described	Distinguishing Characteristics
Natural farming	Japan 1940s	Based on the teachings of Fukuoka, the essence of this method is to reproduce natural conditions as closely as possible. It calls for a farming system that does not require weeding, pesticides, chemical fertilizers or tillage. Biodiversity and always keeping the ground covered are important tenets. (For more information and resources see http://fukuokafarmingol.info/which).
Organic agriculture	United Kingdom and USA 1940s	The term is often used to indicate any farming system that does not use chemical inputs. However, under its official global organisation, "International Federation of Organic Agriculture Movements" (IFOAM), it is a specific certified commercial way of farming with ecological, social and economic objectives. IFOAM currently unites 750 member organisations in 108 countries. In 2005, 2% of total world farmland was certified organic. (For more information and resources, see IFOAM's website: *www.ifoam.org.*)
Permaculture	Australia 1978	The term "permaculture", coined by Mollison and Holmgren, is a blend of "permanent agriculture" and "permanent culture". The goal is perennial agricultural systems that mimic the structure and interrelationships found in natural ecologies. Originating as an agro-ecological design theory, it freely borrows techniques and cultural systems from organic agriculture, sustainable forestry, horticulture, agro-forestry and the land management systems of indigenous peoples, developing organising principles that are transferred through two-week intensive permaculture design courses around the world. (For more information and links to resources, see the Permaculture Research Institute of Australia's websites at: *permaculture.org.au*.)

4. Farm management and cropping systems[1,2,3,6)]

This section examines the management of cropping systems. Cropping patterns involve polycultures (multiple crops in the same space), monocultures (large stands of single crops), conservation agriculture practices, crop rotation, practices that improve soil fertility, integrated weed control, integrated pest management.

Despite the ongoing development of crop diversity by farmers, overall crop genetic diversity has become increasingly narrower throughout the world over the last sixty years. The FAO estimates that of the 250 000 known edible plant varieties available to agriculture, about 7 000 (less than 3 percent) are currently used by people. Today 75% of the world's food is generated from twelve plants and five animal species. Three crops- namely wheat, maize and rice contribute nearly 60% of plant-based calories and proteins obtained by people. The development of improved varieties has led to tremendous positive benefits- in particular production to meet the needs of the growing population. This has unfortunately also caused loss of agrobiodiversity, as multiple "traditional" or local varieties are being replaced with a few , improved, varieties that are grown over large areas.

Definition

What is Agrobiodiversity?[1)]
Agricultural diversity (agrobiodiversity) is the variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, including crops, livestock, fisheries and forestry. It comprises the diversity of genetic resources (varieties, breeds) and species used for food, fodder, fibre fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil micro-organisms, predators, pollinators) and those in the wider environment that support agro-ecosystems as well as the diversity of agro-ecosystems themselves

A number of conservation agricultural practices can be used to increase biodiversity and enhance the sustainability. The rest of the Module briefly gives an overview of some of these practices.

4.1 What is conservation agriculture?[4,7)]

Conservation agriculture is based on three principles namely:

- o Minimum disturbance: soil is not ploughed and seeds are planted directly into the mulch covered field. Soil is the crop farmers' bank - the more you invest in it the more it will deliver!
- o Soil cover: the crop residue is left on the field, or a cover crop is planted. By keeping the soil covered with a crop, mulch or cover crop it has a more constant temperature, less evaporation and improved fertility.
- o Mix and rotate crops: important to rotate crops so as to reduce weeds, control pests and diseases, and improve fertility.

Figure 1 illustrates a no-till field where the main crop is soybeans, which has been planted directly into the field with little disturbance of crop residue.

Figure 1. Soybeans planted directly into a no-till field[8)]

Advantages of conservation agriculture

Environmental benefits	o Reduction in soil erosion (reduces the effect of rain drops and reduce runoff) o Improvement of water quality o Improvement of air quality o Biodiversity increases (quality of soil life e.g. earthworms and plants)

Agronomic benefits	o Improvement of soil fertility through:
	  o increase in organic matter;
	  o soil-water conservation;
	  o improvement of soil structure and rooting depth and distribution

Economic benefits	o Three major benefits namely:
	  o Time saving and thus reduction of labour requirement
	  o Reduction in cost over time –the cost for operation and maintenance are reduced. Fuel consumption, wear and tear of tractors and other machinery are all less
	  o Greater efficiency: conservation agriculture can produce equivalent or higher yields to conventional tillage systems. However, a reduction in maize yields may occur during the first years of implementing conservation agriculture. Crop yields under conservation agriculture are less variable through the stabilising effects of favourable conditions of soil properties and microclimate.

Limitations of conservation agriculture

Lack of knowledge	The most important initial limitation is the lack of knowledge and there is no single definition for the practising of conservation agriculture, because every area is different.
Adoptability of farmers and land users	The success or failure depends on the flexibility and creativity of the practitioners. Trial and error is often the only reliable source of information.
Machinery	Specialised machinery (no till planter) is needed. This can be expensive and a very big limitation for those who want to adopt conservation agriculture.

4.2 Multi-cropping[8)]

This set of practices mixes two or more crops in the same space (horizontally or vertically) during a single season. The principle for these different types of multi-cropping are the same: integrating different crops that allow for complementary synergies in nutrient uptake, attracting natural enemies, buffering against or even repelling pests or weeds, while avoiding competition for nutrients, water, light that harms the productivity of, at least, the main crop.

4.2.1 Intercropping or companion planting

Intercropping is the growing of two or more crops simultaneously on the same field. Crop intensification is in both the time and space dimension.

Figure 2. Intercropping practices between maize and soybeans[8)]

4.2.2 Types of intercropping systems

Different types of intercropping systems are used worldwide:

- *Mixed intercropping:* growing of two or more crops simultaneously within the same row. For example cowpeas and oats grown together in a mixed intercropping system (same row).

Figure 3. Mixed intercropping: maize-cowpeas intercropping system

- *Relay intercropping:* growing of two or more crops simultaneously with part of respective overlapping. A second crop is planted after the first crop has reached the reproductive stage of growth but before it is ready to harvest.

- *Row intercropping:* growing two or more crops simultaneously where both crops are planted in distinct rows, like for instance the planting of maize and chickpea grown under row intercropping.

Figure 4. Row intercropping – growing of sorghum and cowpeas in alternative rows

- Strip intercropping: growing of two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for crops to interact agronomically. The following photos illustrate the planting of maize, sorghum and cowpeas intercropped.

4.2.3 Why practising intercropping

- In many of the rural communities, arable land is seen as a major constraint
- Intercropping provides the opportunity to get to a higher production from the same piece of land
- Intercropping in South Africa is practised in home gardens where maize is usually intercropped with beans and pumpkins
- Intercropping can be seen as local or indigenous knowledge
- The promotion of this practise in combination with no-tillage can provide individual households with a variety of food crops
- Row intercropping fits well into an existing farming system and is fully compatible with the type implements used commonly in rural communities

4.2.4 Cover cropping

Growing an additional low-lying crop for the purpose of keeping the ground covered to avoid soil erosion, increase soil fertility (usually through the use of "green manures" which are in most cases legumes that fix nitrogen) and control weeds. The selection this type of cover crop also includes considerations of whether the crop provides food, fodder or a cash crop.

Figure 5. Example of a cover crop (legume Vetch) together with maize[8)]

4.3 Crop rotation

This practice involves growing a sequence of different crops over time on the same plot. The logic of crop rotation is to build synergies and complementarities through cropping sequences. By rotating crops farmers avoid a build–up of pathogens, pests, weeds, that often occur when a single species (or crops from the same family) is continuously cropped. For this reason crops that are directly related should not be planted in the same plot for about three seasons. Another strategy is to alternate deep rooted and shallow rooted plants to improve the soil structure and to utilise nutrients at different levels of the soil.

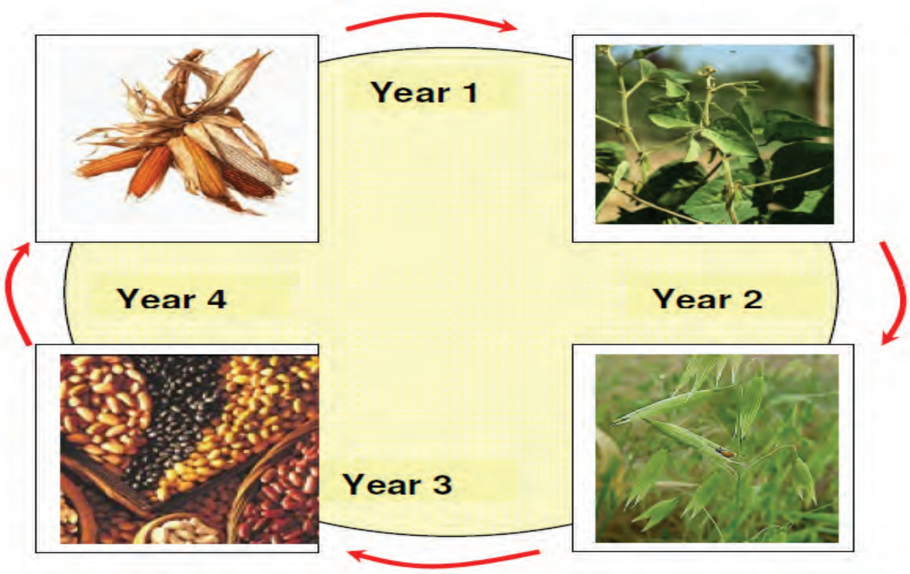

Figure 6. Crop rotation

4.3.1 What to keep in mind with the practising of crop rotation

- Crops must be suited for your soils
- Design crop rotations to meet residue needs of your crop residue management plan
- Rotations that include small grains or pastures provide better erosion control
- Small grains and pastures can always be used to replace any row crop or low residue crop to gain better erosion control
- Maize can always be used to replace soybeans or any low residue crop in rotation to gain better erosion control
- For crop rotations which include hay, the rotation can be lengthened by maintaining the existing hay stand for additional years
- Avoid planting a grass after a grass if possible (remember maize also belong to the grass family)

4.3.2 Advantages of crop rotation and cover crops

Grown during fallow periods	Cover crops are planted to keep the soil covered during fallow periods.
Reduce the need for herbicides and pesticides	Crop rotation and cover crops are planted to brake the life cycle of weeds, pests and diseases.
Protect the soil as a living or dead cover	By keeping the soil covered (living or dead) the soil is protected.
Prevent soil erosion	Due to the soil being covered there will be less runoff.
Conserve soil moisture	The soil is shaded and therefore there will be less evaporation from the soil surface.
Enhance organic matter content of the soil	Improved water infiltration, water retention and soil fertility.

4.4 Catch crops

Catch crops are crops planted in between the main crop to attract pests . The following are examples of catch crops:

- Napier grass: attracts stalk borer
- Cowpeas: attracts leafhoppers, aphids and bollworms
- Sunhemp and cabbage: control nematodes
- Okra: control bollworm and caterpillars

4.5 Integrated weed management[6,7,8)]

Definition

A weed is:

- A plant out of place
- A plant that interferes with human activities
- A plant whose negative characteristics outweigh its positive characteristics
- Weeds vary greatly in structure and function, and weeds as a group tend to have a number of biological characteristics that make them a good competitor against forage crops.

4.5.1 Characterisation of weeds

- Weeds produce large number of seeds
- Weeds are able to reproduce vegetatively via stolons and rhizomes
- Weed seeds have specialised structures for transport, for example burrs to cling to animals
- Weeds exhibit allopathic properties (produce chemicals that inhibit the growth of other plants)

4.5.2 Principles of integrated weed management

Integrated Weed management (IWM) includes all available weed control strategies in the best possible way to manage weed populations. These strategies include:

- Cultural
- Mechanical
- Chemical methods of weed control

All these practices are components of an Integrated Weed Management system and none of these control measures on their own can be expected to provide acceptable weed control. Therefore, an integrated weed management system uses a combination of methods to control weeds.

Cultural methods of weed control	*Crop rotation* important strategy for developing a sound long-term weed control programme. Weeds tend to thrive on crops with similar growth requirements to their own, and therefore cultural practices designed to contribute to a specific crop may also benefit the growth and development of weeds.
	Field scouting a key component to integrated weed management system. Involves a systematic weed collection of weed and crop data from the field (weed distribution, growth stage, population, crop stage,etc.) This information is then used for the planning of an integrated weed management plan.
	Cover crops inclusion of cover crops such as rye or overwintering crops like winter wheat in the cropping system can suppress weed growth. Fast growing crops, crops exhibiting allelopathic properties and cover crop residues on the soil surface will suppress weeds by shading and cooling of the soil.
	Intercropping: intercrops are able to suppress weeds. Intercrops can greatly reduce the yield of the main crop if competition for water or nutrients occurs, and the aim therefore should be to search for synergism.
	Mulch smothers the emerging weeds by reducing the amount of light. It also makes it physically harder for the germination of weeds, since it is difficult to push through the mulch.

	Tillage systems: alter the soil seed bank dynamics and depth of burial of weed seeds. Almost 75% of the weed seed bank is concentrated in the upper 5 cm of the soil in no-tillage fields. In the mouldboard plough system, the seed bank is more uniformly distributed over depth.
Mechanical weed control	*Cultivator settings:* correct setting of the cultivator very important to avoid damage to the roots of growing crop. Cultivators most effective when weeds are small (2-9 cm tall). Depending on the row spacing, the adjustment lever is used so that inter-row weeds are disturbed. Standard tines are used for all weeding purposes.
	Timeliness in the use of cultivators for weeding is very important. Once weeds are taller than 9 cm it becomes very difficult to use the implement.
Chemical weed control	*Advantages of chemical weed control:* herbicides allow the farmer to control weeds where row cultivation is impossible and reduce the number of tillage operations as well as the critical timing needed for operations.
	Disadvantage of chemical weed control: injury to non-target species, crop injury, carryover, container disposal problems and groundwater and surface contamination which is associated with health risks.

Definition

Economic threshold of weed control is the **c**ritical period of weed control which is an important concept in integrated weed management systems. The critical period has been defined as the interval in the life cycle of the crop when it must be kept weed free to prevent a possible yield loss.

Crop	Critical period for weed control
Maize	3rd to 8th leaf stage
Soybeans	1st to 3rd trifoliate stage

Activity

Activity 6

Group activity

What do farmers in your area do to manage weeds and pests? How do these methods match with the integrated weed management principles and methods discussed? Thinking of labour, costs, accessibility and knowledge involved, come up with advantages and disadvantages of each method.

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4.6 No tillage system[10)]

No land preparation (ploughing, discing, etc.) is done prior to no-tillage planting. Earthworms perform the necessary ploughing function along with mulch and the soil becomes more sponge-like. The practice is to plant directly into the soil in one trip over the field, by opening a narrow trench in the soil into which the seed and fertiliser are placed. This is usually done with a ripper or no-tillage planter. In most no-tillage systems, no land preparation or cultivation is done during production.

The hard pan is best corrected by ripping with a ripper. Tips for ripping:

- Rip when the soil is dry to shatter the hard pan
- Follow the contours

Figure 7.Roots deformed by a hardpan. The roots cannot reach water and nutrients in the soil beneath the hardpan[10)]

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My notes............

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Authenticator: Mr Michael Kidson

Module 4a

Cotton

1. Introduction

Cotton is originally a tropical plant but by A.D. 1000 had spread to subtropical areas of both hemispheres. All but four species are wild shrubs that grow in relatively arid areas. During the industrial revolution cotton developed into a dominant fibre type and was then grown on an industrial basis, particularly in the USA. Early Portuguese explorers found natives in southern Africa growing cotton and making fabrics from it as early as 1516. This belongs to the wild species *(G herbaceum*) which has short spin able fibres and originated near what is now the northern tip of the Kruger national Park.

The word "cotton" comes from the medieval Arabic word "kutn", which means a plant found in conquered lands, a reference to Alexander the Great's conquest of India in 327 BC.

In 1516, a certain Barbosa met natives in South Africa who grew cotton and wore cotton clothing. This was the wild species of which still exists today. The first cottonseed was planted in 1690 in the Western Cape, more or less 40 years after the arrival of Jan van Riebeeck. Cotton however requires relatively warm climate and requires substantial amount of moisture for the seed to germinate[7]. American upland cotton was introduced into the Amanzimtoti area of South Africa in 1846 by Dr Adams and was regularly grown in Natal and the Cape Colony from 1860-1870 due to the demand for this fibre which has arisen as a result of the American Civil War. Unfortunately, insect pests ravaged those early crops resulting in disappointing yields. It was not until after the First World War, when prices were high, that the crop expanded[7].

The turning point for cotton production in South African occurred in the 1950s when the Cotton Pest Research Team in Gatooma, Zimbabwe, demonstrated that pests could be controlled by insecticides. High yields of cotton could now be reliably produced and once again cotton production began increasing.[7]

2. Production[1,2,12]

In 1974, due to record prices, the crop rocketed to 205 000 bales and in 1980 South Africa reached self-sufficiency for the first time when just over 300 000 bales of lint were produced. Unfortunately drought and poor prices in 1981 and 1982 caused a drop in production and only 104 000 bales were produced in 1983. The hectares planted pertaining to seed cotton purchases by RSA and Swaziland ginners can be seen in Table 1:

Table 1. The hectares planted pertaining to seed cotton purchases by RSA and Swaziland ginners [13]

YEAR	IRRIGATION (ha)		DRYLAND (ha)		TOTAL (ha)	
	RSA	Swaziland	RSA	Swaziland	RSA	Swaziland
1990/91	32155	181	58696	35325	9114	35505
1991/92	19048	81	28711	30000	47759	30081
1992/93	7240	102	27886	17277	35126	17379
1993/94	11258	1139	55941	11548	67199	12687
1994/95	19038	662	35096	11988	54134	12650
1995/96	17609	385	72809	19007	90418	19392
1996/97	15954	0	67017	40473	82971	40473
1997/98	20361	400	69578	30998	89939	31398
1998/99	31263	450	67356	32932	98619	33382
999/00	10486	0	40282	23875	50768	23875
2000/01	19379	0	38153	16694	57532	16694

The production areas for cotton in South Africa include Limpopo, Mpumalanga, Northern Cape, Northwest and KwaZulu-Natal (Table 2). Approximately 80% of the crop is grown in the

Limpopo, Mpumalanga, Northern KwaZulu-Natal and Swaziland. South Africa produced in 99/00 approximately 47 514 metric ton cotton lint and 75 057 metric ton lint was consumed. 60% of this consumption was produced in South Africa, while the rest was imported.

Table 2. Production areas for cotton production in South Africa[1,2]

PRODUCTION REGION	HECTARES IRRIGATION	HECTARES DRYLAND	YIELD IRRIGATION kg seed cotton/ha	YIELD DRYLAND kg seed cotton/ha
LIMPOPO PROV.				
Loskop	2350	0	3800	0
North & South Flats	58	292	2500	800
Dwaalboom/Thabazimbi	90	0	3800	0
Weipe	1422	0	4000	0
NORTHERN CAPE				
Vaalharts	1909	0	5000	0
Lower Orange River	200	0	5000	0
Rest of Northern Cape	5215	0	4481	0
NORTH WEST				
Stella/Setlagoli	0	0	0	0
Taung	460	0	5000	0
KWAZULU-NATAL	0	490	0	600
MPUMALANGA	0	703	0	583
EASTERN CAPE	0	0	0	0
RSA TOTAL	**11704**	**1485**	**4385**	**631**
Swaziland*	0	4000	0	550
Botswana*	0	0	0	0
Namibia*	0	0	0	0
Zimbabwe*	0	0	0	0
Mozambique*	0	0	0	0
GRAND TOTAL	**11704**	**5485**	**4385**	**572**

** Particulars relate to expected purchases of seed cotton by RSA & Swaziland ginners from these countrie*

3. Morphology and growth of the cotton plant[1,9]

The cotton plant is a woody shrub that grows to a height of 0.5-2 m, depending on the season. It has an indeterminate growth habit i.e. there are not a fixed number of nodes and size of plant therefore depends on the growing conditions.

- It grows very slowly above ground during the first six weeks after germination, but below ground it develops a deep taproot that can grow up to 25 mm per day. It is this strong taproot that is the main contributing factor to its drought resistant properties. The time required from germination to the appearance of the first buds is about 6 weeks. This is perhaps the main reason why the cotton plant is so sensitive to weed competition during this period.
- In the following 2 weeks, the first flowers are visible. The flowers are yellow on the day of opening, turning red the next day and dying on the third day. The dry flower is pushed off as the boll grows.
- Two months after flowering, the green bolls which are the size of a small hens' egg, split or open, exposing the white seed cotton which comprises about 34% lint and 66% seed (by weight).
- The bolls open over a two-month period in the same order they flowered. The early bolls are borne near the ground and main stem; the last bolls are at the top of the plant and at the extremity of the branches. Each plant can produce up to 50 bolls, depending on plant population, length of season and availability of moisture. Each boll contains about 30 seeds and each seed produces from 2000-7000 fibres, a remarkable 3-5 kilometer of fibre per boll.

There are two types of branches produced on a cotton plant and each node on the main stem has the capacity of producing one or the other.

1. Vegetative branches (*Monopodia*). The plant normally produces only 3-4 vegetative branches at the base of the plant, although the number will vary with variety, season, weed competition and plant spacing. The main stem branch is also a monopodium. Vegetative branches continue to make leaves until some stress causes them to stop.
2. Fruiting branches (*Sympodia*). These branches are the only ones that carry bolls. They are sometimes called zigzag branches because of the way they develop. The first fruiting branch normally occurs at the 4-6th nodes from the bottom of the plant. The tendency to develop sympodia depends on the variety and the environment. Moderate day and cool temperatures favour sympodia development. Competition for space early in the life of the plant will make it leggy and force the first fruiting branch to be produced on a higher node. As it takes about 6 days for each branch to develop, this means boll formation is delayed, which can reduce yield potential.

The cotton plant requires high temperatures, lots of sunshine, low humidity, about 600 mm of well distributed rain or irrigation and seven frost-free months to grow well. It is best suited to medium to heavy textured soils, which have good drainage, adequate natural fertility, and good water holding capacity and protection from erosion. Cotton should not be grown at altitudes above 1200 meters due to the lower temperatures linked to higher altitudes which restrict growth and fruiting. The best cotton is grown under irrigation in the sunny Lowveld areas below 600 m above sea level, where yields as high as 5 tons have been achieved.

Cotton is, however, drought tolerant and dryland yields of up to 1,5 tons can be achieved in areas below 1 000 altitude with as little as 400 mm of rain during the growing season, providing it is well distributed.

Under normal conditions of temperature and moisture, the root emerges from the seed after 15-20 hours and starts growing very rapidly. By the time the cotyledons have expanded, the root can be 20 cm deep. Temperatures below 18°C will adversely affect germination and increase the chance of seedling disease. Taproot growth stops at temperatures below 15°. It is therefore important to delay planting until the average soil temperature has reached 18°C, measured 10-15 cm below the surface of the soil at 8 am. Very wet or compacted soils will also seriously reduce root development. Problems arising from adverse growing conditions during the seedling stage can have long-term effects on cotton plant growth. Experiments in the United States of America showed that if seeds were chilled for 6 days at 10°C just before emergence, the first flower was delayed by 10 days and the yield at first pick could be reduced by up to 30%.

The young cotton plant pulls itself through the soil to emerge from the soil 5-7 days after receiving moisture. Best germination will be achieved if the seed is 10-20 mm deep (provided that the seed can be kept moist). If the seed is planted too deep, the young arched stem is unable to push through the soil (especially if the soil surface forms a hard crust).

The stem then breaks and the plant dies. Planting depth is therefore of paramount importance for healthy plant growth.

The initiation of the flower bud occurs about 5 weeks before flowering. Growing conditions at this stage will therefore influence the development of the boll. For example, environmental effects influence the number of locales (or segments) produced by a boll. The position of the first sympodia can be influenced by late thinning or early weed control. The first buds or 'squares' become visible about 5-6 weeks after germination and the first flowers about two weeks later.

Cotton is over 90% self-pollinated. Fertilization takes place on the day the flower opens (yellow). The next day the flower turns red and then is squeezed off by the growing boll. Temperature and humidity can adversely affect fertilization.

The improperly fertilised flowers usually result in one locule failing to develop, giving rise to malformed bolls called 'parrot beak'. The date of first flower is when 50% of the plants have one yellow flower. The boll grows most rapidly 15-18 days after flowering, reaching mature size 25 days after flowering. This coincides with fibre elongation (which is genetically determined). Secondary wall thickening strengthens and matures the fibre. This continues until the boll matures and cracks about 8 weeks after flowering, but the maximum deposition occurs from 30-40 days after flowering. Fibre maturity and the time to boll burst is temperature dependent. Maximum temperatures above 40° as well as the minimum night temperature will both affect production. Fibre thickening ceases at temperatures below 13°C and the period from yellow flower to boll burst can take as long as 85 days at the end of the season compared to only 55 days initially. A late-planted crop can therefore take as long as 190 days to mature compared to about 140 days if planted at the optimum time.

Example

Work in California has shown that four temperature factors could explain 76% of the yield fluctuations over an 18-year period. These are:

1. Cool weather during seedling development (equivalent to mid October – mid November in South Africa).
2. Heat (number of degree-days with a maximum temperature above 38° during a period equivalent to February 1 – March 3 in South Africa).
3. Hot nights (number of degree-days with a minimum temperature above 20°C during a period equivalent to January 15-February 14 in "South Africa).
4. Cold nights (number of degree-days with a minimum temperature below 16° during a period equivalent to December 15 – January 30 In South Africa).

(It must be noted that the Californian cotton crop is irrigated and planted at a time equivalent to mid October in South Africa).

The potential yield of cotton in South Africa can be calculated by determining heat units for the various areas over the 7 months growing season (October-May).

Heat units for a specific day = <u>(max temp+min temp) – base temp</u> / 2

$$\text{Heat units for a specific day} = \frac{(\text{max temp} + \text{min temp})}{2} - \text{base temp}$$

Normally: i) maximum temperatures above 30°C are taken as 30°C
ii) minimum temperatures below 10°C are taken as 10°C

With this method, the flowering dates of male and female plants on a land are synchronised for the production of hybrid seed or for plant breeding (the male and female plants are planted at different dates to have them flower at the same time). It can also be used for the scheduling of an orderly pattern of harvesting.

Information required:

1. Base temperature for a specific crop i.e. cotton=16°C; maize=10°C and wheat and peas =4°C
2. Amount of accumulated heat units required for the growing season or part of the growing season. It is important to take that into consideration for different cultivars. Information is available from seed companies.
3. Temperature data: can be obtained from automatic weather station or own records of data.

- If over 3 000 heat units, irrigated cotton will easily produce over 3 000 kg/ha.
- If 2 500 heat units, irrigated cotton will produce 3 000 kg/ha only with very good management.
- If below 2 200 heat units, irrigated cotton will produce 3 000 kg/ha only with great difficulty.

The first boll develops on the first node of the bottom sympodia branches of a cotton plant over a 75-day productive flowering period.

Cotton evolved as a desert shrub and man has improved it to produce consistent survival traits under stress progresses. Indeterminate plants or plants that grow rank especially under cloudy overcast conditions can shed up to 70% of the total number of bolls produced. Cotton grown in South Africa seldom sheds less than 50%, mainly due to the overcast wet (and often cold) weather that occurs during the boll formation period. Bolls produced next to the main stem are less likely to shed than those produced at the end of the same sympodium. Although natural shedding is inevitable, management can however, modify it.

4. Climatic and soil requirements[1,10]

4.1 Climate

Temperature

Temperature plays a dominant role throughout the growth period of the plant and has a decisive influence on fibre yield and quality. High temperature gives high yield of high quality. Cotton doesn't grow well below 10°C and need a high quantity of heat units.

Sunlight

Cotton grows best in areas where 60-90% of daylight hours are sunshine. Excessive cloudiness (more than 50% cloud cover) results in retarded growth and an increased loss of flower buds and young bolls through abscission or falling off. Long overcast period during the ripening stage will decrease the yield and the quality.

Moisture

The rate at which a cotton plant takes up water depends on the availability of moisture in the soil and also on other factors such as high soil and air temperatures and good soil aeration. Cotton is inherently fairly drought-resistant, and its strong root system improves this resistance. For maximum production sufficient moisture is essential, especially during the flowering and fruiting stages. Drought during these stages of growth results in excessive shedding of flower buds and young bolls. Enough water especially during the peak flowering and bulb formation stage results in high yield of good quality.

Hail

The crop is very sensitive to hail damage. Areas subjected to sever hail should be avoided.

4.2 Soil requirements

Cotton grows well on a wide range of soil types, its main requirement being an adequate rooting depth. Anything, which restricts the depth of rooting, reduces growth of the aboveground parts of the plant, and this limits the cropping potential. The most common restriction is waterlogging, and good drainage is therefore important. Shallow soils overlying impermeable rock are unsuitable, but good growth can be achieved in rocky and stony soils where drainage is not impeded. A hard pan can restrict root development. It may be advisable to break up the pan occasionally; this may be a plough pan caused by repeated ploughing at the same depth, or a laterite or ironstone pan formed by the weathering of minerals in certain types of soil. Soil compaction by the passage of farm machinery can also restrict root development.

Cotton grows satisfactorily in sandy soils. What is called 'black cotton soil' is not necessarily the most suitable soil for cotton. It is a popular rather than a scientific term, covering a range of soils with differing characteristics. Cotton should be well drained. Cotton requires a firm, uniform seedbed of a fine tilth.

Cotton tolerates a fairly wide range of soil acidity and alkalinity; it stands acidity as well as most major crop plants, and can stand high pH values better than most.

5. Cultural practices

5.1 Seedbed preparation

The cotton plant has a very deep and extensive root system, which is an important resource that should be exploited to the full. Cotton roots can penetrate 180 cm, and 90 days after planting there can be as many roots at a depth of 120 cm as in the topsoil. This network of roots covers a very large volume of soil, which enables the plant to obtain water even under very dry conditions.

Cotton seedlings are very sensitive, and to enhance germination and the developing of the root system, a fine seedbed is important. The seedbed has to be firm, and prevent too deep planting.

Good quality cotton seed has a high germination rate, but a fine, firm seedbed is essential to obtain a good stand.

5.2. Planting date

One of the most important factors determining the planting time for irrigated cotton is soil temperature. Cotton should not be planted before the top 30 mm of the soil has maintained a minimum temperature of 17°C for approximately 10 days. This means that the second half of October to mid-November can be considered the best planting time for all the cotton-producing areas of the Republic.

If the soil temperature is too low, germination is slow. Together with the severe incidence of seedling diseases ("damping-off") at low soil temperature, this causes a poor stand, which is one of the most important disadvantages of too early planting.

With early planting there are advantages of higher yields and better fibre quality. Since red bollworm and red spider mite usually occur later in the season, these pests can be partially avoided. When planting is delayed, pest control later in the season is of greater importance and early cold weather can also affect the yield and quality of the fibre. Therefore: Plant cotton during the second half of October (that is when soil temperature reaches 16 to 18°C).

A uniform planting depth is promoted by an even seedbed of fine structure, but it must be firm and moist. Plant the seed about 25 mm deep in clayey soil, or to a maximum of 50 mm in sandy soil for the development of a strong, healthy seedling.

To ensure a good stand, a high seeding rate is applied and plants are thinned later. At a dense seeding rate the tender seedlings help each other to emerge. With acid-delinted seed a seeding rate of 20 to 25 kg/ha is sufficient. The best stands are obtained where the seed is lightly pressed into a firm damp seedbed and covered with loose soil. The soil above the seed should be compressed as little as possible. A light irrigation of 15 to 20 mm after planting, or during emergence will promote a good stand. If rain compact the soil, the surface can be lightly loosened with a spike-tooth rotary cultivator before emergence.

5.3 Planting method

Various mechanical planters for cotton planting are available in the RSA for cotton planting. The correct choice of planter plates is important to assure dense planting of seed. Precision planters which space seeds in groups of three to four at desired intra-row spacing are also on the market. This facilitates thinning afterwards to the required plant population. Planting to stand is only advisable under conditions that are extremely favourable for germination and emergence. Optimum soil temperature and moisture and seedbed condition are essential.

5.4 Plant spacing and row width

It is most important that plant population and therefore spacing be adapted to local conditions. In this way the best use is made of the available climate condition and water availability.

Cotton is usually planted in rows spaced one meter apart. Using skip rows it is possible to control weeds by mechanical means. Research showed an increase in yield under irrigation with an interrow spacing of 600 to 750 mm. plant populations of about 70 000 plants per hectare under irrigation and about 30 000 plants per hectare under dryland are considered ideal. Plant population can also be used to reduce the detrimental effect of a very late planting date. Under these conditions a high planting population resulting in more competition between plants forcing the plants to complete the growth cycle sooner and higher yields are obtained.

5.5 Thinning

Cotton is planted much denser than required, to ease the mechanical resistance of the soil during germination, as well as to ensure optimum plant population. This necessitates subsequent thinning of the plant population to remove surplus seedlings. If thinning is delayed too long, "long-legged" plants result which carries fewer bolls and lodge easily. Too dense a stand results in excessive competition between plants. This increases the moisture stress in the plant and results in shedding of squares and young bolls. Thinning may start within three weeks after emergence when the plants are 15-20cm high, but must be completed when seedlings are six weeks old.

In the case of irrigated cotton, the stand is thinned to a spacing of 120 to 200 mm in the row. The plant population and spacing for dryland cotton will depend on local conditions.

PRACTICAL TIP

Thinning is a simple but very important action done by hand. The use of thinning sticks makes this task easy and accurate. Lengths of twigs, polythene piping, or even khaki-bush stems can be cut to the desired length. The end of the thinning stick is placed against-the first seedling of a row. All surplus seedlings along the side of the stick are removed. A seedling is left close to either end of the thinning stick. Where wider gaps occur in the seedling row, two seedlings are left together in the open spaces. The labourers soon learn to judge the spacing and dispense with the stick.

5.6 Replanting

Producers must consider the feasibility of replanting when poor population was obtained after germination. Plant date, available soil water and cultivar play an important role. Plants of cultivars with a strong vegetative growth will topple at very low plant populations and this can create problems at harvesting. Under dryland conditions is a plant population of below 15 000 plants per hectare not desirable.

5.7 Irrigation [11,1]

Irrigation guidelines for successful cotton production:

Cotton yield is directly proportional to the amount of water consumed. Cotton under good management should yield 0.6 kg cotton seed /m^3 consumed.

Table 3. Approximate irrigation requirements of cotton planted in different climate regions on a loam soil under centre pivot irrigation

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm)
Dry, hot west (N Cape) 15 Oct, peak Jan	250	190	820	250
Dry, hot, east (dry bushveld) 15 Oct, Peak Jan	490	365	460	125
Humid, hot summers (wet lowveld) 15 Oct, Peak Oct	715	390	145	35

- *Germination of the seed*
  Soil should be at field capacity to a depth of 100cm at the time of planting. To ensure fast germination and emergence of cotton, it is essential that the seed should be firmly in contact with the soil.
- *Emergence*
  A light irrigation should be applied immediately after planting (15-20mm water). This would replenish the soil

water and ensure good contact between the seed and the soil. After emergence no irrigation is required for the next three weeks. If the so-called "stress period" after emergence where no irrigation is incorrectly applied may damage the crop. Irrigation can start 3-4 weeks after planting, when the top soil has dried out. An application of 20-25mm/ha per irrigation is usually sufficient.

- *Mature cotton*

  The water consumption of cotton increases as the leaf surface area increases, and reaches a maximum as soon as the leaf canopy covers the total soil surface. Cotton develops a full leaf canopy between 80-100 days after planting. This stage also coincides with the peaks of flowering and boll setting, with the result that cotton is very sensitive to water stress at this stage.

6. Fertilization of cotton [1,10]

Soil analysis is important in the determination of fertilizer requirements and the possible improvement of soils on which cotton is cultivated. It is recommended that representative samples of the topsoil and the subsoil have to be taken and analyses by a reliable laboratory.

Cotton does not perform well on acidic soil, particularly not if the acidity is associated with aluminum toxicity. Such conditions are usually associated with pH values lower than 5.5 as measured in a saturated water paste. The type of lime and amount are depending on the pH level of the soil, texture and cation exchange capacity or basic saturation of the soil. If liming is required, it must be applied before planting and be well incorporated.

The use of gypsum to improve ameliorate of the soil can sometimes be justified when the soil has high levels of exchangeable sodium or when the calcium content is relatively low compared to the magnesium content.

When the fertilization requirements are determined for cotton planting, it is important to consider the yield potential and the set target yield. Table 7 shows the amount of each of the three macro elements (per hectare) taken up by the cotton plant. It is clear from this table that the fertilizer requirements for a dryland crop in Limpopo of 700 kg/ha will require less nutrients than to produce a cotton crop under irrigation in Limpopo of 4 t/ha.

Table 7 Nutrient requirement for the production of the different cotton yields

Seed cotton yield (kg/ha)	N	P	K
1000	90	15	60
1500	140	18	65
2000	180	20	70
2500	215	28	85
3000	230	30	100
3500	240	30	115
4000	245	30	130
4500	250	30	140

Nitogen (N)

Sufficient nitrogen is required for obtaining of a good cotton yield (Table 7).When the nitrogen amount required for a specific target yield is determined, the following factors must also be taken into consideration: residual inorganic nitrogen (plant-available nitrogen) present in the soil, soil with high mineralization potential, and the nitrogen content in the irrigation water (nitrates).

If 30 kg/ha residual nitrogen, 60 kg/ha mineralized nitrogen and 32 kg/ha nitrogen obtained from irrigation water are available, the total amount of N available for actual utilization by plants will be 122 kg N/ha. According to Table 7, and amount of 250 kg N/ha is required to achieve a target yield of 4500 kg cotton/ha. In this case of abovementioned example, there will be a shortage of 128 kg N/ha. The amount of nitrogen that has to be applied is calculated at an 80% utilization of the applied nitrogen:

128 x (100/80) = 160 kgN/ha.

In this case of the example, it can thus be assumed with a high degree of certainty that 180 kg N/ha will be sufficient for the production of a good yield of 4500 kg cotton/ha.

It is generally accepted that plants take up more than 70% of their total nitrogen within the first 13 weeks after planting. It is recommended that nitrogen should be applied in installments, particularly on light soils, and that the full application of nitrogen should be completed by week 9 after planting. The ninth week usually coincides with the first bloom.

Phosphorus (P)

Although cotton does not exhibit a very strong response to applied phosphorous, it is important that phosphate fertilizer should be applied to ensure the maintenance of reserves and to supply the nutrient requirements of cotton. The amount of phosphorus required to supply the nutrient requirements is revealed in Table 8.

Table 8. Phosphorous fertilization in kg/ha for achievement of different target yields (kg/ha)

Phosphorous analysis (Bray 1)	Target yields (kg/ha)			
	1000	**2000**	**3000**	**4000**
<10	15	20	30	30
11-15	10	15	20	25
16-20	0	10	15	15
21-25	0	0	0	0
26-30	0	0	0	0
31-40	0	0	0	0

Potassium (K)

Potassium plays an important role in the nutrition of the cotton plant and fairly large amounts of potassium are taken up (Table 7). However the response to applied potassium is usually not dramatic and the reason is that cotton is generally cultivated on soils that contain sufficient amounts of potassium. Cotton's potassium requirement is indicated by the amount of extractable potassium in the soil and the potassium balance relative to other basic cations.

Micro elements

Deficiencies of micro- elements are not really mentioned in respect of cotton in South Africa, but because cotton can utilize large volumes of soil with its extensive root system, it extracts sufficient amounts of micro-elements form the soil.

7. Growth regulation as management aid in cotton production[2,4,5]

High temperatures, optimal irrigation and fertilization practices, or prolonged periods of rain and cloudy weather can cause extremely vigorous growth in cotton. Extensive vegetative growth in cotton can be detrimental to cotton yield, and also cause difficulty with harvesting since the rank growth causes shedding of the squares and young bolls. These two factors also provide a favourable environment for the development of boll rot and other pathogens.

Mepiquat chloride (PIX) can control the excessive growth of cotton plants. It reduces the height and canopy and allowing better light and air penetration into a leaf canopy. As a result fewer bolls are shed on the lower branches. The problem of excessive growth starts during the period of rapid growth that occurs from square formation till early flowering (50-80 days after emergence). During this period the leaves are active and high levels of carbohydrate is produced while there are only a few small bolls that can utilize these reserves. The application of PIX during this period is recommended.

Application of mepiquat chloride:

- First application: at the appearance of the first flower buds or advanced flower bud stage when plants should be approximately 25cm in height
- Follow up application depending on the tempo of growth, normally every two weeks. The intervals between applications may be extended to 18 days when moderate growth occurs.
- Final application should be made at the end of the effective flowering period.

8. Weed control

The implementation of an effective weed control program starts with the preparation of the seedbed and is a prerequisite for optimum yields and good fibre quality. To ensure that the seedbed is free of weeds, the field can be irrigated two weeks before planting (if possible) to stimulate the germination of weeds. These weeds can be destroyed before planting by means of a light tilling.

Weeds that germinate during the first 6-8 weeks after planting compete with the young cotton plants for space, light, water and nutrients. Effective weed control during this period is very important since young cotton plants damaged by competing weeds, hardly ever recover. To control these weeds pre-emergence herbicides can be used at the time of panting.

Chemical and mechanical weed control must be integrated with each other. Post emergence mechanical weed control through tilling has the added advantage of breaking up the soil surface that has become compacted as a result of irrigation or rain, and therefore improves the soil water infiltration at the same time. The disadvantage with mechanical weed control is the soil compaction of the basal soil layers which impedes root growth.

Important rules in the application of herbicides:

- Identify weeds correctly and determine the scope of the problem
- Know the soil type involved
- Choose a herbicide suitable for the circumstances under which it will be used
- Do not exceed the dosage instruction given on the herbicide container
- Ensure that the spraying equipment is correctly calibrated
- Use only a flat fan nozzle for the application of herbicides

Genetically modified cotton[2,13]

Cotton cultivars that are genetically modified to contain the Bt gene and/or the glyphosphate tolerant gene, are now available. The Bt gene control bollworm complex while glyphosphate, used for control of weeds, can be sprayed directly onto cotton cultivars that contain glyphosphate-tolerant genes, provided that certain guidelines are followed. Producers who want to plant these cotton cultivars should contact the seed merchant who supplies these cultivars for seed. The GMO Act, Act 15 of 1997, controls all genetically modified crops in the RSA.

9. Physiological condition : early senescence (red leaf disorder)

This is an abnormality where the leaves age prematurely and are even shed. This occurs mainly in cotton cultivated along the Lower-Orange River, although it was found elsewhere in South Africa. Early senescence is a physiological condition, known as “premature senescence”. The first signs or early senescence are usually observed in February, when the leaves begin to yellow. Initially, the older leaves of the plant discolour and turn red to brownish yellow or bronze-coloured, but later the symptoms also spread to younger leaves. Early symptoms of senescence can be mistaken for verticillium wilt, because the symptoms are sometimes very similar.

Possible control measures include the following:

- Prevention of unfavourable conditions is most probably the most important control measure.
- Potassium deficiencies should be prevented by ensuring that potassium levels of the soil are satisfactory before planting.
- Essential that sufficient nitrogen should be available to the plant.
- Waterlogging as well as water stress should be prevented. Moisture stress must be avoided since it determines the number of bolls produced.
- Consider tolerant cultivars wherever their use is practical.

10. Pest and disease control[1,13]

Many insects occur on cotton, but not all of them are necessarily pests. The most important cotton pests can be divided into three groups namely:

- Bollworm complex (American bollworm, red bollworm, spiny bollworm, cotton leafworm and cutworms)
- Spider mites (red spider mite, two spotted spider mite, crimson spider mite and dark red spider mite)
- Other pests (cotton leaf miner, American leaf miner, whitefly, thrips, cotton strainers,etc).

The first two groups can be considered as the “key pests” since their control may affect the incidence of the third group. Injudicious control of the bollworm at the beginning of the production season often results in the build-up of mite and some other pest populations at a later stage. The reason being that so called ‘hard” insecticides, that destroy the natural enemies of the mites and other pests, are used. In the absence of natural enemies the mites and other pests can quickly multiply to large populations. Sensible control of especially bollworm holds the key to efficient control of cotton pests. For the control of bollworm, producers can use chemical control measures as in the past or the use of cotton cultivars resistant to bollworm.

Following the principles of integrated pest control can create conditions where the biological control of spider mites and some other pests is encouraged. The advantage of it is that these groups seldom achieve pest status. Integrated control includes the use of a combination of pesticides based on thorough scouting, as this will encourage the use of so-called "soft" insecticides that do not destroy the natural enemies of pests.

The following integrated control strategy for bollworm is recommended:

Time in the season	Action
Early season (0-6 weeks) after emergence	Scout weekly When seed treatment is used, spraying often not required In case of thrips, use endosulfan spray
Early middle season (7-12 weeks) after plant	Scout weekly Spray preferably endosulfan when bollworm density equals or exceeds the threshold. Do not use "pyrethroids"
Late middle season (13-18 weeks)	Scout weekly Spray preferably endosulfan when bollworm density equals or exceeds the threshold. Do not use pyrethroids or other "hard chemicals". Only use pyrethroids or other hard chemicals when very large infestation of bollworm occurs.
Late season (19-22 weeks after emergence)	Cease scouting One pyrethroid spray if red bollworm or cotton strainers occur Control aphids, mites, whitefly and leafhoppers if necessary

11. Harvesting [1,10]

- **Mechanized picking**

For the mechanizing of the cotton picking process and to ensure a smooth picking operation and cleaner seed cotton, it is advisable to defoliate the cotton plant. Natural defoliation occurs late in the season but it is not always complete.

For successful defoliation the condition various factors should be taken into consideration:

a. Plant condition
   - Physiological maturity – when the plant's active growth ceased.
   - Nutritional and moisture status of the plant: defoliants are less active when the cotton plants are wilted.
   - Maturity of the bolls: the translocation of carbohydrates to the green bolls virtually ceases when the crop is defoliated. To prevent a loss in the yield, make sure that as many bolls as possible must be fully mature before the plant is defoliated.
   - Boll rot: rainy weather and high humidity towards the end of the growth period promote boll rot, and under such conditions it may be advisable to defoliate the lower parts of the cotton plant.

b. Weather conditions

   The physiological processes that occur during shedding of the cotton leaf depend on temperature. Defoliation is more successful under warmer conditions, but retarded when day temperatures are lower than 21°C.Wind also affects the coverage obtained during spraying.

Defoliation is usually completed within 7 days, but under cool conditions can take longer. A wide variety of chemicals have been developed for defoliation of cotton, and the list of registered defoliants is available in: *"A guide for the use of plant growth regulants, defoliants and desiccants",* which is obtainable from the Department of Agriculture in Pretoria.

- **Hand picking**
  It takes a boll at least 40 days to mature physiologically, and another 5-10 days pass before it opens and starts to dry out. Depending on weather conditions (humidity and temperature) cotton is usually pickable 50-60 days after flowering. Training of labourers in hand picking is very important for optimal production.

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Module 4b

Sugarcane

1. Introduction

It was in India, between the sixth and fourth centuries BC, that the Persians, followed by the Greeks, discovered the famous "reeds that produce honey without bees." They adopted and then spread sugar and sugarcane agriculture throughout the world. A few merchants began to trade in sugar – a luxury and an expensive spice until the 18th century. Prior to 18th century, cultivation of sugar cane was largely confined to India but spread rapidly and was introduced into South Africa ~1850.

The South African sugar industry makes an important contribution to the national economy, generating in the region of R6 billion in annual direct incomes. The industry also provides significant employment opportunities, particularly in rural areas.

The South African sugar industry produces an estimated average of ~3 x 10^6 million tons of sugar per year (~~30 x 10^6 cane p.a.), which places South Africa amongst the top 10 producers worldwide. Sugarcane refers to any of six to 37 species (depending on which *taxonomic* system is used) of tall perennial grasses of the genus *Saccharum* (family *Poaceae*, tribe *Andropogoneae).* They have stout, jointed, fibrous stalks that are rich in sugar, and measure 2-6 m tall. *All sugar cane species interbreed and the major commercial cultivars are complex hybrids.*

The main product of sugarcane is sucrose, which accumulates in the stalk internodes. Sucrose, extracted and purified in specialized mill factories, is used as raw material in human food industries or is fermented to produce ethanol, a low pollution fuel. Ethanol is produced on a large scale by the Brazilian sugarcane industry.

2. Climatic requirements

Sugar cane grows best in warm, sunny, frost-free weather areas, between 15º and 30º latitude. For ideal growing conditions the growing season should be warm with mean day temperatures of 30ºC, with adequate moisture and incident solar radiation. For natural ripening, the ideal conditions are when mean temperatures are low (between 10ºC and 20ºC), but frost free. In South Africa these conditions prevail in winter (May-July). This causes sucrose content to peak in spring (August – mid-October). Harvesting and milling of cane take place both sides of the peak, starting in April and ending in December.

2.1 Temperature

Optimum temperature for sprouting (germination) of stem cuttings is 30 to 35°C. Optimum growth is achieved with mean daily temperatures between 22 and 30°C. Minimum temperature for active growth is approximately 20°C. For ripening, however, relatively lower temperatures in the range of 20 to 10°C are desirable, since this has a noticeable influence on the reduction of vegetative growth rate and the enrichment of sucrose in the cane.

Temperature and radiation are directly correlated with one another and these weather factors modify the time taken for plants to reach their full growth potential. A long growing season is essential for high yields. The normal length of the total growing period varies but it is generally 15 to 16 months. Plant (first) crop is normally followed by 8 to 10 ratoon crops, and in certain cases up to a maximum of 15 crops are taken, each taking about 1 year to mature.

2.2 Sunshine

The higher the incident radiation (up to full natural light intensity), the higher the expected yield. Light intensity and day length influence stem elongination. Under high light intensity sugarcane stalks are thicker and shorter. In poor light intensity, the stalks are thinner and longer, and the leaves yellowish in colour.

Significant yield increases can be obtained by proper weed control. Daylight has an effect on flowering.

2.3 Rainfall and moisture

Adequate supply of water is essential for cane growth. The crop grows well under conditions where rainfall is at least ~800-1100 mm (dryland) and irrigation up to 1500 mm. During early growth, sugarcane can tolerate mild water stress, but is most sensitive in the stalk elongation phase when adequate water supply is essential to limit yield loss. In irrigated areas water is withheld at the end of the growing season to facilitate infield harvesting operations as well as to ripen the crop (storage of sucrose in stems).

3. Soils

In general sugarcane is grown on a wide variety of soils, and four categories according to colour are often found in the sugar industry:

- Grey soils
- Black soils
- Red soils and
- Brown humic soils

The limitations of each soil group should be taken into account with the management of soil. Grey soils have the most limitations, followed by black, brown humic and red soil groups. The relative high surface run-off potential and low water holding capacity of the grey soil group underline the need for practices that conserve moisture and minimize run-off. Red and brown humic soils are as a rule well aerated and free draining. Where yellow or mottled colours appear, they are indicative of some restriction to drainage.

Soil type and slope should guide the grower in deciding on:

- Whether minimum tillage should be used instead of conventional tillage
- The method of eradicating the old crop
- The method and timing of seedbed preparation
- Optimum row spacing

Best soils are nevertheless those that are more than 1 m deep, but deep rooting to a depth of up to 5 m is possible. The soil should preferably be well-aerated and have a total available water content of 15 percent or more. When there is a groundwater table, it should be more than 1.5 to 2.0 m below the surface. The optimum soil pH is about 6.5 but sugarcane will grow in soils with pH in the range of 5 to 8.5.

4. Varieties

Varieties are classified as early, mid or late season varieties and should be planted accordingly. The following sugarcane varieties were approved for planting in 2012.

GOVERNMENT GAZETTE No. 35031, 17 FEBRUARY 2012
VARIETIES OF SUGARCANE FOR PLANTING EXCLUSIVELY WITHIN CONTROL AREAS
EACH CONTROL AREA for 2012:

- **Lowveld** N14, N17, N19, N22, N23, N24, CP66/1043, N25, N26, N28, N30, N36, N40, N41, N43, N46, N49 and N53
- **Pongola** N14, N17, N19, N22, N23, N24, CP66/1043, N25, N26, N28, N30, N36, N40, N41, N43, N46, N49 and N53
- **Umfolozi** NCo376, N12, N14, N17, N18, N19, N21, N22, N23, N24, N25, N26, N27, N28, N30, N33, N35, N36, N40, N41, N42, N43, N45, N46, N49 and N53
- **Felixton** NCo376, N12, N14, N17, N19, N21, N22,N23, N25, N27,N33, N35,N36, N39, N40, N41, N42, N43, N45, N47 and N51
- **Entumeni** NCo376, N12, N16, N17, N21, N23, N24, N25, N27, N28, N29, N31, N35, N36, N37, N39, N40, N41, N42, N43, N45, N47, N48, N50, N51 and N52
- **Amatikulu** NCo376, N12, N14, N17, N19, N21, N25, N27, N29, N31, N33, N35, N36, N39, N40, N41, N42, N45, N47, N51 and N52
- **North Coast** NCo376, N12, N14, N16, N17, N18, N19, N21, N22, N25, N26, N27, N28, N30, N31, N33, N35, N36, N37, N39, N40, N41, N42,,N43, N45, N47,N48, N50, N51 and N52
- **Midlands North** N12, N16, N21, N23, N25, N26, N27, N31, N35, N36, N37, N39, N40, N41, N42, N43, N45, N47, N48, N49, NSO, N51 and N52
- **Midlands South** N12, N16, N21, N23, N25, N26, N27, N28, N30, N31, N35, N36, N37, N39, N40, N41, N42, N43, N45, N47,N48, NSO, N51 and N52
- **Sezela** NCo376, NCo382, NSS/805, N12, N14, N16, N21, N25, N26, N27, N28, N29, N30, N31, N33, N35, N36, N37, N39, N40, N41, N42, N43, N45, N47, N48, N49, N50, N51 and N52
- **Umzimkulu** NCo376, N12, N14, N16, N17, N21, N25, N27, N31, N35, N36, N37, N39, N40, N41, N42, N43, N45, N47, N48, N50, N51 and N52

5. Production guidelines

5.1 Land preparation and planting (re-establishing)

Critical to the planting and subsequent growth of new sugarcane is the successful removal of old cane in order to ensure no “carry over” of diseased plants. This can be achieved *via* the use of appropriate weed killers and/or efficient mechanical control i.e. ripping, ploughing.

Cane fields are particularly vulnerable to erosion when they are ploughed and fallowed before replanting. Minimum tillage systems based on the use of chemicals is very effective in comparison to conventional systems of land preparation.

Tilth and timing of seedbed preparation is very important. With conventional land preparation, good tilth may be obtained depending the soil type. It is for example easier to achieve good tilth in black and red structured soils when the soil has enough moisture (under rainfed conditions usually during spring). Brown humic soils are not so sensitive to the moisture condition and can be worked virtually at any time of the year. The final tilth preparation should be done only a day or two before planting, and there is no need for field operations to depths greater than 150 mm.

Land preparation forms a very important part of cane husbandry, apart from disease and weed management. Poor land preparation and consequent poor and uneven germination must constitute one of the most important limitations to good yields.

5.2 Planting and plant density

Planting operations should be carefully planned ahead of the time. The planting operations influence the potential productivity of the field for an entire crop cycle, which may be between 10-15 years.

The following planting time is recommended according to the three main bioclimatic regions:

- **Semi arid northern region**
  Because of irrigation, moisture is usually not a limiting factor and temperatures are such that planting can be done throughout the year. Ideally, planting should be completed by early summer to give the crop the benefit of a full growing season. The incidence of smut disease is higher in fields planted in mid-summer, so spring and autumn plantings are preferable.

- **Midland misbelt region**
  In this region mosaic disease and temperature are the factors that prescribe the relatively short period when planting should take place. The plant crop is able to weather its first winter far better if a full canopy has been formed, so planting should be completed by October. Because the soil temperatures are low, it is unwise to plant before September. As a general rule, planting should range from mid September to end of October. For mosaic disease control, no planting should be done form the end of October till the end of February, as this will help reduce the incidence of mosaic. Autumn planting can be done provided the conditions are favorable for a good germination.

- **Coast lowlands**
  This region falls between the two extremes mentioned above. Planting can commence early in August and continue to the end of October. Autumn planting is also favored, but summer planting is avoided due to erosion hazard and the greater risk of contracting mosaic disease.

- **Spring and summer planting**
  Fields to be replanted should be planned for harvest? in May, June and July to afford the best chance of killing the old crop during the dry winter period. This means that the fallow, unproductive period is a long one. When the first good, summer rain falls, the field should be ridged, followed by immediate planting.

- **Autumn planting**
  It is often necessary for reasons such as high eldana infestations, labour shortage or a usually big plant program, to extend to autumn.

- **Winter planting**
  Not uncommon to plant some fields on the coast as early as July in order to spread the work load and to ensure that the planting program is complete before midsummer.
- **Chemical eradication of old crop**
  If Fusilade is used to eradicate the old crop, up to 56 days should elapse before planting as this chemical retards germination.

5.3 Row spacing

Single row spacing can vary from 1.0-1.5 m and will depend on variety, bioclimatic zone, land slope, soils, aspect (i.e. north/south slope, etc.) and irrigation and harvesting techniques (axel width of loaders and haulers). Should mechanical harvesting be contemplated, tram line rows could be considered as harvesters usually harvest two rows at a time. Under irrigation production, where soil moisture is limited, the distance between rows can be decreased within certain limits. Ratoon crop tram rows may yield similar to single rows but one must outweigh the higher cost of increased plant material required per hectare for the denser plantings.

i) Single row spacing

Row spacing		
Close (where land slope is steep, erodible soil types)	10000 m of line /ha	Cane rows at 1 m spacing
	9091 m of line/ha	Cane row spacing at 1.1 m
Intermediate (where soil depth is limited and rainfall low)	8333 m of line/ha	Cane row spacing at 1.2 m
	7692 m of line/ha	Cane row spacing at 1.3 m
Wide	7143 m of line/ha	Cane rows 1.4 m spacing

ii) Tramline row spacing

If mechanical harvesting is required, consideration may be given to tramline planting, for example 600 mm with interrow spacing of 1.4 m. The disadvantage would be the slow rate of canopy formation in the wide interrow which may cause problems with weeds. Tramline row spacing also limits compaction and stool damage during infield loading operations.

iii) Row spacing and crop characteristics

With close spacing competition for sunlight results in tall, thin stalks. Stalk populations reach a peak at full canopy stage, but subsequently stabilize at a lower level, as a result stalk mortality due to intense competition for light. Stalk populations at wide row spacing take longer to peak, have a less pronounced peak, but end up with a final population only slightly lower than that from close row spacing.

5.4 Ratoon management

Ratoon crop is the new cane which grows from the stubble left behind after harvesting the first crop. In the case of sugarcane the first crop is known as plant cane, and successive regenerating crops as first, second, third, etc. as ratoons. This enables the farmers to get up to 15 crops before they have to replant, all depending on how well the crop is looked after.

In principle the management of ratoon crops is similar to plant cane. The basic difference is the normally quicker achievement of canopy closure in ratoons.

Should it be necessary, weeds can be controlled by application of recommended weed killers. As soon as new cane growth is observed, a top dressing of fertilizer is applied according to soil sample recommendations. Most producers prefer to burn the cane prior to harvesting, which is mostly done by hand. There are short term advantages like mill throughput increase, sucrose extraction higher, extraneous matter lowered. The loss of soil and water leads to an inevitable drop in productivity in the long run. Green cane harvesting and the retention of a trash blanket (dead leaf material and cane tops) is not widely practiced. Advantages of such a production system include reduced evaporation loss and increased soil fertility.

6. Weed control

Weed control is usually, necessary in the first few weeks after planting of new cane or harvesting. Weeds are usually chemically controlled due to the high cost of manual control.

7. Fertilization

Cost effective fertilizer advice based on chemical analysis of soil and leaves are recommended. Threshold values established from a large number of trails by SASRI (SA Sugarcane Research Institute) are used for recommendations.

The following threshold values for soil apply:
Phosphorous (P): 31 ppm for plant can
11ppm for rations
Potassium (K): 112 ppm – clay content 30% or less
150 ppm – clay content 30%
225 ppm – >40% clay in the northern irrigated areas
325 ppm – >40% clay in northern areas, >4000ppm Mg+Ca, Winter cut
Calcium (Ca): 200ppm
Magnesium (Mg): 25ppm or if calcium is deficient 75ppm
Zinc (Zn): 1.5 ppm – on soils from the Midlands area where lime in excess of 3t/ha is recommended
1ppm – clay content >15%
0.5ppm – clay content 15% or less
Sulphur (S) 15ppm
Silicon (Si): 20ppm

More specific recommendations and advice available from SASRI extension services.

8. Irrigation

To ensure maximum income ***(PLEASE NOTE:* Income** – ***NOT yield)*** the application of irrigation water is essential, especially in the hot, dry regions of Northern KwaZulu-Natal, Swaziland and Mpumalanga. Irrigation is required to make the difference between evapotranspiration and the effective rainfall. Mainly three methods of irrigation are used for irrigation namely surface, overhead and drip irrigation.

The determination of WHEN and HOW MUCH depends largely on the accuracy with which the application of water is estimated. Knowing where to irrigate, when to start irrigating and when to stop irrigating, depends on knowledge of the amount of available soil water actually in the soil and drying off programs. This is usually determined by direct measurement of the soil moisture content or any other irrigation scheduling method like the use of SASCHED or MY CANESIM software specially designed for irrigation management of sugarcane.

Furthermore the life cycle of sugarcane should be understood. This is divided arbitrarily into FIVE stages namely:

Stage 1: Germination:	Up to time of rapid tilering	Vary with different varieties, seedcane quality, node position on the stalk and the soil and weather conditions
Stage 2: Juvenile	Until full ground cover is achieved	The time to reach full cover (when leaves meet in the interrow and intercept at least 85% of incident light) requires even population of shoots and good growing conditions with adequate water and nutrients necessary. No amount of irrigation or good management can however compensate for a patchy, uneven stand of sugarcane.
Stage 3: Early adult	The period of maximum stalk elongation	Volume of leaf material remains fairly constant during this period, and stalks elongate rapidly provided water and nutrients are readily available. The rate of cane and sucrose production per hectare per month remains constant or increases during this phase of growth.
Stage 4: Late adult	Characterized by a marked decline in growth rates	Rates of cane and sucrose production per hectare per month decline during this growth stage. This is probably due as much to actual crop size (or yield) as to age.
Stage 5: Flowering	Floral initiation takes place in sugarcane when day length is about 12.5 hours.	In South Africa this occurs between 1 March and 21 March when the daylight is approximately 12.5 hours. The number of days with daytime temperature higher than 30°C and night temperatures lower than 20 °C during this period will determine the severity of flowering.

Drip irrigation in Mpumalanga is applied every day since the average irrigation requirement is between 8 and 9 mm during summer. For design purposes, irrigation frequency (or cycle) is often calculated using a daily water consumption rate. This is equivalent to the average deficit between effective rainfall and crop water requirement (Et) of the three highest demand months. The RAW (Readily Available Water) of the soil is depleted at this rate, resulting in a specific number of days of water supply available to the crop without rain before irrigation must commence. In most case this would amount to a quantity equivalent to 50% of the TAW (Total Available Water), which is also called the Refill point. For some irrigation systems, e.g. centre pivot or drip systems, the soil are depleted to an amount which is typically applied by the irrigation system, e.g. for centre pivot irrigation applications of 25 mm is typical, while with drip irrigation, water applications should take place daily, replacing the evapotranspiration of the previous day.

Example

Example to calculate irrigation frequency
Dependent on total available water (TAW) in the soil profile, evapotranspiration and type of irrigation system

AWC (Available water capacity) = Field capacity (FC) – Plant Wilting Point (PWP)

TAW =AWC x effective depth

Et=E_o x crop factor

Soil: Hutton with 55% clay

FC = 300 mm/m
PWP= 100 mm/m
AWC= 200 mm/m
Root depth= 0.5 m
TAW= 100 mm
RAW=50 mm

If E_0 = 8 mm/day (50% crop cover)
Et = 0.7 x 8 mm
= 5.6 mm/day

Max time between irrigation applications to avoid stress
= 50/5.6
= 9 days

8.1 Planning of the irrigation scheduling programme

In order to PLAN the seasonal crop water requirement (and thus the volume of water required for irrigation application), recourse is usually made to the use of weather data and "crop factors" i.e.

Weather data

- ✓ Class A-pan evaporation data or
- ✓ Computer based models of atmospheric evaporative demand (" My *Canesim"* or SASCHED developed by scientists at SASRI

Crop factors
These are relationships between actual crop water demand (Et) and atmospheric water demand (Eo) i.e.
Crop factor (f) = Et/Eo

Example

Example 1: Calculation of the annual water requirement and the water allocation to a farm in KwaZulu-Natal

		IRRIGATION SCHEDULING	
CROP	SUGAR		TOP SOIL
FARMER	John	%SAND	48
ORCHARD Nr		%SILT	14
FARM NAME		%CLAY	38
TYPE OF IRRIGATION	DRAGLINES	%GRAVEL/STONES	0%
IRRIG. SYSTEM EFFICIENCY	70%	PROFILE DEPTH(mm)	1000
		WATERHOLDING CAPACITY (WHC)(mm/m)	270
PLANT DEC 2009		PLANT AVAILABLE WATER(mm/m)	135
RATOON DEC 2010		[Usually ~50% of WHC - #12]	
		MAX INFILTRATION(mm/h)	5
Conversion of l/s to m3: [60 x 60 x 24 x 365]/1000 = 31536 m3/y			

MONTHS	JAN	FEBR	MARCH	APRIL	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1.MONTHLY EVAPORATION (mm)	198	173	153	127	111	96	92	150	189	173	161	195
2.DAILY EVAPORATION (mm)	6.4	6.2	4.9	4.2	3.6	3.2	3.0	4.8	6.3	5.6	5.4	6.3
3.CROP FACTOR	0.9	0.92	0.93	0.91	0.88	0.82	0.78	0.74	0.72	0.74	0.81	0.85
4.NET DAILY WATER REQUIREMENT	5.7	5.7	4.6	3.9	3.2	2.6	2.3	3.6	4.5	4.1	4.3	5.3
(mm/d) (Daily evaporation xCrop factor)												
5. IRRIGATION EFFICIENCY 70%	70	70	70	70	70	70	70	70	70	70	70	70
6. GROSS DAILY WATER REQUIREMENT (mm/d)												
(Net daily water requirement÷ Irrigation Efficiency)*100	8.2	8.1	6.6	5.5	4.5	3.7	3.3	5.1	6.5	5.9	6.2	7.6
7. PLANT AVAILABLE WATER	135	135	135	135	135	135	135	135	135	135	135	135
(mm/m)												
8. ROOT DEPTH (mm)	300	400	500	500	500	500	500	500	500	500	500	500
9. AVAILABLE MOISTURE-ROOT DEPTH (mm)	41	54	68	68	68	68	68	68	68	68	68	68
(Root depth/1000)*Plant Available Water												
10. IRRIGATION INTERVALS days	7	9	15	18	21	26	29	19	15	16	16	13
(Available moisture root depth/Net daily water requirement)												
11. APPLICATION RATE (mm/h)	5	5	5	5	5	5	5	5	5	5	5	5
12. IRRIGATION DURATION (h) (Available moisture root depth/Application rate)	8	11	14	14	14	14	14	14	14	14	14	14
13. GROSS WATER REQUIREMENT (mm/month)												
(Gross daily water requirement *31)	255	227	203	165	140	112	103	159	194	183	186	237
14. ANNUAL WATER REQUIREMENT [mm]	2164											
15. ANNUAL WATER REQUIREMENT [m3/ha]	21640											
16. FARM WATER ALLOCATION [l/s]	40											

Question to learners?

If the farm water allocation is calculated, how many hectares can be irrigated?

In Example 1, the water allocation was calculated to be 40 l/s. How many hectares can farmer John irrigate?

The annual water requirement/ha calculated in Example 1 =21640 m^3

Water available: 40 l/s x 31536 m^3/year or annum
= 1 261 440 m^3/year or annum

Area that can be irrigated = 1 261 440 m^3/year or annum÷ 21 640 m^3
= 58 ha

Note: The area under irrigation will usually be larger due to rainfall.

- *In the northern production areas like in Mpumalanga, soils are shallower i.e. 550 mm, and a typical Glenrosa soil form would typically have a FC value of 373 mm/m and a PWP of 249 mm/m. The TAM will be 124 mm/m, while the RAW will be 62 m/m.*

9 Pest and diseases

9.1 Insect pests

Pests are economic pests only when at or above a certain population density. Usually control measures employed against pest are designed to lower the population to a density at which it is no longer an economic pest.

Sugarcane pests are conveniently grouped into the following groups according to their habits or mode of attack: leaf eaters, leaf suckers, stem borers and soil pests. The pest that has the biggest impact on the sugar industry is Eldana (stalk borer) followed by thrips.

Pest group	Sugar cane pest
Leaf eaters	Trash worm Army worm Locust Migratory locust
Leaf suckers	Green leaf sucker Leaf hopper Sugarcane aphid Maize leaf aphid Sugarcane mealybug Soft scale Mites Sugarcane thrips
Stem borers	Eldana borer (cane of all ages may be attacked) Stalkborer
Soil pests	White grub

9.2. Sugarcane diseases

Disease control in sugarcane is mainly concerned with the control of pathogenic problems. The control measures for most of the serious cane diseases should be important, routine aspects of crop management. Effort should be made to plant certified seed cane which is clean of and disease and to perform regular field inspections to eradicate infected stools where possible.

In the notes that follow the different diseases are discussed in order of economic importance.

Ratoon Stunting Disease

Ratoon stunting disease is considered as the most important cause for sugarcane yield losses, especially under dryland conditions. Primary spread of the disease is through infected setts and also spreads through harvesting implements contaminated with the juice of diseased canes. Progressive yield decline takes place due to the disease. Ratoon crop suffers more damage due to RSD than the plant crop. Disease is known to reduce germination and yield. Most characteristic symptom of the infected stalks is the presence of pin head like orange coloured dots of bacteria on the internal soft tissue in the nodal region. Other symptoms include stunted growth, thin stalks with short internodes, pale yellowish foliage and rapid tapering of the stem towards the top.

Smut

Most important fungal diseases of sugarcane in South Africa. Widespread in northern areas and northern Zululand, but can occur in all areas on highly susceptible varieties. Primary spread of the disease is through infected setts (spores and infected seed).

Characteristic symptom is the production of long whip like structures from the terminal bud of the stalk. Losses due to smut in sugarcane depend on various factors i.e. primary or secondary infection; plant or ratoon crop affected; early or late infection. Yield losses range from 30-40% in plant crops and even up to 70% in ratoons. Sucrose content of infected cane is reduced to 3-7%.

Sugarcane mosaic virus [SCMV]

Mosaic, caused by sugarcane mosaic virus (SCMV), is one of the most prevalent diseases of sugarcane in the world. In South Africa, under conditions of severe SCMV infection, reduction in sucrose yield has been reported to be as high as 42% in susceptible varieties.

Presence of darker green blotches on a paler green leaf background – prominent on younger leaves but difficult to identify in bright sunlight. Whole plants can be yellow-green and dwarfed. Basically the only remedy is to plant resistant, healthy, varieties, coupled with good weed control.

Red Rot

It is the most dreaded disease of sugarcane which has caused the elimination of several important sugarcane varieties from cultivation. Yellowing and drying of leaves, from margin to midrib, drying of the entire top including the crown, loss of natural colour and considerable shrinkage of the stalk, appearance of reddish lesions on the rind are some of the external symptoms of red rot disease. Most characteristic and diagnostic symptom of the disease is the presence of reddish discoloured patches or lesions interspersed with white horizontal patches on the internal tissue. As the diseases progresses the internal tissues become dark in colour and dry resulting in longitudinal pith cavities.

Leaf Scald

It is a bacterial disease, widely spread in many countries and first identified in South Africa in ~1968. Disease is favoured by wet seasons, water stress due to drought, water logging and low temperatures. Disease symptoms appear as a "white pencil line" extending entire length of lamina reaching the margin of young leaves and stripes diffuse later resulting in leaf etiolation

Pineapple Disease

Essentially a disease of seed material i.e., setts. Typical disease symptoms are detected in setts after 2-3 weeks of planting. Affected tissues first develop a reddish colour, which turns to brownish black in the later stages. In most cases setts decay before bud sprouts or the shoots have grown, causing germination failure leading to reduced initial crop stand per unit area. The pathogen can spreads rapidly and the foliage turns yellow and ultimately the plant withers. *More detail information on the various sugarcane diseases and pests from your SASRI extensionist.*

10. Harvesting

The processing of sugarcane for the extraction of sugar begins in the field. The variety of cane, soil in which it grows, cultural practices used (including the fertilization and irrigation) and degrees of maturity produce a raw material of varying quality.

Cane harvesting, either by hand or machine begins with March cane estimates, which are drawn up by individual growers on cane Testing Services estimate forms. An estimate is made by listing all fields on the farm, indicating those which are to be harvested, together with their areas, and their ages on 1 April. Since 1985, it has been necessary for growers to list all fields including those not intended for harvesting.

Cane is usually harvest when the cane has approximately 1.5-2 m stalk, uniform and matured. When cane is growing on favourable sites, this can occur at a relatively young age. Age is however important in relation to *Eldana*, as each successive life cycle increases the population exponentially. Yields can range between 80-130t/ha.

Quality of sugarcane is determined by sucrose, fiber and non-sucrose. Under irrigation the sucrose content will be low if cane is cut during a rapid growing period, but the practice of controlled irrigation followed by "drying off" should lead to an increase sucrose percentage, particularly when cane is cut during the optimum sucrose period.

"Drying off" induce ripening through the discontinuing of irrigation for 4-6weeks prior to harvest. On shallow soils, the "drying off' period should be carefully planned not to excessively damage the young cane. Alternatively chemical ripeners such as Fusilade and Ethephon can be applied aerially to ripen the cane.

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Developers: Developed with information obtained from SASRI and various sources cited (J Stevens and P Reid)

Authenticator: Mr F Olivier

Module 5a

Maize

1. Introduction

Maize, in the U.S.A. known as "corn", is one of the most important food crops in many countries, and is grown under a wide range of climatic and soil conditions. It is an annual (planted and harvested within one season) summer crop, sensitive to frost. It is mainly grown under dry land (rain fed) conditions, but irrigation and even drip irrigation are used as well. It therefore could be regarded as a fairly extensive to a very intensive crop, depending on the conditions under which it is grown.

Maize plants are cross-pollinated, a big advantage for the crop breeder in obtaining different cultivars. Seed should be obtained from seed companies. Maize grain is used for human consumption (mainly white maize), but also animal feeding (mainly yellow maize). The total plant (grain plus plant) is used for animal fodder in the form of silage or dry plants.

2. Production [1]

In recent years, the total annual commercial consumption (human plus animal) of maize in South Africa is about 8.6 million ton. The highest total production (mostly dry land) in the RSA was obtained during the 1980/81 production year: 14.872 million ton on 4.488 million ha. That means an average yield of 3.3137 ton / ha.

Since 1970, the total area annually used remained fairly stable for about 25 years at 4 million ha and more. Gradually the area decreased to 3 million ha, and even less. The main reason for the decrease in area could be linked to financial considerations and the exclusion of lower potential soils.

Table 1 indicates the trends or changes in the production regarding area used, total production and what this means in terms of yield per ha.

Table 1. Trends in maize production in South Africa (Figures re-calculated). [1]

Production year	Annual area planted (million ha)	Total annual production (million ton)	Average yield (ton/ha)
1970/71-1974/75	4.6702	8.5186	1. 824
1975/76-1979/80	4.6472	9.4062	2.024
2003/04-2007/08	2.9306	9.7872	3.340

These figures indicate that an increase in production does not mean using larger areas (more land), but rather using improved practices in order to be more efficient. That is the challenge for all people involved in agriculture. The most important provinces for maize production can be listed as the Free State (44%), Mpumalanga (23%) and North West (21%). [1]

3. Climatic and soil requirements[2)]

3.1 Climate

Maize is a summer crop, not grown in areas where mean daily temperature is below 19ºC. The minimum temperature for germination is 10ºC. The critical temperature harming yield is approximately 32ºC. A frost-free period of 120 to 140 days is required.

Approximately 10 to 16 kg of grain is produced for every millimetre water used. Moisture management is aimed at providing moisture to the plant especially during the critical stages, although moisture is required for field practices (e.g. ploughing, chemical weed control). Higher rainfall or irrigation increase yield potential.

3.2 Soil requirements

The most suitable soil for maize is one with a good effective depth. (Remark: under dry land 900 mm + is preferred). It should have good internal drainage, an optimal moisture regime, sufficient and balanced quantities of plant nutrients and chemical properties [soil fertility, including pH (H_20) of 5.8 +]. Maize roots are sensitive to aluminium toxicity.

Soils with 10-30% clay content have air and moisture regimes that are optimal for maize production.

4. Growth and development of the maize plant and relevant guidelines[2,3)]

<u>Stage 0</u> (Planting to emergence of seedling): Primary (first) roots develop. The mesocotyl pushes the plumule (first leaves), protected by the coleoptile, to appear above the soil surface. (The coleoptile should open the soil surface). The number of days from planting until emergence is influenced by planting depth (deeper planting, more days).

The growth point and nodes on the stem are 25 to 40 mm below the soil surface. Under warm, moist conditions seedlings emerge after 6 to 10 days. Cooler or dry conditions delay this period, enhancing seedling diseases. Soil temperature (on 100mm depth) should be at least 15ºC.

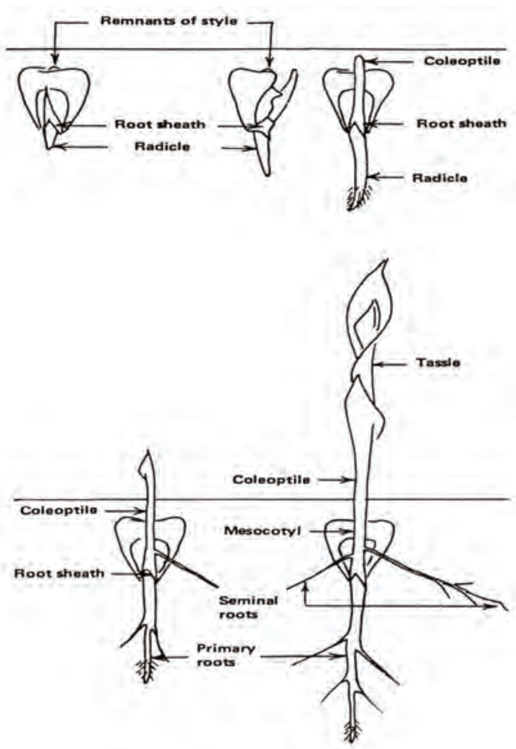

Figure 1. Development during growth stage 0 (from planting to emergence)[3)]

Management Guidelines

- If planted too deep, the mesocotyl cannot push the plumule above the soil surface. The coleoptile then opens below the soil surface, leaves unfurl below the soil surface and die, reducing the plant population. After heavy rainstorm or hail, compacted soil surface should be tilled carefully, enabling coleoptile to penetrate soil surface.
- Depth of planting determines the depth at which the primary roots will develop but not at which the permanent (adventitious) root system will develop.
- Too much fertilizer (especially N) close to the seed may cause burning – reduced plant population.
- During germination, the seed coat bursts, exposing tissues, which are rich in nutrients, to organisms in the soil, thus diseases may develop. To prevent this, seed treatment is essential.

After emergence, the **VEGETATIVE stages** (root, leaves and stem development), **numbered as stages 1-4, follow**.

Remark: Number of stage x 2 = number of weeks after emergence; number of stage x 4 = number of leaves completely unfolded.

Stage 1: (4 leaves completely unfolded; normally 2 weeks after emergence)
The growth point (most sensitive tissue) is still below the soil surface.

The permanent, adventitious root system develops about 30 mm below the soil surface, regardless of planting depth. (The primary roots function effectively for up to 6 weeks)[4]

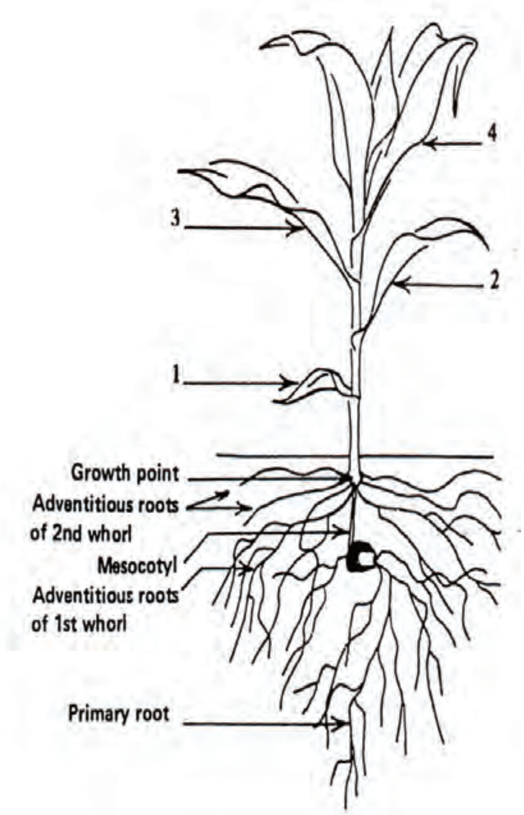

Figure 2. Growth stage 1 (4 leaves fully unfurled – 2 weeks after emergence) [3]

Management Guidelines

- Plants are susceptible to drift-sand damage (very sandy soils).
- Hail and light frost may damage leaves, but because the growth point is still below the soil surface, actual damage should be negligible.
- Waterlogging may harm the seedling because the growth point is still below the soil surface.
- Tilling close to the plants may harm roots.

Stage 2: (8 leaves unfolded; normally 4 weeks after emergence).
Period of rapid vegetative growth (leaves and stem).
Depending on cultivar, tillers begin to develop from nodes below the soil surface.
The **growth point** is about 50 to 75 mm **above** the soil surface.

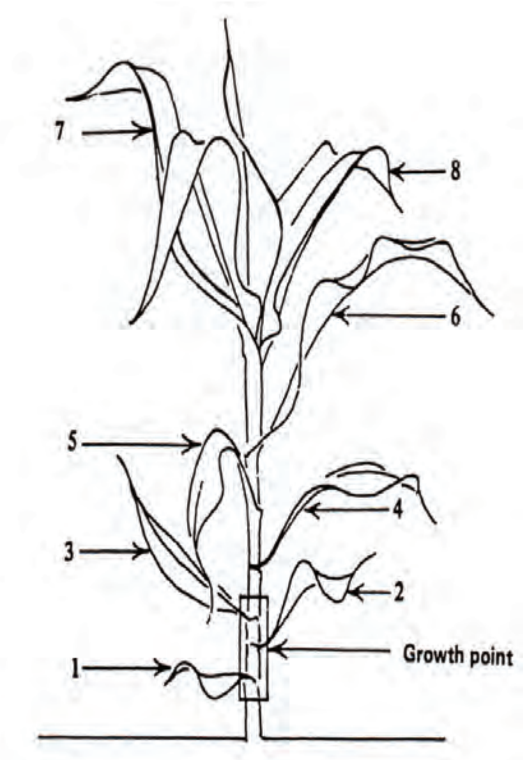

Figure 3. Growth stage 2 (eight leaves fully unfurled – four weeks after emergence) [3]

Management Guidelines

- Nutrient deficiencies will restrict leaf growth. This is the time when N-fertilizer is applied as side dressing to moist soil. Mechanical injury to roots must be avoided.
- Sufficient moisture (rain or irrigation) is vital to promote the vegetative growth.
- Defoliation by hail may reduce yield by 10-20%.
- The growth point starts to appear above soil surface at the beginning of this stage. Damage caused to the growth point now shifts from water-logging to hail damage. (Remark**: investigate** the plant by cutting the plant vertically to determine the position of the growth point with regard to the soil surface)

Stage 3: (12 leaves unfolded; normally 6 weeks after emergence).
The tassel in the growth point starts to develop.

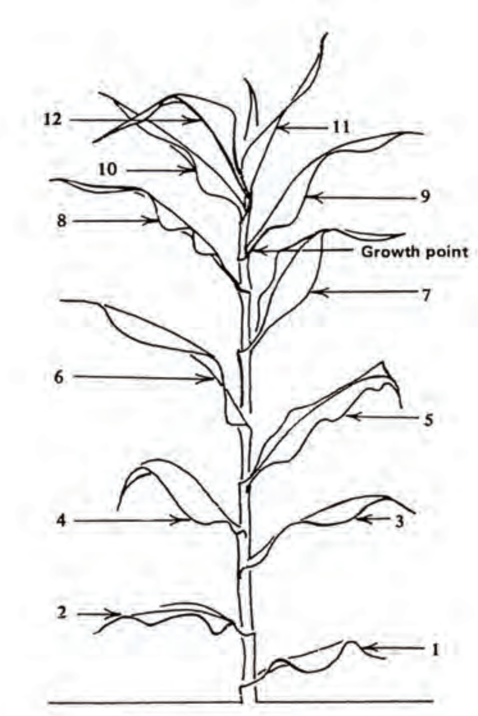

Figure 4. Growth stage 3 (12 leaves fully unfurled – six weeks after emergence) [3]

Management Guidelines

- Water and nutrient deficiencies will affect the size and yield of the ears (cobs).
- Plants breaking below the growth point (which is now situated at the highest node of the stem) will not recover.

- Hail damage increases (more leaves are damaged)

* **Remark:** During this and later stages: If freak frost does occur, external damage to leaves is visible after a few days. (To determine real damage after frost, wait about 4 days; then try to pull out the top part of plant. If growth point is damaged, it will die off and this top part of the plant can be pulled out. If it stays intact, damage is external leaf damage only).

Stage 4: (16 leaves unfolded; normally 8 weeks after emergence).
Stilt roots (also known as prop roots or brace roots) start to develop from the seventh node above soil surface, from where they enter the soil to support the plant. Hot soil surfaces may affect the development of these roots. The beard (or silk) begins to develop on the upper ear or cob.

Management Guidelines

- Water and nutrient deficiencies will reduce number of kernels per ear.
- Hail damage will reduce yields.

Stage 5: (Appearance of beard or silk and pollen shedding, generally referred to as tasselling or flowering; REPRODUCTIVE phase).
All leaves are completely unfolded and the tassel is visible. The plant has reached its maximum height. Pollen from the tassels now pollinates (fertilizes) the beard. That is why this stage is regarded as the **critical stage**.

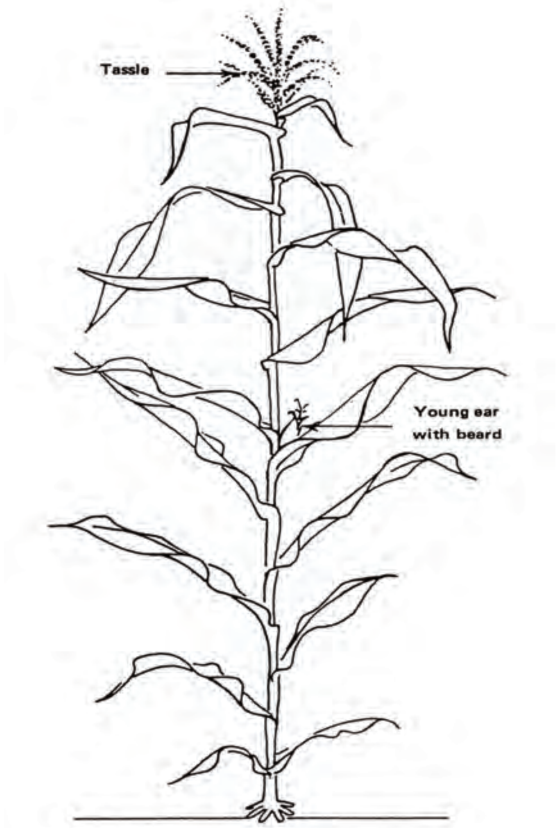

Figure 5. Growth stage 5 (beard appearance and pollen shattering – about 66 days after emergence)[3]

Management Guidelines

- The nutrient level in the leaves is closely related to the final yields.
- Demand for nutrients and moisture is high.
- Pollination is adversely affected by excessively high temperatures or water stress.
- Planting dates should be chosen so as to ensure this stage coincides with favourable growing conditions.

Stage 6: (Green-mealie stage).
The grain mass increases rapidly. Translocation of nitrogen and phosphorus from the older plant parts to the developing kernels begins. Starch begins to accumulate in the endosperm of the kernels.

Management Guidelines
- "Well filled" kernels depend on sufficient moisture.
- *Loss of leaves results in poorly filled kernels at the tip of the cobs.

Stage 7: (Soft dough stage).
Grain mass increases, sugars converted into starch.

Management Guidelines
- Moisture supply is vital for kernel mass.

Stage 8: (Hard dough stage)
Sugars in the kernel disappear rapidly.

Management Guidelines
- Moisture stress still reduces grain mass.
- Correct stage to make silage.

Stage 9: (Physiological maturity).
When the kernel has reached its maximum dry mass, a layer of black cells develops at the kernel base. No translocation of nutrients from stalk to kernel.

Management Guidelines
- Physiological maturity can be determined by removing the fruit stalk at the kernel base to expose the black cells.

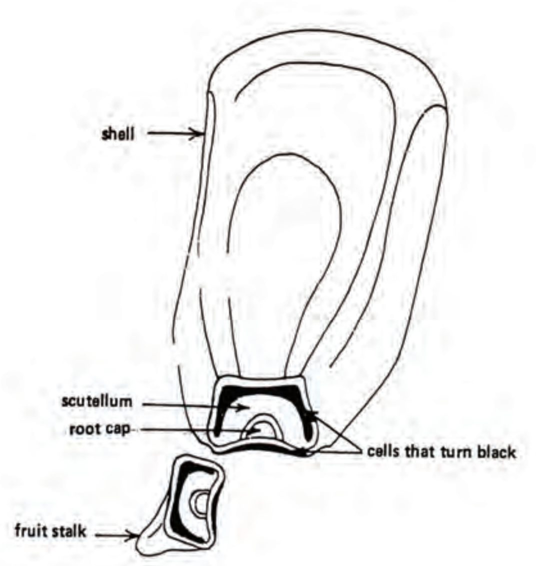

Figure 6. Development of the black layer in the maize kernel (stage 9)[3]

Stage 10: (Drying of the kernels).
Loss of kernel moisture depends on climatic conditions and cultivar.

Management Guidelines
- Monitor the moisture content of the grain.
- The cobs may be stored when content is not more than 18.5%.
- Start harvesting as soon as possible (below 14%) to reduce grain losses.

5. Production potential[2,5)]
This is determined by climate (especially rainfall or irrigation) and the soil as well as the management level of the producer. The farmer should manage production inputs in such a way as to maximize their utilization. This sometimes is referred to as "balanced field practices". Neglecting weed or insect control while applying high quantities of fertilizer is not balanced or good management. All practices must be attended to!

One of the reliable methods is *long-term* yield data collected by each individual producer, as this reflects inherent yield of the specific environment, as well as the effect of agronomic practices such as fertilization, soil cultivation and plant population and managerial abilities of the producer.

Remark:

- Soil classification to determine the soil depth, clay content and type of limiting layer is an aid in determining a realistic soil potential for a crop.
- The Taxonomic System for South Africa (MacVicar *et al., 1991*) classifies soils with two main categories or levels of classes: the soil form and the soil families.[5]
- **All field practices (and financial considerations) should be based on a realistic yield potential. High input costs in a situation of lower yield potential are a waste of money and increases risk!**

6. Cultural practices

6.1. Soil tillage[2,5]

Soil tillage is a sensitive operation that has to be carried out with great care. There is not only a cost factor associated , but intensive tillage also impact on the degrading of the soil and the infiltration rate of soil and hence influence the potential for crop production. New tillage systems like no-till and reduced or minimum tillage developed to try and stop the degrading process and sort under the conservation tillage umbrella, which aims at the minimizing of the mechanical manipulation of soil and try to restore soil to its original characteristics over time.

(Additional reading recommended: Chapter 1.10, Fertilizer Handbook. 2007)[5]

6.1.1. Reasons for soil tillage

- **Seedbed preparation**

Is aimed at creating conditions favouring germination and root development. Good contact between seed and soil and a uniform planting depth is needed. Favourable subsoil conditions promote good root distribution. A well-prepared seedbed should be level, fine, firm and weed-free:

✓ **Weed control**

Primary and secondary tillage and use of herbicides facilitate weed control.

✓ **Soil and water conservation:**

Breaking up the surface crust promotes rain infiltration. To combat wind and soil erosion (especially sandy soils), the soil surface should be kept rough (but not more than 100 mm depth, otherwise it will promote evaporation):

- To incorporate manure / fertilizers / lime;
- Mixing of soils (e.g. to remove compacted limiting layers).

6.1.2. Primary tillage (Ploughs and / or rippers)

Where a hardpan or plough-sole (soil compaction at depth of ploughing, caused by tractor wheels in the plough furrow) is identified, preventing infiltration of rain or irrigation and root development, rippers should be used to break this layer. Under wet, clay conditions, the main disadvantage of the ripper is that it compacts the soil laterally and inwards, which can limit lateral (sideways) root development.

It is aimed at improving aeration of soil, incorporation of plant residue and lime (where necessary), reducing wind and water erosion. Ploughing largely contributes to good mechanical weed control (e.g. purple nutsedge).[6] Depth of primary tillage increases with an increase in the sand content of soils.

6.1.3. Secondary tillage (Seedbed preparation)

Implements used are tined cultivators and harrows. A seedbed should be level, fine, firm and weed-free.

6.1.4. Tillage practices[2,5)]

Different tillage systems may be considered.

- ✓ **Conventional clean tillage**

Applied fairly generally, using a plough to incorporate plant residues. Secondary tillage is then aimed at weed control, water conservation and seedbed preparation. The soil surface is exposed to wind and water action, promoting wind and water erosion. It also results in reduction of the organic matter content of the soil.[5]

- ✓ ***Conservation tillage***
  - *No-till:* soil is left undisturbed from planting to harvesting. Best control of wind (sandy soils) and water erosion. High management level and special planters required. The advantage in terms of cost saving is less dramatic since the additional costs of herbicides may exceed the saving in cultivation costs.
  - *Stubble mulch:* soil is disturbed before planting, without burying plant remains of previous crop, using chisel ploughs and special implements. Chemical and/or mechanical weed control is applied. Increase in N-fertilization during the first few years is recommended to overcome the N-negative period.[5]

- On sandy soils a decrease in yield during wet seasons can be linked to higher occurrence of soil and air-borne diseases. The advantages of effective control of wind erosion by mulch tillage on these sandy soils exceed its disadvantages. When using mulch tillage on sandy soils, the plough should be used approximately every five years.[5]
  - o *Reduced tillage:* 15-30% of soil surface covered with stubble. Chemical or mechanical weed control.

Remark:

Moving away from conventional tillage to less tillage operations goes hand in hand with **increased dependency of chemical weed and insect control.**

Whichever system is used, ensure that a compacted layer at depth of ploughing, does not occur. If such a limitation (hardpan) has been identified, it should be broken (ripper).

1 ton of grain / ha gives about 1 ton of plant residue, to cover about 10% of the soil. For conservation tillage (increasing water infiltration, reducing water and wind erosion) at least 50-60% of the soil surface should be covered.

Table 2. Major advantages and disadvantages of different tillage systems.[2]

Tillage system	Advantages	Disadvantages
No-till	*Lowest fuel consumption; *Quicker adaptation to optimum planting date; *Lower machinery costs; * Best control of wind and water erosion.	*Higher application of herbicides; intensive herbicide management needed; * Requires: - Good management - Special planters - Initial investment in extra equipment; *Possible soil compaction and accumulation of nutrients in topsoil; *Diseases and possible insect populations.
Stubble-mulch	* Fuel saving (compared to plough); *Good control /better management of: -wind and water erosion; -soil compaction; -weed control (?).	*Soil preparation dependant on spring rains; * Diseases. * Stalk borer
Reduced tillage	* Better fuel economy (less than plough); * Control of - Wind erosion -Insect population *Accumulation of nutrients not a problem.	* Reduced control of water erosion; * Management of weed control.
Conven-tional tillage	* Good weed and insect control; *Lowest management inputs (easier to manage)	*Highest fuel consumption and machinery costs; * Soil water content determines time of ploughing and seedbed preparation; * No control of water and wind erosion.

6.2. Establishment practices

6.2.1. Planting date

Is determined by soil water content, soil temperature and cultivar.[2] Under irrigation, planting date is not dependant on rain but on temperature only. Soil temperature (on 100mm depth) of 15ºC promotes rapid germination.

Planting should be scheduled in such a way that the most heat and water sensitive stage (i.e. stage 5, flowering) does not coincide with midsummer drought. Irrigation at this stage is vital (if available).[2] Purpose of planting: e.g. time of marketing of green maize.

6.2.2. Planting depth [2)]

Varies from 50 mm to 100 mm, mainly depending on the soil type. As clay content of the soil increases, planting depth decreases.

6.2.3. Row width and plant population

Under dryland conditions the distance between the rows can vary from 0.91 m to 2.1 m or 2.3 m. Under irrigation, row width can be as low as 0.6m

Table 3. Guidelines for row width (dryland) [2)]

Wide rows (1.5 m to 2.1 m)	Narrow rows (0.91 m to 1.0m)
✓ Low to medium yield target ✓ Low and medium rainfall ✓ Wind erosion problems • * Weed problems: controlled chemically in rows, mechanically between rows.	• Medium and high yield target • *Medium and high rainfall.

Plant population can vary from 10 000 plants / ha to 90 000 / ha, depending on yield potential, area and cultivars.

Contact seed companies for tested recommendations.

Table 4. Guidelines for a realistic plant population[2)]

Yield potential (ton/ha)	Cooler areas	Temperate areas	Warmer areas
Dryland			
2	16 000	12 000	10 000
3	19 000	16 000	14 000
4	25 000	21 000	19 000
5	31 000	26 000	24 000
6	37 000	31 000	28 000
7	43 000	36 000	
Irrigation			
8-10	55 000	50 000	45 000
10+	65 000	60 000	55 000
Ultrashort cult			
10+	80 000	80 000	90 000

Table 5. Within row spacing (cm) at different populations and row widths.[2]

Plant popu-lation	Spacing within row (cm)				
	Row width (m)				
	0.75	0.91	1.5	0.91 x 2.3 #	2.3
90000	15 **(66)**	12 **(83)**			
80000	17 **(59)**	14 **(71)**			
70000	19 **(53)**	16 **(62)**			
60000	22 **(45)**	19 **(53)**			
50000	27 **(37)**	22 **(45)**			
45000	30 **(33)**	25 **(40)**			
40000	33 **(30)**	28 **(36)**			
35000	38 **(26)**	32 **(31)**	19 **(53)**		
30000	44 **(23)**	37 **(27)**	22 **(45)**	21 **(48)**	
27500		40 **(25)**	24 **(42)**	23 **(43)**	
25000		43 **(23)**	26 **(38)**	25 **(40)**	
22500		50 **(20)**	29 **(34)**	28 **(36)**	
20000		56 **(18)**	33 **(30)**	31 **(32)**	22 **(45)**
18000			37 **(27)**	35 **(29)**	24 **(42)**
16000			42 **(24)**	39 **(26)**	27 **(37)**
14000				45 **(22)**	31 **(32)**
12000				53 **(19)**	36 **(28)**
10000				62 **(16)**	44 **(23)**

(..) indicates number of plants counted within row per 10 m distance (recalculation; rounded off).
 # 0.91 m x 2.3 m known as "railway" row spacing.

Remark:
In order to get the final recommended plant population, and **according to experience**, plants lost during germination or due to soil insects (e.g. cut worm), the number of seeds planted can be increased by say 10%

6.2.4. Cultivar choice:

Maize is a cross-pollinating crop. Seed therefore is bought from seed companies. Their research and recommendations are of great importance. Correct planning of cultivar choice can reduce risk. Differences between cultivars leave a producer with alternatives that can be utilized fully. Verify the reaction of new cultivars before abandoning proven cultivars[2]. Cultivars must be chosen in accordance to the potential of the specific yield potential, but must be able to utilize higher potential conditions and provide an acceptable yield at lower potential conditions.[7]

The following basic factors should be considered:

1. White maize or yellow maize;
   - ✓ Yield potential, adaptability and stability (consult "Maize Information Guide" – MIG – obtainable from *The Director, ARC-GCI, Private Bag X1251, Potchefstroom 2520*) [2]
   - ✓ Length of growing season (expressed as heat units (HU): ultra-short, short, medium and long season cultivars. Planting date and choice of cultivar regarding growing season go hand in hand.
   - ✓ Disease resistance (e.g. ear rot, maize streak virus, grey leaf

spot, rust, cob-and tassel smut, stem rot, root rots).[2]

- ✓ Lodging (plants falling over): differences among cultivars occur. This implies physical losses.
- ✓ Ear prolificacy (multiple cob development) and sprouting (multiple stem development): Add some flexibility to crop adapting to seasonal variations.
- ✓ GMO-cultivars (Genetically Modified cultivars): Bt-cultivars for stalk-borer control are available. Prescriptions with regard to inclusion of non-Bt cultivars must be adhered to.
- ✓ RR (Roundup Ready) cultivars are considered within a weed control program.[8]

2. High lysine maize cultivars, especially for non-ruminants (pigs, poultry), are available.

6.2.5. Fertilization of maize [5)]

(Additional reading recommended: Chapter 5.4, Fertilizer Handbook. 2007)[5]

Fertilizer guidelines are linked to two variables, i.e. yield potential and soil fertility status, as determined by soil analysis.

Determination of yield potential is the first step in fertilizer planning. A realistic potential takes into consideration the production area, climate, soil, planting date, cultivar and the availability of irrigation. It implies an attainable yield over the medium to long term.

Soil acidity (pH): liming is essential for the maintenance of soil fertility. Normally a minimum acceptable pH (H_2O) of 5.5 (on sandy loam soils) and a maximum acceptable acid saturation percentage of 10 to 15 is required.

The **rate** of **N- and K-uptake** by the maize plant reaches a peak approximately two weeks prior to flowering, whilst the peak for **P-uptake** coincides with flowering and maximum water uptake.

The average removal of plant nutrients by maize is shown in Table 6.

Table 6. NPK-removal (kg) by maize per 1 ton of marketable product [5)]

Plant parts	N	P	K
Grain only	15	3	3.5
Total plant (excluding roots)	27	4.5	20 *

***Remark:** Take note of the high removal of K when the total plant is removed (e.g. for silage).*

Scheduling of application (guideline):

- ✓ All the phosphate (**P**) is applied at planting. Where the P-status is low, additional P will be applied prior to planting.
- ✓ A portion of the nitrogen (**N**) is applied at planting. The balance is applied before 5 to 6 weeks since emergence have lapsed (see stage 2 of development of the plant) as a side-dressing under dry-land cultivation. With irrigation, a portion of N may be applied in the form of fertigation up to the last vegetative stage (before flowering).
- ✓ Usually all the potassium (**K**) will be applied prior to or at planting. If higher quantities are required, good results may be obtained with side-dressing or fertigation, up to the last vegetative stage.

Remark: Beware of N- and K-burn if placed in the vicinity of the seed. N and K should be placed 50 mm to the side of the seed and 50 mm below the seed.[2]

Slightly different guidelines may be found. The following guidelines, based on research, are taken from The Fertilizer Handbook (2007)
The guidelines for N, P and K applications are indicated in Tables 7 to Table 11.

Table 7. Guideline for N-fertilization of maize [5)]

Yield potential	2	3	4	5	6	7	8	9	10
	Ton / ha								
N-application	kg/ha #								
	20	45	70	95	120	145	170	195	220

(#) Where yields in excess of 10 ton / ha are obtained (e.g. under irrigation), 20 to 30 kg N per additional ton may be applied.

Table 8. N-guideline (kg N / ha) adjusted for texture according to North West Department of Agriculture. [5]

Clay content (%)	Yield (ton / ha)				
	2.0	3.0	4.0	5.0	6.0
5	23	58	92	126	160
15	10	45	79	113	147
25	0	33	67	101	135
40	0	14	48	82	116

Table 9. Guideline for P-fertilization of maize [5)]

Soil-P Bray 1	P-recommendations for yield potentials (t/ha)								
	2	3	4	5	6	7	8	9	10
mg/kg	Kg/ha								
0-4	20	42	65	88	109	130	130	130	130
5-7	17	31	47	63	67	90	93	95	97
8-14	13	19	30	42	50	59	64	67	68
15-20	10	13	21	29	36	42	47	50	53
21-27	7	10	15	19	26	31	34	38	41
28-34	6	9	12	15	18	22	24	27	30

Table 10. Guideline for K-fertilization of maize on soils with low clay content (<25%). [5]

Soil-K start of season (NH_4OAc)	K-recommendation for yield potentials (t/ha)								
	2	3	4	5	6	7	8	9	10
mg/kg	kg/ha								
10	10	19	28	37	46	55	64	73	82
20	0	11	20	29	38	47	56	64	73
40	0	5	13	22	30	39	47	56	64
60	0	0	8	16	24	32	40	48	56
80	0	0	5	12	20	27	35	42	50
100	0	0	0	10	17	24	31	38	45
120	0	0	0	8	15	21	28	34	41

Table 11. K-fertilization of maize on soils with high clay (>25%). [5]

Soil-K start of season (NH4OAc)	K-recommendation for yield potentials (t/ha)								
	2	3	4	5	6	7	8	9	10
mg/kg	kg/ha								
<40	16	30	44	58	72	86	100	114	128
40	5	16	27	38	49	60	71	81	93
60	0	9	19	30	40	49	59	67	78
80	0	5	13	22	31	40	49	57	67
100	0	0	9	17	25	33	41	48	57
120	0	0	6	13	20	27	34	41	85
140	0	0	5	11	17	23	29	35	41
160	0	0	5	10	15	20	25	30	35

K-deficiencies seldom occur in the maize producing areas of South Africa. Most of the soils have higher K-levels than the generally accepted sufficiency limits of 80 to 120 mg /kg. In higher rainfall areas on soils with inherently low k-status (<50 mg/kg) large yield losses can occur if insufficient K is applied. The K-status in the topsoil as well as the sub-soil is important. Yield responses vary a lot.
These K-guidelines should be regarded as a compromise of all the variable experimental results.

Other important nutrients to be looked at include:

- ✓ Calcium (Ca) and Magnesium (Mg) – consider type of lime when pH is low;
- ✓ Sulphur (S);
- ✓ Zinc (Zn): Micronutrient, normally sufficient applied by using Zn-containing fertilizer mixtures;
- ✓ Boron (B): only where deficiencies are identified, mainly on light textured soils (E. Free State, highveld region of Mpumalanga);
- ✓ Molybdenum (Mo): on soils with a low pH. Liming increases availability of Mo.

6.2.6. Weed control:

Weed control during the first 6 to 8 weeks after planting is crucial because of competition for nutrients and water. Weeds during harvesting slows down harvesting, reduces the quality (e.g. Thorn apple seed, *Datura*). [2]

Weed control is mainly done by: [2]

- ✓ Cultural practices (mechanical): ploughing during winter or early spring and between rows. Crop rotation may be vital, using alternative crops.
- ✓ Chemical control: This mostly happens in combination with mechanical control (integrated weed control). The period from seedbed preparation to application of herbicides at planting should be as short as possible (a day or two).
- ✓ The use of G.M.O cultivars with the RR-gene makes it possible to use a non-selective herbicide (Roundup-Ready ® herbicide, registration L6702) in a selective way (only Roundup Ready!) [8]

Herbicides can be grouped into: [9]

a) pre- or post-emergence herbicides (control of nutsedge with pre-emergence herbicides is ineffective if applied after emergence); the rate of soil-applied herbicides is mainly determined by the clay% of the soil;

b) selective (kills certain weeds) or non-selective herbicides (kills all plants, directed application); ensure that adjacent crops will not be affected.

c) systemic or contact herbicides (according to mobility within plants);

d) broad-leafed or grass or nutsedge herbicides (according to type of plants affected).

Remarks:

- ✓ The use of chemicals – herbicides – enables the "good" producer to become an "even better" producer. The incorrect use is a waste of money, reducing yields of the crop and spending money to do so. Therefore: Work in close cooperation with companies involved with herbicides. Follow specific recommendations.
- ✓ Identify the weed problem of a specific field. Choose herbicides according to the identified problems.
- ✓ Take into consideration the residual effect of soil-applied herbicides. This determines period of weed control as well as crops used in crop rotation system (e.g. Atrazine used for broad-leafed weeds can be harmful to next crop like beans, sunflower); Rainfall (or irrigation) after the application of soil applied herbicides is required to ensure weed seed and crop germination and therefore efficient control.

6.2.7. Insect control [2,10]

Integrated pest management is a system combining different strategies to protect crops.

These measures include cultivation control (soil cultivation), plant resistance (e.g. Bt-cultivars) and chemical control (seed treatment or spraying the crops).

Seed companies and advisors of chemical companies should be contacted. Correct identification of all insects is vital.

- *Cultivation control:* pest populations are suppressed by cultivation practices, which are detrimental to the pests. These include soil cultivation during winter, eradicating volunteer plants, cultivar choice and adapting planting times.
- *Biological control:* Aphids and hibernating larvae of stem borers are killed by natural enemies.

The following are the most important pests:

- Cut worm (at planting, emergence; reduces plant population): soil cultivation, weed control, chemical control.
- Maize stalk borer (damage to stem and cobs): soil cultivation (clean cultivation during winter reduces threat), planting date, chemical control, cultivars.
- Black maize beetle (at planting; may be confused with cut worm): soil cultivation, chemical control.
- Maize snout beetle: feed on young maize plants, mainly at night. Chemical control.
- Spotted maize beetle (*Astylus*): Larvae can reduce the plant population; adults feed on pollen or young kernels, adults most abundant during January and February. Chemical control.
- Army worm: occur periodically. Chemical control.
- American bollworm (attacks maize cobs, commonly known as cobworm): keep maize lands free of weeds, chemical control.
- Leafhoppers (*Jassidae*): suck sap, usually on lower leaf surface. Transmit streak virus. Systemic insecticides.
- Wireworms: sporadic, feed on seed, newly-germinated plants and roots, reduce plant population. Chemical control.

6.2.8. Nematode control: [2,10]

Plant-parasitic nematodes are present in all production areas of South Africa. Before applying nematode control, check the soil pH, soil nutrients and physical soil condition (compaction).

A progressive yield loss over a number of seasons can be indicative of nematode infestation. Roots are damaged, resulting in yield losses (Not to be confused with Aluminium toxicity in acid soils).

Economic control is difficult, mainly because of the high cost of nematicides. Under irrigation, when infestation levels are high, chemical control can readily be recommended from an economic point of view. For dryland maize yield increases as a result of chemical control are very erratic, the exception being high infestations of rootknot nematodes. These populations may, under favourable conditions increase to such an extent that economic yield losses are incurred. In such cases it is essential to control the nematode population, even though the control measures when regarded over one season are not economically justifiable.

6.2.9. Diseases:[2]

The most important diseases are ear rot, maize streak virus, grey leaf spot, rust, cob-and tassel smut, stem rot, root rots.

Control is mainly based on crop rotation, cultivation practices (incorporation of plant material), weed control, use of disease-free seed and choice of cultivars and maintaining favourable growth conditions.

6.2.10. Crop rotation [11,12]

Crop rotation is the repeated cultivation of different groups of crops which are not botanically related, in a planned sequence during different seasons on the same land (area) in order to not only maintain the productivity of the soil, but to even improve it.

The control of diseases, insects, nematodes and weeds as well as erosion is important motivations. Maize often is grown in monoculture under dryland conditions, although crop rotation would benefit the crop as well. In situations where irrigation is used, the more intensive situation goes hand in hand with using different crops. If legume crops (e.g. soy beans) which fix N, are grown before a grass crop (e.g. maize) this means a saving of N-application. [12]

6.2.11. Irrigation:[2]

Maize can be regarded as an important grain crop under irrigation, as it produces very high yields. Water deficiency is usually the most important yield-limiting factor where efficient maize cultivation practices are applied. A yield of 3 152 kg ha-1 requires between 350 and 450 mm of rain per annum. Approximately 10 to 16 kg of grain are produced for every mm of water used (evaporation).

Within a relatively short period (100 to 120 days) the maize plant produces:

80-100 ton / ha green material;
16-21 ton / ha dry material.

Estimated irrigation requirements for short grower maize are shown in Table 12.

Table 12. Approximate irrigation requirements of maize planted in different climate regions on a loam soil under a centre pivot (SAPWAT)

Area	Seasonal rain (mm)	Effective rain (mm)	Irr requirement (mm)	Peak req (mm)
Early plant				
Dry, cold, summer rain, (Karoo), 15 Oct, peak Dec	155	145	495	185
Dry, cold, winter rain, 15 Oct, peak Jan	55	50	645	240
Dry, hot, west, (North Cape), 15 Sep, peak Dec	105	95	645	260
Dry, hot, east, (dry Bushveld), 15 Sep, peak Dec	300	270	310	110
Humid, warm summers, summer rain, (Highveld), 15 Oct, peak Jan	380	315	280	105
Humid, warm summers, winter rain, 15 Oct, peak Jan	110	90	535	210
Late plant				
Dry, cold, summer rain, (Karoo), 15 Dec, peak Feb	180	170	370	120
Dry, cold, winter rain, 15 Dec, peak Feb	60	50	525	185
Dry, hot, west, (North Cape), 15 Dec, peak Feb	200	155	535	185
Dry, hot, east, (dry Bushveld), 15 Dec, peak Mar	325	245	335	115
Humid, warm summers, summer rain, (Highveld), 15 Dec, peak Mar	330	250	240	85
Humid, warm summers, winter rain, 15 Dec, peak Feb	95	90	460	180

Use these values for planning irrigation requirements for maize produced under irrigation, but make use of an irrigation scheduling service for real-time irrigation management. Successful maize production depends on an adequate water supply throughout the crop's growing period. Water comprises 90 to 95% of plant tissue is one of the most important production factors limiting maize production in South Africa, It serves as an important role-player in several physiological processes.

Approximately 95% of the water that is taken up by the roots of the plant is lost through transpiration, while only a small fraction contributes to growth. Water stress, either too much or too little, may have serious adverse effect on yield. Too much water can lead to water logged conditions and the leaching of nutrients.

7. Harvesting:[2]

For grain production, mechanical harvesting can commence when the moisture percentage of the grain is 14% or less. If harvested at a higher moisture level, artificial drying is necessary before it can be stored.

- Hand harvesting: Ears could be picked from dry plants in the field. The entire plant can be harvested by hand and placed into a stack. Once it is dry, the ears can be picked and threshed, or the entire plant with ear can be utilized as maize hay.
- For silage production, maize can be cut and removed from the field at growing stage 8 (hard dough stage).

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Module 5b

Spring wheat

1. Introduction

Wheat and barley are recognized as being among the most ancient crops. Einkorn seed – a forefather of wheat – which date back to 6700 BC, have been found in the river valleys between the Mediterranean and Red seas. Wheat, oats and barley were grown in ancient Egypt and Mesopotamia.[1]

Wheat is a convenient, economical, nutritious source of food. It occupies population. It is classified into market classes by colour and composition of the grain.

Durum and hard wheat's (*Triticum turgidum)*, are mainly used for pastas and have higher protein content (13% to 16%) and are usually grown in drier climates. The softer wheats (*Triticum aestivum)* have lower protein content (11% to 13%) and are usually grown in more humid climates and are more suitable for the baking industry.[1] Wheat plants are self-pollinated, allowing farmers to save their seed for further planting.

2. Physiology/Phenology

Wheat is an annual grass that has a relatively broad adaptation and is well adapted to harsh climates. Early growth is favoured by moist, cool conditions, with warmer, drier weather towards crop maturity. Wheat requires temperatures below 10ºC to stool and to initiate flower induction early in its growing season. The crop goes into its reproductive phase – it starts stem extension – when day length exceeds 12 hours, after which it is susceptible to frost-induced crop loss during the flowering or anthesis period.[1]

The root systems consist of a relatively sparse primary system that emerges from the seed and rapidly extends to 1-1.5 m in depth. This system is not adequate for full production, for that the wheat plant relies on a well-developed secondary root system, which develops from growth points at the base of the plant. The soil profile should be wet; otherwise the secondary system will not develop to its potential.[1]

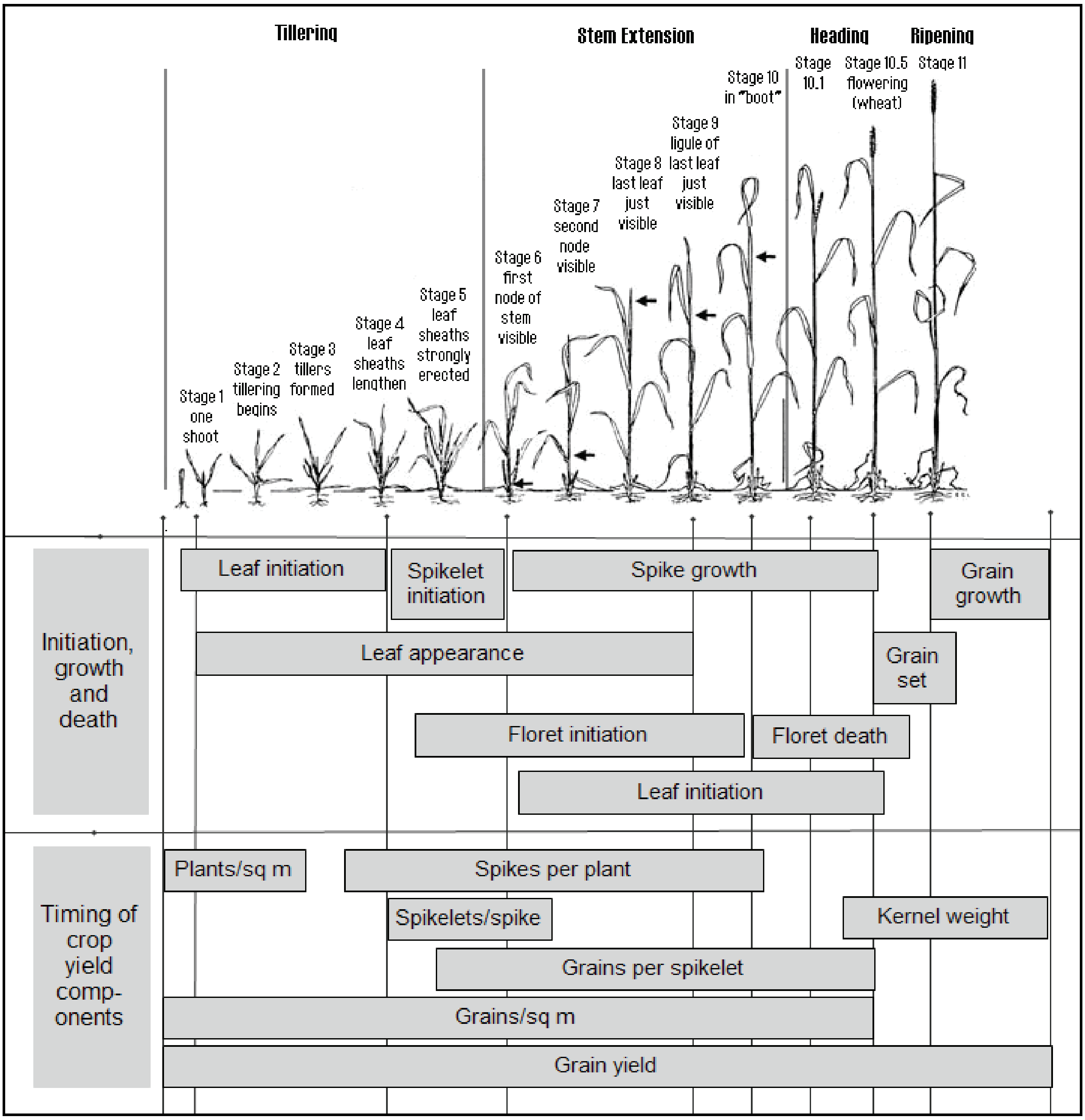

Figure 1. Growth and development of the wheat plant, showing Feekes growth stages as well as initiation, growth and death of plant components and timing of crop yield components.[1,2]

3. Growth requirements

Select a soil type with good water holding capacity.

a. Seedbed preparation[1,2)]

- Ensure that the seedbed is suitable for growing wheat. To get a good stand the seedbed should be well prepared, fine, firm and free of weeds.
- Avoid coarse sandy soils with <6% clay and clay soils with >35% clay.
- pH water: 5.5-7.5.
- Soil salinity < 500 mS/m.
- Check for drainage problems.
- Prepare a fine, firm seedbed, free of weeds, well in advance.
- Use pre-emergent herbicide: consult specialist.

b. Cultivars selection[2]

Seed specialists or your cooperative or ARC Small Grain Centre, get the latest cultivar recommendations for your region.

Keep the following in mind with the selection of a cultivar or variety:

- Yield potential: Cultivars differ in yield reaction to changing yields potential conditions. The difference between cultivars is mainly because of environmental factors (climate and cultivation environment), crop management, and disease-, insect- and weed influences.
- Grading and quality: Protein content and quality are important grading norms which determine the grading B1, B2, B3 and B4.
- Diseases and pests: The occurrence of diseases and pests in a region and the susceptibility of various cultivars must be considered.
- Seed price: The buying of more expensive, selected seed usually will be recovered by higher yields and better quality.
- Hectolitre mass: Hectolitre mass, amongst others, determines the grade of grain delivered and this characteristic is usually strongly associated with a particular cultivar.
- Straw strength: The lodging of wheat usually leads to yield losses. This is a common problem where high yield potential exists, but nitrogen fertilisation (N), row spacing and planting density are also factors that affect lodging.
- Aluminium tolerance: The more acid the soils (pH (H_2O) lower than 5.5) with acid saturation higher than 8% can attain free aluminium ion levels that are toxic to certain cultivars. Cultivars differ in their tolerance to these harmful levels.

- Photoperiod and vernalization: Photoperiod and vernalization of cultivars control the growth period. It is important to choose cultivars that are adapted to weather conditions such as the length of growth season, planting dates, rainfall patterns during the growing season, temperature and the onset and offset of frost.
- Shattering: This attribute refers to the measure how well ripe kernel is attached to the head, as well as to what extent the husks cover and protect the kernel. Certain cultivars are more susceptible to bird damage and losses during harvesting.
- Pre-harvest sprouting tolerance: The tolerance of cultivars against

germination in the head prior to harvesting. Certain cultivars are more prone to pre-harvest sprouting than others.

c. Planting[1,2)]

- Planting time: June-July, preferably June.
- Use only seed treated, amongst others, for loose and stinking smut.
- Planting density: 90-110 kg/ha.
- Planting depth: Cover with about 25 mm soil.
- Planting method: wheat can be planted in rows mechanically or by broadcasting (manually). A higher sowing density is recommended when the wheat is sown manually.

5. Fertilisation[2)]

Based on the results of soil analyses.

- Liming is important on soils with a pH < 5.5 (H_2O).
- In high pH soils add zinc. Treat high pH sodic soils with gypsum or sulphur: consult a specialist.
- On soils with < 20% clay a nitrogen top-dressing will be required for target yields > 5t/ha.

Fertiliser requirement for wheat under irrigation is shown in Table 1.

Table 1. Fertiliser requirements of wheat under irrigation[2].

Target yield (t/ha)	N (kg/ha)	P (kg/ha) for soil phosphorus analysis (Bray 1) at: (mg/kg)				K (kg/ha) for potassium analysis at: (mg/kg)			
		< 5	5-18	19-30	> 30	< 60	61-80	81-120	> 120
4- 5	80-130	36	28	18	12	50	25	25	0
5-6	130-160	44	34	22	15	60	30	30	0
6-7	160-180	52	40	26	18	70	35	35	0
7-8	180-200	> 56	> 42	> 28	21	80	41	41	0

4. Irrigation[4)]

- Plant in soil at field capacity.
- First irrigation about three weeks later.
- Intermediate irrigation should soil crusting be a problem.
- Expected irrigation requirements of wheat, planted 5 July under centre pivot irrigation in different regions: see irrigation requirement table.
- Consideration for follow-up irrigations:
- Longest frequency possible.
- Biggest irrigation depth possible.
- Do irrigation scheduling based on soil water content measurement.
- Greatest water requirement is from ear appearance to harvest. In

general – only a third of the total water requirement is needed during first two-thirds of growing season.

- Water stress will result in crop loss because of fewer heads, fewer spikelets per spike and fewer kernels per spikelet.
- Controlled water stress will reduce irrigation requirement more than crop loss: consult a specialist.

Table 2. Estimated irrigation requirements of wheat for different parts of the country (SAPWAT)[4]

Place	Climate	Rain (mm)	Rainy season	Total (mm)	Peak (mm)	Peak month
Bergville	Mild, humid, hot summers	765	Summer	315	120	Oct
Cradock	Dry, cold (Karoo)	320	Late summer	315	104	Oct
Loskop	Dry, hot (Middelveld)	917	Summer	395	138	Oct
Vaalharts	Dry, hot (North Cape)	405	Late summer	410	138	Oct
Vredendal	Dry, hot (Winter rainfall)	207	Winter	300	149	Oct

6. Maintenance[2)]

- Keep fields weed-free:
- Use only registered herbicides.
- Ensure that the spray equipment is calibrated.
- Ensure that spraying takes place at the right growth stage of the weeds.
- Ensure that the environment is suitable for successful spraying.
- Consult a specialist on herbicides.
- Keep a look-out for aphid and other insect infestations such as: Russian aphid, other aphids, brown wheat mite and bollworm.
- Consult a specialist.
- Keep a look-out for diseases:
- Stem and leaf diseases: Various rusts and mildews
- Diseases of the spike: Common bunt and kernel bunt
- Root and crown diseases: Consult a specialist.

7. Harvesting

Harvest end November-middle December when plant is completely desiccated.

Grain moisture content 12-14%.

Conditions for harvesting:

1. Cimate: the crop should be ripe and dry, and it is best to harvest earlier than later because losses can occur due to shattering

2. Varieties: avoid varieties prone to shattering and lodging

3. Weeds: weeds hamper harvesting and should be controlled

4. Lodging: harvesting is split into mechanical and hand harvesting

Activity 1

1. What are the climatic factors that have a negative effect on wheat production?

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2. What factors should be considered with the selection of cultivars for spring wheat production?

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3. Discuss the planting methods of wheat in relation to the planting depth and soil moisture conditions

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4. Describe the factors that should be kept in mind with the planning of an irrigation strategy for spring wheat. Highlight the factors that should be kept in mind to ensure optimal yield.

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My notes............

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Module 6a

Soybeans

(Glycine max)

1. Introduction

Soybeans are the world's most important source of protein flour and edible oil. It is used mainly as a source of protein for animal feed. Other uses include textured protein for human consumption, cooking oil and lactose-free milk in the food industry as well as in various products in the pharmaceutical and industrial industries.

South Africa has always had a shortage of oil cake and protein meal. For many years fish meal was the most important source of protein but it has gradually been replaced by plant protein from locally pressed sunflowers as well as imported and locally produced soybeans. In recent years the area under soybeans in South Africa has started to increase. Soybean production has become more profitable due to an overproduction of maize and relatively higher soybean prices. Soybeans are also becoming increasingly important as a rotation crop in areas where conservation farming is practiced and it is therefore expanding into new areas.

In the hotter production areas, soybeans can be planted after wheat, resulting in the production of two crops in one year under irrigation. Under rain fed conditions in high rainfall areas soybeans can be rotated with maize. This is becoming increasingly important under conservation farming where crop rotation is essential to control diseases.

Important conversion factors applicable for soybean production:

1 bushel soybeans= 27 216 kg

36.74 bushels soybeans=1 metric tonne

1 bushel soybean per acre = 67.251 kg soybean per hectare

2. Physiology/Phenology

Table 1. Growth stages of soybean[4)]

November/December	January	February	March	April
Plant ⇧ Emergence ⇧	1st flower ⇧	1st pod ⇧ 1st seed ⇧		Physiologically Mature R7 ⇧ Ripe for harvest ⇧
Vegetative	**Flower**			
		Pod development		
		Seed development		**Ripening**

Table 2. Stages of development of the soybean plant[4)].

Vegetative Stages

Count the number of nodes with a fully extended leaf on the main stem from the unifoliolate node

Stage	Description
V1	Fully developed leaves at the unifoliolate node
V2	Fully developed trifoliate leaf at the first node above the unifoliolate node
V3	Three nodes on the main stem including the unifoliolate node
V(N)	N number of nodes on the main stem with fully developed leaves

Reproductive stages

Stage	Description
R1	One flower at any node
R2	Flower at node immediately below the uppermost node with a completely unrolled leaf
R3	Pod 0,5 cm long at one of the four uppermost nodes with a completely unrolled leaf
R4	Pod 2 cm long on one of the four uppermost nodes with a completely unrolled leaf
R5	Beans begin to develop (can be felt when the pod is squeezed) at one of the four uppermost nodes with a completely unrolled leaf
R6	Pod contains full-sized green beans at one of the four uppermost nodes with a completely unrolled leaf
R7	Pods yellowing, 50% of the leaves yellow (physiological maturity)
R8	95% of the pods brown (harvest maturity)

3. Growth requirements [1)]

a. Temperature

Soybeans can tolerate high temperatures well, even better than maize, provided that water is not limited. During germination the soil temperature should preferably be above 15°C; 25°C is considered the optimum temperature. Temperature has an important influence on the rate at which the crop develops.

b. Day length

Soybeans are day length sensitive and need short days to flower. Depending on their day length requirement, cultivars belong to a specific maturity group (MG), which varies from MG 000 (furthest away from the equator) to MG X (at the equator). In South Africa MG IV to VII are grown.

c. Rainfall

The crop has a fairly high water requirement. For production under rain fed conditions a rainfall of at least 650 mm per annum is required in the cooler production areas. Irrigation is needed where rainfall is inadequate especially in the hotter production areas.

d. Soil requirements

For successful production a fertile, deep well drained soil (at least 900 mm) with a good water holding capacity is required. At a young stage the crop is sensitive to water logging. Traditionally, production on sandy soils is avoided due to the risk of root knot nematode infection, lower fertility and lower water holding capacity, as well as damage by wind blown sand. Soybeans can be grown successfully on heavy clay soils. Acid soils are harmful to nitrogen fixation and protein synthesis. If the plant's molybdenum requirements are satisfied soybeans can be grown successfully on acid soils with a pH of lower than 5.2.

4. Production guidelines [4)]

No single cultivation practice is recommended since the specific system depends on the situation. Select the most appropriate system for a particular soil and cropping situation. This will depend on the crop sequence, topography, soil test results, and soil type and weather conditions.

4.1 Land preparation

Conventional cultivation

This entails ploughing in spring when soil moisture is adequate, followed by tilling to prepare the seedbed and incorporate herbicides if necessary. Mechanical weed control is also part of conventional cultivation.

Conservation farming

Under this system the aim is to disturb the soil as little as possible. Crop residue is left on the soil surface as far as possible. The aim is to reduce evaporation from the soil surface and to increase water infiltration during and after rain. Planting is done by means of a specially adapted planter that can plant through the plant residue on the soil surface. The use of RR cultivars simplifies weed control as it allows the use of a non-selective herbicide to remove all weeds in the young crop. As most soils, especially those with low clay content, are inclined to become compacted over time, some type of cultivation will be necessary from time to time.

4.2 Guidelines for the choice of cultivars[2)]

The choice of cultivar is an important facet in the production process and its effect is often underrated. Many soybean cultivars are registered in South Africa. Choosing of the right cultivar is one way of ensuring higher profits at no extra cost. Cultivars vary in maturity grouping, (mainly between MG IV-VII), growth habit, flower colour, hilum colour and pubescence (hairiness). Roundup Ready (RR) cultivars with resistance to the herbicide glyphosate presently dominate the seed market.Further detail is available from your seed company representative.

4.3 Growth habit

Cultivars with an indeterminate growth habit continue to grow while flowering and forming pods. These cultivars are well adapted for production under rain fed conditions with periodic drought stress especially early in the summer. They flower over a longer period and, to some extent, can withstand drought stress during the flowering period. In cultivars with a determinate growth habit the growing tip ends in a pod bearing raceme. Such cultivars are better adapted to production under irrigation where lush growth poses a lodging risk.

4.4 Cultivar choice

Different seed companies are responsible for the production of different cultivars. However, all cultivars are evaluated in the National Soybean Cultivar Trials and the results are published annually. Soybean cultivars are inclined to be adapted to specific environments depending on the length of their growing season, and this becomes apparent in the report. The report is available from the ARC-Grain Crops Institute

4.5 Seed requirement

To ensure a good stand a high percentage germination and viability of the seed is essential. Special care must be taken to ensure that the seed is not too dry at harvesting. Due to a fast deterioration in germination, soybean seed should not be stored for later use.

4.6 Planting date

Soybeans must preferably not be planted before the mean daily temperature of 15-18^{0}C has been reached. Depending on the planting time, temperature and day length will vary. Different cultivars will react differently to these variations. November is considered to be the optimum planting time. In warmer areas planting in December is still acceptable provided that a higher plant population and earlier-maturing cultivars are used. If soil and air temperatures reach acceptable levels early in the season, planting in October is recommended. As a general guideline:

Cool areas: 20 Oct -30 Nov

Temperate areas: 1 Nov-15 Dec

Hot areas: 15 Nov - 30 Dec

4.7 Row width

Soybeans can be grown in different row widths (40-90 cm). In many instances the row width used is determined by the machinery used for other crops e.g. maize, as well as the need for mechanical weed control. For better weed control, care should, however, be taken to ensure that the canopy closes before the onset of flowering This will also prevent flower and pod formation too near the ground to allow for ease of mechanical harvesting.

4.8 Plant density

The row width and plant population must be adapted to the available soil water content. Plant population should be adapted to the available moisture e.g. 300 000 plants for rain fed productions and 400 000 plus under irrigation. A planter with a row width of 90cm or less must be able to plant between 300 000 and 450 000 seeds per hectare.

4.9 Planting depth and planting techniques

Planting depth should be 50 mm for sandy soils and 20 mm for clay. Shallow planting can lead to suffocation, while unnecessary deep planting induces diseases and increases the risk of crust formation.

5. Fertilisation[4,5)]

Fertilise according to soil analysis. Soil analysis will not only lead to more appropriate fertilisation levels, but can also significantly limit unnecessary fertilisation costs

Table 3. Removal of plant nutrients by soybean seed[5)]

Nutrients removed : macronutrients (kg t^{-1} seed)						
	N	P	K	Mg	Ca	S
Per ton seed	65	6	19	3	3	2
Nutrients removed : Micro nutrients (g t^{-1} seed)						
	Fe	Mn	Zn	Cu	B	Mo
Per ton seed	-	20	17	16	-	-

Nitrogen

If the inoculation with locally produced commercial *Rhizobium* inoculant is done properly there is no need for additional N fertiliser. A low soil N content will stimulate the formation of nodules. For effective nodulation in acid soils, molybdenum (Mo) seed treatment (35 kg sodium **molybdate**) or a ground application of 210 g ha^{-1} sodium molybdate is necessary because molybdenum is poorly absorbed in acid soils. The success of nodulation can be determined by examining the root system of plants carefully dug out of the soil. Effective nodules are red inside and early nodulation is indicated by nodules high up on the main roots. Deficiency of both N and Mo is visible as a premature yellowing of the older leafs.

A well nodulated soybean crop leaves approximately 40 kg ha^{-1} in the soil, which can be used by the following crop like maize.

Phosphorus

Soybeans react well to P-fertilisation but deficiency symptoms are difficult to observe in a uniform field. Deficiency is associated with reduced growth and protein content of the seed. Band placement away from the seed at planting is recommended in soils that are inclined to deactivate the P.

Table 4. Phosphorus recommendations for soybeans (kg ha^{-1})[5)]

Yield target (t/ha)	Soil phosphorous analysis (Bray 1) (mg/kg)					
	5	**10**	**15**	**20**	**25**	**30**
1	20	17	15	13	11	10
2	40	31	25	21	19	18
3	60	45	35	31	28	26

Potassium

Most soils have an adequate K content. However, symptoms of K deficiency are clearly visible as browning of the leaf edges starting on the younger leaves. K must be incorporated at planting as it is not mobile in the soil. It is adsorbed to the clay in the soil.

Table 5. Fertilizer recommendations for soybeans (kg ha^{-1})[5)]

Yield target(t/ha)	Soil potassium analysis (mg/kg)					
	20	**40**	**60**	**80**	**100**	**>100**
1	20	16	13	11	10	0
2	40	31	25	22	20	0
3	60	47	39	34	31	0

6. Irrigation[4)]

The seasonal water use of soybeans is determined by the evaporation and the available water in the soil. Under rain fed conditions in South Africa the evaporation exceeds the water supply from the rainfall and stored soil water. This deficit results in a loss of potential production. A large percentage of the area under soybean production, especially in the hotter areas is under irrigation. To plan for irrigation the water requirement of soybeans can be calculated by assuming that the water use efficiency (WUE) is 6 kg grain ha^{-1} mm^{-1} water used. For a yield of 3000 kg ha^{-1} 500 mm water will be needed. With an overhead irrigation system like a centre pivot, 80% efficiency can be obtained. This means that 650 mm of irrigation water will therefore; be needed in order to prevent the depletion of the soil moisture reserves. The irrigation system must be designed to supply the daily needs of the crop during the peak demand period. The peak water demand normally occurs during January-February when atmospheric evaporation requirement reaches a maximum and canopy size and crop factor is relatively large. Rain water also contributes to the water supply of the crop. The normal assumption is that 60% of the rain falling during the growing season will be available to the crop. The soil water status must be determined regularly to adapt the irrigation to the crop's needs.

The aim should always be to achieve a high WUE. This is usually obtained with yields between 2000 and 3000 kg ha^{-1} where effective irrigation scheduling is employed. Various methods and technologies are available for irrigation scheduling. The following important considerations should be taken:

- Take care not to over-irrigate – especially during the early stages of crop growth
- Symbiotic nitrogen fixation is influenced by water stress-the greater the stress the lower the rate of nitrogen fixation
- When using overhead irrigation – it is important that water application does not exceed the infiltration rate of the soil.

Irrigation factor	Seedling germi-nation	Vegeta-tive growth	Reproduction	Ripening

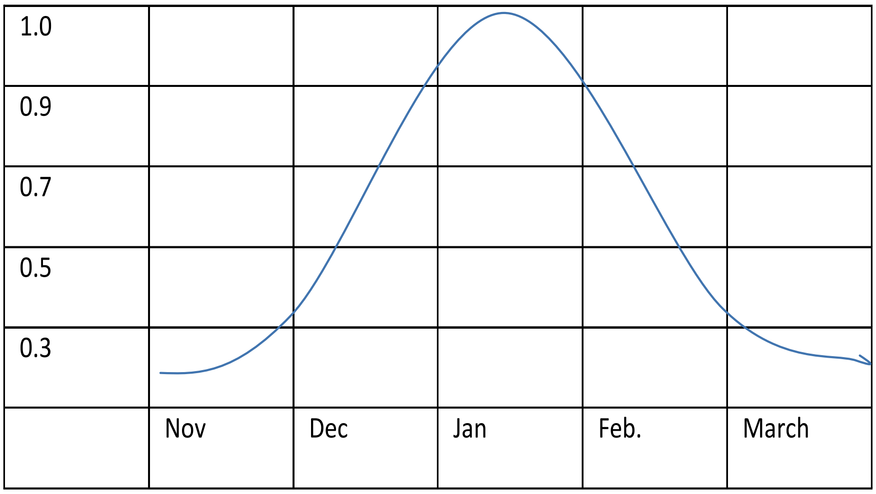

Figure 1. A typical example of growth and water use of soybeans

The principle with application of irrigation is that the soil should never be allowed to dry out. This is of critical importance from planting until the plants have emerged and become well-established, in order to achieve a good stand. The top 30-40 mm of the soil, in which the seeds are planted and the early root development occurs, may dry out rapidly under hot conditions, especially if ridge planting is used. Frequent light irrigations (±10 mm per irrigation) may be necessary, even though the lower soil layers have enough soil water.

The soil water content should be maintained at above 50% of the readily available soil water content throughout the growing period.

Table 6 indicates the approximate amount of irrigation water required for different climate regions. Effective rain indicates the contribution to total water requirement of the crop that rainfall could make under average irrigation management. Peak requirement is the amount of irrigation water that a crop requires during the month of highest requirement. Consult an irrigation specialist for specific irrigation advice.

Table 6. Approximate irrigation requirements of soybeans planted in different climate regions on a loam soil under a centre pivot (SAPWAT)

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm)
Dry, cold, summer rain, (Karoo), 15 Nov, peak Jan	170	150	500	170
Dry, cold, winter rain, 15 Nov, peak Jan	30	10	670	220
Dry, hot, west, (North Cape), 15 Dec, peak Feb	210	150	610	180
Dry, hot, east, (dry Bushveld), 15 Dec, peak Feb	230	100	410	120
Humid, hot summers, (wet Lowveld), 15 Dec, peak Mar	500	260	150	50
Humid, warm summers, summer rain, (Highveld), 15 Nov, peak Feb	380	270	330	100
Humid, warm summers, winter rain, 15 Nov, peak Jan	90	70	590	200

7. Crop rotation

Due to the danger of the build up of diseases and pests, soybeans should always be grown in a crop rotation system. Crops belonging to different plant families, must be rotated, for example soybeans should be followed by maize or wheat. There is also a yield advantage for the crop following soybeans (a mean of 12% yield increase for maize). In conservation tillage system crop rotation is even more important as plant material on the soil surface allows pathogens to survive from one season to the next. A non-host crop allows decomposition to take place without risk to the crop. Under rain fed conditions soybeans and maize are grown in an annual rotation. Where irrigation is available, soybeans (S), irrigation wheat (IW), and maize (M) can be rotated: S, IW, M, IW, S, IW, M, etc.

8. Weed control

At an early stage soybeans do not compete well with weeds. Effective early weed control will allow soybeans to produce a dense canopy that will suppress weeds.

Mechanical weed control

Tilling the field before planting is necessary to destroy all germinating weeds. Tilling once or twice before the canopy closes will control the weeds and allow the crop to suppress the newly germinating weeds. Care should be taken not to disturb the root systems or to produce clods or ridges that will prevent the harvesting of the lower pods.

Chemical weed control

A number of herbicides are registered for application at different stages i.e. before planting, after planting, before emergence and after emergence. Choose herbicides that will control the problem weeds. Care should be taken to apply herbicides according to the labels, for example the concentration should take the clay content into account. Some herbicides are not registered for use on all cultivars and some herbicides suitable for use on rotation crops have a long waiting period. The use of RR-cultivars has made the application of the contact herbicide glyphosate possible and has eliminated the need for mechanical weed control.

9. Insects and diseases[3)]

a. Insects

The Africa bollworm is the most important insect pest and must be controlled chemically if present during the reproductive stage to prevent seed damage.

b. Diseases

Soybeans are relatively free from major diseases. With the area under soybeans increasing more disease problems can be expected, especially if crop rotation is not practiced strictly.

Seedling diseases

Rotting of seed and seedling wilt caused by *Pythium* spp., *Fusarium* spp., and *Rhizoctonia solani* can cause poor stand and yield losses. Seed treatment with a suitable fungicide will protect the seedlings during germination. Crop rotation will reduce the amount of inoculum present in the soil.

Fungal leaf diseases

Along the warmer eastern production areas of KwaZulu-Natal, soybean rust, caused by *Phakopsora pachyrhizi* has become endemic. It has to be treated preventatively with a registered fungicide during the reproductive stage to prevent crop losses. No resistant cultivars are available.

Bacterial leaf diseases

Bacterial blight (*Pseudomonas savastanoi* pv. *glycinea*) and, to a lesser extent bacterial pustule (*Xanthomonas axonopodis* pv. *glycines*), normally occur but presently no yield losses occur. A longer crop rotation cycle is recommended where indications of increasing infection are observed.

Fungal stem diseases

Sclerotinia stem rot (caused by *Sclerotinia sclerotiorum*) is a serious disease under wet conditions e.g. excessive rain, over irrigation or a too dense canopy, which prevents the soil surface from drying. Crop rotation with non-host crops e.g. maize and wheat, the use of disease-free seed, deep ploughing to bury the survival structures and allowing the soil surface to dry out before the next irrigation cycle, will reduce the inoculums and the possibility of infection.

Viral diseases

Soybean mosaic virus (SMV) causes typical mosaic symptoms on the leaves and discoloration of the seed. It is transmitted by aphids, is seed borne and is the most important virus disease of soybeans. It can be controlled by using only disease free seed and by planting resistant cultivars.

c. Nematodes

Root-knot symptoms are caused mainly by two *Meloidogyne* spp. i.e. *M. incognita* and *M. javanica*, which are the two most important nematodes in South Africa. Chemical soil treatment is uneconomical. Avoid infected (mainly sandy) soil and plant resistant cultivars where available.

10. Harvest and threshing[4)]

Soybeans are harvested when the moisture content of the seeds is below 14% and within 14 days after the harvest is ripe to prevent shattering. The crop is not suitable for harvesting by hand. It is harvested with a combine harvester with a wheat table using a low drum speed to prevent seed damage. The cutter bar should be below 120 mm in order to reach the lowest pods. This is only possible on very even soil. Harvest loss should be less than 6%.

11. Marketing[1)]

Soybeans are sold to oil expressers who produce oil and soybean oil cake. The price is determined by the world market. South Africa is a net importer of soybean oil cake and therefore the price is determined by import parity. Soybean oil cake is used mainly as a protein source in animal feed. The poultry and pig industries are the main consumers. This is because the amino acid composition of soybean protein is the plant protein closest to that of the animal protein required for the feeding of single stomach animals

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My notes...........

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Module 6b

Sunflower

(Helianthus annus)

1. Introduction

Sunflower is a crop which, compared to other crops, performs well under drought conditions. This is probably the main reason for the crop's popularity in the marginal areas of South Africa like the areas of the Free State, Northwest province and southern Mpumalanga.

Unfortunately the crop is particularly sensitive to high soil temperatures during the emergence stage and especially in the sandy soil of the western Free State and the North West Province where this problem often leads to poor or erratic plant density.

The crop has a relative short production season and can therefore be planted over a period of at least three months. Sunflower is a crop that only belongs in a proper planned crop rotation system.

2. Physiology/Phenology

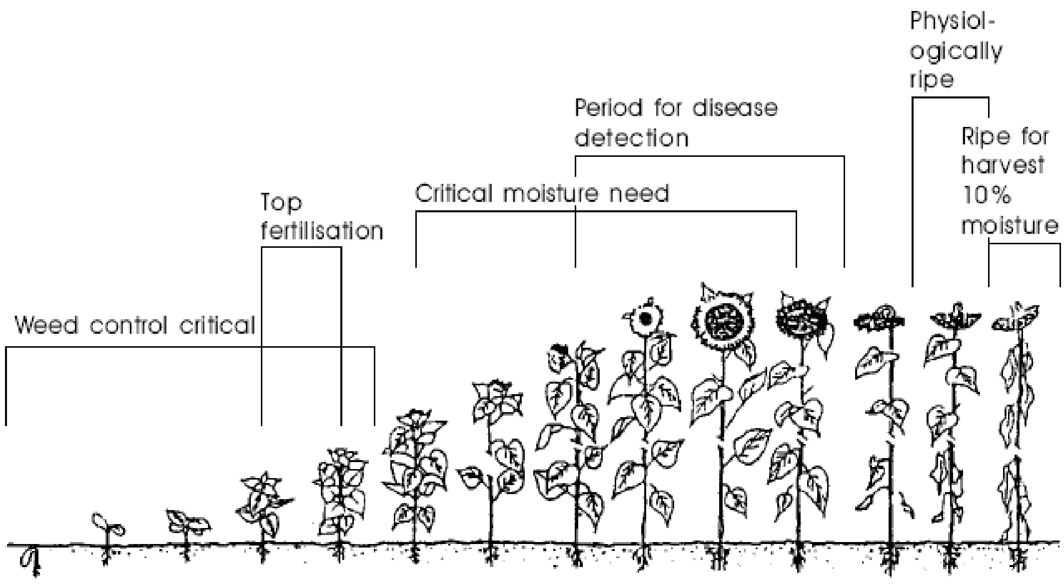

Figure 1. Growth and development of the sunflower plant [2]

3. Growth requirements[1,2]

a. Temperature

Sunflower is adapted to a wide range of daily temperature, although the oil concentration and quality are influenced by temperature. Moderate temperatures, especially during seed development improve oil concentrations and quality. Sunflower is well adapted to summer temperatures in South Africa.

Table 1. Influence of temperature (ºC) on the development of sunflower

Temperature		Days to flower
Max	Min	
24	12	75
34	17	55

b. Rainfall

Sunflowers need more than 400 mm of rain during the summer growing season, they are tolerant to drought.

c. Soil requirements

Sunflowers grow on a wide variety of soil types. Traditionally sunflower cultivation has been limited to soils where the clay percentages vary between 15 and 55% (sandy loam to clay soil types). At present the major planting areas are in soils with a clay percentage of less than 20%.

The sunflower plant has a deep and finely branched highly efficient tap-root system which can utilise water form deep soil layers, even deeper than 2 m. Therefore sunflower also performs well during a dry season, especially in deeper soils or in soils with a shallow water table. Because of the unique water-use pattern and root system shallow soils often found in the eastern production areas, like Westleighs, Estcourt and Kroonstad are also suitable for sunflower production. Sunflower is in general capable of utilising water from the clay horizons of these soils. The potential yields of these soils are, however, limited. Sunflower is unfortunately relatively sensitive for soil acidity and soil with a pH (KCl) below 4.5 should be avoided.

4. Production guidelines

Production stability can be enhanced by the application of cultivation practices which limit soil water stress as far as possible. The point of departure in soil preparation should be to utilise rainfall and soil water to a maximum. Soil preparation should be focused on decreasing runoff, especially in the case of soils with a low infiltration rate. These losses can be limited to a great extent by applying the correct soil cultivation practices.

Primary cultivation practices such as ploughing with a mould board plough or chisel plough are suitable. The aim of the cultivation is to break up limiting layers, destroy weeds, and provide a suitable seedbed and to break the soil surface at the same time to ensure maximum rainfall infiltration a well as to prevent wind and water erosion.

4.1 Land preparation

Sunflower is usually cultivated in rotation with maize or sorghum and benefits from dense mulches of these crops. Mulches protect the soil against the impact of raindrops, which seals the surface and reduces the infiltration rate but also enhance some other pest. Soil compaction can be a serious problem, especially in sandy soils. If the compaction is not broken, the crop cannot utilise the full water capacity of the soil profile, because roots cannot penetrate the compacted layer. In dry years, the root development of sunflower plant will be seriously hampered where compaction exists.

4.2 Guidelines for the choice of cultivars

The choice of cultivar is an important facet in the production process and its effect is often underrated. Choosing of the right cultivar is one way of ensuring higher profits at no extra cost. Although sunflower is subject to diseases, from a production point of view yield and yield reliability are by far the most important criteria when cultivars are evaluation. The choice of the cultivar will depend on the yield, adaptability, growing period, disease resistance, and lodging. Further detail is available from your seed company representative.

4.3 Planting date

Normally sunflower can be planted form the beginning of November until the end of December in the eastern areas and until mid- January in the western areas. In the choosing the best planting date the following factors should be kept in mind:

- The onset and last date of frost
- Soil temperature
- Moisture requirements of the crop
- Rainfall pattern
- Risk of bird damage

High soil temperatures during planting may result in poor emergence. In the western areas with sandy soils, this is a major factor, which often leads to a poor stand. At Viljoenskroon in the north-western Free State, soil temperatures as high as 45ºC have been measured in a sandy soil at plant depth during December. In these parts planting should rather be done before mid-November or when a period of 2-3 days of cooler weather is expected. The optimal germination temperature for sunflower is 22 ºC. Emergence percentage on sandy soil decreases if the average daily maximum air temperature increases above 30ºC.

4.4 Row width

The influence of row width on sunflower yield is quite small. Row widths of 90-100cm are mostly used, but wider rows can also be used. Where other crops such as maize are planted in rows of 1.5 m or even 2.1 m, sunflower can be planted successfully in these row widths in order to fit farm implements. Wide row spacing is only suitable for yield potential lower than 1 500 kg/ha. Row width is however important on cracking clayey soils as illustrated in Table 2.

Table 2. Influence of row width on sunflower yield on heavy clay soils

Row width (m)	Yield (kg/ha)	
	Low potential conditions	High potential conditions
1	1058	1950
1.5	856	1860
2	694	1656

4.5 Plant density[2)]

The correct and uniform plant density with sunflower is the basis of a good yield. Although the plant is able to compensate by head size and number of seeds per head, a very low plant density (e.g. less than 20 000 plants /ha) often limits yield. At a low plant density, heads are forming which are too large, dry out unevenly and eventually impair the harvesting process. Large heads often have serious seed setting problems. High plant densities of 55 000 plants /ha and more cause a higher occurrence of lodging, which should be avoided.

It is important that sunflower be spaced evenly. The accuracy of the planter determines whether an even plant density will be achieved. Guidelines for the plant density are given in Table 3 and for seed requirements in Table 4.

Table 3. Guidelines for plant density at different yield potential levels

Potential (kg/ha)	Plant density (plants/ha)
1000-1200	25 000-30 000
1200-2000	30 000- 35 000
2000-3000	35 000- 40 000
3000-4000	40 000- 50 000

Table 4. Sunflower seed requirements (kg/ha) according to plant density and seed size

	Plants /ha		
Seed size	25 000	30 000	35 000
4	1.42	1.71	1.99
3	1.81	2.17	2.54
2	2.32	2.78	3.24

4.6 Planting depth and planting techniques[1,2)]

Sunflower seeds are planted at relatively shallow depths. In soil with high clay content, seeds are planted at a depth of 25mm. In sandy soils, seeds can be planted at a depth of up to 50 mm although 25 mm is a general guideline for all types of soil. For the planting process, the importance of a good planter cannot be overemphasized. To plant sunflower successfully, the planter should be able to space seeds evenly, should have a good depth control mechanism and should be equipped with press wheels. During germination, seedlings are particularly sensitive to compacted soil, which means the press wheels should only exercise light pressure on the soil to avoid compaction but still ensure good contact between the seed and soil.

4.7 Yield potential

It is important from a management point of view that a reliable assessment of the yield potential, with effective planning is done before cultivation and planting of the crop start. Plant density, cultivar and especially the fertiliser programme cannot be planned unless yield potential has been accurately determined. Table 5 gives a generalised soil depth and rainfall related yield potential.

Table 5. Yield potential (kg/ha) in relation to soil depth (cm)

Soil depth (cm)	Rainfall (mm)		
	500	550	650+
40-60	1000	1200	1500
60-80	1300	1500	1900
80+	1300	1600	2200

4.8 Production tips

- Avoid extremely high temperatures during planting time, as well as the possibility of frost damage.
- The soil water content before planting has a major influence on establishment, growth and survival of the plants during droughts
- Use more than one planting date to spread the risk of drought
- In clay soils, sunflower should be planted. in narrow rows (90 to 100 cm) to improve soil water utilisation
- Planters with press wheels, which apply pressure alongside the seed, are more suitable than those with press wheels exercising direct pressure from above.

5 Fertilisation[2)]

Fertilise according to a resent soil analysis. Soil analysis will not only lead to more appropriate fertilisation levels, but can also significantly limit unnecessary fertilisation costs. Compared to other grain crops, sunflower utilises soil nutrients well. The main reason for this is the finely branched and extensive root system. The roots come into contact with nutrients which cannot be utilised by other crops.

5.1 Macro nutrients

Sunflower normally reacts well to nitrogen and phosphorus fertilisation where there is a shortage of these elements in the soil.

- **Nitrogen**

Where there is a shortage, growth rate decreases dramatically and leaves turn pale green while lower leaves die off. General guidelines for N-fertilisation are shown in Table 6. Due to the variation of N in the soil, these values can be adjusted upwards or down wards with up to 20 kg/ha.

Table 6. Nitrogen requirements (kg N/ha)

Target yield (kg/ha)	N guideline (kg/ha)
1000	20
1 500	30
2 000	40
2 500	50
3 000	60

- **Phosphorus**

A shortage of phosphorus is characterised by retarded growth and in serious cases, necrosis can be detected on the tips of the lower leaves. Fertilisation guidelines are given in Table 7.

Factors which should be taken into account when planning a phosphorus fertilisation programme:

- Attempts should be made to build up the phosphorus content of soil over time

The optimum soil phosphorus level for sunflower is about 10 mg/kg (Ambic1), which implies that phosphorus fertilisation is essential if the level of phosphorus of the soil is below 10 mg/kg.

Table 7. Guidelines for phosphorus fertilisation (kg P/ha)

Soil P (mh/ha)		Target yields (kg/ha)		
Ambic 1	Bray 2	1000	1500	2000
2	7	10	16	21
4	10	9	14	18
6	12	8	12	16
8	15	7	11	15
10	18	6	9	12
12	21	3	5	10
14	24	0	4	8

- **Potassium**

Although sunflower draws huge quantities of potassium from the soil, potassium fertilisation is usually unnecessary.

5.2 Micro nutrients

Shortages of boron and molybdenum can limit the growth and yield of sunflower in the eastern parts of the country. To avoid problems concerning boron care should be taken to apply fertiliser containing it. Local seed companies usually treat their seed with molybdenum which make any additional application unnecessary.
If no soil analysis is available 50 to 100kg/ha of a 3:2:1 (25) fertiliser mixture applied at planting is usually adequate for a yield potential of 1000 to 1500 kg/ha.

6 Irrigation

Although sunflower can be produced under irrigation, due to the excellent water use ability of the plant supplementary irrigation instead of full irrigation is recommended.

Supplementary irrigation:

- Supplementary irrigation is important to ensure that the soil profile is at field capacity to serve as a reserve for the development of the plant when irrigation and rainfall cannot meet the crop water requirements during the growing season.
- Sensitive growth periods of sunflower regarding water use are:
  - Flower bud stage (45-65 days after plant, Figure 1) and flower stage (65-80 days after plant) till seed development stage (80 days after plant)

If only supplementary irrigation is being applied the recommended time for that is during the flowering stage and the second irrigation application from flowering till seed development.

Full irrigation:
The following irrigation applications are recommended where no irrigation scheduling aid is available:

- Before planting to prevent soil crusting and poor emergence with an application after planting. If the soil is irrigated to field capacity before planting, the second irrigation application can be postponed till 30-40 days after planting to ensure that the plant develops a strong tap root system

- The first irrigation application is recommended when the plant is about 40cm high or flower bud stage.

- From two weeks before the plant starts to flower, the irrigation frequency should be increased to avoid that stress occurs.

- From two weeks after flowering the irrigation frequency can be decreased and the last recommended irrigation application should be offered 25 days after flowering regarding medium growth length cultivars.

- The following characteristics should be kept in mind with the use of irrigation scheduling tools and techniques:
  - The leaf canopy of the sunflower plant develops rapidly, which increase water use and could quickly develop into a possible water stress situation if not monitored regularly.

Table 8. Approximate irrigation requirement for sunflower (SAPWAT)

Area and planting date	Jan	Feb	Mar	Apr	May	Total
West free State – North Cape (15 Jan)	8	20	120	102	0	202
Springbok flats – Brits (15 Jan)	1	10	85	119	3	237

7 Crop rotation[2]

Sunflower should be grown in rotation with other grass type (monocotyledones) crops as:

- The risk of diseases and weeds increase with monocropping or where sunflower rotated with other broad leave crops.
- A yield and quality advantage is often measured in a follow-up maize and sorghum crop
- Weed and pest problems lessen with crop rotation.

8 Weed control[1,2]

Sunflowers are very sensitive to weed competition for the first six weeks after planting. Efficient weed control is possible by a combination of mechanical and chemical practices. Several herbicides are available for weed control especially grass weeds.

The following tips are recommended for mechanical control:

- Cultivate before the sunflower is to high for equipment , otherwise plants are damaged easily
- Prevent damaging the sunflower roots, and therefore cultivation should be shallow (less than 75 mm). Throw loose soil onto the row-this will help to suffocate weeds sprouts in the row
- Hoe during the hottest part of the day when the sunflower is wilted- since it reduces stem break

The use of herbicides has many advantages, of which the most important is that effective weed control can be applied during wet periods when mechanical weed control is impossible.

9 Insects and diseases

Although a number of insects and diseases may attack sunflower, it is often not serious enough to have a negative effect on the yield. Soil insects such as cutworm, and several other larvae or beetles may cause damage to emerging seedlings.

10 Harvesting

Sunflowers should be harvested as soon as the seed moisture content is 10% or when 80% of the sunflower heads are brown (physiologically matured). This is done in order to minimise losses caused by birds, lodging and shattering.

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Developer: Dr Andre Nel, ARC Grain Crops Institute

Authenticator: Dr AJ Liebenberg, ARC Grain Crops Institute

Module 6c

Drybean
(*Phaseolus vulgaris*)

1. Introduction

Dry beans are an important food legume and a source of protein (18-23%) in the diet of a large part of the South African population especially along the east coast. Beans originated in Central America (small seeded types) and the Andes mountains of South America (large seeded types) where it is an important staple food. Within the genus *Phaseolus* two species are produced in South Africa, i.e. *Phaseolus vulgaris,* generally known as dry beans and *Phaseolus coccineus* locally known as kidney beans.

2. Climatic requirements[1)]

a. Temperature

Dry beans are adapted to cool summer temperatures and grow optimally between 18 and 26ºC. Cold nights will retard development and extend the growing season. The minimum required frost free period from planting to harvesting can vary between 85 and 120 days. This depends on the growing period of the cultivar and the minimum night temperatures – lower than 18ºC extends the growing period. Temperatures during the flowering of above 30ºC will result in flower and pod abortion in dry beans and above 25ºC in kidney beans. These factors should be kept in mind when deciding on a planting date.

b. Rainfall

In South Africa beans are mainly grown as a rain fed crop in the cool high rainfall areas of Mpumalanga and eastern Free State with an annual rainfall of between 650 and 750 mm. The crop requires 400-450 mm water (rainfall and/or irrigation) for optimal yield. The greatest need for water is during flowering. Drought is normally accompanied by high temperatures compounding its effect. Drought at the end of the growing season accelerates maturity by 10 to 14 days.

3. Soil requirements

Beans grow optimally in deep (>900 mm) well drained soils without any nutrient deficiencies. Beans cannot tolerate the water logged conditions that are normally associated with poorly drained soils. The clay content should be between 15 and 35%. Beans do not grow well on sandy soils. The crop is very sensitive to acidic soils. A pH(KCl) above 4.8 is required.

4. Cultivars and seed

a. Seed types

Seed types are recognized by differences in the colour (most important characteristic), size and shape of the seed. Only three bean seed types are important in South Africa. In *P. vulgaris* (drybeans) the large seeded red speckled beans (also known as sugar beans) comprise about 80% of the production and small white canning beans about 15%. In *P coccineus* only the large white kidney type is grown. It comprises approximately 3% of the production, which is limited to the cool high rainfall areas of Mpumalanga. The red speckled and large white kidney types are sold as dry packed beans whereas the small white type is canned as baked beans in tomato sauce.

b. Cultivars

Within each seed type there are different cultivars that differ in yield potential, growth habit, length of growing season and resistance to various diseases. They may also have seeds that vary in size and shape. Cultivars are the result of crosses made by breeders to combine the good characteristics of different cultivars in order to improve yield, seed quality and agronomic characteristics and to reduce the risk of crop losses due to diseases and pests. Selections are done under field conditions to evaluate adaptation and under high disease pressure (with inoculation if necessary) in the glass house and the field to evaluate disease resistance.

c. Growth habit

The development stages of the bean plant are illustrated in Table 1.

Table 1. Stages of development of a bean plant

Stage No	A. General description of vegetative stages
V1	Completely unfolded leaves at the primary (unifoliate) leaf node.
V2	First node above primary leaf node. Count when leaf edges no longer touch.
V3	Three nodes on the main stem including the primary leaf node. Secondary branching begins to show from branch of V1
$V_{(n)}$	n nodes on the main stem, but with blossom clusters still not visibly opened. V5 Bush (determinate) plants may begin to exhibit blossom and become stage R1. V8 Vine (indeterminate) plants may begin to exhibit blossom and become stage R1.
Stage No	**B. General description of reproductive stages**
R1	One blossom opens at any node.
R2	Pods 12 mm long at first blossom position.
R3	Pods 25 mm long at first blossom position. Secondary branching at all nodes. Half bloom.
R4	Pods 50-75 mm long – seeds not discernable.
R5	Pods 120-50 mm long (maximum length for bush type) and 75 mm (runner type). Seeds discernable by feel.
R6	Seeds at least 4 mm long over long axis. Pods 100-125 mm long (maximum length for running type).
R7	Oldest pods have fully developed green seeds. Other parts of plant will have full length pods with seeds almost as large as first pods. Pods will be developing over the whole plant.
R8	Leaves yellowing over half of plant , very few small new pods, small pods may be drying.
R9	Mature, at least 80% of the pods showing yellow and mostly ripe. Only 30% of leaves are still green.

In the determinate (or bush) bean cultivars the branches end in a flower raceme. Flowering starts all over the plant at the same time. This growth habit is often associated with good lodging resistance and early maturity and requires relatively high night temperatures for optimum yields. In the case of an indeterminate cultivar the growing point remains active after flowering. Flowering starts in the lower canopy. Indeterminate cultivars do well under lower night temperatures. They are inclined to lodge especially in the case of the red speckled type.

d. Cultivar choice

Cultivars are evaluated in the National Dry Bean Cultivar Trials and the results are published annually. The report is available from the ARC-Grain Crops Institute or the seed companies that supply bean seed[2,3,4,5)]. Growers should keep the following in mind when deciding on a suitable cultivar. The seed type of the cultivar is important from a marketing point of view. Cultivars of the same seed type vary; some are widely adapted while others prefer specific production regions. Cultivars differ in their resistance to different diseases and producers should plant cultivars with resistance to the predominant disease(s) in their area and at the same time be confident that there is a good market for that seed type.

e. Seed requirements

Beans are susceptible to a number of seed borne diseases. Seed companies produce disease free certified seed under conditions that are unfavourable for disease infection. Special care is also taken to ensure good germination. Serious yield losses can be expected if producers retain their own disease infected seed. Seed can be treated with fungicide against soil borne fungi causing seed rot. This is especially important if low temperatures can be expected during or shortly after germination. The fungicide will not prevent infection later in the season, or significantly affect any seed borne diseases.

5. Production guidelines

a. Land preparation

A deep, even and firm seedbed that will ensure good contact between the seed and the soil is needed. A seedbed that is too fine will cause soil compaction, which results in poor germination. Undecomposed plant material at planting time will increase the danger of root rot and debris-carried diseases, and cause a nitrogen negative period due to rotting. For this reason it is recommended that beans are planted in a ploughed field rather than under minimum or zero tillage.

b. Fertilisation

A soil analysis is essential for a reliable fertiliser recommendation. South African soils are poor in phosphorous (P) and deficiency is associated with stunted plants producing few flowers and pods. Under commercial agriculture soil P levels are built up by extended crop production. Beans react relatively poorly to P fertilisation except when the nutrient is well below the critical value of about 25 mg/kg (Bray 1). Potassium (K) levels are normally within the recommended range where beans are produced on soil with a clay content of above 15%. Although the common bean is a legume, symbiotic nitrogen (N) fixation is regarded as insufficient for optimum yields due to the short growing period of the crop and the negative effect of periodic drought stress on the survival of the bacteria. The fertiliser recommendations in Table 2 apply for rain fed as well as irrigated productions on soil with clay content above 15%. However, under irrigation and on sandy soils the N application should be raised to 60 kg/ha or higher.

Table 2. Fertiliser recommendations for beans

Yield target (t/ha)	N (kg/ha)	P (kg/ha) for soil phosphorus analysis (Bray 1) at: (mg/kg)							K (kg/ha) for potassium analysis at: (mg/kg)				
		13	20	27	34	41	48	>55	40	60	80	100	>100
1.5	15	16	12	10	9	8	7	0	22	19	17	15	0
2.0	30	22	16	13	12	11	10	0	27	24	21	19	0
2.5	45	28	20	16	15	14	12	0	32	29	26	24	0

c. Planting time

Beans should be planted at a time that will ensure that the mean maximum temperature is below 30ºC at the onset of flowering to prevent flower and pod abortion.

In the cool production areas of Mpumalanga and the eastern Free State, planting is recommended between middle November and end December. This will reduce the risk of rain during harvesting in the case of an early planting and frost damage as a result of a late planning.

In North West and Northern Cape, planting from end December to middle January will reduce the risk of high temperatures during flowering on the one hand and frost damage before maturity on the other hand. In frost risk areas in Limpopo planting can be done from middle January until middle February. In these areas irrigation is recommended to reduce the risk of crop failure due to unreliable rainfall.

In frost free areas planting during March and April is recommended (under irrigation only).

d. Weed control

The successful control of weeds is essential for high yields. Bean fields should be kept weed free for the first 6-8 weeks, i.e. until the onset of flowering. Weeds compete with beans for water, nutrients and sunlight during this period. If the crop is well developed at flowering it will cover the area between rows and will suppress the competition of weeds. If not, weeds should be removed by hand hoeing.

Mechanical weed control with a tiller or by hand – at least twice before flowering is effective. However, wet conditions can prevent movement in the field and therefore a combination of herbicides and mechanical control is more reliable and effective. Contact your local representative for the most effective registered herbicides. Beware of the possible presence of residue of harmful herbicides from previous crops.

e. Spacing

The general practise, mainly because it is rotated with maize, is to plant beans in 900 mm rows. This spacing facilitates the use of the same machinery on both crops. If the bean plants cover the area between the rows at flowering time (in the case of medium and long season cultivars), there is little yield advantage in narrower between-row spacing. Short season cultivars (85-90 days) have small plants and their yield can be improved by closer row spacing (700-750 mm). However, this row spacing should allow the essential mechanical weed control. These recommendations also apply for beans under irrigation.

An in-row spacing of 75 mm is recommended. There is no yield advantage in spacing plants denser in the row. For large white kidney beans a spacing of 150 mm in the row is recommended due to their strong trailing growth habit and large seeds.

6. Irrigation

Irrigation is applied to supplement rainfall under rain-fed conditions to increase yield. Its main application is, however, where beans are grown in dryer parts of the country during the summer or in frost free areas during the winter. Furrow and drip irrigation is generally used for seed productions during the summer in the lower Olifantsrivier area of the Western Cape. Sprinkler and centre pivot irrigation is the most common irrigation method.

Before seedbed preparation the soil should be irrigated to field capacity at a depth of 1 m. As soon as the soil is dry enough the seedbed should be prepared and planted. Irrigation scheduling is essential for the optimum yield per unit of water. Several methods of scheduling can be applied; but keep in mind that scheduling based on soil water content is the recommended approach. Scheduling approaches that rely on predictions are not to be recommended, although predicted values can give a good estimate of expected irrigation requirements and are usually used when planning crop irrigation requirements.

A critical period for water application is from flowering to young pod stage, water stress during this period could result in high yield losses. Over-irrigation, on the other hand, could result in crop losses due to water logging, root rot and the fungal disease *Sclerotinia*.

Table 3 indicates expected irrigation requirements for medium grower dry beans grown in different parts of the country as determined through the use of SAPWAT.

Table 3. Expected irrigation requirements for medium grower dry beans grown in different parts of the country (SAPWAT)

Area	Planting	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Dendron – Vivo	End Jan				20	12	112	116			303
Ermelo – Standerton	Mid Dec			18	33	86	52				189
Lowveld	Mid Mar						20	56	125	86	287
Lower Olifants River	Mid Oct	22	125	252	189						587
North Cape	Mid Jan				18	64	112	34			228
Warmbad – Marble Hall	End Jan				22	5	114	112			253

7. Crop protection

a. Diseases

Beans are susceptible to a number of viral, bacterial and fungal diseases with the potential to cause serious yield losses. For efficient management it is important to keep the following in mind.

- The most effective control measure is to plant resistant cultivars and use supplementary chemical control when resistance is inadequate.
- Use disease free certified seed to control seed borne diseases.
- The incidence of a disease or pest can vary from year to year depending on climatic factors. Good management can reduce the number of disease causing units (for example spores), thus reducing the extent and rate of epidemic development.
- Rotation with maize (or other cereal or grass crop) for at least two seasons between bean crops is essential to prevent infection through infected plant debris and volunteer plants.
- Diseases spread rapidly by means of wind, water, machinery, equipment, clothing, insects, etc. Isolation of different fields by minimising movement between them (and within each field) will prevent the rapid spread of a disease. This is especially applicable if different seed lots and planting times are used.
- Inspect bean fields regularly for diseases (especially during wet periods) or pests that require chemical control measures to ensure application at the first signs to prevent the development of an epidemic.

i. Virus diseases

Viruses cannot be controlled chemically. *Bean common mosaic virus* (BCMV) is the most important virus disease. It is seed borne and disease free seed must be used. It can be controlled by planting resistant cultivars. All the most important cultivars are resistant and the seed free of BCMV.

ii. Bacterial diseases

Three seed borne bacterial diseases can attack beans, i.e. common blight *(Xanthomonas axonopodis* pv. *phaseoli)*, halo blight *(Pseudomonas savastanoi* pv. *phaseolicola)* and bacterial brown spot *(Pseudomonas syringae* pv. *syringae)*. The use of disease free certified seed is effective in postponing the onset of an epidemic for long enough to prevent serious yield losses. A few cultivars with resistance against specific bacterial diseases are available.

iii. Fungal diseases

- **Rust** *(Uromyces appendiculatus*) is the most important fungal disease in high rainfall areas such as. KwaZulu-Natal and Mpumalanga. Rust coloured pustules, often surrounded by a yellow halo, develop on the leaves. A brown rust coloured dust (spores) is visible when rubbed. Rust is wind borne and can spread over long distances if the climate is favourable. It generally appears after the onset of flowering and can cause serious yield losses due to early defoliation. Resistant cultivars are available but some additional chemical control might be necessary during very wet periods.

- **Angular leaf spot** *(Pseudocercospora griseola)* occurs mainly in the humid eastern bean production areas. Angular dark grey or brown lesions develop on the leaves and spore carrying organs are visible on the lesions on the under side of the leaves. The disease is wind borne and serious crop losses can occur mainly on large seeded beans, e.g. red speckled, due to early defoliation. Resistant cultivars are available. No fungicides are registered but it can be controlled with some of the fungicides registered for rust control. The two diseases often occur together.

- **Anthracnose** *(Colletotrichum lindemuthianum)* can cause serious yield losses under cool wet conditions. Sunken brown lesions with a reddish brown border develop on the pods. It is seed borne and can be controlled by planting disease free seed and practicing crop rotation. None of the local cultivars are resistant to all the local anthracnose races. Chemical control is possible but less effective.

- **Seed decay** and post-emergence **damping-off** *is* caused by a number of different soil borne fungi (*Fusarium* sp., *Rhizoctonia solani and*

Pythium sp.). It can seriously reduce the plant population, resulting in poor yield. Cold wet conditions during germination, poor drainage and soil compaction favour the fungi with resulting poor stand and crop loss. Root rots can also occur later in the season as a result of stress conditions.

- **Sclerotinia** stem rot (*Sclerotinia sclerotiorum*) usually occurs after flowering under cool wet conditions when the canopy covers the area between the rows, keeping the surface damp, for example with over-irrigation on winter plantings. Stem and pod infections usually start at dead flowers that stick to the plant, causing lesions that develop in a woolly mass of fungal growth. Hard black survival structures (sclerotiums) develop and can survive in the soil for many years.

b. Insects

- The **African bollworm** *(Helicoverpa armigra)* feeds on the developing seeds in the pods, resulting in poor seed quality and yield loss. Young caterpillars are almost black; older ones vary from black to brown, green or pink. The underside and bands along the sides are pale white. If they occur during the pod stage chemical control is necessary.

- The **common bean weevil** *(Acanthoscelides obtectus)* is a storage insect. Females lay eggs loosely inside mature pods in the field or among the seeds in storage. The larvae burrow and feed inside the seeds and pupate. The mature insects appear through a small round opening when temperatures are favourable in the summer. The pest can be controlled by fumigating the seed immediately after harvest.

c. Nematodes

- Root knot nematode infection can be identified by the presence of patches of stunted and yellow plants with galls on the roots. No resistant cultivars are available. Sandy soils are inclined to have higher nematode populations and should be avoided. Chemical control with registered nematicides can be done but is not always cost effective.

8. Harvest and threshing

Dry beans can be harvested as soon as all the pods have dried, but before they are so dry that the seeds begin to shatter. To ensure minimal seed damage, the moisture content of the seed during threshing should be about 15%. For long term storage, however, it should not be above 12%.

Poor quality can result from rain just before or during the harvesting process; seeds can discolour and can germinate in the pods, especially those that touch the soil. Harvesting can be done in one of the following ways:

- The plants can be pulled by hand and the seeds beaten out on a trashing floor or tramped out by animals or a tractor. This is only practical for small harvests.
- The plants can be pulled by hand and packed in heaps or wind-rows and threshed with a stationary thresher.
- The whole process can be mechanised, i.e. pulled, wind-rowed and threshed with a combine harvester. In some cases the pulling of the plants and making of the wind-rows is still done by hand.

9. Marketing

Beans are sold directly to bean dealers or, in rural areas, directly to the consumer on the local market. Red speckled beans are cleaned, fumigated against bean weevils and packaged in plastic bags for sale in shops and supermarkets. Prices are determined by supply and demand. The local production is much lower than the demand and beans are imported annually, mainly from China. Prices are therefore determined by the seed quality and the import parity that in turn depends on the availability of Chinese beans.

Small white canning beans with the right canning quality are mainly planted under contract for dealers who clean the seed to the quality required by the canners. Canning beans are also imported on a regular basis.

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5) McDonald Seeds, P.O. Box 40, Mkondeni, 3212. Fax 033 346 0121

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Module 6d

Groundnuts

(Arachis hypogaea)

1. Introduction

In South Africa groundnuts are grown in the summer rainfall areas under irrigation and rain fed. The high mechanisation and labour costs however limit the size of production. From 1970-1982 the yearly average production was 204 000 tons compared with an average production of 94 000 tonnes from 1982-1994.

Small-scale farmers, especially in the northern and eastern parts of South Africa grow groundnuts mainly for home consumption.

2. Growth requirements [1,2]

This tropical, subtropical crop requires areas with long frost-free periods.

a. Temperature and humidity

Since groundnuts require a period of high temperatures of which at least 160 days are frost free, the mean daily temperature for optimum growth is 22-28°C with a minimum temperature of 18°C.

The temperature of the water absorbed by the seed is also of critical importance as far as germination is concerned. If the temperature of the water is high enough, enzymes that stimulate energy exchange are activated. If the water temperature is relatively low and slowly increases, the enzymatic process is not accelerated and results in reduced germination. The golden rule is not to plant unless the soil temperature has reached a stable 18°C at 5cm soil depth. Do not plant in dry soil and irrigate with cold water.

Vegetative growth consists of plant components like the leaves, stem and flowers. The number of leaves on the groundnut plant increases with rising of temperature form 20°C to 35°C. The maximum area of leaves (leaf canopy) are reached when temperature are around 30°C. Stem growth of groundnut plants is also enhanced when temperatures are above 20°C. Flower initiation is also closely related to mean temperature on the condition that the variation between day and night temperatures is less than 20°C. The maximum number of flowers are formed when the average dally temperature is 27°C.

b. Soil requirements

The groundnut pod is produced on pegs, formed above the ground after fertilisation that penetrates the soil surface. Groundnuts have a well-developed tap root system which, depending on the soil type, can reach a depth of 1.8 m. It is therefore important that the seedbed must be prepared deep, without compaction layers. Soils with a high potential for the production of groundnuts are thus typically 900-1200 mm deep, structureless, yellow or yellow-red soils with a sandy-loam to sand texture in the topsoil. Shallow soils should be avoided due to the lower water retention capacity as well as possible water logging that can occur. Most soils normally selected for production, in which the sand fraction is relatively high, also are inherently low in phosphorous, calcium and boron.

3. Production guidelines[1,2]

3.1 Land preparation

Groundnuts are usually produced on light sandy soils which are subject to wind erosion. Therefore when the seedbed is prepared, this should be kept in mind. A uniform seedbed, with sufficient planting depth, weed control and good soil water retentions is a precondition for optimum production yields. Producers often are tempted to incorporate groundnuts in a minimum tillage system, however plant residues should be well incorporated into the soil and this will also ensure that weed seeds are well buried and fewer disease problems also occur. The use of tine implements is therefore not recommended for groundnut production.

3.2 Planting

The success or failure of groundnut production is determined at planting. When planting in soils prepared with a mould board plough, time must be given for the soil to warm up and the top to dry out before planting starts. When planting in irrigated soil, the soil must be irrigated before planting. Groundnuts planted in dry soil and irrigated afterwards germinate slower. A good indication of the correct soil condition of the seedbed is when dust is stirred up at the planter.

The best planter for use in groundnuts has to comply with aspects like accurate and regular spacing of the seed (75 cm apart), good depth control, and no damage to seeds. Important is that groundnuts are not to be cultivated unnecessarily and are certainly not earthed up. The following cultivation is recommended after planting:

- Herbicide can be applied
- Gypsum can be applied
- Soil crust, which might have formed as a result of heavy rain or irrigation should be broken
- Wind erosion action can be controlled
- Weeds can be mechanically controlled

3.3 Planting date

Groundnuts should be planted as early as possible in the season when the danger of cold spells has already been reduced. In the Highveld regions this period is the last week of October till mid November. Groundnuts planted late; usually produce lower yields and experience more foliar diseases. In warmer areas, early October plantings are recommended especially cultivars with a long growing season like Norden and Selmani. Short season cultivars (like Harts and Kwarts) must no be planted later than middle November till the first week of December.

3.4 Planting depth and spacing

Planting depth is a very important manageable factor that determine production yield. The correct planting depth is 50-75mm which will ensure that the plant develops and produces optimally. Surface crusts should be broken before plants emerge.

Plant populations are normally determined by the availability of moisture while cultivar choice is very important when produced under irrigation. Table 1 provides the adjusted number of plants per hectare according to the different row widths, and with-in row plant spacing of 75 mm.

Table 1. Plant populations

Row width (mm)	Plant populations/ha
300	444 000
450	296 000
600	223 000
750	177 000
910	147 000

Various plant patterns can be followed namely single-row, double-row, tramlines, etc. The specific plant pattern is not so important, but rather the space available for the plant should be adequate. Too dense spacing can result in competition between plants for light, nutrition and soil water, resulting in plants, which develop only a main stem with a few pods. Groundnuts should not be planted closer than 50 cm in the row. Too low plant densities give rise to problems where plants are subjected to diseases like tomato spotted wilt and rosette virus infection, resulting in stunted or dead plants.

Table 2. Recommended row width for groundnuts

Cultivar	Row width (cm)
Norden and Selmani	60-72
Harts and Kwarts	30
Sellie and other cultivars	45

Narrow spacing usually sets higher demands on the management ability of the producer, especially with regarding to the application or spraying of chemicals.

The following seed requirements according to the seed size and row width apply (Table 3).

Table 3. Seed requirement in kg/ha

Seed size (seeds/28g)	In-row spacing (cm)	Between row spacing (cm)				
		30	45	60	75	91
50/60	7.5	226	150	113	90	75
60/70	7.5	191	127	96	76	64
70/80	7.5	166	110	83	66	55
80/90	7.5	146	97	73	58	49

3.5 Seed treatment

Seed quality and purity are of extreme importance and therefore certified seed should be used. This seed should be treated with a fungicidal protectant, and currently two seed coating agents are registered for use in groundnuts, namely Mancozeb and Thiram. By treating the seed it will germinate better and produce more vigorous seedlings

3.6 Crop rotation

A well-planned 2-3 year crop rotation system should be followed to ensure good yields of high quality. One of the best crop rotation systems recommended is where a grass fallow is followed by groundnuts. However, the seedbed must be well prepared. In practise, groundnuts are usually following maize, small grains, sorghum or millet in a crop rotation system. Groundnuts must not follow cotton or other crops with a taproot, since the danger of Sclerotium is higher.

Groundnuts following tobacco also have a risk of diseases and poorer quality as a result of the high potassium fertilisation levels required for the production of tobacco.

3.7 Yields (t/ha)

Under low yield conditions cultivars like Robbie, Sellie, Kwarts, Anel , PAN 9212 and Akwa still produce an acceptable yield of 0.8t/ha- 1.5 t/ha.

Under irrigation conditions a potential yield of 3-5 t/ha is possible with cultivars like Akwa, Jasper, Robbie, etc. with a shelling of 75%.

4. Fertilizing[1,2]

If a soil analysis is available fertilise according to it. Groundnuts are well adapted to a soil with a pH_{H20} of 5.3 or higher. If the soil pH is higher than 5.3, certain elements become unavailable e.g. iron and zinc. In irrigation area where pH levels occur, yellowing of groundnuts occur which could be related to iron deficiency. If lime is acquired (pH_{H2O} < 5.3) it should be done immediately after harvesting of the previous crop.

When groundnuts are grown in rotation with heavily fertilized crops, good results can be obtained without fertilisation.

Nitrogen (N)

Since groundnuts are leguminous, nitrogen is normally sufficient from N fixation but can be affected by low soil pH. Where root nodules do not appear on the roots, it is advisable to fertilise between 30-40kg N/ha. Nodules, which are effectively fixing nitrogen, have a pink coloured appearance. In very sandy soils where initial growth must be stimulated, 20kg N/ha can be banded in the soil.

Phosphorous (P)

Groundnuts prefer residual phosphate to freshly applied P. The P fertilisation is guided by the levels of removal by the crop, for instance apply 20 kg P/ha when the target yield is 5 ton/ha and the soil test is 20 mg P/kg.

Potassium (K)

Groundnuts require sufficient levels of potassium, and the soil test should at least be 80 mg/kg K to ensure good yields. An over supply of potassium in the soil can induce a calcium deficiency; which result in lower yield and quality. Where additional potassium is applied, it should be ploughed in so that the pods do not come into direct contact with the applied potassium.

Calcium (Ca)

Groundnuts require large amounts of calcium (Ca). Ca deficiencies usually appear on sandy soils with less than 100mg/kg Ca present in the topsoil. Ca deficiencies result in “black plumule”, and therefore Ca deficiencies should be prevented near pod formation. In situations were less than 100mg/kg Ca is present in the soil, gypsum is added at a rate of 200kg/ha on the planter track directly after planting.

Boron (B)

Boron deficiency usually occurs in very sandy soils which has an impact on seed quality (“hollow heart”). 1kg/ha B must be applied with or after planting, and this application can be combined with the gypsum application. Boron uptake increases with gypsium application.

Other elements

In acid soils the availability of molybdenum (Mo) becomes a problem. This is important for normal growth and the uptake of nitrogen (N). In these situations it is advisable to treat the seed with molybdenum by applying of 50 g molybdate per 50 kg seed.

5. Cultivars[1,2]

There are several cultivars available and growers can select from a range of cultivars in the market. A choice of cultivar also exists with regarding resistance or tolerance to various diseases and nematode problems. Table 4 provides a short overview of available cultivars, but the specialist assistance of a seed representative is recommended with cultivar choices.

Table 4. Characteristics of different groundnut cultivars

Cultivar	Growth period (days)	Irrigation or dryland
Akwa	150	Dryland and Irrigation
Anel	150	Dryland and Irrigation
Billy	180	Irr
Harts	140	Dryland and Irrigation
Jasper	150	Dryland and Irrigation
Kwarts	150	Dryland and Irrigation
PAN 9212	150	Dryland and Irrigation
Robbie	150	Dryland and Irrigation
Sellie	150	Dryland and Irrigation
Norden	180	Irrigation
Selmani	175	Irrigation

6. Irrigation

As in oil crops the seasonal water use of groundnuts is influenced by the atmospheric evaporative demand as well as the availability of water in the soil profile. Between 3-8.5 kg groundnut seeds are produced for every 1mm/ha water applied. Therefore in order to produce a crop of 3 000 to 5 000 kg/ha, 500mm of water is required. It is therefore important that an appropriate irrigation system is selected which operates at 100% efficiency in terms of application and distribution.

Guidelines regarding irrigation of groundnuts

The following aspects require attention with the irrigation of groundnuts:

- Due to the cold sensitivity of groundnuts during germination, it is not advisable to irrigate directly after planting. The irrigation water can cool the soil to such an extent that germination and emergence can be retarded or impaired. Rather irrigate prior to planting, which can then later be followed with an irrigation application when the soil is warm.

- Due to the fact that groundnuts are planted on sandy soil, which is prone to drying out of the top layer. Therefore it is recommended that a high frequency of irrigation should be applied, even when the leaf canopy covers the soil surface.

- With overhead irrigation it is important that the rate of irrigation application does not exceed the infiltration rate or capacity of the specific soil. If this should happen, run-off will occur.

- When supplementary irrigation is applied, it is important to schedule such an irrigation application according to the critical period of crop growth namely the second half of the growth season.

Table 5. Approximate irrigation requirements of groundnuts planted in different climate regions on a loam soil under a centre pivot (SAPWAT)

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm)
Dry, hot, west, (North Cape), 15 Oct, peak Jan	221	132	965	243
Dry, hot, east, (dry Bushveld), 15 Oct, peak Jan	470	295	580	139
Humid, hot summers, (wet Lowveld), 15 Oct, peak Jan	673	325	252	52

7. Weed control[2]

Effective weed control is very important for achieving optimum yields. Weeds can be controlled either mechanically, chemically or a combination of the two. When chemical weed control is considered, the choice of the correct herbicide is important as determined by the specific weed species, soil type and cost of the herbicide. Pre-emergence herbicides for groundnuts should be washed into the soil within 10 days after application. Post-emergence herbicides are in general more expensive, especially when used on late germinating weeds.

8. Insects and diseases

Two nematodes cause problems in the industry namely the pod nematode *(Ditylenchus africanus*) and the scab pod nematode *(Tylenchorhynchus brevilineatus).*The pod nematode cause a brown discoloration of the pods which leads to the down-grading of seed. The scab pod nematode form a black pattern on the pods and later attack the whole pod. A variety of chemicals are registered for the control of nematodes on groundnuts.

Two viruses that are prominent in the production of groundnuts are the tomato spotted wilt virus (TSW) and the rosette virus. The TSW virus infected plants present a chlorotic appearance and occasionally malformation of the leaves and growth points. The virus is transmitted by thrips. The second virus, Rosette virus, typical symptoms include yellowing of the plants, shortening of the internodes on the stems (dwarf appearance) which results that only a few pods form. Rosette can be combated with attendance to spacing in the row and the control of aphids. Insects that are commonly found on groundnut are aphids *(Aphis craccivora),* underground larvae of various insects that attack the pegs and young pods under the soil surface.

Diseases in groundnuts can be classified as leaf, stem and pod diseases and viral diseases

- Leaf diseases normally occur with periods of favourable temperature, high rainfall and humidity. These diseases are more prevalent during wet seasons. Leaf spot (early and late) can cause severe yield loss. Web blotch which mainly occurs at moist, cool temperatures became a problem amongst groundnut producers since 1970 and also cause significant yield loss. Rust is sporadic problem and cannot be considered as of economic importance.

- Pod rot diseases that cause real problems in the production of groundnuts are black pod rot, which appears under irrigation and Sclerotium under general production. Other rot diseases that are not generally of great importance include Fusarium, botrytis, Sclerotinia and Aspergillus.

For more information on the diseases and pests commonly found on groundnuts consult "Groundnut Diseases and Pests" published by the ARC.

9. Harvesting and marketing[2]

Harvesting date
The determination of the harvesting date of groundnuts usually presents problems to farmers, extension officers and researchers. The groundnut plant gives clear indications when to harvest, but these signs should be observed and interpreted as such. The following factors determine the harvesting date of groundnuts:

- Development of the plant: groundnuts should be harvested when 75% of the pods have reached maturity, and the number of days from plant till harvesting will vary for the cultivars and because of differences in seasons.

- Pod colour (inner wall of the pod): when 75% of the pods of a selected number of plants show the dark discoloration of the inner wall

- Pod colour (outer wall of the pod): when groundnut pods are scraped with a knife and 70% or more of the pods appear black or dark brown, the crop can be harvested

- Seed colour: immature seed is usually white, while pink seed colour indicates maturity

- Cultivars: various harvesting dates apply for short, medium and long growth season cultivars. The ideal harvesting date can already be determined at 120, 140 and 150 days after planting.

Harvesting process
In order to ensure a good quality product the correct procedure in harvesting of groundnuts should be followed. Groundnuts can either be harvested by hand or mechanically.

1. Hand or stack method: this process entails the lifting or cutting of the taproots 10-15cm under the soil surface. After the plants have been lifted with a groundnut lifter or pulling by hand, it is collected in bundles of 10-20 plants and placed in stacks to dry. Plants are stacked with pods facing upward so that rain water can drain off the stack. Picking can commence once the pods can be removed from the stems without causing long shreds. Groundnuts should not be left on the field for months.

   A reasonable rate for and picking is 2-3 bags of pods per labourer per day, or 15-20 bags of pods per hour by a mechanical picker.

2. Mechanical harvesting includes the following processes namely lifting, drying in wind rows, picking and conditioning. If a producer wishes to harvest mechanically, the whole process should be adopted. Picking is done by a groundnut combine harvester which can handle groundnuts at moisture levels of 25-30%. Conditioning implies the removal of moisture from the pods and the seed at a rate which does not impair the quality of the seed.

Shelling

Generally farmers do not shell the groundnuts but sell it in pods. However, when shelling is consider on the farm the following should be kept in mind:

- Care must be taken that groundnuts are not too dry when shelling is started
- Ensure that the drum speed and screen size for every cultivar which is shelled is adapted
- Avoid foreign material in the bag during picking – clean the groundnuts before these are fed into the sheller

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Module 7a

Citrus

1. Introduction

Citrus has an important place in human history, featuring in religion and mythology of many cultures. The first reference to citrus is found in India in ~800BC and by ~300BC references are to be found in the Far East and European literature. Citrus was introduced into South Africa in ~1652AD, with the importation that was made by Jan van Riebeeck.

In terms of volume, citrus are the largest fruit crop in the world and, also, the most important fruit in world trade. The northern hemisphere accounts for 62% of the world fresh citrus fruits exports[6]. The countries that play a major role in the world export of citrus fruits are Spain which exports 25% of citrus fruits, followed by United States which exports 14%, South Africa exporting 11%, Turkey and Argentina exporting 5% and Mexico, Netherland and Greece exporting 4% and other countries [6]. The major destinations of the citrus fruits are Germany which imports 10% of the world citrus fruits, followed by France with 9%, Netherlands with 8%, Japan, United Kingdom and Russian Federation imports 6% and United States, Canada and Saudi Arabia imports 4%[6]. South Africa's market share in the European Union ranged from 18.3 to 22, 5% from the year 1997 to the year 2004 and increased to 24, 1% in 2005.

South Africa has been producing lemons and oranges for the last three centuries [10]. In South Africa there are approximately 1300 citrus fruit export farmers and 2200 small scale farmers who supply the local market[9]. South Africa is the third largest trader and producer of citrus fruits in the world and it is exporting 64% of its citrus fruits internationally[10].

In South Africa citrus fruits are grown in the Limpopo Province, Mpumalanga, KwaZulu-Natal, Eastern Cape and Western Cape where subtropical conditions namely warm to hot summers and mild winters prevail. These areas provide good conditions for growing the full range of citrus fruits. Limpopo province produced 28.4% of citrus fruits in South Africa during 2005, followed by the Eastern Cape which produced 22.6% [7].

In the genus Citrus, grapefruit trees have the largest and lime the smallest build as indicated in Table 1.

Table 1. Tree morphology of various *Citrus spp.* [1]

Botanical name	Tree size (m)		Tree shape	Branches
Citrus medica (Citron)	shrub	3 m	Irregular, bushy and spreading growth	Short, thick, irregular, thorny branches
Citrus grandis (Pummelo)	large	4.5-9 m	Compact, rounded or sometimes flattened head	
Citrus reticulata (Mandarin)	Small spiny	3 m	Round	Branches often protruding. Open head with short round or angular thorny branches.
Citrus limon (Lemon)	small	3-6 m	Mostly round, slightly spreading.	Small, stiff, interlocking or drooping branches.
Citrus aurantium (Bitter Seville)	me-dium	6-10 m	Rounded top	Dense , compact rounded head
Citrus sinensis (Orange)	me-dium	7-10 m	Rounded top	Compact, conical head. Sometimes slightly upright. Bark is grayish brown.
Citrus paradise (Grapefruit)	large	9-15 m	Rounded or conical	Sometimes spreading. Trunk diameter is 0.46 to 0.76 m. Bank is smooth, grayish brown.

2. Climatic requirements

Climate is primarily the determining factor affecting citrus production.

2.1 Temperature

Citrus trees are subtropical in origin and cannot tolerate severe frosts. Citrus production in South Africa is therefore confined to areas with mild and almost frost-free winters where temperatures (not more than once in several years) drop below 2ºC and almost never below 3ºC. The average minimum temperature for the coldest month should not be below 2 to 3ºC if no protection against frost is provided. Temperature above 39ºC is also detrimental to the tree. A drop in temperature below 13ºC initiates a dormant stage in the tree, while the threshold for root activity in soil temperature is 15ºC and more.

2.2 Rainfall and humidity

Water availability is a crucial factor in citrus production. Because rainfall is often poorly distributed and in most cases deficient, it is necessary to supplement rainfall by irrigation. In the winter rainfall areas, rainfall occurs during fruit maturity and resting phases whiles in the summer rainfall areas rainfall occurs to late for fruit set.

2.3 Wind

High velocity wind can cause damage twofold:

- mechanical abrasions can cause cosmetic damage rendering fruit unsuitable for export
- hot winds can burn trees and cause dieback due to excessive moisture loss caused by transpiration

2.4 Daylength and light

Growth is positively correlated with day length. Flowering in citrus has been found to be sensitive to temperature and water stress, and not to day length. Citrus (except lemons) require shorter days and cooler temperatures in winter for a normal production rhythm.

2.5 Soil climate

The concept soil climate is not so familiar, but refers to the root environment of the plant namely: soil temperature, soil water and even nutrition. The soil climate is important for water uptake and nutrients are being regulated by soil temperature. At a depth of 30 cm soil temperature can varies between 6-16ºC during winter and 24-30ºC during summer. Soil temperatures below 15ºC can restrict the uptake of water by roots, while the assimilation of nitrogen is the best during warmer months.

2.6 Influence of climate on reproductive growth of citrus

The juvenility period (time from plant to first flowering) in citrus is genetically inclined, and relates to tree vigour and heat units. More vigorous cultivars have shorted juvenile periods, while plants in hotter areas will also have a shorter juvenile period than in cooler areas. Fruit set and quality are influenced by climate two months prior to flowering.

- In South Africa the winters are generally cold enough for good in-season crops (especially Valencias and grapefruit) to set.
- Navel trees, however, tend to set smaller crops in the warmer parts of the local citrus areas. The coldest month in most of the better navel areas tends to have a mean temperature of 12 to 13°C. For the tree to become dormant, the mean temperature must be below 13°C. Navels, therefore, need to approach dormancy in winter. The chances of producing consistently good crops diminish progressively as the mean temperature for the coldest month rises above 14°C.

Table 2. Influence of temperature on flowering[1)]

Influence of TEMPERATURE on flowering		
Citrus require shorter days and cooler temperatures in winter to follow a normal desirable production rhythm. Flower induction ensures about a month (± July in RSA) before first flowers become visible. The key factor for flower initiation is a period of rest of 2 week to 2 months depending on intensity.		
Night (min) temperatures should not exceed	19 ºC	Threshold for flower induction
Temperature for better quality blossom	10 to 14 ºC	Cooler = Inflorescence with fewer leaves (white blossom)
Mean temperature for tree dormancy is	13 ºC	Especially important for Navels
Day temperatures (following induction): adversely influencing floral development	25 to 30 ºC	Warm winters result in poor and prolonged flowering
Root temperatures do not influence floral induction. Crop load and late hanging fruit have an influence on tree reserves and together with the environmental factors an influence on the amount of out-of-season flowering.		

Table 3. Influence of water on flowering[1)]

Influence of WATER on flowering		
Lower temperatures are ideal but not essential for flowering as water stress can have the same result.		
With a water stress during June/July needed monthly rainfall or irrigation should not exceed:	50 mm	Water stress-induced rest
Effective rain or irrigation needed to end the water stress induced rest:	100 – 150 mm	Flowering takes place 3 to 4 weeks after first effective water

2.7 Influence of climate on fruit set

Fruit set and fruit drop is also dependent on the cultivar and cultural practices. Water stress and temperature are the most important factors affecting fruit set and fruit drop.

Table 4. Influence of temperature on fruit set[1)]

Influence of TEMPERATURE on fruit set	
Adverse maximum temperatures for fruit set	Temperatures above 34 to 36 ºC for one or more days
Abscission of young fruitlets	Temperatures above 30 to 34 ºC for 12 hours

More detail regarding the influence of temperature and water on flowering in: the cultivation of citrus" by de Villiers and Joubert, Institute for Tropical and subtropical Crops.

Table 5. Influence of water stress on fruit set[1)]

Influence of MOISTURE STRESS on fruit set	
Severe moisture in the plant tissue can cause excessive blossom but also fruit drop and thus lower yields	
Winter soil temperatures during the coldest months and depending on climatic region can be as low as, or even lower than 15ºC	Root activity seize below a soil temperature of 15ºC
No root activity corresponds to no water uptake	Drought stress is simulated
Spring days can be hot, with a low humidity	However, soil temperatures are only rising slowly and are still relatively cool
Hot dry air results in a high evaporation rate and moisture stress occurs if the roots cannot keep up with the demand	Meeting this demand is impossible in dry soils or in cool soils albeit moderately wet
Soil moisture must thus be kept as close as possible to field capacity during the crucial flowering and fruit set period	Maximum fruit set is assured in spite of cool soils and low root activity

Table 6. Influence of cultivar on fruit set[1)]

Influence of CULTIVARS on fruit set		
Shamouti	35 to 40 000 blossoms	However, only 500 to 1000 fruit per tree is harvested
Valencia	70 to 200 000 blossom	
Navels	200 to 250 000 blossoms	
The final fruit set is dependent on flower intensity	Heavy blossom equals 0.1% fruit set	Light blossom results in up to 10% fruit set
Seeded cultivars (Valencia)	Large number of flowers results in a large crop of small-sized fruit	
Seedless cultivars (Navels)	Large number of flowers results in a lower number of fruit. (Navels optimum flower number is 40 to 80 000 flowers)	
Cultivar sensitivity to stress	Poor set in particularly Navels, Delta Valencia, Satsuma and Clementine mandarins is correlated to very high temperatures during November to January	

2.8 Influence of climate on fruit drop

Two important fruit drop periods are evident in citrus as a response to stress by reducing the amount of possible fruit on the tree to a level that corresponds with available water and nutrients.

- Post bloom or initial fruit drop, occurs within a few weeks of flowering. Inadequate pollination, water and temperature stress inadequate levels of nitrogen levels and inter fruit competition cause post-bloom drop and accounts for 80-90% in reduction of total flower number.
- November drop occurs when the fruitlets are 10-30 mm in diameter and is usually caused by a hot spring after a mild winter and accounts for 10% loss of total flower number.

2.9 Influence of climate on fruit quality

Quality is important in the production of export fruit. Fruit quality in broad terms relates to fruit size, morphology, maturity, pigmentation and toughness. Cultivar and climate control each of the three stages in which the fruit development in citrus transpires.

Table 7. Fruit development stages in citrus (based on Valencia oranges)[1)]

September	**Stage 1: intense cell division (± 9 weeks)**
October	
November	**Stage 2: cell enlargement : results in rapid increase in fruit size (± 30 weeks)**
December	
January	
February	
March	
April	**Stage 3: Fruit maturity (little fruit growth) (± 11 weeks)**
May	
June	**Dormant period**
July	
August	

Stage 2 is regarded as the most critical phase with regard to fruit development.

3 Soil requirements [2]

Citrus can be grown in a wide range of soil types provided they are well drained. Fertile, well-aerated soils with a pH of between 6 and 6,5 are ideal. Before developing new areas for citrus planting, a soil survey should be done.

The growth, development and production of a tree depends on the physical characteristics of the soil such as drainage, density, texture, water-holding capacity, structure, soil depth, the homogeneity of the profile, erodibility, and the degree to which water can infiltrate the soil.

These characteristics differ in the various soil types. An ideal citrus soil should thus have the following characteristics: will, in respect of optimum water provision, have the following characteristics:

- Red, yellow-brown or brown colour (Hutton, Clovelly, Oakleaf type)
- Soil without compacted layers since the roots of citrus grow normally to a depth of 600-1000 mm
- Soil with sufficient waterholding capacity
- Clay content of 10 to 35%

4. Varieties and cultivars

In South Africa suitable areas for citrus are grouped together in four climatic zones, namely:[1)]

Climatic Zone	
Cold Areas	The East Cape Midlands, Gamtoos River Valley, Sundays River Valley, Amanzi, Southern Natal, South Western Cape and Citrusdal, Knysna and the surrounding areas.
Cool, Inland	Rustenburg, Lydenburg, Burgersfort, Ohrigstad and Potgietersrus and surrounding areas.
Intermediate Area	Marble Hall, Groblersdal, Nelspruit, Hazyview, Barberton, Letaba Tzaneen and Levubu.
Hot Area and Low/High Humidity	Low humidity Tshipise, Limpopo Valley, Letsitele, Lower Letaba and Hoedspruit. High humidity Malelane, KomatipoortSwaziland Lowveld, Pongola and Nkwalini

4.1. Climatic suitability of cultivars

Citrus in South Africa are divided into cultivar groups because of their origin, characteristics and ripening times. Each cultivar group has a unique climatic requirement that is dependent on temperature, heat units, day length and light and humidity.

The list of Citrus groups is as follows[1]:

- Mandarins: Satsumas, Clemintines and Mandarin hybrids
- Lemons and Limes: Eureka, Lisbon lemons and Bearss lime
- Grapefruit
- Sweet oranges: Valencias
- Navel oranges like Bahianinha, Palmer,Washington
- Midseason oranges like Clanor, Salustiana, Shamouti, Tomango
- Pummelo types like Rose, Star Ruby,etc.
- Kumquat

The following recommendations apply for the various production areas in South Africa:

Cold areas

- Mandarins: Satsumas, Clemintines and Mandarin hybrids
- Lemons
- Navels
- Certain Valencias

Cool inland areas

- Valencias
- Lemons
- Navels
- Certain Mandarins and Midseasons

Intermediate areas

- Valencias
- Midseasons
- Lemons
- Certain navels and grapefruit (marginal)

Hot areas

- Valencias
- Grapefruit
- Lemons
- Marginal for navels and lemons

5. Production guidelines

5.1. Orchard layout and planting systems

Planting distances influence production in the initial years and management practices throughout the commercial lifespan of the orchard. Geographic orientation of the rows is important in terms of proportional distribution of light on both sides of the hedgerow. It is ideal to have a north-south row orientation that allows a more even distribution of light over the total canopy. The square and rectangular planting systems applicable to citrus orchards are illustrated below.

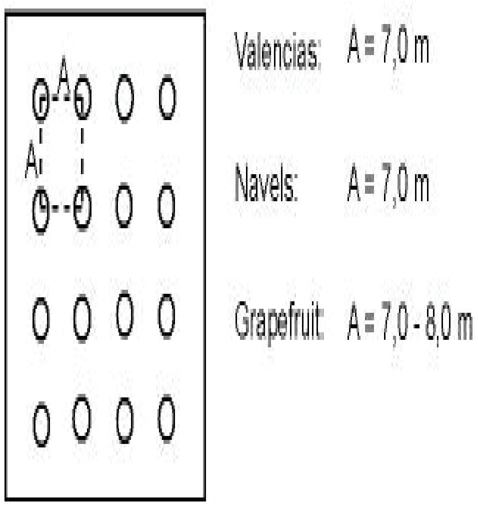


Figure 1. Schematic illustration of the square planting system

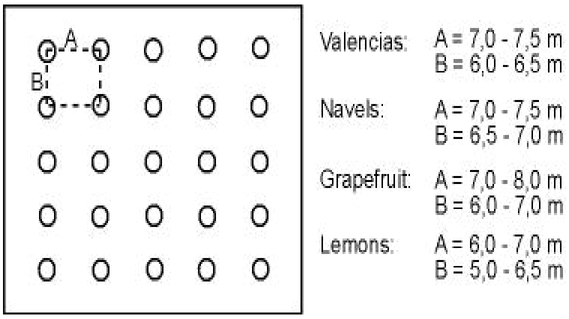


Figure 2. Schematic illustration of the rectangular planting system

The "square system", is preferred where sprinkler irrigation is used. The "rectangular system" is however favoured due to the fact that the smaller planting distance, in the tree rows, increases the number of trees per hectare.

5.2. Planting time

Best time for planting is during august, when natural root growth commences and external temperatures begin to increase.

5.3. Planting

- Proper soil preparation and irrigation installment should be done prior to the planting. Planting holes of 0,5 x 0,5 x 0,5 m are prepared and the soil mixed well with two spades full of compost or decomposed kraal manure and if the soil analysis indicates a low phosphate content, 250g-500g of superphosphate (10.3%) should be mixed with the topsoil and placed at the bottom of the hole. Planting should be done 2 weeks later.
- The young trees are planted to the same depth as they were in the nursery. Keep in mind that loose soil tends to compact. The bud union should be about 300 mm above the ground.

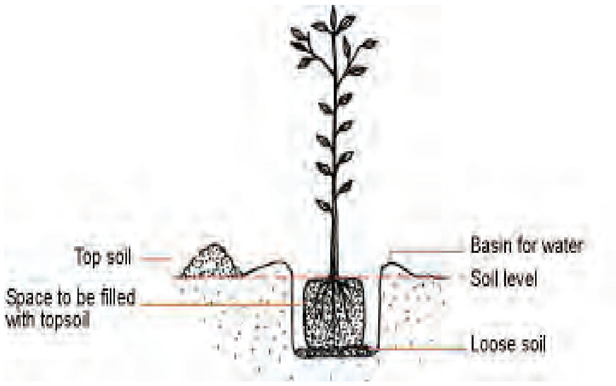


Figure 3. Planting depth for citrus trees

5.4. Planting distances

Various factors should be taken into consideration deciding on the optimum planting densities for different citrus cultivars. Cultivar growth habits, climate, soil potential, rootstocks, implements, slopes and input from farm management are all factors that affect planting distances.

Table 8 provides an indication of the number of trees that can be planted per hectare with different planting distances in the rectangular system.

Table 8. Number of trees per hectare with different planting distances

Planting distance (m)	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5
8.0	315	290	250	230	210	195	180	165
7.5	335	295	270	245	220	205	190	180
7.0	360	315	290	260	240	220	205	
6.5	385	340	310	280	255	235		
6.0	415	370	335	300	280			
5.5	455	405	365	330				
5.0	500	445	400					
4.5	555	485						
4.0	625							

6. Irrigation [3)]

The annual water requirement of an adult citrus tree varies between 850 and 1000 mm per annum. In terms of volume this is between 8500 and 10 000 m^{3}/ha/annum. For the purpose of planning irrigation systems and methods, a good average figure to work on is 9 500 m^3/ha/annum. When the requirements for an immature orchard are calculated (that is where trees do not touch each other) the following guidelines can be used:

- Determine the leaf surface area per tree in m^2 ($\pi \times r^2$)
- Multiply this by the number of trees per hectare which gives the leaf surface area
- Leaf surface area per hectare x 1.36 = annual water requirement (in m^3)

Daily water requirements:
Daily water needs varies between 1 mm (10 m^3/ha) in June to 5 mm (50 m^3/ha) during December depending the plant density

Table 9. Monthly water requirements expressed as a percentage of the total annual water requirement[3)]

Month	Water %
January	15.6
February	11.5
March	8.5
April	4.1
May	2.8
June	2.7
July	2.8
August	4.3
September	7.4
October	10.8
November	13.7
December	15.6

Irrigation scheduling

- *Duration of application*

If one uses micro irrigation systems, irrigation should start when the soil water content is approximately -30 kPa (when using a tensiometer). When one uses a drip irrigation system, it should start when the reading is about -20 kPa. Field capacity for most of the soils is around -10 kPa. The duration of the irrigation is the case of micro irrigation is the time it takes to raise the water content from -30 kPa to 10 kpa.The wetting radius increases as water penetrates deeper into the soil, and it is important that the irrigation depth be equal to the effective root depth. Table 10 provides an indication of how much water is available in the soil between -10 kPa and -30 kPa.

Table 10. Available water (liters) between -10 kpa and -30 kPa in a loam soil (20-35% clay)

Irr depth (m)	Wetting radius (m)							
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.1	0.8	1.5	2.4	3.4	4.6	6.0	7.6	9.4
0.2	1.7	3.0	4.7	6.8	9.2	12.1	15.3	18.9
0.3	2.5	4.5	7.1	10.2	13.9	18.1	22.9	28.3
0.4	3.4	6.0	9.4	13.6	18.5	24.1	30.5	37.7
0.5	4.2	7.5	11.8	17.0	23.1	30.2	38.2	47.1
0.6	5.1	9.1	14.1	20.4	27.7	36.2	45.8	56.6
0.7	5.9	10.6	16.5	23.8	32.3	42.2	53.5	66.0
0.8	6.8	12.1	18.9	27.2	37.0	48.3	61.1	75.4
0.9	7.6	13.6	21.2	30.5	41.6	54.3	68.7	84.9
1.0	8.5	15.1	23.6	33.9	46.2	60.3	76.4	94.3

Note that sandy soils hold approximately 30% water and clay soils approximately 30% more water than a loam soil.

Example

Example 1: Micro irrigation system

A micro sprayer has wetting radius of 1.0 m and the effective irrigation depth is 0.8 m. According to Table 10, about 75.4 litre of water is available between -10 kpa and -30 kPa. If the microsprayer delivers 70 l/hour, the irrigation period will be 1hour to raise the soil water capacity to field capacity (-10 kPa).

Example 2: Dripper irrigation system
A dripper has a wetting radius of 0.4 m and the effective irrigation depth is 0.6 m. According to Table 10, the soil has 9.1 litre of water available between -10 kPa and -30 kPa.If the dripper delivers 3 l/hour, then the irrigation period is 3 hours.

- *Frequency of application*

Once the duration is calculated, the next step is to determine the frequency of irrigation in a given period. This is mainly a function of the plant, namely evapotranspiration.

Formula to use:
Frequency in days= (Number of sprayers or drippers per tree x volume of water between -10 kPa and -30 kPa per sprayer or dripper)/ (daily water requirement)

Example

Example 3: Microsprayer[3]

Consider a tree with one micro sprayer and a daily water requirement of about 75 l in December. The soil beneath the sprayer stores 160 litres, which means that there is enough water for two days. In this case irrigation during December with a micro sprayer will be 2hours every second day.

Example 4: Dripper irrigation[1]
Where a tree has four drippers and the storage volume beneath a dripper is 9 l. Thus beneath four drippers 36 litres is stored. If the tree requirement is 75 l per day during December, this water has to be replenished two times a day. In this case irrigation during December with a dripper delivering 1.5 l/hour will be 6 hours, twice a day.

7. Nutrient requirements

Soil and leaf analysis provides a very good indication of the nutrient status of a tree as well as the actual fertilizer requirements of that tree. Leaf analysis together with soil analysis is the only technique whereby fertilization for a particular planting may be obtained.

The following aspects of soil and leaf sampling are important to take into account:

- *Leaf sampling*

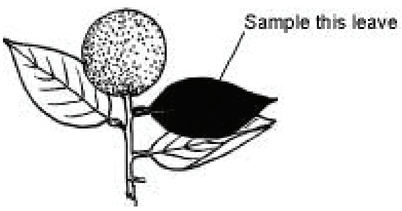
Leaf samples must be taken during the following periods:

- Easy peelers - end of February
- Navels and grapefruit - middle of March
- Mid seasons and Valencias - middle of April

A leaf sample should represent an orchard smaller than 3 ha in which the soil is homogeneous. If soil variations occur, separate samples must be taken. To ensure that a good, representative sample is obtained, 3 to 4 leaves per tree from about 20 trees (60-80 leaves) should be sampled evenly through an orchard. Leaves should not be picked from the same side of the tree. Mature 5 to 7-month-old leaves are picked behind the fruit on the fruiting stem.

Important factors when sampling leaves:

- Different cultivars should be sampled separately.
- Leaf samples must only be taken from bearing trees.
- Leaves should preferably be sampled in the morning when the dew has dried off.
- Leaves must be free of sunburn, disease symptoms or insect damage.
- Leaves should be gathered in clean, new paper bags.
- The bag should be tightly sealed after sampling. If the samples cannot be delivered immediately, the bag should be kept in a refrigerator (not a freezer).
- Samples must be delivered to the laboratory for analysis within 2 days of sampling. Samples dispatched by post will not be suitable for analysis.
- Every sample must be accompanied by a completed questionnaire, as this information is important for recommendation purposes.
- Leaf samples should be taken annually from the same trees (mark trees with paint).



- *Fertilisation – general guidelines* [1]

a. Pre plant fertilisation

Lime: the lime requirement can only be determined by a timely soil analysis before soil preparation.

Phosphorous: Phosphorous is an immobile element and needs to be applied before planting based on the soil analysis.

b. Fertilisation of young non-bearing trees

After planting the trees it should be well established (4-6 weeks) before any fertilizer is applied. The following NPK fertilser rates during the first four years after planting is recommend.

Table 11. N,P,K fertiliser rates for young citrus trees[4)]

Tree age (years)	Fertiliser rate (g/tree)			
	N	P	K	
			Navel	Other citrus
1	70	26	0	100
2	140	26	75	150
3	210	26	100	250
4	280	26	125	250

Nitrogen

During the first year, nitrogen may be applied from early spring till March monthly with irrigation. The total quantities must be divided into 8-10 equal applications.

Phosphorous

Phosphorus may be applied in a single application during September.

Potassium

Potassium (usually) KCl (50%) should also be applied in two or three applications during spring (August-October).

Foliar sprays

It is often necessary to apply micronutrients. These elements are dissolved in water and applied as a spray onto the tree. Deficiencies of zinc, copper and manganese often occur and may be applied in 10 l water at the following concentrations:

- 15 g zinc oxide
- 20 g copper oxychloride
- 20 g manganese sulphate.

The micronutrient solutions should be sprayed during early spring when the leaves are actively growing. A boron deficiency can be rectified by spreading 20 g borax per large tree under the canopy or by spraying with a solution of 10 g solubor/10 l water.
Contact your fertilizer representative for more detail recommendations.

c. Fertilization of mature trees

For mature citrus fertilization should be done according to annual soil and leaf analyses.

8. Orchard floor management[11)]

The orchard floor must be managed in a way that the crop will be able to perform optimally. Aspects that should receive attention with orchard floor management are weed control, mowing, mulching and cover crops.

9. Tree manipulation

- Citrus trees are not usually pruned, although dead wood must be removed regularly.
- To avoid low branches touching the ground, trees are skirted soon after the crop is removed.
- Branches touching the ground hamper the removal of fruit lying underneath the tree, impede irrigation and promote ant infestation of the trees.
- When trees become too big and start growing into one another, pruning is recommended.

10. Pests, disease and weed management

10.1 Pest management

The use of pesticides should be restricted to a minimum as there is a balance between pests and their natural enemies. When pesticides are used injudiciously, this balance is disturbed and a vicious cycle is created

Ants

- Some of the most important insects to be controlled are the brown house ant and the pugnacious ant
- To keep ants out of the trees, insecticides sold under various trade names can be applied around the tree trunks.
- Ant nests, particularly those of the pugnacious ant, underneath or near the trees can be treated with registered chemicals.

Red scale

Red scale is controlled satisfactorily by natural enemies; provided ants are kept out of the trees (see Ants).

Soft brown scale

Soft brown scale secretes a sticky substance, known as honeydew, on the leaves and fruit. The honeydew subsequently turns black as the result of sooty mould that grows on it. Soft brown scale is controlled very well by various parasitoids and predators, provided ants are kept out of the trees (see Ants).

Citrus thrips

Severe attacks by citrus thrips cause young shoots and leaves to become thickened and distorted. Developing apical shoots may turn black and fall off. During development the peels of young citrus fruit can also be blemished by citrus thrips. This mostly starts from the stem-end and may spread downwards extending over the rest of the fruit. However, it does not affect the eating quality of the fruit.

Orange dog

Orange dog is frequently a problem on young trees since it feeds mainly on the young leaves.

The smaller caterpillars are black with yellow and those that are larger, green and brown. They can be identified by the unpleasant smell that is exuded when touched. They can be collected by hand and destroyed.

Citrus psylla

Citrus psylla is the vector and transmitter of a major citrus disease known as greening. Citrus trees have 3 normal growth flushes during the year: spring growth during August/September, followed by a second in November/December and the last during February/March. Lemons are, however, the exception since lemon trees form new leaves throughout the year. It is during these flushes that the trees are subject to psylla infestation. It is therefore important to examine the trees thoroughly during these periods to determine the degree of infestation and to organize control of the pest accordingly.

The female lays easily discernible orange-yellow eggs on the edges of young leaves. When the eggs hatch, the young nymphs move to the underside of the leaves where they establish themselves to feed and cause pock-like malformation of the leaves.

Control of the pest must be aimed at destroying the nymphs as soon as possible after they have hatched. Because all the eggs do not hatch simultaneously, it is essential to use a spray with a fairly long residual action.

False codling moth

Larvae of this moth feed inside the fruit and cause decay. Remove and destroy all dropped and infested fruit from the trees weekly. Also remove all out-of-season oranges in November and again once the fruit has been harvested. Infested fruit serves as a source for reinfestation.

Citrus bud mite

This mite is exceptionally small and hides in the flower and axillary buds. It causes malformed growth points, flowers and fruit and also peculiarly shaped leaves. The growth of young trees is seriously hampered and yields can be reduced dramatically. Young citrus trees up to the age of 10 years, as well as older navel and lemon trees, should be sprayed once a year to control this pest.

10.2. Weed management

It is very important to keep the area under the canopy free of weeds. Nutgrass and quick grass, especially, should not be tolerated. Weeds may be removed by hand. Be careful not to damage the shallow feeder roots or the trunk when spades or other tools are used. Wounds promote penetration of soil pathogens which cause root rot. Weeds also act as pathways for ants.

10.3. Diseases

A. Fungal diseases

Citrus black spot

This disease is common in the hot low-lying areas of Mpumalanga and KwaZulu-Natal and can be controlled effectively with chemical remedies.

Scab

Scab often occurs on rough lemon seedlings. The symptoms are a corky roughness on the leaves and young twigs. It can be controlled chemically.

Phytophtera root and collar rot

Root rot refers to the rot of feeder roots and collar rot refers to the rot of the trunk at the soil surface. These symptoms are caused by *Phytophthora citrohthora* and *P parasitica*.

Registered nurseries are continuously checking to ensure that the trees they supply are free of Phytopthora. Any practice that allows free standing water for periods will increase Phytophtora like poor drainage, microjets spraying on the stem,etc.

B. Graft transmissible diseases

Greening

It is an important disease which is prevalent in the relatively cooler, high-lying areas (above 600 m). Typical symptoms are yellowing of the leaves and malformed fruit. One side of the fruit along the central axis does not develop normally and remains smaller, resulting in asymmetrical fruit. The smaller side remains greenish while the rest of the fruit turns orange. The disease is caused by a bacterium for which no chemical treatment is available. It is transmitted by psylla (see *Citrus psylla*).

As greening is usually localized within one or two branches of the tree, it is advisable to cut out such branches. Saw them off as close to the trunk as possible. If the entire tree is affected, it would be better to remove and replace it.

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Module 7b

Mango

1. Introduction

Jan van Riebeeck planted mango trees in the Cape in about 1653. The project failed because of the unfavourable climate for mangoes in the Western Cape. Mangoes are grown over a wide area in South Africa. The total area under mangoes in South Africa is more than 8000 hectares. However, the main production areas are in the Limpopo Province with the Letsitele Valley/Tzaneen, Hoedspruit/Phalaborwa, Letsitele/Lower Letaba and the Trichardtsdal/Ofcolaco areas accounting for 60% of total production. In Mpumalanga, the Onderberg/Malelane region is the most important mango-production area, producing 22% of the total production[1].

In terms of world production, however, South Africa is a very small player with only approximately 8000 ha in production compared to the over 1 million hectare in India. China, Brazil and Nigeria have substantially increased output over the last five years. In this period china has shown a spectacular increase of 60% in production[2].

2. Climatic requirements[2,3,4,5,7]

Of the commercially important tropical and subtropical crops the mango is the most tolerant to a wide range of climatic conditions. It can be successfully cultivated under conditions which vary from very hot, very humid, to cool and dry.

2.1 Temperature

Although mangoes will survive at near freezing temperatures, very little growth will take place and the average winter temperatures should preferably be above 5°C[5].

For optimum growth and production, average maximum temperature should be 27-36°C[3,5]. At temperatures above 46°C, with low humidity, all growth ceases[4]. Certain cultivars are less tolerant to high temperatures and low humidity, and will display symptoms like sunburn on the fruit itself like Sensation, Edward, Isis, Fascell and Keitt.

2.2 Rainfall and relative humidity

Mango yields are very low when annual rainfall is less than 300 mm or greater than 2500 mm[6]. Young and tender leaves of mango trees are susceptible to a number of fungal and bacterial disease, and hot and humid conditions are favourable for the development of these diseases.

2.3 Wind

Even mild wind will cause scratch marks on the fruit which will result in harmful fungal and bacterial damage, leading to loss of income. Stronger winds will cause fruit drop.

To limit wind damage, the following steps must be taken:

a. avoid windy areas
b. Establish wind breaks-either artificial or by means of rapidly growing trees such as Casuarina trees.
c. Prune the non-bearing flower panicles as soon as it is evident that they will not bear fruit. These panicles, when dry and hard, is the main cause of scratch marks on fruit.

2.4 Daylight hours

The longer the daylight hours are, and the more intensive the sunlight, the better the fruit colour and thus marketability of the fruit. This is especially notable in cultivars such as Zill, Kent, Keitt and Isis.

2.5 Elevation

Mangoes will grow well at altitudes that vary from sea level to over 1200 m. It is generally accepted that production at altitudes above 600 m is not commercially viable[7].

3. Soil requirements for cultivation under irrigation [1,2,7]

Mango trees grow and produce well on various soil types. The tree often develops a fairly strong taproot shortly after planting. This taproot can continue growing until it reaches the soil water-table, and under favourable conditions can penetrate the soil to a depth of 6 m. However, most of the roots responsible for nutrient uptake are found in the top 500 mm of soil, with the largest concentrations in the top 250 mm. Depending on the conditions under which the mango is grown, i.e. dryland or under irrigation, the response to the soil type will vary.

3.1 Drainage

Trees grow best on a slight slope which enables runoff of excess water and prevents waterlogging. Depressions or basins are poorly drained and plantings on these sites should be avoided. The roots will turn black and become desiccated in oversaturated soils as a result of a lack of aeration. Under such conditions the parts of the plant above the ground will wilt and show symptom of chlorosis.

Trees do not grow and produce well in soils with impermeable layers (mottled layers usually with a light grey of white colour, hard banks, and compacted layers of stratified rocks).

Trees also do not thrive on very steep slopes because excessive drainage in this case could lead to water shortages and soil erosion.

3.2 Soil depth

Under irrigation, mangoes grow well in soils with an unimpeded depth of more than 1 m. If irrigation scheduling is well planned, there should be no problem on soil with a depth of 750 mm, provided that any soil or rocky layers, etc. that restrict root growth to a depth of 750 mm allow excess water to drain easily. If not, a temporary shallow soil water-table could develop above this layer, with resulting damage to the trees.

3.3 Soil texture

The ideal soil texture for mango cultivation under irrigation is a sandy loam or loam (with a clay content of 15 to 25%), but soils with a clay content of up to 50% are also suitable.

3.4 Soil structure

The ideal soil has a fairly loose, brittle, crumbly structure. Compact or strongly-developed soil structures prevent effective water infiltration and root penetration. These soils are normally associated with high clay content in the subsoil.

3.5 Suitability of soil types for mango cultivation

Optimum soil types for cultivation under irrigation are Hutton, Clovelly and Oakleaf. Soils such as Bainsvlei, Fernwood, Cartref, Glenrosa and Swartland can be considered to be marginal for production. All soils where waterlogging is a problem should be avoided i.e. Arcadia, Estcourt, etc.

3.6 Soil chemical requirements

Mango trees grow best in soils with pH values of 6 to 7.2. If the soil-exchangeable aluminum (Al) is not more than 30 ppm, soils with a pH of 5,5 or higher may be used.

At pH values lower or higher than 6 to 7.2 the trees may suffer element deficiencies, especially phosphate and potassium.

Furthermore:

- A minimum calcium content of 200 ppm is desirable.
- The ideal potassium status is from 80 to 200 ppm.
- A phosphate content of at least 20 ppm is required.

3.7 Soil preparation

Keeping in mind that trees will be in production for some decades, proper soil preparation is very important because it has to last for the lifetime of the plantation.

The most important advantages of proper soil preparation are:

- Better root development
- Improved soil drainage and reduced runoff
- Improved water penetration (rain and irrigation)
- Better utilization of nutrients
- Greater tolerance towards diseases
- Larger fruit size
- Increased yield
- Prolonged economic lifespan.

Components of soil preparation

- *Soil examination*

This process determines the most effective way to prepare the soil. A soil examination should supply the following information:

- Soil type
- Soil strength (compaction)
- Soil texture
- Soil depth
- Drainage capacity of the soil.
- A chemical analysis is necessary to determine lime or phosphate requirements. Soils where mangoes are to be planted should be sampled at least 9 months prior to planting.

- *Supplying nutrients*

Calcium and phosphate move very slowly downwards in soils. If there is a shortage of one of these elements, especially in the subsoil, it should be incorporated into the soil during soil preparation because there will not be a chance to plough it in afterwards.

If it is necessary to rip the soil, lime should be ploughed in beforehand.

4. Production guidelines[1,2,7]

4.1 Cultivars

Important characteristics include time of ripening, internal quality, external appearance, fruit size, resistance to bacterial black spot and other diseases, tree size and consistent yields.

None of the existing cultivars are totally resistant to bacterial black/ spot. The most important cultivars are the following:
[PLEASE NOTE: The following list is incomplete as cultivars are continuously either added to or removed from this list. Should you be required to advise in this regard, contact expert advisors]

Tommy Atkins

- Early cultivar
- Large fruit (450-700 g) with an ovoid to slightly oblong shape and an attractive skin colour.
- Shelf life is good and the cultivar is tolerant to bacterial black spot and anthracnose.
- Trees are of average size and produce regular high yields.
- Fruit is not entirely fibreless, has a watery taste and is susceptible to internal breakdown, jelly seed and stem-end rot.
- Because of its attractive external appearance good prices are realized on both local and export markets.
- The cultivar is recommended for planting in all production areas.

Zill

- Early cultivar which tends to produce low yields.
- Fruit is fibreless, of good quality, medium sized, with a mass of 230 to 400 g and an oval to ovate shape. The fruit develops a good colour only under very hot conditions.
- Trees are large and grow vigorously.
- Zill is susceptible to physiological disorders such as jelly seed and does not store well.
- Main advantages are: an early cultivar and good taste.
- Zill can be marketed locally or exported from areas where external colour develops well.
- New Zill orchards are no longer being established on a large scale.

Kensington

- Early midseason cultivar with little support in South Africa.
- Good resistance to bacterial black spot.
- Trees are vigorous and give consistently high yields.
- Fruit size is medium to large (> 450 g) Fully-ripe fruit has an unattractive yellow colour with slightly orange cheeks.
- Shelf life is good.
- Physiological disorders such as jelly seed are rare.

Irwin

- Early midseason cultivar but not suitable for all the production areas.
- Trees are dwarfed to some extent and give consistently good yields.
- Fruit is elongated, of average size (340_450 g), with an attractive colour and can be stored for long periods, but is slightly fibrous.
- Irwin is highly susceptible to black spot and the fruit tends to split in areas with high humidity.
- Recommended only for hot, dry areas.

Neldica

- Early cultivar which ripens at the same time as Zill and Tommy Atkins.
- Fruit shape is slightly elongated and round. Skin colour is a very attractive red, pale red and yellow. The fruit is

large (400-500 g) with limited fibers around the seed.

- It shows great tolerance to bacterial black spot at Messina but not at Nelspruit. It is not susceptible to scorch.
- The trees are moderately vigorous.
- Recommended for hot, dry areas and is suitable for both local and export markets.

Kent

- Trees are large and give consistently satisfactory yields.
- Harvesting period is classified as late midseason.
- Fruit is large (500-700 g) with a rounded base, fibreless and the internal quality is very good. The skin colour in cooler, humid areas is often poorly developed.
- Kent is considered as one of the best tasting mangoes.
- Highly susceptible to bacterial black spot and is only recommended for hot, dry areas.

Heidi

- Late cultivar.
- Fruit size varies from medium to large (450-600 g). The fruit is round, slightly elongated with flat sides. The skin colour is very attractive and appears purple, red and yellow when ripe.
- Excellent taste and the fruit is fibreless.
- Good tolerance to black spot, even under conditions of moderate to severe disease prevalence.
- Trees have a compact growth habit and are slightly dwarfed.
- Leaves are typically long and very narrow.
- Widely recommended although susceptible to sunburn in hot, dry areas.
- Fruit size can be reduced to some extent in very hot regions.
- Suitable for both local and the export markets.

Sensation

- Late cultivar and a consistently good producer.
- Fruit is fibreless with an attractive colour. Fruit size is small (200-350 g). If left on the tree until it develops a yellow colour, it tends to develop jelly seed.
- Trees are dwarfed and can therefore be planted at higher densities than most other cultivars.
- Grown for both the local and export markets.
- In late areas there is the benefit of good prices realized at that time.
- Trees should receive nitrogen fertiliser immediately after harvest to ensure an adequate post-harvest flush.
- A disadvantage of this cultivar is that the fruit ripens unevenly, which necessitates selective harvesting. In very late areas Sensation tends to bear alternately.
- The cultivar shows tolerance to bacterial black spot and is recommended for all areas.

Keitt

- Keitt is the latest of all the recommended cultivars.
- The fruit size is medium to large (400-500 g). The fruit is fibreless, oval with rounded base. Skin colour often poor. The fruit has an exceptional keeping quality and can be left on the trees long after normal harvest time without the risk of jelly seed developing.

- The trees are of medium size and the growth habit is characteristically open and appears somewhat disorderly with slender branches.
- The cultivar is highly susceptible to bacterial black spot and is only recommended for very hot and dry areas.

Crimson Pride

- Crimson Pride is heavy bearers producing Kensington shaped fruit with an attractive pink blush.
- Fruit size is large between 600 and 670g
- Internal fruit quality good
- Taste inconsistent when harvested too early

4.2 Orchard layout and planting[2]

The producer must ascertain the optimal plant distances for his specific situation. Plant distances influence production in the initial years and management practices throughout the lifespan of the orchard. Extensive orchards take many years to reach optimum production and large, overcrowded and inefficient trees will eventual result. Intensive orchards on the other hand will reach optimum production sooner and have smaller, more manageable trees with better light penetration into the canopy and more effective leaf distribution.

The rectangular planting system where the row width is greater than the in-row space is recommended. Tree height is influenced by the planting density in the orchard. The tree height must no surpass more than 70% of the width between rows.

Geographical orientation of the rows is important in terms of proportional distribution of light on both sides of the hedgerow. It is ideal to have a north-south row orientation that allows more even distribution of light over the total canopy.

Table 1. Guidelines for mango planting distances[1]

Cultivar	Standard semi-intensive planting (a degree of manipulation is still necessary) (m)	Intensive planting (for specific training system, manipulation techniques, rootstocks and soil types) (m)
Sensation	5 x 2.5	5 x 1.5
Tommy	6 x 3	5 x 2
Atkins	6 x 3	5 x 2
Heidi	6 x 3	5 x 2.5
Keitt	6 x 3	5 x 2
Kent		

Rootstock, soil and climate must be taken into account and adaptations made accordingly

4.3 Planting time

Although mango orchards are planted throughout the year (especially in the warmer production regions), the best time is August to September after the risk of cold weather has passed. A work row of 2 m is preferred and a semi-dense planting with a tree spacing of 3 m.

4.4 Planting procedure

- After proper soil preparation the holes for planting should be large enough for the bag containing the tree to fit inside. Cut the bags open before planting to ensure that the trees have well-developed root systems and the roots are undamaged.
- Irrigation systems should already be installed before planting the trees.
- As soon as active growth is observed after planting, each tree should receive 4

applications of 25 g LAN at intervals of 6 weeks, i.e. a total of 100 g for the first year. A groundcover should be established in the work-row between the tree rows just after planting.

4.5 Planting distance

Various factors should be kept in mind with the planning of the optimum planting densities for the different mango cultivars. Cultivar growth habits, climate, soil potential, rootstocks, implements, slopes and input from farm management are all factors that affect planting distances.

5. Irrigation[2]

Mangoes are to, some extent, drought resistant but will not achieve optimum growth if they do not receive sufficient water (especially during the fruit-developing phase). Correct irrigation is very important for maximum production in most mango-producing areas of the country.

The availability of irrigation water, cost effectiveness and phenological cycle of mangoes are important factors to consider when deciding on an appropriate irrigation system.

Mar	**Vegetative – flush**
Apr	
May	
Jun	**Flower development**
Jul	
Aug	**Flowering and fruit set**
Sept	
Oct	**Fruit development**
Nov	
Dec	
Jan	
Feb	**Harvest**

Figure 1. Phenological cycle of a mango tree

Water requirements

The annual water requirement (with no rainfall) of mature mango trees varies between 800 and 1 000 mm per annum.In terms of volume that is between 8 000 and 10 000 m^3/ha/year for a mature orchard with ±70% area covered by tree canopy.

Daily water requirement varies between 2 mm (20 m^3/ha) in June to roughly 4.4 mm (44 m^3/ha) in December. Daily water use for a mature mango is usually expressed in liters per tree, which greatly varies depending on the planting density. The monthly water requirement is expressed as a percentage of the total annual requirement.

If the total annual water requirement is 8 000 m^3/ha, the requirement for July will be approximately 2.6% of 8 000 m^3/ha or 208 m^3/ha according to Table 2. If an orchard has 500 trees, the requirement for July would be: 208 m^3/ha ÷ 500 trees = 0.42 m^3 or 420 litres per tree.

Table 2. Monthly water requirement expressed as a percentage of the total annual water requirement[2]

Month	%water
Jan	13.0
Feb	11.7
Mar	9.6
Apr	0.5
May	0.3
Jun	1.3
Jul	2.6
Aug	9.1
Sept	12.2
Oct	13.5
Nov	13.8
Dec	12.4

Some degree of stress during flower bud development (May to July) is, however, advantageous.

Scheduling

i) Duration of application

The volume of water that is applied per irrigation is a constant and is a function of the soil type and the irrigation system used. The rate at which the soil dry out to a certain refill point will determine how frequently it needs to be irrigated.

If one uses a micro irrigation system, irrigation should start when the soil water potential is approximately -30 kPa. If one has a dripper system, it is recommend that irrigation starts at -20 kPa. Field capacity for most of the soil types in South Africa is in the region of -10 kPa.

The duration of irrigation in the case of micro irrigation is thus the time it takes to apply enough water to raise the soil water content from -30 kPa to -10 kPa.

Figure 2. Irrigation practices influence mango yield

Table 3 provides an indication of how much water is available in the soil between -10 kPa and -30 kPa, at a given irrigation depth and wetting radius for loamy soils (25% clay).

Table 3. Available water (liters) between -10 kpa and -30 kPa in a loam soil (20-35% clay)[2]

Irr depth (m)	Wetting radius (m)							
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.1	0.8	1.5	2.4	3.4	4.6	6.0	7.6	9.4
0.2	1.7	3	4.7	6.8	9.2	12.1	15.3	18.9
0.3	2.5	4.5	7.1	10.2	13.9	18.1	22.9	28.3
0.4	3.4	6	9.4	13.6	18.5	24.1	30.5	37.7
0.5	4.2	7.5	11.8	17	23.1	30.2	38.2	47.1
0.6	5.1	9.1	14.1	20.4	27.7	36.2	45.8	56.6
0.7	5.9	10.6	16.5	23.8	32.3	42.2	53.5	66.0
0.8	6.8	12.1	18.9	27.2	37	48.3	61.1	75.4
0.9	7.6	13.6	21.2	30.5	41.6	54.3	68.7	84.9
1.0	8.5	15.1	23.6	33.9	46.2	60.3	76.4	94.3

Example

Example 1: Micro irrigation system

A micro sprayer has wetting radius of 1.0 m and the effective irrigation depth is 0.8 m. According to Table 3, about 75.4 liter of water is available between -10 kpa and -30 kPa. If the microsprayer delivers 70 l/hour, the irrigation period will be 1 hour to raise the soil water capacity to field capacity (-10 kPa).

Example 2: Dripper irrigation system

A dripper has a wetting radius of 0.4 m and the effective irrigation depth is 0.6 m. According to Table 3, the soil has 9.1 liter of water available between -10 kPa and -30 kPa.If the dripper delivers 3 l/hour, then the irrigation period is 3 hours.

ii) Frequency
Once the duration is calculated, the next step is to determine the frequency of irrigation in a given period. This is mainly a function of the plant, namely evapotranspiration.

Formula to use:

Frequency in days= (Number of sprayers or drippers per tree x volume of water between -10 kPa and -30 kPa per sprayer or dripper)/ (daily water requirement)

Example

Example 3: Micro sprayer

Consider a tree with one micro sprayer and a daily water requirement of about 75 l in December. The soil beneath the sprayer stores 160 liters, which means that there is enough water for two days. In this case irrigation with a micro sprayer will 2hours every second day.

Example 4: Dripper irrigation
Where a tree has four drippers and the storage volume beneath a dripper is 9 l. Thus beneath four drippers 36 litres is stored. If the tree requirement is 75 l per day during December, this water has to be replenished two times a day. In this case irrigation during December with a dripper delivering 1.5 l/hour will be 6 hours, twice a day.

6. Nutrient requirements of established orchards[2]

6.1 Pre plant preparation
General guideline is that soils to be used for cultivation should be sampled at least 9 months prior to planting to determine their chemical suitability. Following analysis, the correct amount of lime should be applied. This requires manual application to the soil due to poor movement of these constituents and this is achieved by means of deep ripping (600 mm).

6.2 Established orchards
Recommendations for macronutrient fertilizers differ for trees under irrigation and those grown under dryland conditions. However, application of micronutrients, (generally foliar), are the same for both conditions.

Macronutrients for mangoes under irrigation
During the first 4 years, nitrogen (N) can be applied as 4 equal installments in July, October, January and April. Thereafter, with fruit-bearing trees, N application will depend on cultivar and climatic variables which influence the seasonal stage at which the fruit is ready for harvest, i.e. early, mid or late season (December/January or February/March respectively). An orchard may, however, be ready for harvest at various stages in different seasons. Depending on the season of bearing, general times and rates of fertilization are given in Table 4.
[Please note: Application of N after August may induce excessive vegetative growth to the detriment of fruit set and development and is therefore undesirable]

Table 4.Time and rate of N application[2,7]

Proportion of N to be applied			
Harvesting time	After harvest	March	May to August*
December/January (early season)	1/2	1/4	1/4
February/March (mid/late season)	3/4		1/4

**Stage at which flower panicle begins to shoot*

Timing of the application stage of other macronutrients (primarily K and P) is not as critical as N. However, to minimize the risk of root burn, these nutrients should be applied in between applications of N. Potassium (K) fertilizers, because of their high solubility, should be split into the same number of applications as N. Phosphorus (P) sources, on the other hand, have comparatively low solubility's and can thus be applied at the panicle stage, as can additional lime or gypsum.

Micronutrients

Micronutrients are essential to all plants and include Zn, B, Mn, Fe, Cu and Mo. Soils suitable for mango production are generally low in zinc (Zn) and boron (B). It is therefore important to supplement these elements according to leaf analyses. Nutrients can be applied by means of foliar spray once a month after harvest, while trees are flushing, at blossom break, at fruit set and once a month after fruit set up to 1 month before harvest.
Zinc and boron are compatible and can be sprayed simultaneously, preferably during cooler times of the day.

Lime and fertilizer placement

Lime must be applied into the entire soil volume in which the root growth is expected, prior to planting. In established orchards, mechanical incorporation is not practical and therefore gypsum should be applied. While gypsum is not a liming material and has no neutralizing power, it may lead to significant reduction in subsoil Al (aluminum).

Nitrogen and potash fertilizers should be applied as top dressing once trees are properly established and growing vigorously, preferably after a year has passed. Table 5 provides general fertilizer guidelines according to tree age in g/tree/year in the absence of a leaf or soil analyses.

Table 5. General fertilization according to tree age in g/tree/year (in absence of leaf and soil analyses)[1,2,7]

Year	Nitrogen (N)	Phosphorus (P)	Potassium (K)
1	70	25	200
2- 3	140	50	200
4- 6	210	75	250
6- 7	280	100	375
8- 9	350	125	500
10 or more	420	150	650

Nutrients should only be applied to the drip/irrigated area of a tree. Fertiliser close to the roots could result in scorching.

Micro nutrients

Boron deficiency results from excessive leaching, over liming and excessively dry weather. Deficiencies can be prevented by pre-plant soil application of 50 g solubor/tree (levels of 100 g could be phytotoxic).

Leaf and soil analyses

The aim of leaf and soil analyses is to determine the nutrient status of mango trees or suitability of a soil for the production of mangoes.

Figure 3. Mango leaf

A single leaf or soil sample should be representative of an area not greater than 3 ha. However, if there are soil variations, separate leaf and soil samples must be taken and the orchard management adapted accordingly.

Leaf analysis is only applicable for producing mango trees (normally a tree age of 5 years and older).

- Select about 20 healthy trees by walking diagonally from the corners through the orchard (see figure). The trees should be homogeneous in appearance and representative of the orchard.
- Exceptionally good or poor trees must not be sampled.
- The 20 selected trees must be clearly marked, for example with paint, so that both the soil and leaf samples can be taken from the same trees every year.
- Where possible, pick 4 leaves from alternate sides of the tree at about shoulder height. Eighty leaves per sample should be sufficient.
- Different cultivars should be sampled separately.
- Leaves sampled must be free of sunburn, disease and insect damage.
- Leaf samples should be collected in the morning, after the dew has dried off.
- Leaf samples should not be taken if trees are under stress i.e. drought or high temperatures. After a heavy downpour, wait at least 2 weeks before taking samples.
- After sampling, leaves should be placed in clean, perforated or open plastic bags.

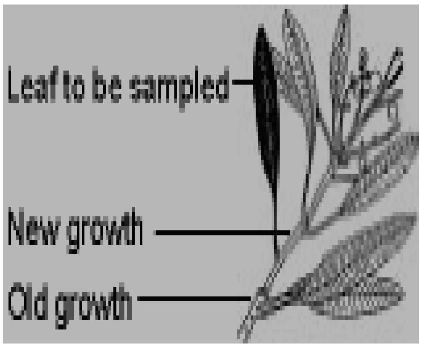

Figure 4. Seven months-old, fully developed, hardened-off, leaves from fruit-bearing twigs

- If samples cannot be delivered immediately (within 48 hours), they can be stored in a refrigerator and should be transported in a cooler bag. The sample must be accompanied by the relevant orchard information including previous production figures, tree age and fertiliser programmes of the past. Any problems concerning the specific orchard, such as small fruit, should be mentioned.

Soil sampling

Sampling depth:
Topsoil: 0-300 mm Subsoil: 300-600 mm

Number of samples

A sample comprises of a combination of at least 10 subsamples. A composite sample should not represent more than 3 ha. Samples from different orchards or lands should not be combined.

7. Weed control

Weeds are usually controlled between rows in an orchard by means of mechanical mowing. Chemical mowing, where herbicides are used, can be applied at low concentrations as an alternative. The idea is not to kill all the weeds but to slow down growth. Chemical control is normally followed by mechanical mowing. The advantage of this method is that mechanical mowing is limited, resulting in less traffic in the orchard.

8. Diseases[2]

The major field diseases comprise three on flowers (in order of appearance through the season, powdery mildew, blossom blight, malformation) and two on the fruit (antrachnose and bacterial black spot).

Powdery mildew
This is a fungal disease found in all mango-growing areas and in the case of all cultivars. It is usually a lesser problem in areas with warm winters. If not controlled properly, it could cause crop losses of 80 to 90%.

Symptoms
Infection starts as isolated white powdery patches on young tissue of the shoots, leaves, flowers or fruit. Once a certain stage of maturity is reached, the fruit is no longer susceptible. Infected flowers fail to open and drop from the inflorescence without fruit formation. On small fruit (pea size), mildew causes skin cracking and corky tissue. Younger fruit will drop. After the fruit matures beyond marble size, there is no longer a risk.

White powdery patches can occur on young leaves which then curl and become distorted. As the leaf matures and the fungus disappears, brown patches remain. Mature leaves are not susceptible.

Control
Various fungicides are registered for effective control.

Malformation
It is a fungal disease which is spread by grafting and buying infected trees from nurseries. Blossom malformation is easy to control, but if left unchecked can devastate an orchard.

Symptoms
Affected flowers look like cauliflower heads. The axes of the panicles are shorter and thicker than normal, branch more often, and a profusion of enlarged flowers is produced. These panicles develop more slowly than normal, retaining their green colour but the flowers are mostly sterile.

Control
The disease can be eliminated by breaking off affected panicles and putting them in black plastic refuse bags and allowing these to `cook' in the sun for a day or two, or by burning. If this is done every year the incidence of the disease becomes insignificant.

Blossom blight
It means the 'blackening and death' of a plant part, usually from central focus.

Symptoms
Blossom blight caused by *Fusicoccum* species starts as a wilt of the affected part of the inflorescence, often with a distinct curvature. The stems blacken and die back from the tip downward. Internally, browning is in advance of

surface lesion. Large black lesions can also appear lower down the stem and once they girdle the stem, will kill al distal part. Infection peaks at 100% blossom fall and this later act as a source of inoculums for the stem.

Control
No control measures are registered specifically for blight. Because of this systemic nature of *Fusicoccum* infection, only systemic fungicides will be effective during flowering.

Anthracnose
It is an important post-harvest fungal disease which affects all mango cultivars to varying degrees. Because the disease is rain-linked, the fruit will be less affected in warm areas where it matures early and where it does not hang on the trees throughout the rainy season.

Symptoms
Small brown-black spots appear on the leaves, which could later enlarge and coalesce to form large blackened irregular patches, usually with a faint yellow halo. The tissue will die and later fall out.

Control
During wet periods control measures are important, especially when the trees are in bloom, to prevent losses as a result of blossom blight and also during fruit development to reduce post-harvest problems. Specific sprays for anthracnose are not usually necessary because the fungus is controlled by the fungicide program followed for powdery mildew and bacterial black spot.

Bacterial black spot
Symptoms
Bacterial black spot is a rain-related disease.
Fruit lesions begin as water-soaked spots which later become raised and black cracking open to exude a gum-containing bacterium. There is often a tear-stain pattern where the gum has washed down the fruit and started a number of new lesions. Infection of small fruit and especially the fruit stalk will cause fruit drop.

Control
Copper sprays are the only method of combating the disease and are not always successful when disease prevalence is high. One or two post-harvest copper sprays to cover the post-harvest flush and final stage of the rainy season are effective in reducing inoculums pressure during the following summer.

9. Pests[2]

Fruit flies
Mangoes can be severely damaged by female fruit flies laying eggs in the fruit and by the maggots (larvae) which then develop in the flesh of the fruit.

Control
Successful fruit fly control in mango orchards depends on a combination of the following:

- Eradication of invaders (host plants such as bug tree and brambles).
- Orchard and yard sanitation by removing on a regular basis all mangoes and other fruit that have dropped in the orchard or yard and destroying these immediately.
- Chemical control: The use of traps to determine when a population build-up occurs. By making weekly counts of the number of flies in the traps, a sudden increase in the population can be detected and chemical control can commence.

Mango weevil

The mango weevil is present in all the mango-producing regions of South Africa and is spread through the transportation of infested fruit. As the weevil develops inside the mango seed, it can be transported inadvertently from one place to another. No alternative host plants are known.

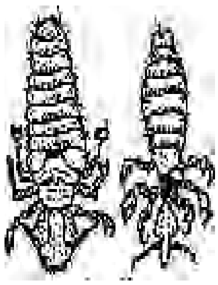

Figure 5. Mango weevil

The symptoms are most apparent in the seed. Infestation is also evident as small, dark marks on the fruit skin where the female weevil laid her eggs. With cultivars ripening towards the end of February and later, the weevil which developed in the seed, feeds through the fruit skin to the outside, resulting in an unattractive hole in the fruit. The pest status of the mango weevil has consequently increased.

Control

Dropped fruit in the orchard or discarded seeds left lying around are the major sources of infestation. Fruit should be buried at least 600 mm deep or finely chopped with a hammer mill. The most important period for orchard sanitation is during January and February as most weevils have by then become adults and could escape from the seeds

Large black tip wilter

The large black tip wilter can be a serious pest on young mango trees of up to 4 years old. They are black, about 25 mm long and live on plant sap. In mango trees, they concentrate on young, new flush, leaf veins or flower stalks. Plant tissues die off where tip wilters feed. Host plants include weeds, vegetables, ornamental plants, granadillas, citrus and also mangoes. Tip wilters secrete a repugnant odour when disturbed. They can cause considerable growth retardation, but are of minor importance on large trees.

Control

There are no insecticides registered for the control of the pest and therefore hand collecting is the only option.

Other important pest to control in the orchard includes:

Pest	Symptom
Mango bud mite	Common in all mango trees-during flowering and growth flushes population peaks. Feed on young leaves causing small brown lesions.
Mango scale	Most common on mango leaves although the insect also attacks the twigs and fruit. Infested fruit and leaves turn pale green or yellow where scales feed. Part of the plant tissue can die off when portions of the leaves are heavily infested.
Thrips	Vast number of thrips occurs on mango flowers and is often of concern to producers. The most important species is the citrus thrips, *Scirtothrips aurantii*. Commercial damage on mangoes is caused by the larvae and adults, feeding on the small fruit causing blemish on the rind.
Mango gall fly	Leaves with wart like galls are common in mango orchards. The cause for this symptom is the mango gall fly, *Procontarinia matteiana.*

10. Harvesting[2]

Achar fruit

Many growers have peach mango trees or other fibrous types. The fruit is harvested while still relatively small. The seed should not be allowed to harden because this causes rejection by the factories. Fibreless types can also be used for achar and this often comprises small fruit that would otherwise drop naturally, or fruit where pollination was unsuccessful and the fruit is seedless and likely to drop (mules).

Fresh fruit

Only the best-quality fruit is suitable for local and export market, as it has to undergo transport and cold storage for 28 days in order to reach foreign markets by sea. Fruit picked too green will never ripen properly whereas overripe fruit will spoil as a result of softening and the development of various diseases. It is therefore important to start picking at the correct stage.

Drying/juice

Fruit used for drying or juice are not harvested especially for that purpose, but rather selected from fruit that cannot be used for any of the other categories.

Handling of fruit (orchard to pack house)

- Fruit should be handled with extreme care.
- Excessive tree height is a distinct disadvantage.
- Fruit should be carefully placed in non-abrasive containers and attention should be given to the prevention of sunburn (keep lug boxes in the shade).

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My notes............

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Developers:

- Developed with information obtained from Institute of Tropical and Subtropical Crops (J Stevens and P Reid)

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Module 7c

Avocado

1. Introduction

The avocado has been known in South Africa from almost as far back as the arrival of the first Dutch settlers. Avocados were introduced by the settlers from the West Indies and other Dutch Colonies, as well as by Portuguese navigators and settlers. These species were all seedlings of the West Indian origin.

Due to the poor quality and transportability of the fruit of West Indian seedling trees, numerous attempts to export avocados failed. Therefore, many cultivares were imported from Mexico and California, to overcome this problem.

By 1930 the total commercial plantings in South Africa comprised only about 10 000 trees. The avocado industry has grown rapidly over the past 15 years. At present more than half of the avocado production is exported and the remainder marketed locally. The export and local market potential for avocado is still very good. The economics of avocado growing has developed to the stage were only high quality fruits fetch good prices and only the growers that have high yields per ha make real profit.

2. Climatic and soil requirements[1]

2.1 Temperature

Cool subtropical conditions with a mean daily temperature of 20 to 24ºC. Light frost can be tolerated except during flowering and fruit set (August and September). For Fuerte, the daily mean temperature during flowering should preferably be above 18.5ºC, but definitely above l3ºC.

2.2 Relative Humidity

A high relative humidity has been shown to be desirable, as it decreases stress conditions, (particularly high temperature) that play an important role especially during flowering and fruit set. The mist-belt areas of South Africa are especially suitable in this regard. The humidity should exceed 50% at 14:00.

2.3 Rainfall

All avocado cultivars grown commercially in South Africa are known to be sensitive to water stress. A rainfall exceeding 1 000 mm p.a. is desirable, and it should be well distributed, with the only dry period in June and July. However, most of the suitable areas in South Africa experience a dry period during flowering, and it is therefore probably essential that supplementary irrigation be available.

2.4 Wind and hail

Avocados tend to have brittle branches, so that high wind is likely to cause severe damage. Apart from this, the majority of blemishes causing a downgrading of fruit most probably result from wind. The trees should be protected during the first few months after fruit set. Wind-breaks may be useful, especially in Natal and Eastern Cape, where hot, dry winds during flowering and fruit set can cause much damage. Because of the brittle wood and large leaves, hail can also cause severe damage. However, the avocado has the ability to recover well after hail damage. If the hail occurs during the early staqe of fruit development and the damage is not too severe, fruit lesions may recover to a reasonable degree. A reduction in grade is therefore not a major problem when early hail occurs, but it does become one when hail occurs late in the season. Severe hail in the early part of flowering and/or fruit development can cause severe crop losses deu to flowers and/or fruit being knocked off the trees.

From a climatological point of view, the best areas for commercial avocado production are therefore the cool, subtropical parts of the Transvaal and Natal situated at an altitude of 825 to 1250 m, where rainfall is fairly high and mist is common.

2.5 Soil properties

Only reddish-brown, red and dark-brown soils, particularly in the subsoil, are suitable (these soil colours usually indicate that there is no restrictive/waterlogged conditions). Temporary to permanent waterlogging conditions, with concomitant root rotting, usually occur in yellow, grey, light-brown and white soils. Accepting that root rot, *Phytophtora,* is the most important soil stress factor in South Africa, avocado cultivation probably requires the most careful selection of soil of all fruit crops.

Physical soil requirements

Fast internal drainage throughout the soil profile to a depth of at least 2 m. In examining soil pits to determine suitability for na avocado orchard, signs of wetness which will disqualify the soil include iron/magnese concretions in a layer or increasing with depth.

Avocado is a relative shallow rooted tree and depends on soil type, few roots penetrating deeper than 1 m or spread more than 1 m from the dripline. This however does not mean that deep well drained soil of at least 1.5-2 m is required, especially in areas where relative high rainfall occur.

Good soil aeration with high soil oxygen is required since avocado roots have no, or at best rudimentary, root hairs. Their comparative intolerance with waterlogged soil and root fungus is important to take not off. Root decay is caused by the low oxygen supply, saturated soil and *Phytopthora cinnanomi*.
Avocado roots are relatively ineffcient at water uptake, but must supply a large leaf canopy. High soil water holding capacity (WHC) helps to reduce a potentially important soil stress factor, namely low soil water content, especially durng the critical fruit set, fruit drop and fruit growth periods.

Chemical soil requirements

- Soil pH: tree growth and yield are best between pH (H_2O 5.8 and 6.5[2]
- Avocado is a salt sensitive tree, and therefore soils with high salinity should be avoided.
- The following soil analysis norms for typical avocado soil is recommended:[1]
  - P (Bray 1) 20-60
  - K: Sand:70 and Clay:250
  - Ca: 500-2000 ppm
  - Mg: 200-400 ppm
  - S: > 20 ppm
  - Zn: 5-20 ppm
  - Cu: 3-8 ppm
  - Na: < 20 ppm
  - Fe: 4-20 ppm
  - B: sand 0.25-12 Clay
  - Mn: 6-40 ppm

- Al: < 30 ppm
- Organic matter: > 1%
- Resistance: > 500 ohms
- Ca:Mg ratio: 2.5-5

3. Growth cycle of avocado[1,2]

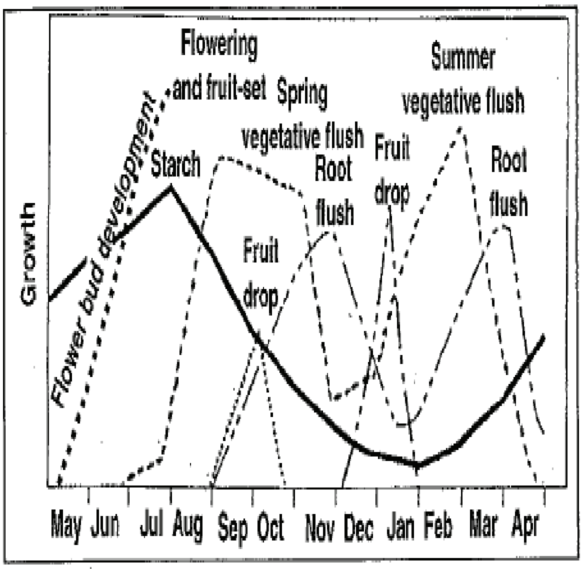

Figure 1. Growth cycle of avocado *(Fuerte)* showing the relationship between vegetative and reproductive growth [1]

A critical period – when undesirable stress does harm – is mainly during fruit set early in spring. This critical period influence leaf and root function, and impacts on the current new seasons' potential crop. It is important for growers and advisors to understand the phenological phases of the avocado, and to help them with observation during key periods namely:

- Flowering and initial fruit set
- Summer flush
- Autumn and winter when root flushing and bud initiation for next season's crop occur.

4. Avocado cultivars [1,2]

Avocado growers should produce high yields of good-quality fruit, acceptable to the consumer. There is, however, no single cultivar that can fulfill all the requirements of the grower, the packer, the retailer and the consumer at the same time.

Fuerte
A cultivar with a good production potential

Flowering and harvesting months		
	Warm regions	**Cool regions**
Flowering:	June-September	July-October
Harvesting:	March-July	May-September

Tree characteristics

- Tree growth habit: large and spreading
- Hardiness: tolerates temperatures as low as -4°C

General

- Limitations: alternate bearing, sensitive to microclimate for fruit set
- Comments: fruit set increased by a pollinator
- Post-harvest storage: susceptible to physiological disorders during storage.

Hass

Good production potential in cool areas. Fruit is smaller in warm areas.

Flowering and harvesting months		
	Warm regions	**Cool regions**
Flowering:	July-September	August-October
Harvesting:	April-August	July-November

Tree characteristics

- Tree growth habit: fairly upright.
- Hardiness: tolerates temperatures as low as -2°C

General

- Limitations: fruit becomes too small with age and in warm regions
- Comments: susceptible to environmental factors
- Post-harvest storage: good

Pinkerton

Consistent heavy bearer.

Flowering and harvesting months		
	Warm regions	**Cool regions**
Flowering:	September-October	
Harvesting:	April-July	June-October

Tree characteristics

- Tree growth habit: moderately spreading
- Hardiness: tolerates temperatures as low as -1 to -2°C

General

- Limitations: flowering and fruit set over extended period
- Comments: fruit may develop internal disorders if picked when over mature
- Post-harvest storage: pick at optimum maturity stage to avoid post-harvest problems

Ryan

Good production potential; bears heavily and fairly consistently – depending on the specific production area.

Flowering and harvesting months		
	Warm regions	**Cool regions**
Harvesting:	July-September	August-November

Tree characteristics

- Tree growth habit: fairly upright, medium grower
- Hardiness: frost tolerant

General

- Limitations: poor quality, fruit sometimes does not become soft
- Comments: suitable for planting in drier inland areas
- Post-harvest storage: average

5. Production guidelines [1,2,3]

It is vital for the future of the avocado industry that farmers plant only high quality, disease-free trees.

- *Within on-farm nursery*

The most important criteria relates to the prevention of disease, notably *Phytophthora* root rot. Therefore, at ALL TIMES, the conditions in the nursery must conform to the highest phyto-sanitary conditions and practices.

- *Purchasing new saplings*

When purchasing new trees, purchase **only** from registered nurseries. (ANA acredited nurseries)

- *Layout of the orchard*

Planning the initial layout of an orchard is of the greatest economic importance for the producer. An avocado orchard is an investment that should be profitable within 7 to 10 years. Planning must therefore be done in such a way that – taking the limitations of each avocado producer into account – a profit can be made in the shortest possible time.

There are three patterns according to which trees can be arranged in an orchard, namely:

- rectangular (which leads to hedge-type tree rows)
- square (which leads to a change of direction when thinning trees diagonally)
- diamond-shaped (which also leads to a change of direction of tree rows with every thinning).

Production per tree is emphasised and therefore the recommended system to use is the retangular system, since it allows for movement of orchard implements between the rows for spraying, harvesting and pruning. It also allows for sunlight to penetrate into the orchard rows, for maximum utilisation by the lower parts of the trees.

- *Soil preparation*

A suitable soil tillage method can only be decided by doing a proper soil survey. Firstly, the suitability of the soil for avocado production must be determined. This must be follwed by a chemical and physical assessment of the soil profile. After the extent of the soil compaction and subsoil acidity has been established, the most applicable soil cultivation method can be determined.

For soils showing minor or no subsoil compaction or acidity, all lime and phosphorous can be spread evenly at least three months before planting.

Ridges are an option on marginal avocado soils (soil depth of 1.5-2 m) or soils with abrupt transition in terms of clay content from the top to the the subsoil.

- *Spacing of trees*

The choice of plant spacing and the pattern of planting are management decisions that are affected by the following factors:

- Cultivar
- Situation of orchard (e.g. north or east facing)
- Soil type and depth – trees do not grow as large on poor and shallow soils.
- Expected short and long-term production.
- Access for machinery, depending on orchard practices.
- Thinning practices.

The final decision must however be based on economic principles, since each of the above aspects has an influence on the ultimate economic merit of the orchard.

In the Lowveld , avocado orchards are currently being planted at a density of ± 300-350 trees per hectare. Table 1 provides guidelines for tree spacing for the different avocado cultivars.

Table 1. Guideline spacing for new plantings (Spacing (m) and tree number per hectare[1]

	Planting density (m)
Fuerte/Hass	8-9 x 4-6 m
Pinkerton/Lamb Hass/Maluma/Ryan	6-7 x 3-5 m

However, for economic decision-making, production per hectare is the critical criterion. This also leads to more effective land use during the productive life of the orchard. It has been found that if trees are spaced in such a way that no thinning will be necessary during the life of the orchard, only slightly more than 50% of the land is utilised. Effective land use therefore, means that the trees are initially spaced close together, to be thinned systematically and selectively at a later stage, to derive maximum economic benefit from the orchard. The problem is therefore how to plant the trees initially, and when to start removing some of the trees.

- *Planting time*

Best planting time for avocado trees is during early spring. Trees planted this time of the year have a full growing season ahead to establish themselves before winter. These trees can already bear fruit the second season in warmer climates.

- *After planting care*

Water avocado trees directly after planting. If possible , use a water cart for the first irrigation as this will settle the soil around the root system. Afterwards regular light irrigation every 2-3 days is necessary to keep the root system from drying out.

Light dressing of fertiliser (25g LAN/tree) for the first few months after planting is advisable. To keep the tree grow vigorously.

- *Pruning and manipulation*

In order to keep avocado orchards economically viable, it is necessary to follow a pruning program. The reasons are as follow:

  - Promote light penetration into the tree to keep the shoots active
  - Maintain the size and shape of the tree for effective ligth utilisation
  - Maintain size and shape for optimal tree management
  - Encourage regular shoot and branch renewal and thise ensure that active gwoing new wood becomes avaialable for fruiting
  - Ontain tree complexity for maximum bearing units to develop and for maximum production

6. Irrigation[1]

Irrigation management is one of the most important aspects in avocado farming. Avocados are particularly sensitive to soil water deficits or excesses and respond by losing vigour and by ultimately showing decreased fruit production per unit area. Aspects directly influenced by an optimal water regime include flowering, fruit set, fruit drop, fruit size and fruit quality.

An avocado tree generally has a poorly developed root system, producing very few root hairs. Feeder roots are primarily found in the upper 5-25 cm of the soil and are thus very susceptible to drought and water-logging
However, the avocado is also known to be very sensitive to drought stress, especially during

Figure 2. Ringneck is an indication of water stress

Mulching around avocado trees are therefore highly recommended, and engourages surface feedrer roots to develop. These roots are able to absorb nutrients and water much easier out of the much, than from the soil below. The mulch not only serves as a very effective way of reducing moisture loss from the soil, but also contributes to the plants nutrition requirements. Much also benefitis the roots by creating a low Phytophthora environment, wherein the roots can thrive! The mulch also increases the soils organic matter content, as well as stimulating the increase in micro organisms in the root zone.

The aim of avocado irrigation is therefore to maintain the soil moisture content between the two extremes, except in June and July, when a drier period is required to stimulate flowering.

The annual water requirement (including rainfall) of mature avocado trees is between 8 000 and 9 000 m^3/ha/year.[3] The first 70 days after fruit set seems to be the most critical for a water stress.

Daily water usevaries between 15-45 m^3/ha/day from June to December respectively.

The majority of the absorptive roots of the avocado are within the upper 25-60 cm of soil. Irrigation should thus be applied to a depth of at least 60 cm, providing there are no impenetrable layers in the soil. Research in South Africa [and Israel] indicates that, for the cultivars Fuerte, Edranol and Hass, at least, irrigation should begin when the 200 mm tensiometer reading is in the region of 20-30 kPa, but before it reaches 40 kPa. At the same time, however, irrigations should not be such that soil-moisture tension is less than 10 kPa at either the 200 mm or 400 mm level.

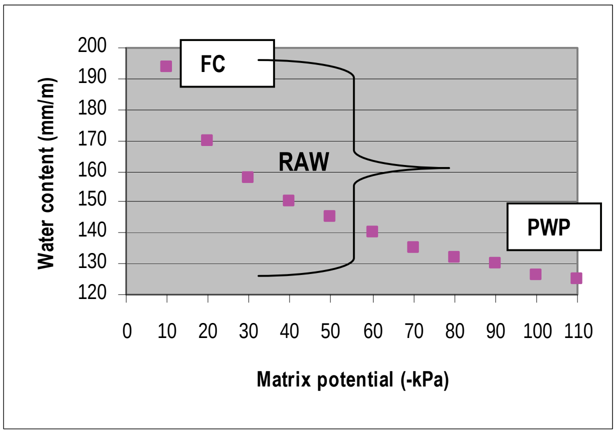

Figure 3. An example of a retention curve[1]

Example

Example 1. Micro irrigation

Figure 3 (retention curve) used for the following example.

Effective root depth:600 mm
System efficiency: 85%
Water content at Field capacity (FC): 194 mm/m (calculated from retention curve)
Water content at permanent wilting (-100 kPa)(PWP): 126 mm/m (also calculated from retention curve)
Plant Available Water (PAW) or Readily Available Water (RAW) : FC- PWP
= 194-126
= 68 mm/m
Refill point=50% of RAW: = RAW/2
= 68/2
= 34 mm/m
Since we have only to irrigate to the effective root zone, the value must be adapted as follow:
= 34x600/1000
= 20 mm/m
Taking the system effciency of 85% into account: = 20x100/85
= 23.5 mm

To calculate the volume of water to be applied per irrigation block, the follwing should be done:
Wetting area of the micro sprayer: = 10 m^2
Number of micro sprayers per block: = 500
Water volume per irrigation: = (wetting area x number of sprayersxirrigation requirement to be applied)/1000
= (10x500x23.5)/1000
= 117.5 m^3

For drip irrigation with a low application rate, irrigation must take place on a daily basis and therefore a different scheduling approach compared to micro sprayer irrigation will be followed.

7. Fertilization[1,2]

Fertilising must not be neglected and should be done according to leaf and soil analyses. If the programme is not based on leaf and soil analyses, it will be based on guesses!!.

A harvest of 10 tonne fruit per hectare removes 10 kg Nitrogen, 2 kg Phosphate, 20 kg Potassium, 2 kg Calcium an 5 kg Magnesium.

Young trees [1-3 years]

Under no circumstances must fertilisers be applied against the stems of the young trees.

Time and quantities of application

If fertilisation is applied in the **first year** after planting, the nitrogen and potassium must be divided into at least four applications and applied during the warm months. After that the application times are as follows: Nitrogen and potassium are applied in three equal applications in July, December and April, while phosphate is applied in December.

Fertilization of mature trees

Calcium and magnesium

Calcium and magnesium play an important role in the fruit quality of avocado trees. However no significant correlation have been obtained between these nutrients and crop yield.

Phosphorous

Phosphorous is important for avocado trees , especially for the development and stimulation of root growth of young trees. Since P fertilisers move very slowly, a pre-plant phosphorous application is essential where soil reserves are low. Guidelines for for phosphorous requirements based on tree age are given in Table 2. These values are only recommended where soil and leave analyses indicate low P levels.

Potassium

Potassium nutrition is important for yield and fruit quality of mature avocado trees. Although crop removal values are relatively high for avocado fruit, the application rates will depend on the soil reserves. Normally potassium is not required during the first 5 years after planting if the soil potassium reserves are high. However, in many cases potassium needs to be appleid from a young stage. Table 2 provides guidelines according to tree age, and adjustments must be made according to soil and leaf analyses.

Nitrogen

Nitrogen is the most important nutrient for growth, flowering and fruitset of avocado trees. A low nitrogen level in an avocado tree will be indicated by premature leaf shedding with small and few fruit. However excessive nitrogen promote highly vegetative trees and dense foliage, large and deep green leaves as well as long shoot growth and reduced yields. The guidelines in Table 2 for nitrogen is based on tree age of conventional planting.

Table 2. Quantity of fertiliser per annum per tree according to age[1]

Age (Years)	Nitrogen	Phosphorous	Potassium
1	42	21	75
2	84	42	150
3	126	63	225
4-5	168	95	300
6-7	224	126	500
8-9	280	158	600
10-12	336	189	600
Max	420	189	750

Fertiliser must be spread evenly about 200-500 mm from the stem, since avocado trees are very sensitive to root damage.

Micro nutrients

Since most soils are either naturally low in zinc or the zinc is not available, this element must be applied every year. The following concentrations are recommended:

- ZincSulphate at 6 g/m^2 tree canopy during July/August, and again in Oct/Nov if nesesary
- Apply the Zinc on heaps, or banded for best results

Many avocado orchards are also low in Boron and it is desirable to spray the trees during flowering, and fruit set at 150g Solubor/100 litres water.Zinc and Calcium is nomally applied with the boron spray.

- Boron should also be applied to the soil at a rate of 3g Solubor, or 6g Borax/Boronat per m^2 tree canopy during +/-July, and again in +/-Nov if nesesary
- Apply the Boron spread-out for best results

8. Tree manipulation

Many farmers have started manipulating tree growth. The main idea is that soil, water and light should be optimally utilised. This means that more trees per hectare should be planted but light interception must not become a problem as trees grow bigger. Trees should therefore be pruned* carefully, removed, restricted with hormone or other control measures.(*Pruning is a problem, because it stimulates growth and result in more wood and leaves as opposed to fruit. One must therefore have enough knowledge to prune successfully. Fruit set can also be improved if branches are kept horizontally.)

Girdling (ringbarking) of branches or trees can result in higher yields, but should not be done by an uninformed person.

Uniconazole (Sunny) can be used to sucsesfully control vegetative growth, and thereby improve fruit set/retention. Timing and concentration of this spray is crutial for the sucsess of this application.

9. Diseases[1]

The avocado is affected by about 20 diseases, including various types of root rot, cankers, wilt, a viroid disease, as well as several fruit and leaf diseases.

Phytophthora root rot

From a production point of view, root rot as caused by the fungus *Phytophthora cinnamomi*, is one of the most serious avocado diseases, limiting high production. The severity of infection varies, but the potential loss is an eventual 100%, if no control measures are taken. The pathogen needs free water to distribute itself and avocado trees should not be planted on soils with drainage problems due to excessive water.

Symptoms

When infected, the whole tree assumes a sparse appearance. Leaves of such trees are smaller and paler in colour, turn yellow, wilt and are then dropped. Tree growth is retarded and individual fruit tends to remain small and show symptoms of sunburn, due to the lack of foliar shading. Infected feeder roots turn black and become brittle as they die. Where the disease is severe, virtually the whole feeder-root system may be destroyed and the tree dies of water stress.

Dispersal of the pathogen requires free water. It is therefore important to avoid planting avocados on soils that are prone to waterlogging. The fungus has a very wide host range, which includes papaya, granadilla, macadamia and various ornamental species.

Control

A Biological and cultural control

1. Selection of planting site

Ideally the soil should be deep, well drained, high in organic matter, low in salinity, not excessively alkaline and in a site not prone to flooding. However, many plantings are made on shallower soils with poor internal drainage or those with impervious clay or rock sub soils. Most importantly, the soil in the immediate vicinity of the planting site should be free of *P. cinnamomi*. It is difficult to obtain such soils.

2. Planting trees on ridges

This is a very successful method of reducing excessive soil moisture and soil compaction in heavy soils with poor internal drainage.

3. Irrigation practices

Irrigation practices should be aimed at keeping soils moist, but not too dry or too wet. Flood irrigation favours development of *Phytophthora*, while severe drought stress can reduce root vigour and thus decrease its physiological resistance to attack.

4. Resistant rootstock choice

Much research is done on resistant rootstocks

- Martin Grande is more resistant to *P. cinnamomi* than Duke 7, G6 and Edranol on grafted trees.
- Grafted rootstocks (Duke 7, G6 and Martin Grande) became more susceptible to root colonisation by *P. cinnamomi* than ungrafted trees.
- If Hass is grafted onto rootstocks, these rootstocks show a higher susceptibility than ungrafted rootstocks.
- Hass on Duke 7 is highly susceptible to *P. cinnamomi*, but yielded three times more fruit than Hass on G6 or Martin Grande. This result shows that more than one factor should be taken into account when choosing rootstocks.
- Currently the newest/best rootstocks that are available in South Africa – which are both *Pc.* tolerant and high yielding are Clonal Bounty, and Dusa and Velvic seedling.

B. Chemical control

Chemical control is used freely and should be in combination with biological control. Three chemicals are registered for control of Phytophtora and range from leaf applications to tree injections to soil applications.

Antrachnose

Stem end rot is caused by ± 10 pathogens and *Thyronectria pseudotricha* is the most serious. *Anthracnose* is caused by *Colletotrichum gloeosporoides* and *Dothiorella* rot by *Dothiorella aromatica*. The last two fungi normally live together and are known as the *Dothiorella/Colletotrichum* complex. (DC complex).

Symptoms

The most important symptom, economically, is spotting of the fruit. These lesions are brown in colour and may enlarge, coalesce and eventually cover large area of the fruit surface. Such fruit often drop prematurely. The pulp beneath the lesions becomes soft and discoloured, rendering the fruit inedible. Where leaves are infected, a brown necrotic band spreads inwards from the margin, and in severe cases, it may spread through the petiole into the branch. Branches then show brown or purple lesions and may die. Infected flowers turn red or brown and later drop.

Control
Anthracnose is successfully controlled by the program as for *Cercospora spot.*

Post-harvest decay of fruit can be controlled by dipping fruit in chemicals which penetrate the skin and kill the fungi. Prochloraz is currently used.

Cercospora spot (Black spot)

This is a fruit-spotting disease, caused by the fungus *Pseudocercospora pupurea*. The fungus also colonises leaves and during humid conditions inoculums comes from sporulation in leaf and fruit lesions. The fungus survives unfavourable conditions in old leaf lesions.

Symptoms
Brown fruit lesions, 3 to 5 mm in diameter, but irregular in shape, develop initially. These lesions dry out and crack, creating entry points for secondary pathogens. Leaf spots are small (1 mm in diameter), brown and angular. They remain scattered or may coalesce.

It takes about 3 months after infection before symptoms become visible. Several factors influence the incidence of black spot. Some of these are:

- Rainfall, temperature and humidity: sporulation takes place after good rains.
- High temperatures and high humidity also favours sporulation.
- Harvest date: The longer the fruit hangs on the tree, the more drastic the symptoms.
- Cultivar: Susceptibility differs. The order of susceptibility is as follows: Fuerte, Ryan, Edranol and Hass. Hass is for all practical purposes resistant against black spot

Control
Control is based on spray applications of copper oxychloride and/or benomyl. Timing is of vital importance in applying the first spray. Before any steps are taken, the producer should do the following:

1. Forecast the critical infection period.
2. Plan proactive spraying.
3. Apply the correct fungicide.

Stem canker
This is another expression of *Phytophthora* infection, but it may be caused by *P. citricola* and *P. castorum*, as well as *P. cinnamomi*.

Symptoms
The cankers are characterised by discoloured bark, close to ground level. The brown discoloration extends into the wood. Infected trees normally decline slowly, but may die suddenly.

Control
To prevent this disease, it is important not to wound stems near ground level and to avoid continued wetting of the stem. Where lesions occur, removal of dead tissue is recommended, followed by covering with a bituminous sealant.
Fosetyl-Al, applied for root rot control, will also control stem canker to some extent.

Avocado Sun Blotch (ASBV)
Sun blotch was identified in California in 1923 and was thought to be a physiological disorder. For years it was believed to be a virus disease, but it is now known to be caused by a viroid.

Symptoms
The viroid causes general decline of the tree, resulting in decreased yield and poor general

quality. The most noticeable symptom on the tree is a low, spreading growth habit. Twig symptoms consist of yellow or white streaking on green twigs while heavily infected leaves are distorted. Fruit symptoms appear as yellow or red indented areas. The viroid has been shown to move from infected rootstocks into previously clean scions.

Control

There are no curative measures available. The only course of action is to remove infected trees and replant in the gaps. Only material which is known to be virus-free should be used as planting stock. *(ANA accredited nurseries undergo regular testing for this viroid – of their mother material, as well as the nursery trees themselves, to try and ensure growers get 100% virus-free plant material.)*

10. Pests

The number of insect pest damaging avocado fruit increased during the last decade, which could possibly be attributed to the expansion in the industry. Very few insecticides are currently registered for the control of avocado pests. The persisten damage caused by pierce-sucking bugs in particular necessitates urgent registraion of more relatively soft insecticides,which can fit into an Integrated Pest Management (IPM) program, especialy late in the season

11. Harvesting and handling of fruit

The maturity of the fruit is closely related to their moisture content. The fruit is normally ready to be picked when it has a moisture content of ±less than 80% for most cultivars, and less than 78% for Hass.

Conversely, the following procedure may be applied to determine maturity:

- Pick a representative sample of fruit which have already attained the average mature size of the cultivar concerned.
- Store the fruit at room temperature until it ripens. An avocado is ripe when it yields slightly to light pressure applied on its whole surface.
- If these samples ripen within 8 to 10 days and show no sign of shrivelling, and a low percentage of stem end rot, the fruit may be considered mature.

Hanging fruit to long on the other hand, will also normally cause a decline in internal fruit quality, with especially grey-pulp becoming more of a problem, as well as a shortened shelf life.

Table 3. Harvesting seasons for the most common avocado cultivars

Cultivar	Harvesting season
Fuerte	March to September
Pinkerton	April to October
Hass	April to November
Ryan	July to November
Edranol	June to October

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Module 7d

Litchis

1 Introduction

Litchis are indigenous to southern China and northern Vietnam, and the first litchi trees were imported into Natal in 1875.The South African litchi industry is now well established, and the major production areas are in the sub-tropical areas of Mpumalanga, Limpopo and the Natal South Coast.

2 Climatic and soil requirements[1,3]

2.1 Temperature

The average maximum temperature in the litchi producing areas of South Africa should be at least 23°C during October and 24°C during November, with a relative humidity of 50 % and higher. The average monthly minimum temperature in areas where litchis are produced should be above 2°C. Areas where heavy frost occurs are not suitable for litchi production. It should, however, be cold and dry enough in winter to ensure good dormancy.

The minimum temperature in some Lowveld areas (Malelane and Komatipoort) does not drop low enough in winter to give the trees the proper dormancy period.

2.2 Soil requirements

Litchis grow very well drained soil like Hutton, Bainsvlei, Oakleaf, and Clovelly soil types.

Poorly-drained soil or soils with impenetrable layers shallower than 1 m below the surface are not suitable for litchis. Relevant soils are, for example, Estcourt, Kroonstad, Arcadia, Swartland, Longlands, Westleigh, and Avalon forms.

Although gravelly or rocky soils drain well, these soil forms do not supply enough water to the trees because of poor water holding capacity. Good irrigation practices, such as wetting the soil more frequently with small quantities of water will make these soils more suitable.

3. Cultivars[1,3]

Litchis were originally imported from China, India, Taiwan and Florida USA. Cultivars grown in South Africa were divided into the following groups:

a. Mauritius group

This group is usually planted locally as well as abroad and produces satisfactory yields and fruit of good quality, e.g. H.L.H., Mauritius, Muzaffarpur, Late Large Red, Hazipur, Saharanpur and Rose-Scented.

b. Chinese group
These trees produce very poor yields, but the fruit is of excellent quality and has a high percentage of chicken-tongue seeds. Cultivars include Haak Yip, Shang Shou Huai, Kontand, Glutinous Rice and Three Months Red.

c. Madras group
These trees bear colorful red fruit, but fruit quality is poor. Cultivars include Kafri, Shorts Seedless, Johnstone's Favourite, Emmerson, Durbhanga, Maries, Mooragusha, Madras 19, Hazipur/Saharanpur, Red McLean, Brewster and Bedana.

Note: Currently these groups are no longer in use.

4. Tree quality[1,2,3]

A good air-layer tree has a single erect stem. The first scaffold branches should branch horizontally at a height of about 200 mm. Any acute forks that branch lower than 200 mm should be avoided.

In grafted trees the graft-union height should be about 200 mm from the ground so that the first scaffold branches can branch at 300 mm. The graft union must be strongly attached and nurserymen must remove the grafting strip so that girdling cannot occur.

Grafted trees have a better root system than trees developed from air layers and therefore show rapid initial growth. Air layering is, however, preferred to grafting because of a better end product.

Aftercare of grafted trees

Trees can also be propagated by means of grafting. Weekly aftercare is very important and suckers and wild shoots that develop on the rootstock below the graft wound must be removed.

After 5 to 6 weeks the buds start swelling and growing. A small cut can then be made through the plastic next to the bud. The bud grows through this cut, but the plastic strip must not be removed too soon. Once the first new growth has hardened off, the strip can be removed.

5. Phenological cycle[2]

The vegetative and reproductive growth of the litchi tree depends on the ability of the tree to produce and store carbohydrates. Not only climate influence the carbohydrate (starch) reserves in the tree, but also orchard management:

- Creating of optimal condition (irrigation, fertilization) for growth after harvest.
- Controlling late autumn flush for growth after harvest through irrigation and fertilization.
- Lifting water stress as soon as flower panicles appear to avoid stress conditions and photo inhibition.
- Promote photosynthesis and carbohydrate assimilation through correct tree shape and pruning to help increase light interception.

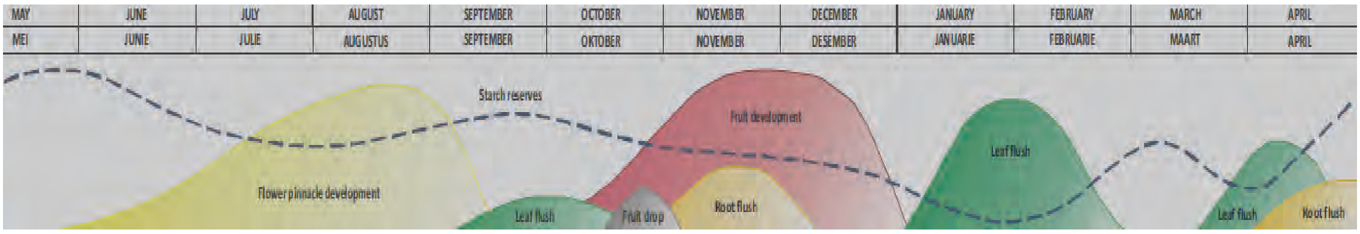

Figure 1. Phenological cycle of a litchi tree[4]

6. Production guidelines

6.1Soil preparation

Examine the soil for suitability in respect of depth, drainage and compacted layers. It should preferably be 1 to 2 m deep. Prepare the soil according to the results of the soil analysis, especially when large quantities of lime are required. If the soil is suitable for litchi production, it must be prepared well in advance.

Before planting, the soil must be tilled/ripped as deep and as thoroughly as possible so that it will not be necessary to make the planting holes too big.

If the soil is very acid, heavy lime applications may be necessary. Two-thirds of the recommended quantity of lime must be scattered over the planting area, mixed with the topsoil and then ploughed in as deep as possible, at least 9 to 12 months before planting. Calcium (lime) moves very slowly downwards into the soil and must therefore be worked in to the depth of the root zone.

A cover crop can then be planted and ploughed in about 6 months later to improve the organic matter content of the soil. The remaining lime (one third) and all the required phosphate must be scattered and incorporated at the same time. The trees can be planted 3 months later.

6.2 Planting

Remember that litchi trees have a long life and become large. Trees should be planted far apart to eliminate competition and to prevent branches of adjoining trees from growing into each other. The entire outer area of the tree must be exposed to sunlight and air movement.

6.3 Planting distance

A 25-year-old tree can reach a crown diameter of 12 m. If trees are widely spaced and later become uncontrollably big an economic yield will not be possible. If the trees are to be spaced closely together, size must be controlled from the start by pruning. The ideal planting distance is 9 x 6 m.

Planting the trees

- Litchi trees can be transplanted any time of the year, but the best time is during spring or at the beginning of the rainy season.
- Planting holes should be square and 300 x 500 mm.
- Mix the topsoil with compost and put it back into the bottom of the hole.
- When planting the tree, remove the container and loosen the soil around the roots **without damaging** the roots.
- After planting, compress the soil slightly by standing on it.

- Wet the soil around the tree immediately after planting.
- Place mulch around the newly-transplanted tree.
- Irrigate young trees regularly after planting. They must never suffer from a water shortage or too wet conditions

7. Fertilization[1]

Do not fertilize newly transplanted trees too soon. Fertiliser should only be applied about 1 year after transplanting. The applications must be very light and broadcast evenly, but not against the stems of the trees. Irrigate after applying fertiliser.

Leaf and soil analyses are the only true indicators according to which sensible fertilization can be applied to a specific planting.

7.1 Leaf analysis

The following aspects are important:

- The correct time for sampling is from mid-September to mid-November.
- The correct leaf must be sampled
- The first leaf sample of a specific planting must be accompanied by a soil sample. A leaf and soil sample must represent a planting of not more than 3 ha.
- The sampling method is important:
    - Select about 20 healthy trees, well distributed throughout the planting.
    - The trees must be of homogeneous appearance and representative of the average trees in the planting.
    - Sample 4 leaves per tree.
    - Do not take samples from obviously good or weak trees.

7.2 Fertilisation application and quantities[1,3]

- Correct fertilisation can only be applied according to the soil analysis for young trees and soil and leaf analyses for fruit-bearing trees.

Figure 2. Litchi tree at flowering stage [1]

- Fertiliser should be broadcast evenly about 0.2 m from the stem to 0.5 m outside the drip area of the tree. Irrigate lightly immediately after application.
- Fertilisers **must not** be worked into the soil. As soon as the trees are established and start growing, fertiliser must be applied regularly according to the quantities given in the Table 1.

Table 1. Quantity of fertilizer (g) per tree per year according to age[1,3]

Age years	LAN (28 %)	Superphosphate	Potassium chloride
1	200	250	50
2-3	500	250	100
4-5	1 000	250	200
6-7	1 500	500	300
8-9	2 000	500	400
10-11	2 500	750	500
12-13	3 000	750	750
14-15	3500	1 000	1 000
15>	4 000	1 000	1 000

Nitrogen (N), Phosphate (P) and Potassium (K)

a. When flowers appear

- 50% of annual nitrogen and potassium (K)
- 100% of annual phosphate

b. Early fruit set

- 20% of annual nitrogen and potassium

Foliar spray

- **Zinc (Zn), copper (Cu) and boron (B)**

Spray on appearance of first male flowers

- **Cytokinins** on female flower stage (optional)

Figure 3. Female and male litchi tree flowers[1]

- **KNO_3 (2%)** on female flower stage (optional)
- 1-2 applications of **$CaNO_3$ (2%)** or similar within 6w after occurrence of female flowers

However, if no other fertiliser is available, kraal manure can be applied as follows (Table 2).

Table 2. Application guidelines for kraal manure if no other fertilisers are applied

Tree age(years)	Kraal manure (kg/tree/year)	Time of application
1	5	± 1 kg every 6 weeks from September to April
2-3 **4-5**	15 25	Give 5 equal dressings between September and April
6-7 **8-9** **10-11** **12-13** **Maximum**	40 55 70 80 100	Give 1/2 the quantity before blossoming and the remainder after harvesting

8. Irrigation[1,3]

Because of the varying root distribution in different soils (deep in sandy soils, shallow in clay soils) water is very important for the optimum development of the plant. In sandy soils short irrigation cycles with small quantities of water are usually effective. In clay soils water is available for longer periods, but it is important that the soil does not become too wet or too dry.

Litchi trees need regular watering and therefore it is essential that enough water must be available from the flowering stage until after the February/March flush following the harvest.

Because the edible portion of the litchi fruit has a water content of 86 %, the availability of water remains important during the development period. A water shortage will delay development of the fruit and adversely affect the size, mass and quality of the litchis.

Irrigation must continue after harvesting to ensure that a normal growth flush occurs during February/March, just before the beginning of the dormant period. During dormancy (April to July) irrigation should be reduced, but the tree should not suffer drought.

The following guidelines apply for the irrigation of litchi trees[4]:

- **Phenological Stage: May to June**
  Increase irrigation as soon as flower pinnacles appear

	Micro	Drip
Tensiometer (0-30 cm)	-30 to-50 kPa	-20 to -30 kPa
Tensiometer (30-60 cm)	-20 to-30 kPa	-10 to -20 kPa

Figure 3. Flower pinnacle development[1]

- **Phenological Stage: July to December**

Ensure optimum irrigation for good fruit set during flower pinnacle development

	Micro	Drip
Tensiometer (0-30 cm)	-10 to-30 kPa	-4 to -15 kPa
Tensiometer (30-60 cm)	-15 to-30 kPa	-10 to -20 kPa

Figure 4. Fruit development[1]

- **Phenological Stage: Jan to March**
  Ensure optimum irrigation for good recovery and starch accumulation

	Micro	Drip
Tensiometer (0-30 cm)	-20 to-30 kPa	-10 to -20 kPa
Tensiometer (30-60 cm)	-30 to-50 kPa	-20 to -30 kPa

- **Phenological Stage: April (root flush)**

	Micro	Drip
Tensiometer (0-30 cm)	-30 to-50 kPa	-20 to -30 kPa
Tensiometer (30-60 cm)	-40 to-60 kPa	-30 to -40 kPa

Table 3 provides general guidelines (liter/tree/day) for litchi trees at specific canopy coverage.

Table 3. Irrigation requirements guideline (liter/tree/day) at specific canopy coverage/ha planted 9x6 m (185 trees)[4]

Orchard maturity	M	J	J	A	S	O	N	D	J	F	M	A
At planting	4	4	8	11	15	19	23	23	23	19	15	11
25%	9	9	19	28	38	47	57	57	57	47	38	28
50%	19	19	38	57	76	95	114	114	114	95	76	57
75%	28	28	57	85	114	142	170	170	170	142	114	85
100%	38	38	76	114	151	189	227	227	227	189	151	114

9. Insect pests

Nematodes

Symptoms

A progressive die back of foliage and leaf drop, together with low production and small fruit.

Control

It is CRITICAL that, during orchard establishment, only nematode free trees be planted. If, however, nematode damage is noticed, immediate soil treatment, with a product such as 'fenamiphos" or equivalent, must be done. Such treatment must be repeated annually in spring until all trees have fully recovered

Bark borer

Symptoms

The larva of the bark borer moth feeds on the bark and wood of living trees. Trees do not die but branch die-back can occur.

Control

There are no registered insecticides to control these borers. Two naturally occurring parasitic wasps do, however, help control this pest.

Litchi moth

Symptoms

This moth lays its eggs on the fruit skin during fruit development stage. The hatched larvae eat through the fruit skin and penetrate the seed. Damage is not visible but skin crack could develop. Infected fruit CANNOT be exported.

Control

The application of a chitin synthesis inhibitor, applied before harvest, must be sprayed onto the fruit. A "litchi paper bag" also offers suitable protection

Fruit fly

Symptoms

Fruit flies sting fruit during the ripening phase. Sting marks are invisible but the effect thereof is clearly seen when fruit fermentation occurs at the sting marks.

Control

Protection of the fruit is based on preventative control i.e. a poison bait applied once or twice weekly to part of every tree BEFORE fruit coloring commences, ending before harvest.

10. Harvesting and packing

The stage of maturity at which fruit is harvested is one of the most important factors that determine the ultimate quality at the point of sale. Litchis do not develop further after picking. The fruit must therefore remain on the tree until quite ripe. Litchis harvested too early have an unattractive colour and have a sour taste.

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Developers: Developed with information obtained from Institute of Tropical and Subtropical Crops and SUBTROP (J Stevens and P Reid)

Authenticator: W Retief, SUBTROP & R Cronje, ARC.

Module 7e

Banana

1. Introduction

Bananas are amongst the most important commercial subtropical fruits grown in South Africa. The major production areas are in the warm, sub-tropical areas of South Africa, with nearly 80% in Mpumalanga and Limpopo Provinces. Bananas are planted for sale in local markets or self-consumption and only a fraction of all bananas are sold in the world markets. The production technologies used for small scale and commercial operations are so different that they are usually separated into two distinct economic activities. On the one hand, small scale production for consumption in the household or sale in local markets makes a limited use of external inputs and is labour intensive. On the other hand, production for commercial operations uses external inputs intensively and is technologically sophisticated. The industry operates in a deregulated environment where prices are determined by market forces of demand and supply. Due to climatic constraints, the area under plantations has stabilized at roughly 12 000ha with a total yield of

In 2008/09, bananas had a gross value of production R1.2 billion.

2. Production areas

Bananas are mainly produced in Mpumalanga (Onderberg and Kiepersol), Limpopo (Levubu and Letaba) and both North and South Coasts of KwaZulu-Natal. The total hectares under banana trees is estimated at 11 360 ha with the

Onderberg area near Malelane in Mpumalanga Province had been the highest contributor with 36% of the total land under banana cultivation. Second is Kiepersol in Mpumalanga Province with 22% of the total land under banana cultivation. This means that Mpumalanga Province is the major producer of bananas in South Africa with approximately 58% of the total land under banana cultivation.

3. Climatic requirements[2]

3.1 Temperature

Banana cultivation, worldwide, is restricted to 30^0 latitude N and S of the equator. However, all the major large banana production areas are in the tropics, between 20º N and S latitude. Those areas between 20^0 and a little beyond 30º N and S will be considered under the subtropics. The South African production areas are between 24º and 21º S and these areas are typically subtropical.

The most important difference between the local climate and the tropics is the variation in day and night temperature. Tropical areas show only a slight variation of 4ºC between winter and summer and minimum temperatures never fall below 16ºC. Opposed to these temperatures, the average yearly temperature at Burgershall is 20ºC, with a daily variation and a winter/summer variation of 9ºC. The minimum temperatures fall below 16ºC for 7 months of the year.

A banana plant will produce 4 leaves per month in tropical areas but the leaf emergence rate at Burgershall is 3.5 per month during summer, and 0.5 per month during winter. This rate reflects the variation in average monthly temperatures. Banana growing in South Africa is therefore controlled by climatic conditions and the growth rate is high from November to March and practically stops between May to August.

3.2 Frost

Bananas cannot be grown in areas where frost occurs regularly. However, many plantations in South Africa are planted in areas where frost occurs occasionally. Frost rapidly kills banana leaves and only a few hours below freezing during one night are sufficient to ruin a plantation. Frosted leaves rapidly turn black.

•*Management of frost damage*

To manage a plantation that has had severe frost damage, the banana farmer must realise that a minimum of four healthy leaves are required to mature a young banana bunch. Each plant must therefore be considered on its merits as follows:

- A bunch that is mature can be left on the plant for a while since it may mature to still produce a marketable crop.
- A bunch that is <50% developed should be removed.
- A plant that has not yet flowered should be left as it might produce a marketable bunch.
- A young plant will develop normally but flowering might be delayed.

3.3 Hail

Almost every year some subtropical banana locality in South Africa has a severe hailstorm, which devastates some plantations and damages others. The problem that faces the banana farmer after a severe hailstorm is to decide on a plan of action which will enable him to salvage as much fruit as possible and to return to full production in the shortest possible time.

In general, the plan of action following a severe hailstorm should be according to that described earlier for frost damage, in which each plant is treated on its merits. In addition, the following points should be borne in mind:
Hail damage to banana bunches can be partly offset by the use of polyethylene covers, depending on the severity of the hail and the thickness of the cover. During a light hail, covers certainly afford some protection and they should be seriously considered over summer for both wind and hail protection.

3.4 Wind

There is no evidence that moderate wind, causing tearing of leaves into strips, causes yield losses. However, it is good practice that wind breaks form an integral part of banana plantation cultivation practices.

4. Soil requirements[2]

4.1 Site selection

The best banana soils are deep, well-drained loams with high water-holding capacity, high fertility and organic matter content and an absence of acidity or salinity.

In the subtropics, such as South Africa, site selection is also affected by regional climatic variations.

4.2 Site Preparation

a) Soil sampling

A representative soil sample is an essential prerequisite before. The analysis of such a soil sample will indicate the pH and chemical composition of the soil and whether any remedial applications are necessary, usually lime, phosphate or potassium. In addition, a similar sample should indicate whether a pre-plant nematicide application is necessary. To be representative, the soil sample should comprise at least ten sub-samples, taken from a depth of 100 to 200 mm and from sites spread systematically over the entire area. Not more than three hectares should be used per main sample and less if the soil type changes.

b) Soil preparation

Mechanical soil preparation depends to a large extent on topography. On flat land, the soil should normally be ripped, ploughed and disked before planting. Cross ripping to 1 m depth is also very effective, especially where compaction or impeding layers are present. Any lime, phosphate or potash should be incorporated with this operation. Following these operations, only small planting holes or planting furrows, are required.

On sloping land a different strategy may be required, primarily to prevent sheet erosion. Effective conservation planning is essential in order to retain topsoil but dispose of excess water safely. Phased development of a sloping banana site involves establishing grassed waterways, digging storm water drains, and designing a conservation structure. On slopes greater than 25%, contour channel banks may be sufficient. Construction is easier than terraces, but the banks should be covered with a binding grass. Trash lines in the channels are especially important on sloping land. Where slope or rocks prevent mechanical cultivations, large planting holes must be prepared by hand

4.3 Drainage

In the subtropics, lower rainfall reduces the need for elaborate drainage, but temporary water-logging problems do occur on certain coastal soils during heavy summer rains. Depending on the frequency and severity of the problem, mechanically-dug trenches or ridge and furrow planting systems, to deepen the water table, will have to be constructed.

5. Cultivars[3,2]

Dwarf Cavendish

Dwarf Cavendish is the most widespread clone in existence (though not the most abundantly produced) and the shortest in stature grown commercially. It bears well under a wide range of conditions and seems to be better adapted to growth in cool climates than other clones, except Williams. It is the basis of many subtropical banana trades but has been replaced by the taller Williams in some areas. Its low stature makes it less susceptible to wind damage. It is susceptible to choke throat and very susceptible to leaf spot, and is also attacked by Race 4 of *Fusarium* wilt – causing Panama disease.

Williams

Williams is about 50% taller than Dwarf Cavendish and propping of plants is necessary. Choke throat seldom occurs and hands are wider spread apart; the bunch is cylindrical and less compact, facilitating easier cutting than that of Dwarf Cavendish.

Chinese Cavendish

The shorter Chinese Cavendish is less prone to lodging is recommended for the warmer subtropical areas.

Grand Nain

Gran Nain is also recommended for the warmer subtropical areas, and should be established at a density of 2 200 plants/ha, spaced 3x1.5 m depending the specific climatic conditions

6. Production guidelines[1,2,3]

PLEASE NOTE: The following guidelines are generic and could require adaptation based on cultivar choice.

Plan your banana production well![4]

6.1 Planting and management

The land should be deep ripped, ploughed and disked, incorporating necessary pre-plant fertiliser and nematicide.

Before identifying of planting positions, provision must be made for access roads to facilitate removal of the fruit from a plantation and for carrying out cultivation practices. It is important that bunches should not be carried too far as this can increase the percentage of bruising and subsequent wastage. Once the soil has fully and finally prepared, the planting positions should be identified with wooden stakes. On level ground, the staking of the land is relatively easy. However on sloping land it should be first contoured and then the stakes can either be laid on contour or in straight lines. For general management the latter is thought to be more practical.

The planting holes need to be only slightly wider than the bag and about 100 mm deeper. The soil level in the bag should be about 100 mm less than the soil level in the field. The plastic bag should be cut carefully so that the entire root ball can be planted without the soil breaking up, which exposes and damages the roots. After planting, the young pseudostem is supported with extra soil which is packed around it. There is a tendency for the swelling rhizome of a young plant to climb above soil level if planted too shallow, resulting in unstable plants which easily topple over. As an added precaution, a mound of soil should be heaped up around the pseudostem base, about two months after planting, when the root system will have anchored the young plant to a large extent.

After planting, the land should be thoroughly watered. The first 5 months is the period when plants are physiologically very active and when root and leaf growth is at a maximum. There must therefore be no stresses on the plant or any constraints whatsoever.

6.2 Planting times

The optimum time for planting bananas is dictated by two major factors namely:

- timing the **crop harvest** to coincide with high market prices and
- timing the **planting date** to benefit from, or to avoid, certain climatic conditions. Very often these two factors interact to severely limit the planting date range.

Timing for markets is usually fairly effective for the plant crop, much less so for the first ratoon and almost impossible for the second ratoon.

In the subtropical climate of South Africa, **summer planting** (December/January) has been identified as the optimum in most areas. **Winter planting** (June/July/August) is not recommended since temperatures are too cold for sucker emergence and fruit is harvested in the low price summer period. Also, flowering takes place in winter and in the case of Dwarf Cavendish this causes a high incidence of "Choke throat". **Spring planting** (October/November) is dangerous because most bunches are initiated within the plant in July, some eight months after planting. The cold night temperatures during initiation induce small, stunted bunches with few hands and short, distorted fingers. Such bunches emerge from the pseudostem in November and are appropriately called "November dump" bunches. **Autumn planting** (March/April/May) induces a very long cycle time over two winters, with subsequent low yields/annum, and poor prices are obtained from the spring harvest. However, in hotter localities, such as Komatipoort, planting to harvest intervals is much shorter due to the extra heat units. Thus an autumn planting (March/April) is ideal because fruit will be harvested after only 13 months (April) and will not develop over the second winter as in cooler areas. Prices are also high in April/May. In cooler areas, however, summer planting gives high yields, good quality fruit and high prices from an autumn/winter harvest.

6.3 Planting densities

The spacing of banana plants is a subject of extreme complexity and therefore no general recommendations can be made to suit all situations. However, it is vitally important that the appropriate planting density be chosen because it is one of the major determinants of yield/ha/annum. An important principle to consider with bananas is that the harvest to harvest cycle is not specifically annual as it is with tree crops in which flowering is determined seasonally.

A mild, subtropical climate, with cold winters, requires a density of less than 2 000 plants/ha in order to enhance growing temperatures and accelerate the cycle time. Most banana areas in South Africa fall into this category. In the case of Komatipoort, where mean temperatures throughout summer, autumn and spring are about 4ºC warmer than at Burgershall, a density of between 2 000 and 2 500 plants/ha would be advisable.

6.4 Plantation vigour

Vigour is usually determined by soil type and standard of management. Canopy characteristics such as leaf area index and transmission of photosynthetically active radiation can be used to correlate with yield levels to determine optimum planting density for a given level of plantation vigour. In general, plantations of extremely high vigour can have a lower planting density and plantations of medium vigour can have a higher planting density. However, a plantation of very low vigour cannot tolerate a high density to compensate for this because individual plants then become as weak and stunted as to be worthless for commercial purposes.

6.5 Plantation life

The intended life of the plantation plays a major role in the density choice. It has been clearly demonstrated in South Africa, Israel and elsewhere that bananas, planted for a single crop cycle, can tolerate a density at least double that recommended for long term ratoon cycles. Bananas planted for two cycles can either have a density intermediate between that recommended for single cycle and that for long term ratoon plantations, or have a high to low density thinning scenario. For example, at Burgershall planting densities can be:

- Single cycle – 3300 plants/ha
- Two cycles – 1700 to 3300 plants/ha, depending on thinning practice.
- Ten year plantation – 1700 plants/ha

The economics of these different scenarios will, however, dictate the final decision.

6.6 Spatial arrangement

It is not only the density of plants per hectare which is important, but also the way they are spaced in relation to each other. At the standard recommended density of 1 666 plants/ha for Williams bananas (at Burgershall), the influence of rectangular (3 x 2 m), hedgerow (4 x 1,5 m) and tramline (6 x 2 x 1,5 m) spatial arrangements was investigated over five crop cycles. Overall productivity, measured in yield/ha/annum, was highest at the rectangular spacing followed by the hedgerow and tramline spacing. The yield differences were, however, slight. Therefore the choice of planting patterns will depend on the circumstances of the grower.

6.7 Fruit protection and manipulation

Fruit protection operations are designed to reduce the chances of the bunch falling to the ground and to prevent skin blemishes from mechanical scarring and from diseases and pests. Protection is carried out weekly by doing the following: deleafing, bagging and propping operations.

- *Deleafing*

  After the stem emerges, no new leaves are produced but some of the older leaves and the bract leaves may be touching the recently emerged hands. This will lead to leaf scarring. Leaves that touch or could touch the fingers are cut off flush with the pseudostem and the bract leaves are pushed away from the upper hands of the stem. Usually no more than one, and in the most two leaves are removed.

  Fruit protection deleafing is sometimes done with sanitation deleafing. This consists of removing all the leaves that have collapsed, and in areas with heavy leaf spot infection, the leaves with 50% or more of the area spotted Leaves that have turned yellow or which hang down more than 90% from the stem must be cut off and used as mulch in the rows. If this is not done, the old leaves surrounding the plant may reduce light penetration for suckers, provide place for snails and also restrict general plantation management. Leaves that are not removed may form a blanket around the stem and result in a cooling effect of about 2°C lower in winter.

  The height at which to cut down the old pseudostem after harvest is still discussed amongst scientists. In South Africa it is recommended to compromise by cutting half way down the pseudostem and thus obtain some advantage of both high and low cutting.

- *Debudding*

After bunch emergence, the male bud should be removed as quickly as possible to enhance the development of the lower hands. It should only be removed when the peduncle is at least 15 cm below the last female hand. The peduncle is broken off 15 cm below the false hand. The removal of the male flower bud removes unwanted mass from the hanging bunch and also possible sites for thrips and mites to proliferate.

If the flower parts on the end of each finger have wilted, it should also be removed to restrict spreading of cigar end rot.

- *Bagging*

Low winter temperatures cause the plant to grow slower and bunch developing during winter will take longer to mature. Apart from physiological restrictions due to bunch development, the fingers are also exposed to wind, hail, dust, sun and leaves rubbing against the bunch.

The polyethylene bag is placed over the bunch and loosely tied above the upper hand and the lower end at least 150 mm underneath the last hand. The lower ends are left open.

In addition to preventing pod blemishes, bagging creates a greenhouse effect around the stem by raising the temperature. Blue bags cause a bigger temperature increase than white bags. Fruit development is promoted and fruit-filling takes place quicker. Bunch mass also increases because fingers are longer. The bag must be put over the bunch within a month after flowering to get its full benefit. Fruit quality will also be better because the bunch is protected against the wind, sun, hail, dust and leaf rubbing.

- *Summer bunch covers*

Covering of bunches during summer in the subtropics has different objectives to winter covering. The microclimatic changes(increase in temperature and humidity) are not required in summer and the main benefits are mechanical protection of the fruit from wind damage during storms, from light hail and from harvesting and transport damage. In addition, the build-up of bunch pests in summer can be reduced by spraying the bunch or by inserting a vapour-releasing pest strip inside the cover. However, it is also true that pests can build up inside covers at a faster rate than normal if such control measures are not applied. Thus, increased pest activity and physiological rotting of fingers under covers during summer was recorded in a trail conducted at Burgershall. These problems are prevented in the tropics by using perforated bunch covers for aeration and pesticide-impregnated covers. However, these types of bunch covers have not yet been made available to South African banana growers.

- *Propping of banana bunches*

One of the problems facing banana growers is the falling over of pseudostems supporting immature or mature bunches, causing total bunch loss or partial damage, respectively. To overcome pseudostem lodging, there are three main methods of bunch support namely:

- Wooden stakes or props are used where timber is inexpensive and readily available. With short banana cultivars (e.g. Dwarf Cavendish) single props are used while with taller cultivars (e.g. Williams) it is advisable to use double props.
- A second method of "propping" is based on the mutual support principle and involves tying adjacent plants together with polypropylene twine. For best results,

bunches have to be leaning in exactly opposite directions, therefore the tramline planting system comprising adjacent double rows is most suited.

Figure 1. Double propping in a uniform stand with well developed bunches

- An overhead cable system of propping bananas is now widely used. A series of 5 mm wires is suspended above each banana row, supported by uprights, braced by cross wires, and stabilised at the end by anchors embedded in concrete. Bunches are tied to the overhead wire with polypropylene twine. The main advantages are that no bunches are lost, labour is easier, chafing of bunched is reduced and plantation access is unimpeded.

6.8 Desuckering

Desuckering is a term used to describe the practice of removing unnecessary suckers on the plant. It is a way of pruning and one of the most important acquired skills in the management of a plantation. In fact, the quality of the pruning, as indicated by population and spacing is a good indicator of the quality of management.

Desuckering is the technique of selecting the most vigorous sucker in the best location with respect to adjacent mats and eliminating the undesirable suckers. In the past, only one basic method of desuckering existed, but with the introduction of tissue cultured plants, a new system had to be developed.

a. Desuckering – The conventional method

Unwanted suckers should be removed before 10 leaves are formed or a height of 200 mm is reached. If these suckers are let to grow, they will compete with the selected sucker for nutrients, water and light and the selected sucker will develop slowly.

Suckers should be totally removed, including the growing point just beneath the soil surface. It does not help to cut off the sucker at soil surface. It should either be removed by a pruning spade or by pouring 5 ml diesel into the centre of the cut surface. The diesel method is preferred because the risk of damaging roots is less and nematode and the spreading of Panama disease are reduced.

The time of sucker selection is very important in order to get the correct cycle times. It should not be left to grow too early or too late. A general rule applies:

- *Cooler areas:* Keep the first follower in its position by August.
- *Warmer areas:* Keep the first follower in its position by September.

In South Africa it was shown that the average height of young Williams suckers was 15 mm per month in summer and only 10 mm per month in winter. As a result, monthly desuckering must be done in summer and two monthly desuckering in autumn and winter.

b. Desuckering – The sectorial method

Normal sucker selection means desuckering with diesel until 8 months after planting. Diesel for desuckering still applied in winter destroys all sucker potential around the corm of the plant. No suckers are available in spring for sucker selection.

The development of new sucker potential in spring is dependent on climatic factors and root generation. New suckers must be in the right direction and the danger of selecting a sucker in the wrong direction is big. This happens because every sucker that appears more or less right will be selected. This management error leads to the fact that at harvest the sucker which is still fully dependant on the mother, will compete with the developing bunch for carbohydrates, thereby delaying the cycle time from 2-4 months per ratoon.

The recommendation is to cut back the first flush of suckers at ground level when they are still small, without damaging the growing point of suckers. This may be done two or three times while the mother plant is still developing.

c. Number of suckers selected per plant

Normally the planting density is determined initially and thereafter it is maintained by selecting one sucker per plant throughout the plantation life. However, there are two variations on this, both of which have been practised in South Africa:

- Planting at half the recommended density, then selecting two R1 suckers from each plant, to double up the ratoon density. The attraction of this system is that planting material costs are halved, and the two first ratoon suckers develop rapidly under open canopy. However, this method is not recommended because plant crop yields/ha are too low.
- Planting at double the recommended density, then selecting one sucker on alternate plants and no suckers on the other half, so that density is halved in the first ratoon (e.g. 3333-1666 plants/ha). The advantage is that yield/ha and cash flow are boosted in the plant crop, whereas the disadvantages are that establishment costs are increased and the R1 suckers grow under a dense canopy thus delaying the ratoon cycle.

d. Direction of sucker selection

Many plantations in South Africa have become completely random, having lost their initial spatial arrangement due to poor sucker selection. It is essential that all the R1 suckers are selected in exactly the same direction and that subsequent ratoon suckers follow this direction closely. Selection of ratoon suckers, irrespective of direction, means that the plantation rapidly loses its symmetry and row structure, making accessibility more difficult and weakening the plantation physiologically.

With systematic plantations such as recommended in subtropical localities including South Africa (rectangular, hedgerow or tramline arrangements), the direction of selection must be uniform in order to “march” the mats equally and maintain the original arrangement.

7. Fertilization[1,2]

A sound fertilisation programme is based on soil and foliar analyses and the yield potential of the area being fertilised.

Taking leaf samples

Samples should be taken from September to April, when 50% of the plantation is flowering.

Do not take samples during hot, dry periods.

Do not take samples just after heavy rains. Wait at least 2-4 weeks.

Take the sample (the third youngest leaf) when the flower is fully opened and one or two hermaphroditic hands are visible. The flower buds on the fingers must still be moist.

Only healthy plants should be sampled. Leaves should be free from sunburn and insect/disease damage.

The sample is taken in the middle of the leaf by tearing a 150 mm strip on both sides of the main vein. The outer halves of these strips are cut away. The inner halves are placed in a **clean** plastic bag.

At least 10 (preferably 20) plants should be sampled. These plants should be evenly spread over the land. If the land is bigger than 3 ha or has different soil types, extra samples should be taken.

In the case of a plant crop, 50% of the plants should be flowering, 20/30% of the plants of the first ratoon and 10% of the second ratoon.

Taking soil samples[1,3]

Soil samples are taken the same time as leaf samples. A hole is dug about 200-300 mm deep and 500 mm away from the stem of the plant. All the soil of the sample sites are mixed together and a sample of 2 kg is sent for analysis.

It is also important to provide information on the current fertiliser programme when samples are sent. In this way any results can be logically interpreted and a new programme recommended.

Optimum soil and leaf nutrition norms

1. Soil		
pH (water)		5,7-6,8
Resistance		1000 +
Ca/Mg (ppm)		2,5-5,0
K	(ppm sandy soils)	120-200
	(ppm clay soils)	200-300
P (ppm)		4-27
Al (ppm)		0-30
2.Leaves		
% Ca		0,80-1,25
% Mg		0,25-1,00
Zn (ppm)		25-50
Cu (ppm)		5-20
Mn (ppm)		150-1000
Fe (ppm)		50-200
B (ppm)		15-60

a. Methods of fertilising

Soil applications are still common practice today although a few producers apply soluble fertilisers by means of fertigation. In the case of soil applications, considerable damage is done to the shallow root system of the banana plant if fertilisers are worked in. It is thus recommended that a light irrigation is applied after fertilising.

As better utilisation of fertiliser can be achieved by applying it through the irrigation system, it is possible to apply smaller quantities than in the case of soil applications.

b. Preplant fertilisation

It is important that new plantations receive most of their P and K fertilisation before planting. It is essential to do a soil analysis about 6 months before planting. Any lime and phosphate, and organic fertilisers, where required, must be worked in well about 3 months prior to planting

c. Time of application

The following guidelines apply for the fertilisation of bananas (Table 1).

Table 1. Approximate quantities (kg) of elemental nitrogen, phosphate and potash removed per 46t /ha yield

N (kg)	P (kg)	K (kg)
102	11	330

Nitrogen is applied during the first 6 to 9 months after planting. It is also essential that the young growing plants should be well fertilised and where feasible, they can be given nitrogen virtually every month during the first 4 to 5 months.

Potassium, in particular, is also very important during this period. The plants absorb K and P most efficiently when they are 2 to 4 months old.

As a 'rule of thumb", the following guidelines are recommended for nitrogen, phosphorous and potassium:

- Beginning of September: quarter of the annual nitrogen, plus all the phosphate, and half of the potassium.
- Beginning of November: a quarter of the nitrogen.
- Beginning of January: a quarter of the nitrogen.
- Beginning of March: a quarter of the nitrogen, plus the remaining potassium.

8. Weed control[1,2,3]

Weed control is very important for successful cultivation of bananas and should be done from planting date. Heavy mechanical cultivation should be discouraged at all times as it may cause damage to the root system and cause Panama disease to spread. Only very light cultivation should take place.

Any registered post-emergence weed killer can be used, but plants should be protected with a tree guard apparatus to minimise herbicide damage.

Strip spraying should be done on young weeds and followed with spot spraying.

9. Irrigation[1,2,4]

It is important to understand that the banana plant is adapted to a humid, tropical climate where it is uniformly warm and moist through the year. The plant has a high evapotranspiration potential due to the large leaf area, but it has a shallow superficial root system with a poor water extraction potential (see Example 1). The plant thus shows a rapid physiological response to soil drying and this response to soil drying is greatly enhanced during periods of high evaporative demand.

It has been found that:

- If the available moisture is more than 66% below field capacity, moisture stress occurs.
- If moisture stress occurs 120-180 days after planting, it falls within the time of flower initiation and growth rate, stem thickness and number of hands per bunch decrease.
- If moisture stress occurs before bunch emergence, bunch emergence is delayed by a month and less hands and fingers are formed; thus a decrease in bunch mass.
- Moisture stress, after bunch emergence, results in smaller fruit being formed.
- The plant is more sensitive to moisture stress during flowering than during the time which fruit develops.

Irrigation scheduling

The growth and yield of banana plants are **extremely sensitive** to water stress. This fact, coupled to the relatively shallow root system of the plant, makes accurate irrigation scheduling essential.

Given the above, it is obvious that long irrigation cycles i.e. 7 or more days between irrigations, are detrimental to growth and yield.

Example

Example 1

When tensiometers are used, the reading at which irrigation must be applied is between 20-30 kPa in the upper root zone i.e. in the upper 200 mm root depth.

IRRIGATION SCHEDULING

CROP	BANANAS		ROOT ZONE
FARMER	SHADDAI TRUST	% SAND	
ORCHARD No	1	% SILT	
FARMER	LEVUBU	% CLAY	35-55
IRRIGATION SYSTEM	Drip irrigation system	% STONE/SAND	
		PROFIEL DEPTH(mm)	1000
		WATER HOLDING CAPACITY(mm/m)	270
		AVAILABLE WATER [mm]	160
		MAX APPLICATION(mm/h)	4

MONTH	JAN	FEBR	MAART	APRIL	MEI	JUN	JUL	AUG	SEPT	OKT	NOV	DES
1.EVAPORATION/MONTH(mm)	195	180	180	137	122	118	130	170	193	196	190	190
2.EVAPORATION/DAY (mm)	6.29	6.43	5.81	4.57	3.94	3.93	4.19	5.48	6.43	6.32	6.33	6.13
3.CROP FACTOR	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
4.DAILY WATER USE (mm) ((Evap/day)* Crop factor))	5.98	6.11	5.52	4.34	3.74	3.74	3.98	5.21	6.11	6.01	6.02	5.82
5.AVAILABLE MOISTURE (mm/m)	160	160	160	160	160	160	160	160	160	160	160	160
6.ROOT DEPTH (mm)	450	450	450	450	450	450	450	450	450	450	450	450
7.AVAILABLE MOISTURE/ROOT DEPTH (mm) (Root depth/1000)* Available moisture	72	72	72	72	72	72	72	72	72	72	72	72
8.Depletion of available water %	30	30	30	30	30	30	30	30	30	30	30	30
9.Permissable depletion of available water [mm] ((Depletion of available water %)* (Available moisture /root depth))	22	22	22	22	22	22	22	22	22	22	22	22
10.CYCLE LENGTH (days) Permissable depletion of available water (mm) ÷ (Daily water use)	4	4	4	5	6	6	5	4	4	4	4	4
11. APPLICATION RATE(mm/h)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
12. IRRIGATION CYCLE (hours) (Permissable depletion of available water÷Cycle length)	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20
13. APPLICATION/MONTH [mm]	185	189	171	134	116	116	124	162	189	186	187	181

10. Diseases[1,2,4]

Panama disease (*Fusarium* wilt)
Panama disease is one of the most devastating diseases for any banana farmer. The problem is however that there are 4 races of *Fusarium oxysporum cubense* and the susceptibility differs according to country. Although sources of resistance have been identified in Races 1 and 2 in banana breeding programmes, little is known about resistance to Race 4 the one affecting South African plantations. Nearly all cultivars in South Africa are therefore susceptible to Race 4. The fungus only affects bananas and spores can survive in the soil for 20 years or longer.

The first external symptom of Panama disease is an irregular yellowing of leaf margins of the older leaves. The yellowing quickly spreads to the inside of the leaves while the leaf margins turn brown or dark grey and dry. These symptoms eventually spread to all the leaves. Where the external symptoms of Panama disease can easily be confused with Armillaria rot, drought or a severe potassium deficiency, the internal symptoms are indistinguishable. When the rhizome is cut just above the soil level, vascular discoloration can be detected. The colour varies from yellow to brown to red or black and a few yellow strands may occur. For further proof of the disease, the stem can be cut through 0.5-1 m above the rhizome. Yellow and red spots will occur on the cut surface.

All these symptoms are the clearest during the hotter summer months. Hardly any symptoms can be detected in late autumn and winter. Currently there are no effective control measures against this disease and the only really effective methods are by quarantine and exclusion, or by planting resistant varieties. Once soils are infested, the only method of reducing the population is by long periods with non-host crops.

Cigar end rot
Cigar end rot is caused by the fungus *Verticillium theobromae*. The pathogen attacks flowers and flower leaves and as fruit develops, it spreads from the flowers to the fruit. The fruit skins have a black appearance and the infected parts show a wrinkled, folded appearance. In the end, a mass of fine powdery spores develop on the infected parts; these spores look like cigar ash.

The only way of controlling this disease is to remove the flower leaves 8-11 days after bunch emergence.

Armillaria rot
Armillaria corm rot is caused by the fungus *Armillariella mellea.* Infected plants appear stunted, have yellow leaves which may be dead or hang down the pseudostem. This disease can easily be confused with Panama disease and it is only when the corm is cut and the internal symptoms examined that they can be distinguished.

Where the plant is infected with Armillariella, a brown discoloration of the whole corm is seen. Within this are white sheets of the fungus. The corm will show a soft, wet rotting at an advanced stage. (A "Panama-infected" corm has a white matrix with small spots of red or black discoloration)
This disease occurs within the first 2 years of planting on new ground. The fungus is associated with forest and bush trees and if the land is not properly stumped, the fungus will attack bananas when these are planted.

Erwinia rot
Erwinia corm rot of bananas caused by the bacterium *Erwinia chrysanthemi.* This bacterium appears to be widely distributed in the soils of our major banana growing areas, but very few cases

of it attacking the standard cultivars Williams or Dwarf Cavendish have been recorded to date.

Fruit Spot (Pin spot)
Sporadic but sometimes serious fruit spotting has occurred for many years on banana fruit in the hotter areas of the Lowveld

The symptom of flower thrips damage is a small red or black spot surrounded by a dark green water-soaked halo. In this, the central spot is raised as can be easily felt by running a fingertip over the spots. The disease is most common during the summer rain season. The disease is controlled by chemicals.

Crown rot
Crown rot is the major post-harvest problem of bananas, especially during the hot summer months. This disease is caused by a number of fungi of which *Fusarium* spp. and *Verticillium* spp. are the most important.

The fungi are part of the flora found on flowers and leaf trash in the banana plantation. They are present on the fruit and flowers when placed in the dehandling tank and form part of the flora in the water which is used to remove latex. Usually these fungi remain in the tissue near the surface of the crown.

When the bunch is cut into hands, a big wound is produced from where pathogens can penetrate the crown, even down into the necks of the fingers. When severe, fingers will drop from the crown when it is suspended. Crown rot is particularly important when fruit is stored or shipped for long periods

Control involves good cultural and packing plant practices.

1. Careful handling of fruit during harvesting helps to reduce bruising.
2. Plantations, transport wagons and pack houses should be kept clean
3. Packing stations should be thoroughly washed after use and flowers and other trash and garbage should not be allowed to accumulate in or around the packing plant.
4. It is recommend that bunches should be hung in order to reduce bruises forming when they arrive at the pack house.
5. After dehandling, the fruit should be washed in clean water, as an adequate flow of clean water through the tanks help reduce inoculum in the water.

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Module 8a

Pasture and fodder production

Study objective

After completion of this module, the learner should be able to have a basic understanding of:

- Factors which influence the choice of cultivated pasture species
- Characteristics of temperate and tropical pasture plants
- Difference between grasses and legumes (structure and development stages)
- Requirements for establishment of pastures
- Management principles for optimum production
- Utilisation of pasture plants

1. Introduction

In this module, the terminology 'pasture" is used to mean herbage, which has been sown or planted by man, intended for consumption by animals. Such pastures are also called "sown pastures" or "established pastures" or simply 'pastures". The sward can consist of a grass or a legume, or can comprise mixture of grasses, or mixtures of legumes, or can comprise a mixture of grasses and legumes. Legumes form part of the family *Leguminosae,* and through symbiotic relationship with nodular bacteria, they have the ability to draw nitrogen from the air and to make it available for their own nutrition and grasses growing alongside.The most economic form of pasture utilisation is directly *via* the grazing animal, and the aim with pasture establishment is provide grazing at a time when the natural veld production is either low or of poor quality.

2. Factors which influence the choice of pasture species

The following factors are important regarding the choice of pasture species and should be considered[1,8].

Table 1. Factors influencing the choice of pasture species

Rainfall	Summer/winter Pattern intensity Total for season
Humidity	
Temperature	Maximum/Minimum Frost/Frost free Mild climate/Severe climate (very hot/very cold)
Elevation	
Soil	Types (sandy, clay and loam) Shallow/deep Retains moisture/well drained
Aspects	Warm/cool
Irrigation	Unlimited/supplementary
End use of pasture	Grazing:summer/cool season Hay Haylage Silage Foggage
Pastures required for use in	Spring/autumn/summer/winter Combination of above
Type of animal	Cattle:beef/dairy Sheep: wool/mutton Cattle and sheep (mix) Age of animals Cow/calf

The choice of cultivated pasture types can be divided into temperate and tropical cultivated pastures with different establishment and grazing management requirements:

2.1 Tropical /subtropical pastures[1]

Tropical/subtropical species are predominantly summer growing, frost sensitive and best suited for the warmer parts of the country. To differentiate between the required management systems, Tropical pastures are divided into four definitive categories[1]:

- Warm season tuft forming grass types like *Eragrostis curvula(weeping love grass), Cenchrus cilliaris(buffalograss), Digitaria eriantha (smuts fingergrass). These grasses with a few exceptions have an inherent low digestibility and are associated with a lack of resistance to heavy grazing.*
- Sod forming or creeping grass species like kikuyu (*Penisetum clandestinum),*stargrass *(Cynodon spp.)* and bhai grass *(Paspalum notatum)*.These grass species recover well following heavy grazing but like the warm season tufted grass species they have a low digestibility relative to cool season grasses.
- Tropical legumes include species like greenleaf desmodium, glycine *(Glycine wightii),* siratro, stylo, medicago (lucerne) and lotonis. Careful consideration should be given to the selection of areas with climate, soils, rainfall suitable for the cultivation of these pasture legumes.
- Grass and legume mixtures – the characteristics will vary according to the particular species of grass and legume which are used.

2.2 Temperate or cool season pastures[1]

Temperate species are better adapted to cooler areas and grow rapidly in spring and autumn provided enough soil moisture is available. Annual temperate grass species like ryegrass are also useful for irrigated winter pastures in the warmer areas. Temperate pastures can be divided into grasses, legumes and mixtures of grass and legumes:

- **Temperate or cool season tufted grasses** grown in South

Africa include Italian ryegrass *Lolium multiflorum*), tall fescue *(Festuca arundinacea)* and cocksfoot *(Dactylis glomerata).* These grasses are moderate resistant to hard grazing although they differ in their ability to withstand light or heavy grazing. The one side of the spectrum represents perennial ryegrasses, which require heavy grazing to survive. On the other side of the spectrum, are Italian ryegrass and cocksfoot which do best when lightly grazed. These grasses are excellent for the making of hay and silage.

- **Temperate legumes** include clovers such as white clover *(Trifolium repens*) and red clover *(Trifolium pratense*) have an advantage over grass species in that they are often less costly to maintain due to the lower fertiliser nitrogen requirements. These pastures produce high quality dry matter, and are fairly tolerable for intense utilisation, provided it is not subject to extensive competition from associated unpalatable species which may remain largely ungrazed.

- **Grass and legume mixtures**- the characteristics will vary according to the particular species of grass and legume which are used. The behaviour of white clover/ryegrass pasture will differ considerably from that of *Glycine/Panicum* pasture.

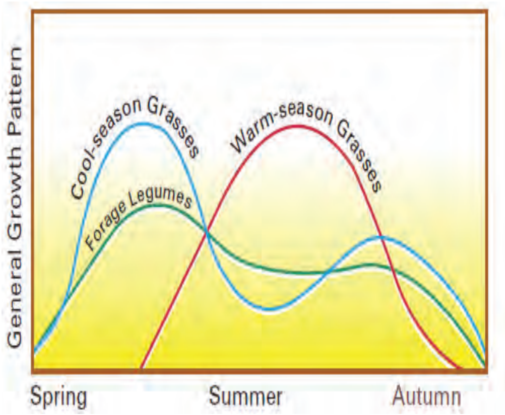

Figure 1. Different types of pasture plants are productive during different periods of the growing season[8]

Productivity of pasture plants varies during the growing season. An important classification of pasture grasses is whether they have their highest production and growth rate during the cool portion of the growing season (cool season grasses) or during the warmer days of the growing season (Warm season grasses) as indicated in Figure 1. Legumes grow most rapidly during the spring months.

3. Structure and development of grass plant [1,9]

The structure of the grass plant is similar among many species of grasses (Figure 2). A grass plant is a collection of tillers or shoots that grow from buds at the base of the plant. Each tiller is composed of a series of repeating units consisting of a leaf, stem node, stem internode, and a bud. Each leaf is attached to the stem at a node, with an associated dormant bud.

The principal developmental phases of the grass plant are vegetative, transition and reproductive. Management decisions like irrigation must be linked to plant development to optimize yield, quality and regrowth potential.

Early in the development of a grass tiller, the distance between nodes on the stem is very short. At the top of the stem is the growing point where new stem and leaves originate. As long as the growing point remains intact, it is capable of producing new leaves.

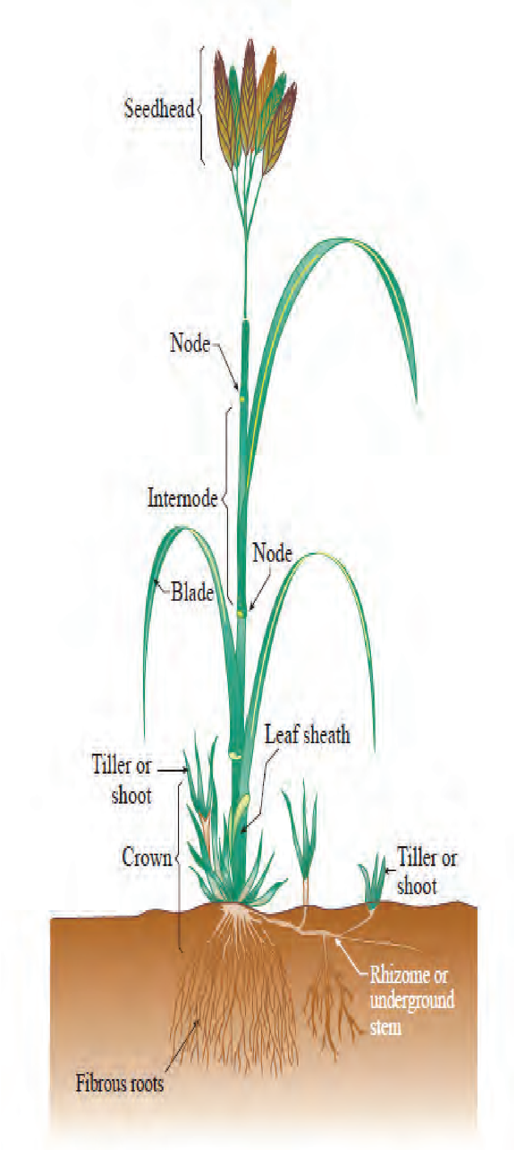

Figure 2. The grass plant with respective parts

In the ***vegetative phase***, shoots consist predominantly of leaf blades. Leaf blade collars remain nested in the base of the shoot and there is no evidence of sheath elongation or culm development.

Later in the development of the grass plant the growing point undergoes a change. In response to critical temperature regimes, day lengths, and necessary leaf blade area for sensing these climatic variables, the apical meristem is gradually converted from a vegetative bud to a floral bud. It stops producing leaves and begins to produce immature seed head of the plant. This is called floral induction. This conversion phase is termed the ***transition phase***. During the transition phase, leaf sheaths begin to elongate, raising the meristematic collar zone to a graze able height[1,9].

The ***flowering phase (reproductive phase)*** commences with the conversion of the shoot apex from a vegetative condition to a floral bud. Much of this is unseen until the emergence of the seed head from the sheath of the flag leaf (boot stage). The almost sudden appearance of the seed head is caused by rapid elongation of the peduncle (uppermost internode of the culm). Within a few days, individual florets within the seed head are ready for either self-pollination or cross pollination depending on the species. For cross pollination to occur, the floral bracts (lemma and palea) must be spread apart to allow for the exchange of pollen. Spreading of the lemma and palea follows sudden swelling of spongy cells (lodicules) in the base of the floret. Figure 3 illustrates these different development phases of the grass plant.

Figure 3. The different development phases of the grass plant

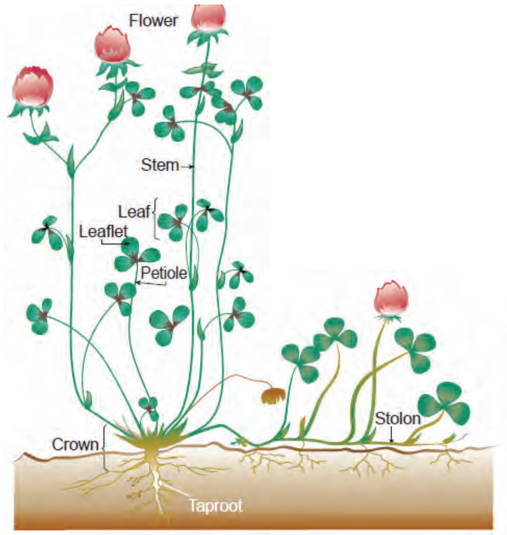

Figure 4. The parts of the legume plant (not all parts are always present on all species)

4. Structure and development of legumes[1]

Legumes are a special class of plants since it can fix atmospheric nitrogen into their own plant-available nitrogen. Legume development differs from that of grass plants. Legumes begin to grow in length immediately with leaves arranged alternately on opposite sides of the stem (Figure 4).

The legumes develop as vegetative growth to an early stage of reproduction called the ***bud stage***. Buds are green, immature flowers that develop quickly to open bloom or flowering stage. Legumes also have many potential regrowth points. Aside from the buds at the stem tip and along the leaf-stem junction, most legume species also have dormant buds at the stem base, or crown of the plant. These crown buds are the source of the first growth in the spring and can quickly produce new, leafy regrowth when growing stems are grazed or clipped.

An obvious difference between forage legume species is the type of growth habit:

- Prostrate white clover *(Trifolium repens)* type: stems trail on the soil surface to form rooted stolons
- Upright tufted types like the red clover types *(Trifolium pratense)* and lucerne *(Medicago sativa)* are good examples
- Twining type exhibited by many of the tropical legumes like *Desmodium spp*. and *Glycinne spp*.
- Shrub type like *Leucaena leucocephala.*

The growth rate of a plant is how fast a plant adds new dry matter over a period of time. Figure 5 shows a typical pattern of growth and yield.

When a plant is short with minimal leaf area, its daily growth rate is slow. As the plant accumulates increasingly more leaf area, its ability to capture sunlight increases rapidly and its growth rate per day reaches its highest level in the late vegetative stage. As the stems develop to flowering and seed production, few new leaves form and the lower, older leaves start dying-off. During reproduction the dry weight of the plant is not increasing, but is being redistributed within the plant as the stems mature and seeds develop. These development stages of the pasture plant require special management inputs to ensure optimum production.

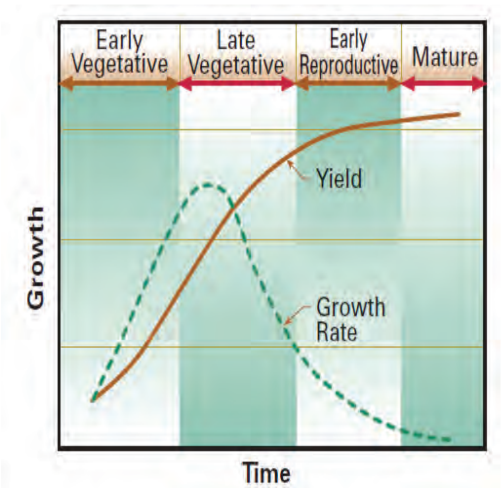

Figure 5. Growth rate changes during growth cycle of pasture plants

5. Establishment of pastures[4,8,7,9]

a. Site selection and soil characteristics

Both the landscape position and the soil series of the site selected for planting pastures play an important role in determining the type of pasture which should be planted, the pasture species which should be planted and the planting technique that should be followed.

The following properties of the site require attention before the preparation of the seedbed receives attention:

- Runoff and erosion: the steepness of the land is the main consideration in relation to the runoff and soil erosion. If there is any danger of runoff and soil erosion the necessary precaution measures are important (contours, terracing, etc.) If the slope is very steep and a great deal of runoff is expected then broad strips of creeping and sod forming grasses can be planted across the slope of the land in order to slow down the rate of flow of the water and promote infiltration.
- The subsoil of the site may be of such a nature that it prevents deep percolation of water and so causes the topsoil to become waterlogged. Consider the planting of moisture loving grasses like *Penisetum purpureum* (napier grass) and bana grass *(P. purpureum x P. americanum).*

The potential yield of a cultivated pasture is to a great extend determined by the soil characteristics and the fertility of the soil. Poor drainage may create unfavourable conditions for pasture crops and can lead to the establishment of undesirable plants like weeds.

b. Seedbed preparation

Most grasses and legumes seed is very small and therefore it is necessary for the seedbed to be even, weed free, firm and fine.

c. Time of establishment

At the establishment of pastures, the sowing date is very important. If summer weeds are a problem, late summer or autumn plantings are recommended, while spring and early summer plantings can combat the effects of winter weeds. It is important to study the establishment needs of the respective pastures with regard to the sowing date and density of the possible pasture crop.

d. Sowing or planting techniques

Pasture seeds are usually broadcast but in certain circumstances, sowing in rows is preferable. These operations can be done either:

- By hand or hand operated seeding machine
- Wheat planter from which the teeth/knives have been removed so that the seed falls just on the top of the soil
- Fine seed planter used for vegetable production
- Mixing the seed with phosphate or lime and sow it with lime spreader
- Ordinary seed drill can also be used to plant it in rows
- If cash crops are planted in wide rows, pastures can be established between such cash crops

If seed is mixed with fertiliser it must be applied as soon as possible after mixing. If the seed/fertiliser mixture is left to stand overnight, the seeds may be killed. The establishment methods describe above are suitable for most grasses with the exception of *Cenchrus cilliaris* ((blue buffalo grass).

The sowing of legumes requires the effective inoculation prior to sowing of legume seed with rhizobium bacteria. Inoculated legume seed should not be mixed with fertilisers and also not be exposed to direct sunlight.

The seedbed preparation for vegetative establishment of grasses like kikuyu, star grass, K11 and Tifton requires a weed free seed bed. The seedbed needs not to be as fine as for sowing of seed. Runners can be cut into convenient lengths, and the pieces spread over the moist seed bed and disked in. Alternatively they can be placed in furrows and then covered with soil. The aim is to have the land as smooth as possible after planting.

Over sowing is reinforcing a sward by introducing seed of a desired species like for instance the over sowing of ryegrass on a kikuyu pasture. This technique can be useful provided the following conditions are met where applicable:

- Competition amongst species is avoided by permitting one species to compete its growth cycle before planting the other.
- Compatible species and cultivars are selected
- Competition between species is reduced by means of herbicides, row planting, drastic defoliation or sod seeding

e. Seeding rate

The seeding rate recommended is depending on the following factors:

Purity of the seed	The actual percentage of seed in the commercial sample
Germination capacity of the seed	The quality of viable seed expressed as a percentage
Size and weight of the seed	Number of seed per kg of seed is important as seeding rate is expressed on a mass basis
Moisture supply	Not only the amount of moisture in the soil at the time of sowing, but also the irrigation available
Fertility of the soil	The less fertile the soil, the lower the seeding rate to avoid undue competition
Effectiveness of seedbed preparation	The poorer the seedbed , the higher the seeding rate should be.

Method of sowing	Less suitable the sowing technique, the higher the seeding rate
Growth habit of the grass (tuft or creeping)	The greater the area that one plant is capable of covering, the lower the seeding rate needs to be.
Purpose of the pasture	Pastures planted for production of hay and silage are usually seeded heavily to enforce an upright growth habit, while grazing pastures have lower seeding rates because of the lower plant competition.

6. Fertilisation of cultivated pastures[7,5,8]

Fertilisation of cultivated pastures is of great importance with the establishment and the maintenance of pastures. The aim with a pasture fertilisation programme is however to ensure that it is economically feasible in terms of the animal production and dry matter yield. The starting point to a fertiliser programme is a proper soil analysis so that the soil status can be identified.

6.1 Soil pH

The main aim with the correcting of soil pH through the application of lime is:

- To correct soil acidity
- Reduce toxic aluminium levels
- Provide the required plant nutrients like calcium and magnesium
- Increase availability of phosphorous

Grasses and legumes differ from each other in respect of this. Grasses can tolerate low pH, although if there is any calcium or magnesium deficiency liming is required. Legumes on the other hand require moderate acid to neutral soils to produce satisfactorily. Lime applications (calcitic or dolomitic) depending the deficiency status is also necessary for the development of rhizobium bacteria.

6.2 Phosphorus

Both grasses and legumes require satisfactorily levels of phosphorous. Phosphorous for grass pastures is often underestimated, and although grass species can survive on low phosphorous the yield will be below the potential. Generally phosphorous becomes more important when nitrogen is applied, due to the interaction between nitrogen and phosphorous. The maintenance requirements prescribed for phosphorous can vary considerably.

The most important factor which contributes to successful production of legumes is the provision of sufficient phosphorous for the plant's nutritional needs. Lucerne particularly under irrigation, has a great need for phosphorous. Clovers usually grow in relative high rainfall areas, where liming and the necessary application of phosphorous are required for effective cultivation of legumes.

Table 2. General recommendations of P levels for establishment of legumes and grasses

	Grasses (mg P/kg soil) (Bray 1)	Legumes (mg P/kg soil) (Bray 1)
Irrigation	30	35

6.3 Potassium

Table 3 provides general recommendations on soil potassium levels required for the establishment and maintenance of legumes and grasses. These levels must be increased on heavier clay soils. When a pasture is grazed throughout the year, about 90% of the potassium taken up by the grazing stock is recycled *via* the manure and urine. In that case, topdressing with potassium can be reduced. However, if pastures are cut regularly for hay or silage, the potassium is removed. 10kg K is removed for every ton of *Eragrostics curvula* taken off[7]. Annual applications of potassium are required in order to maintain the correct level of potassium in the soil.

Table 3. General recommendations of K levels for establishment of legumes and grasses[4]

	Grasses (mg K/kg soil)
Irrigation	140

6.4 Nitrogen

Nitrogen is the key to the successful production of grass pastures. In any fertilisation programme there must be a balance between nitrogen and the other nutrients like P and K. The amount of nitrogen applied should be correlated to moisture and the type of pasture.

Nitrogen is applied up to six times and the frequency of application will depend on species, production, and length of growing season, weather and where the herd sleeps. Summer pastures use nitrogen more efficiently during the early part of the growing season, and it may be advantageous to top-dress accordingly.

Well nodulated legumes require no nitrogen. Should a newly established legume pasture turn yellow, it can mean that the *Rhizobium* bacteria have not yet started to fix nitrogen from the air and the plant is therefore suffering form a nitrogen deficiency. A topdressing of nitrogen will normally overcome this problem satisfactorily.

Definition

Rhizobia are bacteria that live in association with the roots of legumes (pulses) in a symbiotic relationship. Rhizobia are able to take nitrogen from the atmosphere and bind it into a soluble form that plants can use.

The following quantities of fertiliser based on herbage removed are portrayed in Table 4.

Table 4. Approximate quantities (kg) of elemental nitrogen, phosphate and potash removed per 1000 kg dry matter or 70 AU grazing days[4]

Element	N	P	K
*Complete removal	20-30	3	15-25
#Grazing	10-15	1-2	10-20

**Complete removal: silage, hay, zero-grazing*
#Grazing: animals remain on pasture almost 24 hours a day

6.5 Trace elements

A deficiency of the trace elements can inhibit optimal production of legumes (especially molybdenum), but can be rectified easily. Prior consultation with an agricultural advisor is recommended.

7. Irrigation of cultivated pastures[6]

The major question to be answered is when to irrigate and how much water is adequate. Too much, apart from the fact that it is wasteful and expensive, can also cause leaching of plant nutrients, rising water table and water logging conditions. Too little water can set growth back severely.

The amount of irrigation on pastures and fodder required depends on the soil moisture characteristics, root development (root depth) and the development of the leaf canopy after defoliation when the crop has been cut or grazed. The pasture crop growth stays at or near the optimum until 50% of the plant available water (PAW) has been used up and after which the rate of growth rapidly decreases.The Et/E0 ratio or crop factor varies according to a fixed pattern during the crop's growing season.

Table 5. Irrrigation requirements of pasture crops (SAPWAT)

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm)
Fescue / Cocksfoot				
Dry, cold, summer rain, (Karoo), peak Oct	319	302	1035	126
Dry, cold, winter rain, peak Jan	381	330	738	118
Dry, hot, west, (North Cape), peak Oct	335	269	1431	174
Dry, hot, east, (dry Bushveld), peak Sep	582	489	1129	149
Humid, hot summers, (wet Lowveld), peak Sep	852	593	669	109
Humid, warm summers, summer rain, (Highveld), peak Sep	600	501	810	117
Humid, warm summers, winter rain, peak Jan	526	397	690	107
Ryegrass (perennial)				
Dry, cold, summer rain, (Karoo), peak Oct	319	291	674	123
Dry, cold, winter rain, peak Oct	381	330	394	85
Dry, hot, west, (North Cape), peak Nov	Perennial ryegrass does not survive very hot summers			
Dry, hot, east, (dry Bushveld), peak Nov	Perennial ryegrass does not survive very hot summers			
Humid, hot summers, (wet Lowveld), peak Nov	Perennial ryegrass does not survive very hot summers			
Humid, warm summers, summer rain, (Highveld), peak Sep	600	464	635	118
Humid, warm summers, winter rain, peak Oct	526	400	385	90
Clover (Ladino / White / Red)				
Dry, cold, summer rain, (Karoo), peak Dec	317	300	904	158
Dry, cold, winter rain, peak Dec / Jan	367	288	768	146
Dry, hot, west, (North Cape), peak Dec	331	266	1446	208
Dry, hot, east, (dry Bushveld), peak Oct	589	492	1041	140
Humid, hot summers, (wet Lowveld), peak Sep	855	601	554	87
Humid, warm summers, summer rain, (Highveld), peak Oct	605	507	710	106
Humid, warm summers, winter rain, peak Dec	518	359	832	159

Guidelines for irrigation management of pastures:

- General mistake is that irrigation is applied too late a stage, which also leads to delay in nitrogen application. Usually fertiliser is applied after defoliation or cutting of hay, before irrigation.
- With each irrigation the soil must be brought too field capacity in the root zone of the pasture.
- The frequency of irrigation usually varies according to availability of water, soil water content, evapotranspiration rate and the rooting depth.

8. Weed control in pastures[2,3]

In agronomy a weed is usually defined as any plant species which adversely affects the profitability of an undertaking because of its overwhelming presence. In the case of pasture, the definition of a weed is much more difficult. In cultivated pastures very often it may be the same species in one set of circumstances, while in another circumstances it may be acceptable or of no importance.

The following types of weeds may occur in cultivated pastures:

- Poisonous plants like lantana, gousiektebossie, etc.
- Harmful plants: any plant which animals do not graze and which inhibit the development of the pasture
- Non-productive plants: this relates to the relative nutritive value and not so much to their direct competition with pasture crops.

The weed spectrum and pressure in pastures vary according circumstances. In newly established pastures the weed spectrum usually is determined by factors such as the previous crop, sowing date, sowing method, etc. It is also only annual weeds that usually pose a great problem with newly established pastures, and the degree of success will depend on the controlling of weeds in the previous crop and in the soil preparation.

In established pastures factors like drainage, soil pH, availability of nutrients, physical damage by grazing animals, grazing intensity and climate play an important role in the establishment and occurrence of weeds.

Control of weeds can be applied by regular cutting, which is not always cost effective or by chemical control. There are currently many chemicals registered for use on grazing and pasture crops. Please contact your agricultural advisor in this regard.

9. Utilisation of pastures[4,8,7]

Herbage from a pasture may reach the animal in the following ways.

Table 6. Utilisation of pastures

A. Direct feeding	
Grazed pastures	Management practices like frequency and duration determine the productivity and longevity of grazed pasture. Complete utilisation of the herbage is made difficult by trampling and selective grazing – and with poor management the utilisation can be as low as 50%.
Zero grazing	The herbage is cut and transported to the animal. The pasture is evenly defoliated to the correct height and trampling is avoided.
B. Conserved fodder	
Foggage	Late summer or autumn spared growth, which may become frosted, can be used as winter forage. In general sweet grasses make better foggage than sour grasses because of their better nutritive value and palatability in the dormant phase.
Hay	Certain hay crops can be treated as cash crops and sold of the farm. Hay making is dependent on fair weather. Legume hay requires at least a couple of days of sunny weather to cure or drying can be done artificially by means of heat or wind. Hay should not be stacked until the moisture content drops to below 18%.
Silage	Cut fodder may be stored at a moisture content of 65-75% in suitably constructed silos. It is less dependent on weather conditions, and can be produced from succulent crops unsuitable for hay.
Haylage (ensiled hay)	Fodder with a moisture content of 40-60% may be stored in airtight silos. Grass/legume mixtures and lucernes can successfully be ensiled in this way.

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Module 8b

Lucerne
(Medicago sativa)

1. Introduction

Lucerne (*Medicago sativa*) is a cool season perennial leguminous plant with a productive life-span of three to twelve years. The plant, which grows 30-90 cm tall, arises from a much-branched crown that is partially embedded in the surface layer of soil. As the plant develops, numerous stems bearing many trifoliolate leaves arise from the crown buds. Racemes of small flowers arise from the upper axillary buds of the stems. With approaching maturity, corkscrew coiled pods containing from two to eight or more seeds develop abundantly in regions with much sunshine, moderate heat, dry weather, and pollinating insects.

It is known for its tolerance of drought, heat, and cold; for the remarkable productivity and the quality of its herbage; and for its value in soil improvement. It is widely grown primarily for hay, pasturage, and silage. Lucerne originated in the Near East and Central Asia where it has been cultivated from as early as 1400-1200 BC. Lucerne is also known as Alfalfa, which means "best fodder" and it is often referred to as the king of fodder crops, since it yields large volumes of high quality hay which is rich in protein. It has the highest feeding value of all common hay crops and when grown on soils where it is well-adapted, it is the highest yielding forage plant. Lucerne is one of the most important legumes in agriculture. Its primary use is as feed for dairy cattle where it can supply up to 50% of the protein content of feed.

Most of the improvements in lucerne over the last decades have consisted of better disease resistance on poorly drained soils in wet years, better ability to overwinter in cold climates, and the production of more leaves. Multi-leaf lucerne varieties have more than three leaflets per leaf, giving them greater nutritional content by weight because there is more leafy matter for the same amount of stem[1, 2, 3].

2. Phenology[1, 2, 1]

At germination the root appears first and lengthens rapidly so that by the time the plant has developed to the stage where the first trifoliate leaves appear (Figure 1, (d)), the root is about nine times deeper in the soil than the plant height.

The root system for most lucerne cultivars consists of a tap root that grows deep into the soil; rooting depth may exceed 15 m if the subsoil is porous. At two months after germination it could be as deep as 1 m. Some cultivars form a divided rooting system that develops from the crown of the plant.

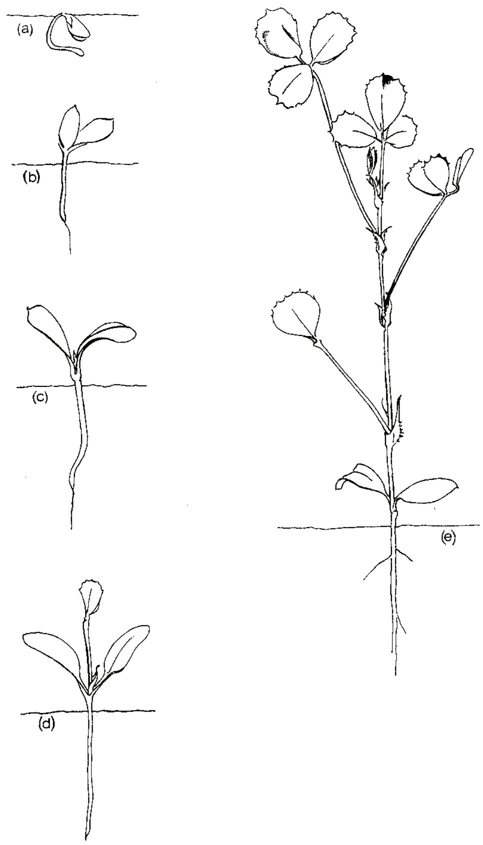

Figure 1 Development of a lucerne seedling; (a) germination, (b) and (c) seed leaf stage, (d) simple leaf stage, (e) seedling with trifoliate leaf.

Figures 2 and 3 show the root crowns of young and mature plants in relation to the rest of the plant. The depth that lucerne roots can penetrate into the ground is determined by factors such as soil type, impervious soil layers and the presence of a water table.

Although lucerne roots can penetrate the soil to great depth, most of the roots are found in the upper soil layers, as indicated in Table 1.

Table 1 – Root distribution of the lucerne plant under irrigation

Depth (m)	Percentage roots
0.00-0.75	60
0.76-1.50	15
1.51-2.25	11
2.26-3.00	9
3.01-3.75	3
3.76-4.50	2

Table 1 shows that even though total rooting depth is down to 4.5 m, 75% of the roots are found within the first 1.50 m of the soil.

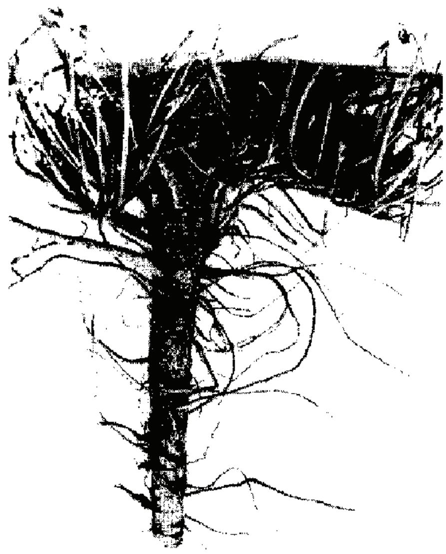

Figure 2. A root crown of lucerne.

The first stalk grows out of the growing point between the two seed leaves. The following stalks grow out of the leaf stems of the seed leaves and from the bottom, first real leaf. As the stalks on the basis lignify, the crown is formed. This crown is the basis of the growth points from where all stalks develop when the above-ground growth have been taken off through cutting or grazing.

The growth points for regrowth develop in and therefore regrowth of stalks come out of the crown. Each time the plant has reached a specific physiological age, or if it has been cut, new growth points start developing into a new generation of 5 to 20, or even more, stalks. These stalks grow upright and usually reach a height of 400 to 600 mm. The stalk develops out of 6 to 12 internodes, depending on growing conditions, until the growth point differentiates in a flower stalk under the influence of light stimuli (Figure 3).

Figure 3. Development of lucerne from flower stage to seed formation; (a) seed pods, (b) enlarged seed, (c) enlarged individual flowers, (d) raceme, (e) stalk with flowers and twigs.

The leaves of the lucerne plant is composed of three leaflets, but sometimes 4 to 6 leaflets develop on a leaf stem. The leaf stems are alternatively arranged on the stalk. The leaflets differ in form and size and can be elliptic to round. The colour can vary from light green to dark blue-green. About half the mass of the plant is made up of leaves.

Lucerne flowers are carried in clusters on the tip of the stalks. In each flower cluster 5 to 8 flowers and in some cases 40 to 50 single flowers are found. The best known flower colour is purple, varying from light purple to dark purple and nearly black in some cases. White and yellow flowers are sometimes found. The colour of flowers varies with age.

The flower of the lucerne is a typical legume flower, consisting of an intergrown calyx – a keel petal and four calyx petals, two of which are intergrown (Figure 3). Nine of the ten filaments are intergrown to form a tube, while the tenth is single. The anthers with pollen are at the tip of the filaments. The ovary is superior with curved style carrying the stigma. The style and intergrown filaments is kept under tension by the keel and the flower must be 'unlocked' before fertilization can take place.

Lucerne has a remarkable capacity for rapid and abundant regeneration of dense growths of new stems and leaves following cutting, provided that enough water for optimal production is present. This makes possible from 1 to as many as 13 crops of hay in one growing season. The frequency of harvest and the total seasonal yields are dependent largely on the length of the growing season, the adaptability of the soil, the abundance of sunshine, and especially the amount and distribution of rainfall or irrigation during the growing season.

Being a legume, lucerne is, in symbiosis with R*hizobium* bacteria, able to fixate atmospheric nitrogen into a form that the plant can use. Its nitrogen-fixing abilities increase soil nitrogen and its use as an animal feed greatly improves agricultural efficiency.

This plant exhibits auto-toxicity, which means that it is difficult for lucerne seed to germinate and grow in existing stands of lucerne. Therefore, it is recommended that lucerne fields be rotated with other crops such as maize or wheat before reseeding. Most varieties go semi-dormant in the autumn, with reduced growth in response to low temperatures and shorter days. Non-dormant varieties that grow through the winter are planted in areas with warmer winters, whereas semi-dormant varieties are planted in areas with colder winters. Non-dormant varieties can be higher yielding, but they are susceptible to winter-kill, have poorer yield persistence and require more careful management than semi-dormant varieties.

The deep, well-developed rooting system of lucerne accounts for its unusual ability to tolerate drought. Not infrequently, newly established fields of lucerne survive severe summer drought and heat when other leguminous plants with shallower and more branching roots succumb. One of its survival adaptations is that it goes dormant under water stress conditions, and then revives when the stress situation has been relieved.

3. Production guidelines[1,2,3)]

a Soil

Before considering the cultivation of lucerne, it is necessary to conduct a comprehensive investigation of the soil to ensure that it would be possible to grow lucerne economically. The soil should be deep, with no restrictive, impervious layers or hard pan; well-drained; with high calcium content; well-supplied with plant nutrients such as phosphate and potassium; and a pH_{water} of 5.8-8.2. It is moderately sensitive to high salt levels in both the soil and irrigation water.

Lucerne prefers a calcium-rich, non-clay soil that is at least 1.2 m deep:

Clay	< 35%
pH_{water}	5.8-8.2
Soil salinity	< 200 mS/m
Ca:Mg	2:1

The land should ideally be even, without weeds, with clods no more than 10 mm in diameter and be firm-textured. A normal-sized person walking on the land should not sink in deeper than the tops of his soles.

b Seedbed preparation for irrigated lucerne

Select a non-duplex soil type with good water holding capacity that is deeper than 1.2 m. Land preparation should preferably be started during the spring or at the latest during mid-summer before the expected autumn planting date. If a cash crop was grown beforehand, at least two months must be allowed between its harvest and the planting of lucerne in order to allow the complete breakdown of the crop residue.

Lands which have been in use for several seasons must be deep sub-soiled and ploughed to break up hardpan areas. The most important considerations for ploughing are to improve root penetration, drainage and aeration of the soil and to reduce soil compaction. Furthermore, it helps to control weeds, breaks down and works into the soil any harvest residue, and breaks up large clods. A cultivator or harrow should be used for the final preparation of the seedbed. The seedbed must be fine-textured and grainy, not powdery, to ensure good contact between the seed and the soil. Compact or roll the land to ensure a firm seedbed. A Cambridge roller can be used before seeding, while the soil is still dry, and after seeding, before the land is irrigated.

If the soil is acidic, it must be limed based on soil analysis. Adjust any known trace element deficiencies such as molybdenum in acid soils; zinc in calcareous and alkaline soils; sulphur in very sandy soils. Exposure of the soil stimulates the activity of micro-organisms which use organic material as a food source. This can result in a poor carbon-oxygen ratio in the soil, which usually leads to soil compaction.

c Cultivar selection

For cultivar selection make use of advice of the seed specialists or the National Lucerne Organisation. Select cultivars suitable for your area and purpose, whether for hay, grazing or silage. Selection must be based on adapted cultivars which are resistant to diseases and insect pests found in the production area. Select non-dormant varieties for areas with warm winters, otherwise select semi-dormant varieties.

Climate overrides the dormancy characteristics of lucerne; a non-dormant variety planted in an area with cold winters will react as if it is semi-dormant, but as non-dormant varieties are less cold-tolerant, severe cold-damage could occur.

d Sowing/planting[2, 3]

Lucerne under irrigation is usually planted at 18 to 20 kg/ha in early autumn when cool temperatures promote the establishment of the crop and the on-coming winter reduce the potential weed problem.

Seed can be broadcast by hand or by using a fine-seed planter or planted in rows with an adapted vegetable seed planter.

Lucerne needs a minimum of 6 weeks growth after germination and before winter if it is to survive the winter. This allows the plant to form a crown and build up sufficient root reserves for winter survival. In a frost-free area, any planting time is suitable if a registered herbicide for weed control is available and affordable. Good germination and establishment of lucerne are promoted by sufficient soil moisture and cool temperatures.

Tips for establishing of lucerne

- The seed colour is important: only yellow to olive green to brown seed should be bought. Dark-coloured seed should be avoided, as it indicates that the seed is either old or has been exposed to water.
- Only seed cleaned by a dealer, and accompanied by a label guaranteeing purity and germination, should be used.
- Seed must be inoculated with the correct *Rhizobium* bacteria before planting to ensure that nitrogen fixation takes place in the crop. Inoculants should be stored in a fridge.
- Wash seed that has been treated with a fungicide and/or an insecticide before inoculation.
- On acidic soils the seed need to be coated to protect the inoculants. Wet the seed with a recommended adhesive to ensure that the inoculant will adhere to the seed. The most common adhesive used is a 2% methyl-cellulose solution.
- After the seed is wetted, sprinkle inoculant over it and mix thoroughly. One packet of inoculant should cover 10 to 15 kg seed.
- Spread seed open to dry to prevent germination before sowing.
- The inoculation of the seed should not take place in direct sunlight; otherwise the inoculant will be killed.

- Lucerne seed is small, and should be planted 5-10 mm deep. On sandy soils planting depth could be increased to 10-20 mm. Covering the seed with soil protects the inoculated *Rhizobium* bacteria from direct sunlight which would kill it.
- Soils that tend to form a crust should be kept wet until the lucerne has germinated and become established.
- If the first sowing shows poor germination, re-planting can be done within 2-3 weeks.
- However, it is sensible to disc out the poor stand and re-sow later in the season.
- At emergence, lucerne is extremely susceptible to cold, and late summer planting is only successful if soil moisture is adequate for sufficient growth to take place before the first frost occurs.

Figure 4. Lucerne planted in rows

e Fertilization[2, 3]

On low pH soils liming is required to correct the pH. For maximum yields, the land should be limed to a pH_{water} level of 6.7 to 6.9. Yield of lucerne drops rapidly in soils if the pH_{water} is less than 6.7.

Liming and the addition of low soluble nutrients, like phosphate, should be done during tillage before sowing, but preferably three to 12 months before sowing lucerne, because this is the last chance to mix lime and relatively insoluble plant food well into the soil. Liming is the most important fertility factor for the establishment and maintenance of high-yield, high-quality lucerne. Guidelines for liming must be based on the exchangeable acidity in the soil and not simply on its pH and texture. The advantages of liming for lucerne include the following:

- Helps production of optimal yield;
- Increases availability of other elements, e.g. phosphorous and manganese;
- Reduces iron and aluminium toxicity;
- Improves establishment of the stand;
- Increases productive lifetime of the stand;
- Nitrogen-fixing bacteria *(Rhizobium)* are more active;
- Provides calcium and magnesium;
- Improves soil texture and tillage.

Lucerne responds well to the application of fertilizer during its productive life. Fertilization should always be based on the results of soil analyses and not on extraction values.

Nutrients that usually need to be supplemented, other than lime, include phosphorus, potassium and sulphur. Check the nutritional status of the soil every three to four years and supplement as required.

In high pH soils, the application of zinc and gypsum usually increase yields on soils that tend to be saline and/or sodic. The availability of phosphate and zinc are reduced in soils with high pH values. Gypsum and sulphur are used to reduce the pH of alkaline soils.

Table 2. Extraction of plant nutrients by lucerne:

Nutrient	Extraction (kg/t)
Phosphorus	2-3
Potassium	15-20
Calcium	13-17
Sulphur	2-4
Magnesium	2-4

Application of nitrogen fertilizer will suppress *Rhizobium* activity and is therefore not recommended.

f Irrigation[2]

Lucerne should be planted in moist soil and then not irrigated for about four weeks, unless an irrigation is required to soften a soil crust in places where crusting could partially or completely prevent the emergence of the crop. Irrigation scheduling based on soil water content measurement is strongly advised.

Always check the quality of the irrigation water. If necessary, adjust the quantity of irrigation water to manage the salt balance in the soil profile through leaching. Consult an expert in this field.

The irrigation strategy should be to irrigate at the longest frequency and biggest irrigation depth that the design of the irrigation system and crop as well as soil characteristics will allow. This would ensure a reduced water loss through evaporation during and immediately after irrigation as well as reduced potential loss through percolation beyond the root zone. Root development and root activity would be enhanced by the resultant good air to water ratio in the soil profile.

Table 3. Estimated irrigation requirements of lucerne for different parts of the country, irrigated with a centre pivot system on a loam soil and managed to extract 70% of readily available water with a refill of 20 mm per irrigation (SAPWAT)

Place	Type	Climate	Rain (mm)	Season	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	Jun (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)	Nov (mm)	Dec (mm)	Total (mm)
Cradock	Semi-dormant	Dry cold	320	Late summer	171	119	98	43	0	0	0	17	108	139	158	192	1059
Loskop	Non-dormant	Dry hot	621	Summer	100	87	92	74	45	42	72	113	158	129	106	102	1127
Oudtshoorn	Semi-dormant	Dry cold	275	Winter	201	152	114	47	0	0	0	0	62	119	164	197	1085
Upington	Non-dormant	Dry hot	202	Late summer	216	165	140	86	58	33	74	117	167	205	222	235	1725
Vaalharts	Non-dormant	Dry hot	405	Summer	154	115	97	75	38	25	65	108	148	173	168	183	1382

4. Maintenance[2, 3]

a. Weed control

A vigorous stand of lucerne usually does not have weeds and therefore seldom requires weed control.

The occurrence of weeds in established lucerne stands is often the symptom of incorrect management of the lucerne, especially grazing, cutting, fertilisation, and irrigation.

The most effective method of mechanical weed control is in good seedbed preparation. In this way the seed reserves of the weeds in the soil are exhausted. Mechanical weed control should be regarded as supplementary to chemical control.

Chemical weed control comprises the use of herbicides which control a specific range of weeds. Herbicides can either be applied over the whole field or can be used on problem spots in the field.

The following are important for correct chemical weed control:

- Correct identification of the important weeds.
- Time of year when these germinate.
- The depth of germination influences the use of soil-applied herbicides, especially those which are applied before planting and before emergence.
- Growth stage at which the weed is controlled – this is especially important during the establishment phase.
- Soil type must be taken into account as clay soil needs a higher dosage than sandy soil where the herbicide is worked into the soil before planting time.
- The direction and strength of the wind must be noted so that crops bordering the field are not affected by the herbicide.
- Herbicides are poisonous, and with unwise use can cause permanent damage to people, plants and animals.
- Read the pamphlet carefully before using the herbicide.
- Always consult an expert before beginning spraying.
- Apply and use the herbicides registered and published in 'A Guide to the use of Herbicides'.
- When weeds are a serious and continuous problem in lucerne production, consider the use of "Roundup Ready Lucerne" as a cultivar.

Pre-planting herbicides need a clean, firm seedbed. They are applied and then worked thoroughly into the soil in the areas where most weed seed would germinate. It is of cardinal importance to seal the seedbed after working the herbicide in. This application should take place five days before planting to ensure that the lucerne is not harmed.

Pre-emergence treatment is any treatment which is carried out after the lucerne seed has been planted but before the lucerne or weed seedlings have emerged. The herbicide is usually applied over the whole surface. Sometimes it must be worked into the soil during irrigation.

Post-emergence treatment is any chemical herbicide treatment after the lucerne or the weeds have already come up. Post-emergence herbicides consist of either contact or systemic herbicides. It is possible to combat grasses growing in among the lucerne.

b. Insect control

Lucerne is attacked by insects throughout the year. They feed on the stems, leaves, roots and seeds of the plant and can have a serious effect on production.

Lucerne should be inspected regularly for the presence of harmful insects, which can do serious damage to the stand before any control measures can be implemented.

It is important that insecticides are correctly and responsibly applied. Apart from being expensive, unnecessary use can lead to the development of resistance to that insecticide, it may build up to toxic killed and game, domestic animals and human health may be affected.

The goal of successful control is to suppress the unwanted insect population before it can cause damage, while not affecting desirable insects.

Use only registered insecticides at the prescribed rates as published in "A Guide to the Control of Plant Pests". If in doubt, always consult an expert before spraying.

The following insects may affect lucerne production:

- **Beetles**

  White fringed beetle (*Graphognathus leucoloma* Boh.)

- **Aphids**

  Spotted alfalfa aphid (*Therioaphis trifolii* forma *maculata* (Buck.)).

  Blue-green aphid (*Acyrthosiphon kondoi* (Shinji)).

  Pea aphid (*Acyrthosiphon pisum* (Harris)).

- **Mites**

  Black sandmite, red-legged earthmite (*Halotydeus destructor* (Tucker)).

  Lucerne brown mite (*Bryobia neopraetiosa* Meyer).

- **Caterpillars**

  American bollworm (*Heliothis armiger* (Hubn.)). Young larvae vary from nearly black to dark brown, becoming green to brown to red-pink as they mature. The underside is dirty white and it has a broad white to pale yellow stripe down each side. Mature caterpillars are about 30-40 mm long with hairs on the body.

  Lucerne caterpillar (*Colias electo* (L.)). About 40 mm long and the same colour as young lucerne leaves. Adult butterflies have a wingspan of about 40-50 mm and are orange-yellow in colour.

- **Miscellaneous**

  Lucerne seed chalcid (*Bruchophagus roddii* (Gussak.)). A small, highly active wasp that lays eggs in lucerne seed. The entire contents of the seed are eaten.

  Elegant grasshopper (*Zonocerus elegans* (Thunb.)). Adults are 30-50 mm long, has a dark head with orange or red eyes and the thorax-shield is yellow-green or bluish. The abdomen has contrasting yellow, orange, blue and black patterns. It produces a stinking yellow liquid when disturbed. May cause severe defoliation in localised areas.

c. Disease control

Various diseases occur in lucerne which may kill seedlings, reduce yield and shorten the lifespan of the stand. The occurrence and severity of the problem depend on environmental conditions, soil type and crop management.

Prevention of disease in lucerne by good management practices is the most effective method:

- Start by planting *Rhizobium*-treated, high quality seed of an adapted, disease-resistant cultivar. Losses due to disease can be prevented or minimised by using disease-resistant cultivars. There are many cultivars already available which have resistance to a variety of diseases, and new ones are released every year.
- Plant it in a weed free seedbed which is well-drained, fertilised and has a pH of 6.5-7.5.
- Soil fertility must be adjusted according to soil tests before planting and maintained by top dressing.

The following is a list of lucerne diseases prevalent in South Africa

a. Diseases occurring mainly on seed and seedlings

- *Fungal diseases*
  Pythium seed rot, damping-off of seedlings and root rot (*Pythium spp.*)

b. Diseases occurring mainly on leaves and stems

- *Fungal diseases*
  - *Leptosphaerulina* leaf spot (*Leptosphaerulina trifolii*)
  - Spring black stem and leaf spot (*Phoma medicaginis*).
  - Rust (*Uromyces striatus*)
  - Common leaf spot (*Pseudopeziza medicaginis* Sacc. var. *trifolii*)
  - *Stemphylium* leaf spot (*Stemphylium vesicarium*)
  - Summer black stem and leaf spot (*Cercospora medicaginis*)
  - Downy mildew (*Peronospora trifoliorum)*
  - Yellow leaf blotch (*Leptotrochilia medicaginis*)
- *Bacterial diseases*
  Bacterial wilt: *Clavibacter michiganense* subsp. *insidiosum*
  Synonyms: *Corynebacterium insidiosum*, *Corynebacterium michiganense* subsp. *insidiosum*
- *Viruses*
  - Lucerne mosaic virus (AMV)
  - Witches broom virus

c. Diseases caused by nematodes

- Lucerne stem nematode (*Ditylenchus dipsaci*)

d. Diseases occurring mainly on stems and crowns

- *Fungal diseases*
  - Anthracnose (*Colletotrichum trifolii* and *C. destructivum*)
  - *Colletotrichum trifolii*: Symptoms vary from small irregular black areas on stems of resistant plants to large sunken oval to sometimes diamond-shaped lesions on stems of plants which are susceptible. The large lesions are tan-coloured with a well-defined black margin. Small, black fruiting bodies are sometimes visible in the centre of the lesion.
  - *Colletotrichum destructivum*: small separated lesions, irregular in form, pale brown to black, occur on the stems.
  - *Rhizoctonia* diseases (*Rhizoctonia* spp.)
  - *Sclerotinia* crown and stem rot (*Sclerotinia spp.*)

e. Diseases occurring mainly on crowns and roots

- *Fungal diseases*
  - *Fusarium* wilt (*Fusarium oxysporum* f. sp. *medicaginis*)
  - *Phytophthora* root-rot (*Phytophthora megasperma* f. sp. *medicaginis* and *P. dreshsleri*)

- Crown rot and root rot complexes (*Colletotrichum, Fusarium, Pythium, Rhizoctonia, Phoma, Phytophthora, Sclerotinia, Stagonospora* and *Ditylenchus*)

f. Diseases caused by nematodes

- Root knot nematode (*Meloidogyne spp.*)

5. Harvesting [3]

The correct time for cutting is when new growth from the buds in the crown of the plant starts. At this stage the crop has started replenishing its root reserves which gives it the stamina for regrowth. Continuous cutting at an earlier stage depletes root reserves, so that regrowth becomes weakened. Cutting must miss the new growth otherwise regrowth will have to start again from out of the crown buds.

a. Hay and Silage

Lucerne is an ideal crop for grazing, making hay and silage and for storage for use during periods when the natural veld productivity and quality is low. Its high protein content makes it an ideal fodder crop.

- *Hay*

Cutting, curing, baling lucerne and then storing the bales for later use as hay is the most common hay handling system in South Africa.

- *Silage*

Silage is the storage of green fodder in silos or in bunkers (trenches) at ground level. The material is allowed to ferment under anaerobic conditions and is then fed to the animals as a brownish fodder which still contains a moderate amount of moisture.

Silage is usually fed directly to milk cows from bunkers. Where milk cows are fed silage, the intake is normally less than with hay because of its strange taste and high moisture content. The animals must therefore be allowed enough time for intake of the required amount of silage.

b. Grazing[2,3,4]

Certain cultivars are specifically developed to withstand grazing. These usually are also resistant to diseases and pests. Grazing of lucerne is usually by production animals such as dairy cows, beef cows with calves, ewes with lambs or animals intended for slaughter as part of their finishing off for the market.

Lucerne can be used in mixed legume-grass pastures or in conjunction with cool-season grass pastures to give a year round pasture.

Should the stand diminish to less than 10 plants per square metre, the land will no longer be sufficiently productive to be economical and the lucerne must be ploughed out.

The stock numbers on lucerne grazing should be such that the fodder is taken off completely in about three days – the intention here is to simulate cutting of the crop. After grazing it should have a rest period of four to six weeks, depending on how fast the crop regrow to cutting stage.
In areas such as the Highveld with very cold winters, where lucerne may be killed by frost, it is important that about 20 cm growth be left to protect the crown through the winter.

c. Seed production[2]

Successful lucerne seed production is strongly linked to climate: dry, warm summers with temperatures 25ºC to 35ºC are ideal. A long, dry period is further necessary for the ripening and gathering of the seed harvest. Lucerne seed is produced mainly under irrigation in the arid and semi-arid parts of South Africa.

Rain during seed ripening will cause dark discolouration which will negatively affect seed quality and classification.

Lucerne flower induction is linked to sunlight intensity; therefore the seed producer should aim at flowering for seed production in the middle of the summer.

Relatively sparse stands of lucerne (14 000 to 44 000 plants per ha) gives maximum seed yields. Under these conditions sunlight penetrates deeper into the stand, resulting in more flowers and bees, as pollinators, can easily reach more of these flowers than in dense stands.

Honey bees are required as pollinators, but if day temperatures go too high (> 43ºC), the bees become lethargic. Bees prefer lucerne nectar with a high sugar content, which results from a relatively dry soil during flowering.

General practice is to aim at high hay production yields until mid-summer, then allow the crop to go to seed. Irrigate before the bees are put out for pollination and after pollination. No irrigation during seed forming and drying is recommended.

Lucerne that is left to seed should be cut when 60 to 80% of the pods are ripe. The lucerne is cut, stacked to dry and threshed on the land.

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My notes............

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Developer: P van Heerden

Authenticator: G de Kock

Technical Learner

Irrigated Crop and Fodder Production

Level 5

Module 9 (a-l)

Vegetable production and irrigation guidelines

Technical Learner Guide

Irrigated Crop and Fodder Production

Level 5

Module 9a

Potatoes
(Solanum tuberosum)

1. Introduction [1,2,3]

The potato *(Solanum tuberosum L.)* originated in the Andean Mountains in Peru, South America and was taken to Europe by the Spanish explorers to fight scurvy. From the latter years of the 17th century, potatoes became a staple food for a great part of the world's population. There is no certainty how the potatoes reached South Africa, but it is believed that the Dutch East India Company brought potatoes to South Africa from the Netherlands[3].

The propagation of potatoes may be from true potato seed (sexual propagation) or from tubers (asexual propagation). Commercial production of potatoes in South Africa is mainly through asexual propagation by means of tubers.

2. Production[5,2,4,3,6,7,8,9]

Potatoes are mainly grown in rotation with maize and wheat, and the planting of the crop is done almost throughout the year in 14 regions of South Africa. Potato production comprises table potatoes and seed potatoes with the former produced for the consumption and the latter for regeneration. Currently 88% of potatoes are produced for consumption and the remainder is produced for regeneration. Today the domestic potato farmers harvest on average about R2.8 billion worth of potatoes per year[4]. The industry comprises of approximately 1 700 potato farmers, which includes approximately 650 active commercial producers and approximately 1000 small scale farmers. Approximately 66 000 farm workers are employed.

South Africa ranks 28th in the world in terms of total potatoes production and contributes about 0.3% to the global potato production. In terms of Africa, South Africa produces about 11% of the total potato production.

Potato production takes place across South Africa with all nine provinces making a contribution to production. Table 1 below summarizes South Africa's total potato production according to province and the type of harvest. The major potato production areas in South Africa are situated in the Free State, Limpopo, Western Cape and Mpumalanga.

Table 1. Production of potatoes in South Africa per province[6]

Province	Total harvest (%)
Limpopo	17.74
Mpumalanga	10.04
Gauteng	1.41
North West	3.4
Free State	29.67
KwaZulu-Natal	7.65
Western Cape	19.55
Eastern Cape	6.61
Northern Cape	3.93
Total	**100**

Production levels of potatoes in South Africa have shown steady increases over the years, with production rising by 23% between 1991 and 2005[7]. During 2008 about 2 million tons of potatoes was produced on a total area of approximately 50 000 ha. In terms of production, the number of hectares planted to potatoes has steadily been declining from 1991, while the yield per hectare of potatoes has been increasing. The area planted to potatoes has decreased by 25% since 1991, while the yield per hectare has increased by 45%. The main reasons for this increase in average yields are: use of higher yielding cultivars, larger proportion of production under irrigation and better production practices.

The gross value of South African potato production accounts for about 44% of major vegetables, 14% of horticulture products and 7% of agricultural production[7]. During 2005 a total of 59% of all potatoes were distributed through the fresh produce markets to a number of end markets. The remainder represents direct sales from the producers to wholesalers, retailers, processors, some informal traders and consumers[6,8].

3. Morphology and growth of the cotton plant

The potato is a herbaceous, dicotyledonous plant. Due to its reproduction through tubers, it may also act as a perennial plant.

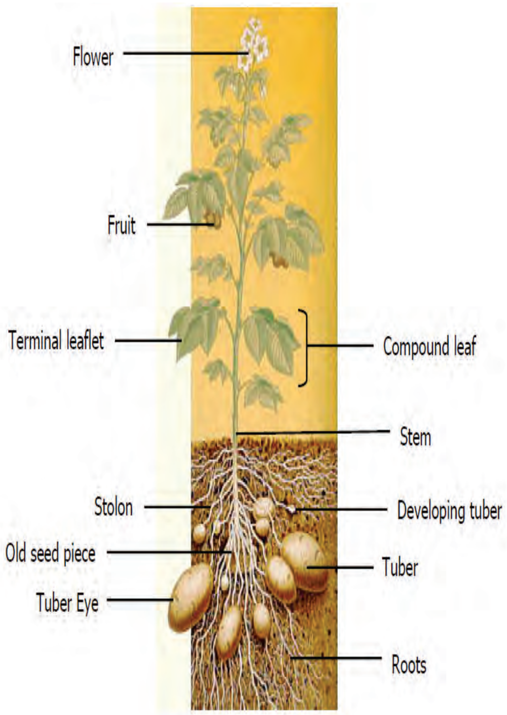

Figure 1. Vegetative and reproductive growth of potato plant[27]

Germination is epigeal, i.e. the cotyledons are borne above ground by elongation of the hypocotyls. The potato plant consists of stems, leaves, tubers, roots, inflorescence (flowers) fruit and seed. The above-ground stem is herbaceous and erect in the early stages. Several axillary branches are usually produced, and the stems are round to sub-triangular in cross-section. Leaves are alternate in a counter-clockwise spiral around the stem. Leaves are compound and leaflets vary with variety. Very small secondary leaflets grow between the primary leaflets of the compound leaf. Stomata appear on both surfaces on the leaflets but are more numerous on the lower surface.

3.1 Growth and development[11]

The growth and development of the potato plant can be divided into five stages (Figure 2).

Growth stage I: Sprout development

Sprouts develop from eyes on seed tubers and grow upward to emerge from the soil. Roots develop at the base of the sprouts, and during this stage the seed tuber is the source of energy for growth, as photosynthesis has not yet begun.

Growth stage II: Vegetative growth

After emergence of the sprouts, leaves and stems develop from aboveground nodes. During this stage photosynthesis begins to produce carbohydrates for growth and development. At this stage the plant still uses energy obtained from seed tuber. Roots and stolons develop from underground nodes and the stage last until tubers start to develop at the tips of the underground stolons.

Growth stage III: Tuber initiation

Tubers form at the end of stolons and are very small at this stage. This stage is a relative short period and depends on climatic conditions, nutrition and variety[11].

Growth stage IV: Tuber bulking

During this stage tubers enlarge and gain weight. Cells in the tuber expand up to 18 times their normal size as a result of the accumulation of water, starch and nutrients. Tuber bulking occurs in a nearly linear fashion if growth is optimal. Tuber becomes the dominant site for the deposition of carbohydrates and mobile inorganic nutrients within the plant.

Growth stage V: Maturation

Vines turn yellow and lose leaves, photosynthesis gradually decreases, tuber growth rate slows, and the vines eventually die. Dry matter of tubers reaches maximum, and skins of tubers thickens, or set.

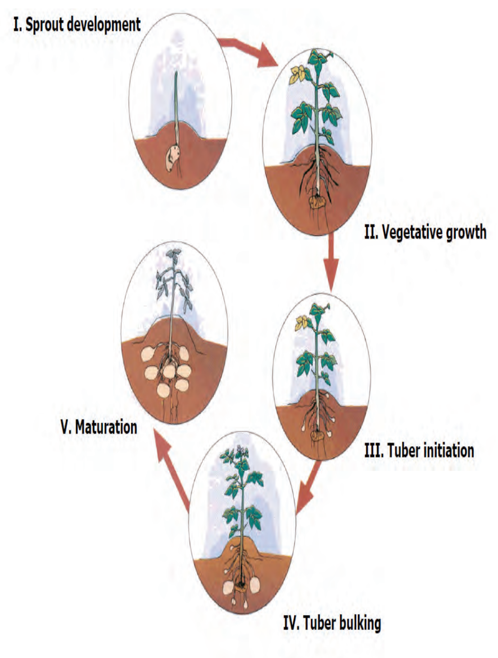

Figure 2. Schematic presentation of the growth stages of the potato[11]

Water is a major constituent of the potato plant, making up 90-95% of green tissues and 75-85% of tubers[20]. Under optimal growing conditions, well watered potato plants transpiring at average rate will replace their entire water content about four times a day. If the water content of the plant decreases by 10% and the soil water content are limited, growth is slowed and may even cease.) It was found that water stress did not reduce the number of harvestable tubers by reducing the number of tubers initiated, but by reducing the number of tubers that reached a certain minimum size[21]. Water stress has a negative influence on the yield of large and medium tubers of 14 different genotypes[22].

4. Climatic and soil requirements[1,10,18]

For optimal production, potatoes require a cool temperate and the following factors are important.

4.1 Climate

Temperature

Potato plants prefer a cool, temperate climate with temperatures between 15 and 22°C. Low temperatures lead to early tuber formation, while high temperatures promote foliage growth but retard tuber formation and development. Cool temperatures are favourable for tuber initiation (optimum 16-18°C). Tuber initiation and formation stops at 30°C.

Daylength

High average day length during the growing season increases yield as this increase the foliage development before tuber formation. However, less than 14 hours is ideal for optimum tuber formation.

4.2 Soil requirements[18]

Potatoes grow well on a variety of soil types, but not all soils give optimal yields of good quality. Several physical and chemical factors must be considered when selecting soils for the cultivation of potatoes. A minimum of 600 mm soil depth is required, with no compacted or limiting layers present. Potatoes can be cultivated on soils of essentially all texture classes, but deep, well-drained soils of light to medium texture are preferred. Soil texture (the ratio of clay to silt and sand) influences the rate of water infiltration and the water holding capacity of a soil. In general, coarse textured and light sandy loam soils are best for potato cultivation. Although sandy soils are usually ideal for mechanical tillage and harvesting, these soils have a limited water holding capacity and will only produce good yields if rainfall and irrigation is adequate. The availability and quality of soil water is an important factor in determining the yield and quality of the potatoes. Inadequate water during critical growth stages may increase the occurrence of diseases (such as common scab) and tuber deficiencies (such as growth cracks, malformation and secondary growth).

Excessive water from rain and irrigation in sandy soils may also cause leaching of mineral nutrients, especially nitrogen, beyond the root zone of a shallow rooted crop such as potatoes. Fine textured soils (higher clay content) have lower infiltration rates than sandy soils. Infiltration rates are especially important in the selection of type, rate and duration of irrigation. Fine to medium textured soils are able to hold more plant available water than coarse textured soils, and are therefore more suitable for rain fed production. Such soils require less regular irrigation than lighter soils. The disadvantage of heavier soils is that the formation of clods may complicate tillage and may easily cause waterlogged conditions. Poorly drained soils are undesirable, since the accompanying poor aeration may harm tuber development because of an oxygen deficiency.

Apparently tubers are more sensitive than roots to oxygen deficiency in the soil. Especially in heavier soils, the growing tubers compact the soil around them, and this further decrease oxygen uptake through the lenticels. The better aeration of light soils therefore constitutes one of the reasons why tubers of a better quality may be expected from such.

5. Cultural practices[17,19,4]

5.1 Seedbed preparation[4]

A well-developed, deep root system is essential for the optimal utilization of nutrients and to tolerate drought periods. In comparison with other crops such as maize and wheat, potatoes have a very shallow and poorly developed root system, which will not grow through layers with a resistance larger than 1000 kPa. Compacted layers (plough layers) that usually develop on sandy soils must be alleviated by deep ripping. Seedbed preparation is often complicated on very heavy soils, stony soils or a sloping field. With stony soils, which may otherwise have good soil properties, the stones may be removed mechanically to facilitate tillage and harvesting. Use fumigants and pelleted compounds to take care of nematodes and insects before planting.

5.2 Planting date[18,8]

The following guidelines are important to follow to avoid temperature stress:

- Select the time of planting so that tuber initiation and tuber growth coincide with falling temperature
- Plant adapted cultivars that are tolerant of high temperatures
- Plant after last frost as potatoes are susceptible to frost, especially after tuber formation has commenced

Table 3. Relationship between planting dates for potatoes and annual temperature [1]

Production areas	Mean annual temperature (°C)	Growing season
Cold	13-16	Oct-Feb
Cool	16-17	Aug-Oct,Jan
Warm	17-18	Aug-Dec
Hot	18-20	July–Nov
Very hot	>20	April-July

5.3 Planting depth and spacing[18,8]

If planting by hand, furrows are made for planting 100-150 mm apart. Modern potato planters, equipped with cultivator tines, and which enable furrows to be made plant at the following spacing:

a. Table potatoes: 750-1000 mm x 300 (if using seed potatoes smaller than 80 g) – 400 mm (if using larger seed potatoes)

b. Seed potatoes: 750-1000 mm x 250-300 mm (all sizes)

5.4 Planting density and sowing rate[18,8]

Seed potatoes should be stored at 15-20°C before planting. When sprouts emerge on several eyes and are a cm in length, the seed potatoes are ready to be planted. If potatoes are planted before sprouting, they can rot or the plant may take a long time to grow. Both conditions result in an uneven stand. The total yield increases as the number of stems increases up to a point where the maximum yield is achieved. Tuber size is limited in higher the populations because of competition between stems for water and nutrients in the soil. So the general recommendation is to plant at lower populations for table potatoes (usually the larger potatoes), while seed potatoes producers will plant at higher densities because they prefer smaller potatoes. Optimum stem population for table potatoes is 160 000stems/ha and for seed potato as high as 300 000stems/ha.

Since certified seed potatoes are expensive, it is important that producers use their seed as efficiently as possible to get the optimum plant populations. To obtain this, this inter-action between seed size and spacing must be appreciated, as these two components determine the amount of seeds required per hectare for the optimum plant population.

Spacing between rows does not have a significant influence on yield, and the row width can vary between 75-150 cm, but 90 cm is the most popular.

5.5 Cultivars choice[8,14,10]

The need for a cultivar must be synchronised with the local environmental conditions in such a way that tuber formation will take place at the best time in the development period. Also choose cultivars that meet the market needs (fresh produce or processing).

Potato cultivars are utilised according to the end-use product that they are destined for. For households, firm potato cultivars such as BP1 and Vanderplank are favoured when making salads because they do not break easily but the Up-to-Date cultivar is favoured for mashing and baking because it is brittle. In the processing industry cultivars that are frequently used in the manufacture of crisps are Hertha, Pimpernel, Lady Rosetta, Fiana, Crebella and Erntestoltz. Crisps represent approximately 40% of the total domestic processed potato products. Vanderplank, BP1, Up-to-Date and Hertha are used in the manufacturing of frozen French fries. The manufacturing of frozen French fries represents approximately 41% of the total processed potato products. Vanderplank, Buffelspoort, BP1 and Up-to-Date are used for fresh French fries.

Table 4. Growing period and cultivars planted in the main potato production areas [4]

Production area	Irrigation/ dryland	Planting time	Main cultivars
Limpopo	Irrigation	Jan-Mar (S) Apr-Aug (W)	BP1, Up-to-Date (UTD), Mondial
Northern Cape	Irrigation	Aug (W) Nov-Jan (S)	UTD, Darius, BP1, Mondial
Western Free State	Irr (70%) DL (30%)	Aug-Oct (W) Nov-Feb (S)	Mondial, Buffelspoort, UTD
South western Free State	Irr (99%)	Aug-Nov Dec-Jan	Mondial, Valor, Buffelspoort
Eastern Free State	Irr (7%) DL (93%)	Aug-Dec	UTD, Mondial plus others
Sandveld	Irr Darling a little bit of dryland	Throughout the year Jun/Jul Jan-Apr	BP1, UTD, Buffelspoort, van der Plank, Avalanche
Ceres	Irr	Oct-Dec	Van der Planck, Lady Rosetta
South western Cape	Irr	July -Oct	BP1, vd Plank, Buffelspoort
Eastern Cape	Irr	Oct-Mar Apr -Sept	Mondial
North eastern Cape	Dl (40%) Irr (60%)	Aug-Nov	BP1, UTD, Darius, Fabula, Mondial, Avalanche
KwaZulu-Natal	Irr (80%) of summer planting and all of winter planting	Feb-Jul Aug-Jan	Mondial, BP1, Buffelspoort, Hertha, Darius, Fiana

North west	Irr	Aug (Early) Nov-Jan (main)	Early: Hertha Buffelspoort, Pentland Dell, Fiana, Mondial Main: BP1, Pentland Dell, Darius, Mondial, Buffelspoort
Gauteng	Irr	July-Nov (W) Dec-Feb (S)	Vd Plank, Mondial, Buffelspoort, UTD
Loskop valley	Irr	Feb-Jul	UTD, Mondial, Lady Rosetta, Fiana, Darius,
Southern Cape	Irr	May-Oct Nov -Apr	BP1, Mondial, vd Plank, Astrid
Mpumalanga	Irr (90%)	Aug-Dec	Table potatoes: Mondial, BP1, UTD Processing: Pentland Dell, Fiana

The Potato Certification Service ensures that high-quality planting material is locally available by supervising and administering registrations to ensure that seed potato growers meet requirements with regard to certain bacterial diseases and viruses.

5.6 Crop rotation[19]

The recommendation is that strict crop rotation is followed, and potato fields should have a period of between 3-4 years before being replanted to potatoes. During these period crops like maize, wheat, grain sorghum and pastures (like *Eragrostis*) can be used in rotation with potatoes. Vegetable crops, especially those related to potatoes (e.g. tomatoes, brinjals and peppers), beans and sunflower should be avoided.

5.7 Ridging[18,19]

The ridging of potatoes (placing of soil around the base of the plant) is a very important cultivation practise. As soon as plants are approximately 300-500 mm high, they should be ridged to prevent:

- Greening of tubers on the surface
- Insect damage e.g. from tuber moth
- Soil around tubers becoming too warm
- Newly grown weeds developing further
- Late blight spores reaching the tubers

Ridging should be to a height of 150-300 mm, depending on plant size.

5.8 Irrigation[12,13,15]

Successful potato production depends on an adequate water supply throughout the crop's growing period. Water comprises 90 to 95% of plant tissue and 70 to 85% of tubers, and is one of the most important production factors limiting potato production in South Africa. It serves as an important role-player in several physiological processes and also serves as a source of carbon, hydrogen and oxygen to the plant. Many of the tuber disorders, such as malformation, growth cracks, brown spot, hollow heart and secondary growth may be ascribed to the irrigation amount and efficiency of distribution of water during the growing season.

An active growing potato plant requires large amounts of water and may replace the water content up to four times per day under optimal growing conditions and average transpiration rates. Approximately 95% of the water is taken up by the roots of the plant and lost through transpiration, while only a small fraction contributes to growth. Water stress, either too much or too little, may have serious adverse effect on potato plants and tuber progeny. Too much water can lead to water logged conditions and the leaching of nutrients, while water stress from too little water is usually the most serious problem with potato production. This sensitivity is mainly attributed to the plant's shallow, poorly developed root system and the harmful effects of water deficiencies on the physiological processes.

The water requirements of potato plants during different growth stages are illustrated in Table 5.

Table 5. The effect of shortage or excess water at different growth stages of the potato plant[4]

Growth stage	Shortage of soil water	Excess of soil water
Planting to emergence	i)Prevents healing of cut seed piece surfaces which lead to decay ii)Delayed and uneven emergence iii) Less haulms per plant	i) Increased clod formation ii)Promotes seed piece decay and thus lowers plant density
Emergence to tuber initiation	Restricts plant development and response to fertilisation	Impairs the development of a well-developed rooting system
Tuber initiation	i)Limits the number of tubers initiated ii) Promotes common scab and some tuber disorders (malformation)	Can induce tuber disorders (brown centre and associated hollow heart) at low soil temperature (<12°C)
Tuberisation (tuber bulking)	i) Limits foliage development and hastens senescence ii) Tuber size is limited and therefore yields are reduced iii) Promotes development of common scab iv) Alternating deficits result in tuber disorders (brown spot, hollow heart, growth cracks, malformation and secondary growth)	i)Promotes luxurious foliage growth that can be conducive to the development of diseases such as early and late blight ii) Increases leaching of nitrogen iii) Leads to enlarged lenticels, which will cause poor tuber appearance and provide access to soft rot bacteria.
Maturation	i)Tuber dehydriation ii) Vascular tissue discolours –if foliage is killed artificially iii)Relative tuber density is decreased	i) Enlarged lenticels ii) Delayed foliage senescence and skin set iii) Higher reducing sugar content and darker chip colour
Harvest	i) Tubers bruise easily ii) Clods are conducive to mechanical damage to the tubers	i) Increased incidence of tuber cracks ii) Soil sticks to tubers, which hampers harvesting and may induce tuber decay during storage

Irrigation water requirements during different stages of the growing season:

- *Period before planting*

The soil must contain about 70 to 80% of plant available water so that large applications to fill the soil profile just after planting will not be necessary.

- *Period between planting and emergence*

During the period the soil around the seed potatoes must be kept moist, to ensure that adequate water is available for sprouting and root growth. Care must be taken that the soil is not too wet, since the seed pieces may rot. Irrigation must be conducted with care; only light applications must be applied. If temperature is high, it is important to cool the soil with light irrigations.

- *Emergence to tuber initiation (vegetative growth)*

During this stage the plants are small and the foliage only covers a small fraction of the soil surface. The transpiration rate is relatively low and the plants require little water. Root depth is still shallow and irrigations must be limited to 15-20 mm at a time. Too much water can lead to the development of undesirably shallow root system. *A depletion of 20-25% of plant available water (PAW) from the root zone may be allowed.*

- *Period of tuber initiation*

Adequate water supply is important, since water stress may lead to the initiation of fewer tubers. Since tuber yields are determined by both the number and the size of the tubers, the yield will be hampered by water stress. The small tubers are also most sensitive to common scab infection at this stage. *At this stage a maximum depletion of 20% PAW must be maintained.*

- *Period of tuber growth (tuber bulking)*

After tuber initiation the tuber growth stage starts, during which a lot of water is required. Water stress during this period has the most detrimental influence on the final yield, in that the size of tubers is limited. The large influence of water stress in this phase (on yield) may be ascribed to the fact that this the longest growth stage in the cycle of the plant .Too long irrigation intervals may give rise to the development of tuber disorders, such as secondary growth, hollow heart, growth cracks and malformation. If the soil is too wet, it is also harmful as waterlogged conditions may lead to ideal conditions for attack by diseases. *A maximum depletion of 20% PAW* during this stage should be maintained.

- *Maturation*

Water requirements during the senescence period are declining, *and 40-50% depletion of PAW must be allowed to promote skin set.* A high soil water content (less than 35% depletion) must be avoided, since it can lead to the development of enlarged lenticels and quality defects.

Irrigation scheduling of potatoes is mainly determined by the following factors:

- Prevailing weather conditions (temperature, heat units, evaporation)
- Growth stage determines the rooting depth and foliage cover. the crop factors to take into account and also the amount of water that may be depleted during each growth stage
- The amount of water uptake is also determined by the soil properties (Table 6).

Table 6. Approximate soil water parameters for different soil texture classes[4]

Texture silt +clay (%)	Field capacity mm m^{-1}	Wilting point mm m^{-1}	PAW mm m^{-1}
0-5	70	40	30
6-10	150	50	100
10-15	160	50	110
15-20	180	60	120
20-25	200	80	120
25-30	220	100	120
30-40	240	130	110
40-50	260	160	100
>50	270	200	70

Table 7. Approximate irrigation requirements of potatoes planted in different climate regions on a loam soil under a centre pivot irrigation (SAPWAT)

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm)
Dry, cold, summer rain, (Karoo), 15 Dec, peak Feb	140	110	360	140
Dry, cold, summer rain, (Karoo), 15 Sep, peak Nov	90	80	395	175
Dry, cold, winter rain, 15 Aug, peak Oct	70	55	335	160
Dry, hot, west, (North Cape), 15 Aug, peak Oct	55	35	490	210
Dry, hot, west, (North Cape), 15 Jan, peak Mar	180	100	400	155
Dry, hot, east, (dry Bushveld), 15 Apr, peak Jun	40	35	260	115
Humid, warm summers, summer rain, (Highveld), 15 Dec, peak Feb	300	170	275	125
Humid, warm summers, summer rain, (Highveld), 15 Sep, peak Nov	250	165	310	120
Humid, warm summers, winter rain, 15 Mar, peak Mar	160	110	100	40
Humid, warm summers, winter rain, 15 Sep, peak Nov	115	85	390	175

As soon as the PAW of a specific soil is known, the allowable depletion for a certain growth stage can be calculated.

Example

Potatoes are produced on a sandy loam soil and during tuber initiation stage; the roots are 300 mm deep. Let us assume the soil depth is 0.15 m and contains 100 mm m^{-1} PAW, while the next layers of 0.15 m contains 120 mm m^{-1} PAW. To calculate the total PAW for the plant at this growth stage the following calculation applies:

0.15 m x100 mm=15 mm water

0.15 mx120 mm= 18 mm water

Total (0-0.3 m) = 33 mm water

The total amount of water in the root zone of the potato plant is thus 33 mm, and the allowable depletion can now be calculated;

= % depletion for each growing phase allowed X PAW

= 25% x 33 mm

=8.25 mm

Thus during the tuber initiation stage, we will irrigate each time 8 mm of water has been withdrawn from the soil profile. When roots grow deeper, we will have to include the figures for the deeper soil layers in the calculation.

Take also the efficiency factor of the irrigation system into consideration, and for a pivot irrigation system it is 80%

Therefore 8.25 ÷ 0.8= 10.3 mm

The real amount of irrigation must therefore be adjusted to 10.3 mm

6. Production potential

In order to produce potatoes during the optimum temperature range of 15-20°C, the planting dates should vary for different areas as discussed. The following potato yield is possible, depending the heat units, soil characteristics and management level:

Dryland : 30-60 t/ha
Irrigation: 40-100 t/ha

Temperature is important as it indicates the energy status of the environment and determines the rate of growth for plants. Daily heat units are expressed as the average daily temperature minus 10°C and it is important to take into consideration for the crop-growing season.

Table 8. Relationship between potato yield and heat units [23,16]

Heat units : Oct-March	Potato yield tons per 100 mm water
1400	8
1300	9
1200	10
1100	9.5
1000	9
900	8.5
800	8
700	7.5
600	7
500	6.5

7. Fertilization[4,14,24]

Soil analysis is the best means to establish the fertility status of a soil and whether there are deficiencies or an oversupply of certain elements in the soil. From the analysis it is possible to determine the optimum fertilizer application level to ensure a high yield of good-quality potatoes. In this way farmers can avoid the excessive or insufficient application of fertilisers. Soil analysis is therefore an aid to both the farmer and the agricultural expert.

Potatoes are adapted to a wide range of pH conditions and may even tolerate quite acidic soils (pH 4H_2O). To ensure optimal production it may be necessary to adjust the pH, since availability of nutrients and the activity of certain pathogens are affected by the soil pH. Both a high concentration of dissolved salts and sodium in the soil may influence the physiology of potatoes. A high salt content adversely affects the uptake of water from the soil solution by the roots. Such soils usually have a high pH, which affects the availability of nutrients. Potatoes are moderately salt sensitive and should preferably not be produced on brackish soils or irrigated with water high in salt content. Yield is hampered when the conductivity of the saturated soil extract exceeds 170 mSm^{-1}. Applications of lime should be ploughed in during the previous season (before the potatoes are planted).

The potato plant has a poorly developed root system. Fertiliser is therefore mainly applied in the planting furrows at the time of planting. It should preferably be placed at the same level as, or under, the seed tubers. It is recommended that potato-planters be equipped with bins for fertiliser application. If the phosphorus requirement is very high, some of the phosphorus can be broadcasted and incorporated into the topsoil. The rest is then applied in the planting furrows along with the nitrogen and potassium. Top dressings are applied on either side of the plant, after which the rows are ridged and irrigated. It can also be applied through the irrigation water.

- **Nitrogen (N)**

Nitrogen is one of the most important elements needed for growth because shortage can result in yield losses. However, an excess of this element can also be determined since it can result in excessive foliage growth at the expense of tuber growth. Excess nitrogen can also adversely affect the keeping quality of tubers, lowers the specific gravity (SG), and may lead to hollow heart particular in cultivars like BP1.

The following guidelines to nitrogen fertilisation for various cultivation conditions are illustrated in Table 9 and Table 10

Table 9. Nitrogen fertiliser recommendations (kg/ha) for different yield potentials under irrigation on soils of different clay contents

	Yield potential (t/ha)					
Clay content (%)	30	40	50	60	70	80
<10	170	220	250	275	300	320
10-20	150	190	220	240	260	280
>20	130	160	180	200	220	240

Table 10. Percentage total nitrogen fertiliser requirement to be applied before and after tuber initiation on soils of different clay percentages

Growth stage	Clay content (%)		
	<10	10-20	>20
Maximum application up to tuber initiation	50-60	60-75	80-100
Maximum application after tuber initiation up to 4 weeks before foliage die-back	40-50	25-40	0-20

- **Phosphorus (P)**

Phosphorous is a very important element required for plant cells. Sufficient quantities of phosphorous stimulate early root growth and increase the plant's water use efficiency. A shortage of this element may result in tubers having poor keeping quality. Guidelines for phosphorous fertilization are provided in Table 11. Phosphorous does not easily leach from the soil and it can therefore be applied in a once-off application or before planting.

Table 11. Phosphorous fertilization in kg/ha on the basis of different soil analysis methods

Soil analysis in ppm (mg/kg		Yield potential (t/ha)						
Bray1	Bray2	10	20	30	40	50	60	70
0-5	0-6	100	115	130	140	160	175	190
6-10	7-12	80	90	100	110	120	130	140
11-19	13-24	60	70	80	90	100	110	120
20-25	25-32	50	60	70	80	90	100	110
25-30	32-39	30	40	50	60	70	80	90
30+	39+	30	30	30	30	30	30	35

- **Potassium (K)**

Potassium promotes the deposit of starch and is important for certain reactions in the photosynthesis process. An excess of potassium in the soil can result in poor tuber quality. Deficiencies can also have adverse effects on quality (dry crisp colour and relative density). Potassium requirement should not only be determined on its concentration (ppm) according to soil analysis, but also on the ratio of potassium to the cation exchange capacity (CEC) of the soil.

Table 12. Potassium fertilization requirements in kg/ha on the basis of soil analysis of soils with a CEC of less than 6 me%

Soil analysis (mg/kg)	Potassium fertilization (kg/ha) for different yield potentials (t/ha)								
	15	**20**	**25**	**30**	**40**	**50**	**60**	**70**	**80**
20-30	230	240	250	285	330	380	420	450	470
30-50	180	190	200	225	265	310	350	380	400
50-70	140	145	150	170	200	230	270	300	320
70-100	90	95	100	115	135	155	200	230	250
100-150	55	60	65	70	85	95	140	170	190
150+	<55	<55	<65	<65	<80	<90	<120	<140	<160

- **Calcium and magnesium**

The calcium and magnesium requirements can be estimated in the same way as for potassium. The following norms indicate desirable percentage saturation of these elements:

Mg: 15-20% of CEC

Ca: 60-70% of CEC

- **Trace elements**

Trace element recommendations must always be made by a qualified advisor.

7. Weed control[18,19]

Weed control before planting should form the basis of the weed control programme. This is important, as implements may damage the shallow rooting system of the crop, and may even injure the tubers at a later growth stage. Rotational cropping with a suitable crop that suppresses the weed growth or one in which the crop was continually kept clean of weeds, is recommended. Herbicides are available and can effectively control early weeds and prevent the establishment of mid-season weeds. Consult the agricultural advisors and representatives to provide up to date registrations of herbicides on potato crops.

8. Pest and disease control[4,13]

Potato diseases fall into two categories namely those affecting tubers and those affecting the foliage. There are fungal diseases like early and late blight, fusarium dry rot, powdery scab, verticillium and silver scurf that are important for the grower to take note off. The main viral disease that affects potato production in South Africa is the potato virus Y (PVY). This virus infects a range of solanaceous crops including potato, capsicum, tomato and tobacco. Carry over is mainly via potato tubers. The best control of this disease is to plant only certified disease free seed and the control of aphids by eradication of aphid weed hosts especially on the solanaceous crops and the planting of border crops in order for aphids to lose their virus inoculums before moving into the potato

The main pests that affect potato production are cutworms, root knot nematodes and potato tuber moth. Consult agricultural representatives from chemical companies in this regard.

9. Harvesting[10,23,26,25]

Ideal time for harvesting is approximately two weeks after the foliage died off. If the skin comes off easily, then the crop is not yet ready for harvesting. The skin should be firm. Temperatures must not drop below 10°C during harvesting to avoid damage to the tubers. Do not drop tubers from a height more than a half meter as this leads to bruising and damage.

Potatoes should be stored in a dark place, as sunlight encourages chlorophyll formation and potatoes turn green. Keep in cool place to prevent sprouting. Damp causes potatoes to rot and do not refrigerate potatoes below 4°C as they become glassy.

Processing forms a significant part of the potato industry. In 1999 processing in South Africa involved 16% of the total potato production worth R279 million at the farm gate level. The domestic processing sector uses potatoes primarily for three main processed products, namely crisps, frozen and fresh French fries. The South African processing industry grew by about 100% over the past five years and is still expanding. The growth in the domestic processing sector is mainly the result of changing consumer needs.

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My notes............

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Module 9b

Sweet potato

(Impoea batatas)

1. Introduction

The sweet potato is an extremely important crop in many parts of the world and also in South Africa. In some Africa countries like Uganda, Rwanda and Burundi sweet potatoes play a role as staple food crop while in maize based countries like South Africa it is regarded as an additional food crop. In SA the largest portion of production (about 50%) is consumed fresh, and a considerable quantity is marketed directly to supply stores. It is however important to take into account that large quantities of sweet potato are produced and sold by the informal sector, and the Agricultural Research Council determined in 2004 that approximately 2000-3000 hectares are under production by small scale farmers and home food gardeners[1]

The sweet potato is a dual-purpose crop, as the roots as well as the leaves are consumable. The storage roots contain large quantities of energy as well as substantial quantities of vitamins and minerals, while the tops may be consumed as green vegetable.

2. Growth requirements[1,2]

To produce high yields of good quality, it is essential that sweet potatoes are cultivated under suitable climatic and soil conditions.

a. Temperature

This tropical plant requires hot days and warm nights for optimum growth, with mean monthly temperatures of 21-29º C. Sweet potatoes are very sensitive to frost and cold and optimum soil temperature of approximately 17.5ºC is required. Sweet potatoes need a growing season of four to five months for optimum production. In areas where no frost occurs (but where cool temperatures prevail) a growth season of 5-6 months is normally required. Growth rate is retarded by low temperatures, which may mean that the growing season needs to be extended for optimum production.

Sweet potato is a short day plant, as short days favour the initiation of storage roots but the crop can still produce successfully during long days if the temperature is favourable.

b. Soil requirements

Sandy to loamy soils are preferred with good drainage to a depth of at least 500 mm. Heavy soils with a fine texture tend to produce more misshapen roots and root rot. In these soil types the storage roots can be damaged easily during harvesting. However good quality storage roots can be produced on these soil types if the crop is planted on ridges and irrigation is managed properly.

The crop is also sensitive to alkaline soil conditions and grows well on soils with a pH of 5.6-6.5.

3. Production guidelines

Sweet potatoes are usually propagated by means of 300-400 mm long vine cuttings. The plant is very susceptible for virus diseases, which can seriously affect growth and yield. The choosing of an appropriate site for production should keep these factors into consideration.

a. Land preparation

The type of soil preparations is determined by the soil texture. If lime and plant residues are worked into the soil, it should happen timeous. Soil preparation should improve water penetration and soil water retention. Cultivation of 250-300 mm deep is usually required as most roots occur in this zone (effective root zone).

b. Ridges and planting

Although the crop can successfully grow on level seedbeds, better results are obtained when the pants are established on ridges. The following dimensions apply: A ridge height of 300 mm on sandy soils, and about 400 mm on soils with a heavy texture, are recommended. The width of the ridges ranges between 250-300 mm wide, and the distance between ridges 1-1.5 m depending on he implements and the width of the tractor. The following recommendation on cultivation on ridges applies for the different irrigation system types selected (Table 1):

Table 1. Planning recommendations of ridges according to various irrigation system types

Irrigation system	Height of ridges	Width of ridges
Sprinkler, centre pivot or drip	300-400 mm	250-300 mm
Furrow	400 mm	150-200 mm

The cuttings are normally spaced at 300 mm apart on the ridges, but the spacing may vary from 200-400 mm, depending on the size of the tubers desired.

Where tubers are to over-winter, it is advisable to re-ridge in order to protect tubers against insects and cold damage.

Plant populations vary from 30 000-60 000 plants/ha depending on soil fertility, market requirements and (size of storage roots) and cultivar. The following recommended spacing applies (Table 2):

Table 2. Recommended plant spacing of sweet potato

Storage roots size	Plant population (plants/ha)
Large (±400 g)	33 000
Medium (± 200-400 g)	40 000-45 000
Small (<200 g)	60 000

Recommendation of soil cultivation with clay content of 20%: [3]

- Plough plant residues into the soil at least two months before planting to ensure decomposing is sufficient before planting

- If lime is required, apply at least one month before planting by working deep into soil
- Fertiliser is applied 3-6 days before planting, work deep into the soil
- Avoid damaging the foliage when spraying with tractor

c. Propagation and time of planting

Sweet potatoes are propagated vegetative by means of runners (cutting). It is important to use insect and disease free propagation material for optimum production. Planting material can be obtained from specialised vine growers< ARC Roodeplaat or from mother blocks on growers' farms. Make sure that the cuttings are virus free because virus infected plant material can reduce the yield by 30% or more. Significantly more cracked roots are produced by virus-infected material.

Plant material of 20 bags is sufficient to establish a multiplication block of 0.75-1.0 ha. This block can yield enough cuttings for 15-20 ha in the next season. P

Planting time will be determined primarily by the climate of a specific farm or production area. Keep in mind that sweet potatoes require a period of 4-5 months of high temperatures to yield well. The following planting dates apply for the various production areas (Table 3).

Table 3. Planting dates for sweet potato

	Cold area (heavy frost)	Warmer areas (Mild frost)	Hot areas (No frost)
Sweet potato	Mid Nov-completed by Dec	1.Miid Nov – Mid Dec 2. End Dec	Jan-March
Harvesting date	Apr-May	1. Apr-May 2. May-Jun	Harvest during winter

Vines are cut in cuttings of 200-300 mm length, and the cuttings should have at least 5 nodes (eyes). Keep the cuttings in water till planting take place, and plant preferably before rooting starts (after 1-2 days in the buck of water).

d. Rotation cropping

Although sweet potato is susceptible to relative few pests and insects, crop rotation is recommended. The crop should not be grown more than once every three years (preferably four years) on the same soil. A rotation system with other vegetable crops can include one year with sweet potato and two years with crops, which do not be ar underground, for example cabbage, green beans, and pumpkins.

Intercropping of sweet potatoes with sugarcane has proven to be economically viable in sugarcane producing areas.

e. Cultivars

The sweet potato industry is based almost entirely on cultivars bred at Roodeplaat in South Africa. The most important cultivars are Blesbok, Ribbok and Bosbok since they are soft textured and not sweet. Ribbok and Koedoe are cream skinned (white sweet potatoes) and are more popular in the southern regions. African consumers prefer cultivars with a sweet and dry taste like Mafutha, and sometimes Koedoe and Ribbok are used when Mafutha is not available.

The orange-fleshed cultivars Beauregard and Jewel are still new on the market and mainly used for export.

f. Yields (t/ha)

Yields depend on various factors like planting and harvesting dates, soil fertility, spacing, cultivar choice, irrigation, fertilisation, and virus status of planting material.

The follo wing are gui delines i n te rms of yield potential (Table 4).

Table 4. Yield potential of sweet potatoes

	Conservative	Average	Good
Sweet potatoes	15-20	30	40+

4. Fertilizing[1,2]

In orde r to repla ce the n utrients th at the crop removes, fertilise accordi ng to soil analysis. Soil analysis will not only le ad to more appropriate fertilis ation levels , but can al so significantly limit unn ecessary fertilisation costs. The nutrients must be readily avail able for the uptake by the plant roots. The placement in the soil, soil moisture, pH and many other factors influ-ence the uti lisation of n utrients by the plant.

4.1 Soil pH

The crop g rows well on slightly acid soil with a pH $_{H20}$ 5.6-6.0. Sweet potato es are sensitive to a lkaline conditions and brack-ish conditions should be avoided.

- **Nutrients removed by sweet potatoes**

The following nutrients are removed by the crop an d sh ould at lea st be repl aced in order to prevent the soil b ecoming infertile over time.

Table 5. Approximate withdrawal of the major nutrients in kg per ton product of sweet potatoes

Nutrient absorption (kg/ha)			
Sweet pota-toes	N	P	K
	3-4	0.5-0.7	4-6

- **Nitrogen (N)**

Maintain the optimum levels o f n itrogen (N) an d d o not apply nitrogen after the middle of the growth pe riod, sin ce the growth of abundant leaves will limit yields.

- **Potassium (K)**

It is importa nt to keep th e ratio of K to N high. Potassium can be applied during the second half of the growth cycle to promote development of strong skin.

The follo wing gene ral fe rtilisation reco m-mendations apply for re asonably fertile soils:

- Pre-plant ap plication: 500 kg 2:3:4 (30) fertiliser mixture per ha
- Top dressing: 4 wee ks @ 150 kg LAN/ha
- Top d ressing (if required) at 6 weeks @ 150 kg LAN/ha

4.2 Organic fertilisers

Sweet potatoes react well to organic fertili-sation an d i f mature d kraal man ure is available, 15 -20 m ^{3}/ha can be broad cast and in corporated befo re planting. T oo much organi c fertili ser can p rolong t he growth pe riod and result in heavy top growth at the expense of the root growt h. Too mu ch a nd un composed compost is not advantageous as it ca n cause roots to be malfo rmed, so affe cting the qu ality of the crop.

5. Irrigation

Although sweet potatoes are considered to be mode rately drought tol erant, the effect of droug ht con ditions depen ds on the growth stage when a water crisis appears. The highest yield and best quality can be expected wh en swe et po tato plants a re established in moist soil and where sufficient water is available to the crop throughout the growing season. Irrigation at the correct growth stage is of great importance.

The following guidelines should be taken into consideration with the planning of an irrigation-scheduling program for sweet potatoes:

- *Planting and establishment stage:* cuttings should be planted into a moist soil, where the soil should be wet to field capacity after planting. Cuttings will develop roots within 2 days, and the recommendation is to keep the soil at 80% field capacity during this stage.
- *40-60 days after planting:* Storage roots form during this period and the soil water content is of utmost importance during this stage of growth. Also vines grow very fast during this stage, and water deficiencies should be avoided.
- *60-120 days after planting:* the rate of vine growth slows down and the storage roots enlarge during this growth stage. Moisture stress at this stage results in small storage roots, which affects the yield potential of the crop. Towards the end of this growth stage over-irrigation can lead to the development of jumbo storage roots. As a result the irrigation amount can decrease towards the end of the growth season.
- Frequency and depth of irrigation depends on the prevailing weather conditions, soil type growth stage of the crop and the depth of the root zone.

Typical irrigation requirements for sweet potatoes planted in different climates and during different seasons can be seen in Table6.

Table 6. Approximate irrigation requirements of sweet potatoes planted in different climate regions on a loam soil under a centre pivot (SAPWAT)

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm)
Early plant				
Dry, cold, summer rain, (Karoo), 15 Nov, peak Jan	200	185	530-	1180
Dry, cold, winter rain, 15 Nov, peak Jan	115	90	625	200
Dry, hot, west, (North Cape), 15 Nov, peak Jan	235	180	755	245
Dry, hot, east, (dry Bushveld), 15 Nov, peak Jan	420	325	455	125
Humid, hot summers, (wet Lowveld), 15 Nov, peak Jan	565	310	115	35
Humid, warm summers, summer rain, (Highveld), 15 Nov, peak Feb	415	315	350	100
Humid, warm summers, winter rain, 15 Nov, peak Jan	115	90	625	200
Late plant				
Dry, hot, west, (North Cape), 15 Dec, peak Feb	225	170	635	170
Dry, hot, east, (dry Bushveld), 15 Dec, peak Feb	350	260	430	120
Humid, hot summers, (wet Lowveld), 15 Dec, peak Mar	500	275	125	35

6. Weed control[2]

Mechanical or hand hoeing is practised when the plants are relatively young. If weeds are well controlled at the early crop growth stage, vigorous vine growth will usually smother late-emerging weeds. Weeds can also be controlled by means of chemicals. The selection of chemical application should be based on products registered for the use on the crop, crop rotation system, weed species and the ease of application.

EPTC is registered for this crop for the control of yellow and purple nut sedge and annual grasses. It is applied pre-plant to clean a seedbed. Linuron is registered for the control of mainly broadleaf weeds and some grasses. This herbicide could be applied at planting.

7. Pests and diseases[3]

Root-knot nematodes can be a major pest and heavy infestation can cause cracking of tubers, which makes them unmarketable. Such nematodes are often a bigger problem on sandy soils favoured for sweet potato production. Soils can be fumigated with registered chemicals or crop rotation systems (where *Eragrosts curvula* is grown for 3 years) can control his problem. The spraying with chemicals registered for it may control pests such as weevils, hawk moth larvae and leaf miner.

Degeneration as a result of viruses is probably the most important cause for poor yields and quality of crops. The use of virus-free plant material and regular destruction of virus-infected plants, are normally sufficient to prevent yield losses. Post harvest tuber tots can cause losses if very wet conditions prevail for a long period of time.

8. Harvesting and marketing[1]

Harvesting usually commence about at 140-150 days after planting, when the ridges have often cracked open to accommodate large storage roots. Where vines are still green, they are cut and removed, about 2-3 weeks before harvesting. Such vines are often used for cuttings for new plantings, but may also be used for stock feed because of the relative high nutritional value of it.

Sweet potatoes also have a very good shelf life when compared with other vegetable crops. Harvesting and storage of sweet potatoes require attention by the producer since storage roots damage easily. The following serve as a guideline for the harvesting of sweet potatoes:

- Smaller plantings are usually lifted manually, using a fork. On larger plantings, mechanical diggers are used.
- Soil should be soft during harvesting to prevent skin damage and breakage of storage roots. It may be necessary to irrigate a few days before harvest.
- The maturity of size should be checked by digging up a few plants before a decision is taken
- Harvested sweet potatoes lying in the field is susceptible to excessive heat, cold and moisture. This practise should be limited to prevent damage to storage roots
- If sweet potatoes are harvested when the growth has already stopped (temperatures below 15ºC), cut these vines off and remove.

Marketable graded sweet potatoes must comply with the following:

- Correct size – not too small (< 100 g) or too large (>1200 g)

- Not cracked
- No rotten spots and in sect damage
- No greening
- No da mage by rod ents, pigs or birds
- No rough skin and thick veins
- No sprouting
- No damage by lifting of the crop

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My notes...........

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Module 9c

Beetroot

(Beta vulgaris)

1. Introduction

Beetroot is very popular as a salad and is very rich in minerals and Vitamin B1. Leaves are sometimes consumed as spinach.

2. Climatic requirements

a. Temperature

The optimum temperatures for growth and development are 15-18ºC, with a mean minimum temperature of 5ºC and mean maximums of 24ºC. Although beetroot is known as a cool season crop, it is tolerant to high temperatures, provided that soil moisture is adequate. It can withstand moderate frost, but growth is affected.

b. Soil requirements

Beetroot can grow on a wide range of soils, but the best results are obtained on well-drained sandy to sandy-loam soils. The optimum soil pH varies from 6-8. Hard compacted soils should be avoided as it will impede seedling emergence and symmetrical root development. Beetroot is moderately tolerant to brackish conditions, but fairly susceptible to boron deficiencies. Thinnings are sometimes transplanted to fill the gaps.

3. Growth requirements

a. Seedbeds and seeding

The common practice that is followed is to make use of well-prepared seedbeds and to sow directly in the field. Beetroot is usually sown to a depth of 15-20 mm and are spaced at 25-50 mm apart (6-10 kg/ha) in rows drawn 200-400 mm apart. In the case of a good plant emergence, excess plants should be thinned out at an early stage, to a final in-row spacing of 50-70 mm. This should result in a plant population of 60-80 plants/m^2.

b. Sowing dates

The following sowing dates apply for the various production areas (Table 1).

Table 1. Sowing dates for beetroot

	Cold area (heavy frost)	Warmer areas (Light frost)	Hot areas (No frost)	Growing period (days) (Plant – harvest)
Beetroot	Aug-Mar	All year	Feb-Sep	75-90 (summer) 100-120 (winter)

c. Rotation cropping

A three or four year rotation cropping is recommended, mainly to reduce the risk of diseases. Beetroot can be rotated with legumes, cereals, tomatoes and cucurbits.

d. Yields (t/ha)

Table 2. Potential production yields

Conservative	14
Average	18-25
Good	40

4. Fertilizing[1]

Fertilise according to soil analyses. Soil analysis will not only lead to more appropriate fertilisation levels, but can also significantly limit unnecessary fertilisation costs. Undecomposed composts or manure should not be applied to this crop, as such material enhance the development of multiple hairroots[2].

- **Nitrogen (N)**

The nitrogen requirements of the crop is about 100 kg/ha. The following recommendations apply[3]:

- ***Clay soils:***

  100 kg N/ha – 50% pre-plant

  Summer: 50%: 20 days after sowing
  Winter: 25%: 40 days after sowing and 25% 80 days after sowing

- **Sandy soils:**

  200 kg/ha: 80% pre-plant

  Summer: 30 kg/ha at 10, 20, 30 and 40 days after sowing
  Winter: 30 kg/ha at 20, 40, 60 and 80 days after sowing

- **Top dressing:**

  4 and 8 weeks after sowing

- **Phosphorous (P)**

Phosphorous is an important element for root development and to ensure vigorous growth. Phosphorous deficiency retards growth and the leaves can become dull green to intense dark green. Where the phosphorous status of soils is adequate, 40 kg of phosphorous applied pre-plant should be adequate for a good crop.

- **Potassium (K)**

The potassium requirement is from 100-200 kg/ha, depending on soil analyses. Apply 50% pre-plant and 50% with the second nitrogen top dressing.

- **Secondary elements**

Be on the lookout for boron deficiencies.

5. Cultivars[3]

There are a number of cultivars available in the seed trade, with new ones continually being developed. A good practice is to keep in regular touch with the seed representative to get the latest recommendations on cultivars possibly suited to the local conditions and the planted planting times.

Popular cultivars that are grown: Crimson Globe, Detroit Dark Red, Star 1102 and Early Wonder.

6. Irrigation

Beetroot has shallow roots and the effective rooting depth is about 300 mm. Frequent irrigation (possibly twice a week during the hot, dry weather period) is usually necessary to keep the effective root-zone moist, and to obtain good yields. Usually the irrigation requirement increases at 6-7 weeks after sowing, when the roots start to enlarge. The quality and shape of beetroot is severely affected if soils become too dry between irrigations.

Table 3 indicates the approximate amount of irrigation water required for different climate regions. Beetroot require more irrigation water during hot seasons and in drier climates than during cold seasons and in humid climates. Effective rain indicates the contribution to total water requirement of the crop that rainfall could make under average irrigation management. Peak requirement is the amount of water that a crop requires during the month of highest requirement. Consult an irrigation specialist for specific irrigation advice

The soil water content should be maintained at above 50% of the readily available soil water content throughout the growing period.

Table 3. Approximate irrigation requirements of beetroot planted in different climate regions on a loam soil under a centre pivot irrigation (SAPWAT)

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm)
Spring plant				
Dry, cold, summer rain, (Karoo), 15 Oct, peak Dec	42	36	428	250
Dry, cold, winter rain, 15 Oct, peak Dec	37	33	343	211
Dry, hot, west, (North Cape), 15 Sep, peak Nov	59	49	360	211
Dry, hot, east, (dry Bushveld), 15 Sep, peak Nov	144	116	250	124
Humid, hot summers, (wet Lowveld), 15 Sep, peak Nov	283	164	64	27
Humid, warm summers, summer rain, (Highveld), 15 Oct, peak Dec	274	172	138	82
Humid, warm summers, winter rain, 15 Oct, peak Dec	81	63	271	172
Summer plant				
Dry, cold, summer rain, (Karoo), 15 Dec, peak Feb	76	61	383	171
Dry, cold, winter rain, 15 Dec, peak Feb	25	17	355	173
Humid, warm summers, summer rain, (Highveld), 15 Dec, peak Feb	288	166	139	77
Humid, warm summers, winter rain, 15 Dec, peak Feb	49	37	303	155
Autumn plant				
Dry, cold, summer rain, (Karoo), 15 Mar, peak May	68	50	125	73
Dry, cold, winter rain, 15 Mar, peak Mar	81	62	78	39
Dry, hot, west, (North Cape), 15 Mar, peak May	99	56	151	89
Dry, hot, east, (dry Bushveld), 15 Mar, peak May	87	56	190	107
Humid, hot summers, (wet Lowveld), 15 Mar, peak May	157	86	115	71
Humid, warm summers, summer rain, (Highveld), 15 Mar, peak May	96	61	127	75
Humid, warm summers, winter rain, 15 Mar, peak Mar	142	102	44	18
Winter plant				
Dry, hot, west, (North Cape), 15 Jun, peak Aug	18	14	216	126
Dry, hot, east, (dry Bushveld), 15 Jun, peak Aug	6	6	252	147
Humid, hot summers, (wet Lowveld), 15 Jun, peak Aug	45	40	171	108

The principle with application of irrigation is that the soil should never be allowed to dry out. This is of critical importance from planting until the plants have emerged and become well-established, in order to achieve a good stand. The top 30-40 mm of the soil, in which the seeds are planted and the early root development occurs, may dry out rapidly under hot conditions, especially if ridge planting is used. Frequent light irrigations (±10 mm per irrigation) may be necessary, even though the lower soil layers have enough soil water.

7. Weed control

Weeds need to be controlled since it is efficient competitors for sunlight, nutrients and water. The specific weeds causing the major problems should be identified, and this will then be used in the selection of the most appropriate herbicide and method of control. Weed control can be mechanical by hand, chemically or by a combination of these methods. Mechanical and hand weeding is usually practised, and later the plant's leaf canopy will cover the weeds and help to suppress weed growth.

There are herbicides registered for the use on beetroot and the professional advice of a representative from a chemical company is recommended.

8. Insects and diseases[1]

Beetroot is often attack by nematodes (controlled by soil fumigation) and cutworms (use of cutworm baits or spray). Other pests include aphids, red spider mite and various leaf-eating insect. No chemicals are registered for the control on beetroot.

The major disease that is commonly found on beetroot is Cercospora leaf spot, which may become a problem during warm, humid conditions. Also be on the lookout for damping-off and downy mildew. Control is through the use of disease-free seed, good quality seed, practising of crop rotation and sanitation to reduce the occurrence of the disease.

9. Harvesting

Harvesting usually starts when the beetroots are from 3-5 cm in diameter. The first harvesting is usually a mere "thinning out". Most beetroots are lifted when they are 5-7.5 cm in diameter and the crop is lifted by hand, cleaned of dead leaves, washed and bunched with 3-6 beetroots to a bunch, based on the clients' requirement. Alternatively, beetroot can packed into pockets after the leaves were cut off.

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Module 9d

Swiss chard

(Beta vulgaris L. cicla)

1. Introduction

Swiss chard is also known as spinach beet, is a biennial but is grown as an annual. It is commonly but incorrectly known as spinach, it belongs to the Chenopodiaceae, or goosefoot family. The leaves are prepared like spinach and the leaf stalks sometimes like asparagus or celery. Swiss chard is a popular substitute for spinach, as it produces a higher yield, and growing it is less troublesome than spinach.

2. Growth requirements

a. Temperature

Swiss chard is a cool weather crop and therefore it thrives in a comparatively cool climate. It does best at a temperature range between 7°C and 24°C. It is half hardy and can withstand light frost, although growth will be retarded at low temperatures. Prolonged exposure to temperatures less than 5°C will induce seed production (bolting). During hot weather, leaves remain small and are of inferior quality.

b. Soil requirements

Swiss chard can be grown on a wide variety of soil types, as long as it is well drained, free of nematodes and reasonably fertile.

3. Production guidelines

a. Seeding and spacing

Swiss chard can either be sown directly or in seedbeds. Sowing directly means that the seedlings will ripen sooner, while sowing in seedbeds means fewer seeds are used and that seedlings are better protected.

When making use of a seedbed, the seeds are sown one hand width (10 cm) apart, and one fingernail (9 mm) deep. Hereafter it should be kept moist and the soil must never be allowed to form a crust until the seedlings are at least 3 cm high. Keep thinning the seedlings to about a thumb-width between seedlings (2 cm). Transplant on a cool day.

When directly drilled into the land it is recommended that the rows are 450-600 mm apart and with a plant spacing of 250-300 mm within the row is recommended. The depth of sowing should not exceed 20 mm. Between 7-9 kg seed is sufficient to plant one hectare.

4. Cultivars

The main variety is Fordhook Giant. Fordhook Giant has darker green leaves and broader leaf stems than Lucullus, which is less popular.

5. Sowing dates

Since Swiss chard is a cool weather crop, in warmer, frost-free areas Swiss chard is usually sown from February to August. In very cold regions it is sown in August/September, up to February. In most other parts of the country, Swiss chard is sown from January-April, or from July-September.

6. Fertilising[1,3,4]

Swiss chard has a long growing season and for this reason it is important to fertilise optimally. Fertilise according to soil analysis. The following recommendations serve as a general guide:

- *Basic preplant application:* 800 kg 2:3:4 (30%)/ha, depending on soil fertility
- *After plant:* 175-225 kg LAN (28%) at 4 weeks and again at 8 weeks. If necessary do topdressing at 12 weeks.

7. Irrigation

The irrigation requirements do not vary much from other vegetable leaf crops. The narrow spacing and leafiness of the crops makes this crop a relatively high user of water.

- After sowing: great importance to ensure that the soil moisture is adequate for growth
- After 2 weeks the irrigation application can increase depending on the development in leaf canopy

Table 1. Approximate irrigation requirements of swiss chard planted in different climate regions on a loam soil under a centre pivot irrigation (SAPWAT)

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm)
Dry, cold, summer rain, (Karoo), 15 Mar, peak Oct	150	120	660	130
Dry, cold, winter rain, 15 Mar, peak Oct	220	170	545	135
Dry, hot, west, (North Cape), 15 Mar, peak Oct	150	85	920	175
Dry, hot, east, (dry Bushveld), 15 Mar, peak Sep	205	140	885	160
Humid, hot summers, (wet Lowveld), 15 Mar, peak Sep	290	180	620	115
Humid, warm summers, summer rain, (Highveld), 15 Mar, peak Sep	250	145	685	125
Humid, warm summers, winter rain, 15 Mar, peak Oct	265	175	320	100

8. Weed control[1]

Few herbicides are registered for chemical weed control and professional advice from a representative of a chemical company is required. Mechanical cultivation and hand weeding can also be practised. Such cultivation should be shallow and not too close to the plant, as it can easily be damaged.

9. Pests[2]

Nematodes (eelworm) can be controlled before planting through the fumigation of the soil. However, it is better to avoid such fields. Cutworms are relatively easy to control through the use of bait. Various caterpillars, and to a lesser extent, aphids, can sometimes be troublesome. No registered chemicals are available for the control of caterpillars on Swiss chard, but products used for beetroot should be successful on spinach.

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10. Harvesting[2]

The crop can be harvested from about 2 months as soon as the leaves have attained a good size. The outer leaves are successionally harvested as soon as they are large enough. It is usually cut at about 5cm above the ground, taking care not to harm younger leaves. Old leaves are not marketed, as the fibre content increases with age. Harvesting from the same plant can continue for several months, until leaf-spot disease become too severe or the plants run to seed. Yields of 20-40 t/ha can be obtained, with a moderate yield of 30 t/ha possible.

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4. Hygrotech, 2000. The production of Swiss chard. Hygrotech, Silverton, Pretoria.

My notes...........

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Module 9e

Onions

(Allium cepa)

1. Introduction

Onions are cool weather crops that have some frost tolerance and are relatively easy to grow. Warmer weather and lower humidity during bulb forming and drying off periods will enhance ripening. The crop does, not like extremes of heat and cold weather patterns.

2. Growth requirements

a. Temperature

Onions require cool conditions during the early months, with an optimum between 12ºC and 24ºC for good vegetative growth. Generally the longer this period, the better the vegetative growth before bulbing and the better the yield. The plants can tolerate heat during the latter stages of growth development. Higher daily temperatures of 25-27ºC accelerate the bulbing process. Low temperatures near bulbing (<13ºC) retard development of bulbs and can trigger bolting.

All onion cultivars are extremely sensitive for day length (photoperiod). In onions bulbing is initiated only when the light period exceeds a certain minimum, which varies from one cultivar to the next[5]. Cultivars like Texas Grano, Granex 33 and Pyramid have a fairly short day length requirement and are referred to as short day length cultivars. Others like Australian Brown, Caledon Globe have longer day-length requirements which can be met only in areas south of latitude 28ºS.These are known as intermediate-day cultivars, grown in the eastern and western provinces of the country.

b. Soil requirements[7]

Onions have a relative shallow root system (200 mm), and the soil requirement to obtain a fair yield is a well-drained sandy to sandy loam soil, well prepared. The shallow root system makes onions more susceptible to water shortage problems than other crops and therefore the crop needs to be irrigated at frequent intervals.

The optimum pH_{H2O} of the soils is 5.5-6.5. A low pH soil can cause aluminium toxity and molybdenum deficiencies. Some diseases like *Sclerotium cepivorum* (white rot) are more prone at lower pH soils. Soils should be ploughed to 20 cm and harrowed to provide a smooth seedbed

3. Production guidelines

a. Sowing times

There are four main methods of producing onions, namely:

- Producing seedlings in *open beds* for later transplanting: sowing is done from early February to about mid April, with transplanting May-late June. The most favourable time may vary with specific cultivar and climate

- Produce seedlings in *seed trays* for transplanting: sowing time similar to seedbeds, but transplanting takes place after only 5-6 weeks. Seedlings are about 3 mm in diameter.

- Seeding *directly into main field*: sowing directly in the field has the advantage of an earlier marketable crop (up to 6 weeks sooner) and is usually done when the weed competition is likely to be light since no registered herbicide against broad leaf weed after planting is registered.

- Produce *"sets" (small bulbs)* for later replanting: the cultivar Pyramid is often used for this purpose. Seed is sown in the normal fashion in seedbeds, but in August or September rather than Feb-March. The best sowing time is to be determined for each locality and cultivar. The onions are left to mature in the seedbed (usually December), and these bulbs are dried and stored in a dry place. They are then replanted in February at normal spacing.

Plant populations of between 600 000-800 000 plants /ha are recommended, with the higher population producing smaller bulbs. Precision planters should be used with an inter-row spacing of 15-20 cm.

b. Seeding rates

The best sowing time for any cultivar is thus to compromise between potential bulb size and the amount of split-bulbs and bolters.

- *Seedbeds*: Seed is generally sown in rows about 150-200 mm apart, and to a depth of 10-15 mm, in well-prepared and well-fertilised soils. Not more than 7-10g of seed is sown /m^2 of seedbed
- *Seedtrays:* 5-7 seeds per cell. Usually 2-2.5 kg seed per hectare is sufficient.
- *Direct seeding:* 6-8 kg seed /ha
- *Onion sets*: 3-40 kg seed /ha

c. Cultivars[4,3]

Many varieties are available from the seed trade. Depending on the specific market, a grower can decide on:

- *Late cultivars:* Australian Brown, Caledon Globe which have an inherent good keeping-quality, but are susceptible to rain during harvesting.
- *Early cultivars:* Texas Grano, Granex 33, Pyramid, Sonic, Early Gold, Star 5501

4. Fertilizing[2,7]

Fertilise according to soil analysis. Soil analysis will not only lead to more appropriate fertilisation levels, but can also significantly limit unnecessary fertilisation costs.

Seedlings occupy seedbeds for 2-3 months before they are transplanted, and therefore it is essential that the seedbeds are well fertilised. A guide is to apply between 500-1000 kg of 2:3:4 (30) fertiliser mixture per hectare, depending on the soil fertility status. Topdressing of nitrogen on the seedlings at about 4 weeks can be considered, but take care not to over-fertilise with nitrogen. Excess nitrogen can lead to tender seedlings.

The production field may require the following treatment depending whether it is early or late varieties:
Early varieties: 80-100 kg N/ha; with 50% preplant and 50% after 4-8 weeks.

Late varieties: 120-140 kg N/ha: 20 kg N /ha preplant and three applications of 40 kg N/ha at 2, 4 and 6 weeks from sowing.

Table 1. Approximate absorption of the major nutrients by a crop of 60 ton per hectare[10]

Nutrient absorption (kg/ha)		
N	P	K
72	21	72

5. Irrigation[9]

Most of the roots occur in the top 300 mm of the soil, and therefore it is important to keep the effective root zone fairly moist throughout growth. Moisture stress during bulb formation and development may seriously reduce yields. No irrigation is recommended for the final 3-4 weeks before maturity, to allow the bulbs to cure properly.

Table 2. Approximate irrigation requirements of onions planted in different climate regions on a loam soil under a centre pivot irrigation (SAPWAT)

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm)
Dry, cold, summer rain, (Karoo), 15 Apr, peak Nov	160	110	750	130
Dry, cold, winter rain, 15 Apr, peak Nov	210	130	670	160
Dry, hot, west, (North Cape), 15 Apr, peak Oct	130	60	970	180
Dry, hot, east, (dry Bushveld), 15 Apr, peak Sep	250	130	870	150

6. Weed control[3,4]

Since the onion is a relative slow growing plant, it can easily be overgrown with weeds. Proper weed control practices are recommended. Chemical control of weeds, supplemented with mechanical and/or hand weeding, is a general practice. It is important to use registered herbicides for the controlling of broadleaf weeds and grasses (annual and perennial).

7. Insects and diseases

Thrips are the most common pest that cause problems. Rasping of the leaves shown as silvery blotches is the most common symptom. Chemicals are registered for the control of this pest.

Table 3 illustrates the main diseases that often occur when growing onions.

Table 3. Symptoms and control of important diseases in the production of onions[6]

Disease	**Altenaria blotch** *(Altenaria porri)*
Symptoms	First symptoms are white, uneven spots which are slightly depressed and sharply defined. The spots become large primarily along the length of the leave. When there are a lot of these spots they flow together, and with time these spots turn to brown and concentric light and dark purple or brown circles which are covered with a black layer of fungal spores.
Control	• Chemicals registered for downy mildew can also be used for Altenaria blotch or use the registered fungicides for Altenaria control. • Seed should be treated before planting.
Disease	**Downy mildew** *(Peronorspora destructor)*
Symptoms	First sign is a purple fungal growth which starts growing on the leaves. The disease usually starts after rain or heavy dew and spread rapidly during wet weather. The affected leaves change to a yellow colour, fall over and die. The bulbs of heavy infected plants stay small and the storing ability is poor.
Control	Spray registered chemicals on cloudy days and during rainy weather because it is impossible to control the disease once it has started.
Disease	**Pink root** *(Pyrenochaeta terrestris)*
Symptoms	The fungus causes the roots to develop a yellow colour and a withered appearance. While the roots are dying, their colour changes to a distinctive pink or brown red. Although the bulb is not affected by the fungus, the bulbs remain small and therefore affect the yield.
Control	• Onions must not be cultivated more than once every three years on the same field • Seedbeds must not be made where onions, garlic, spring onion or leek were cultivated previously • Use tolerant varieties
Disease	**White bulb rot** *(Sclerotium cepivorum)*
Symptoms	Symptoms on the leaves are very similar to that of fusarium rot, the leaves turn yellow, wilt and fall over. The bulbs of affected plants rots at the bottom and the roots are also affected. The sick bulb is covered with a white, flocky fungus which forms black bodies looking like poppy seed. The final stage of the disease is where the roots are almost completely destroyed and the bulbs are rotten.
Control	• Seedbeds must not be made on infected soil • Affected bulbs must not be thrown on a compost heap, but destroyed • Fumigation of affected soil shown good results-but it is even better to avoid infected soil
Disease	**Neck rot** *(Botrytis spp)*
Symptoms	Yellow and dying leaves. The disease is usually present in patches and is often noticed just before harvesting. On the neck one can notice depressed points and the infected tissue underneath becomes soft and brown. Grey fungal growth develops on these points.
Control	• Use tolerant varieties • Dry bulbs well before storing • Spraying of copper oxychloride (2-5%) at leaf drop residues reduce the disease and improve storage

8. Harvesting

Begin harvesting when 30-50% of the foliage has dropped and fallen over. At this stage the entire field is lifted. If the crop is not stored, the bulbs should be allowed to dry thoroughly before marketing. Yields can vary between 15-40t/ha.

Conservative	Moderate	Good
15 t/ha	25-30 t/ha	40+ t/ha

Delaying of harvesting results perhaps in higher yields, but increases the chance of sunburn and reduces the shelf life.

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Module 9f

Carrots

(Daucus carota)

1. Introduction

The carrot belongs to the family *Apiacea* and is related to celery, celeriac, coriander, parsnip and parsley. It originated in Asia and initially the roots were long and thin, with either a purple or yellow colour. These colours, as well as white and yellow, still exist, with orange – red colours being by far the most popular today. Many shapes of the roots exist, from rather long and thin roots to shorter and thick roots. Roots may be cylindrical, conical, or even spherical in shape. The crop is biennial, i.e. it grows vegetative the first season and produces seed in the second. For root production the plant is grown annually.

Carrots are particularly rich in carotene (pro-Vitamin A). It is consumed either fresh, as a salad crop, or cooked. Large quantities are processed, by canning and freezing.

2. Physiology/Phenology[3]

Week	Growth stage
1	Germinate
2	Germinate
3	2-4 cm
4	4-7 cm
5	6-8 cm
6	8-10 cm
7	10-13 cm
8	15-20 cm
9	20-25 cm
10	Harvest/Processing
11	Harvest/Processing
12	Harvest
13	Harvest
14	Harvest
15	Harvest
16	Harvest

3. Growth requirements

a. Temperature

Carrots are a cool weather crop, belonging to the moderately hardy group of plants which are not very sensitive to winter cold and frost. If heavy frost occurs before harvesting, the leaves will be severely scorched. Carrots do best under cool conditions (10-25ºC), and the seed also germinate quite well, though slowly, under cool conditions. Carrots develop slower during winter, than summer.

Carrots and can tolerate low temperatures, but also endure considerable amount of heat. Therefore carrots can be grown throughout the year, except in very cold or very hot areas. Temperature and soil water content influence the shape, colour and quality of carrots. The best quality carrots are obtained when the weather conditions favour regular uninterrupted growth. The plant growth is optimal between temperatures of 15ºC to 20ºC, and the roots also develop the best colour and flavour at such temperatures. At temperatures below or above the optimum, poorer colour develops. The roots also tend to be shorter, often with a poor flavour, when high temperatures prevail. Insufficient soil water conditions results in thinner and longer roots, while very wet conditions have the opposite effect and can also give rise to a lighter colour. Carrots develop a rougher appearance when the temperatures are fairly high in summer and where there are varying soil water conditions.

b. Soil requirements

The aim in growing carrots is a high yield of straight and smooth roots. The soil requirement to obtain this is a well drained sandy loam or loamy soil, well prepared. Heavy stony, compacted or poorly drained soil interferes with good root development and is less suitable.

Avoid fairly humus rich soils, as carrots tend to be rougher and to form forked, hairy roots. Sandy soils are subject to wind erosion, and should also be avoided. Carrots are also very sensitive to salinity; therefore brackish soils should be avoided.

c. Soil cultivation

Since carrot seeds are small, it is sown directly in the field. Therefore it is of great importance that the soil should be properly prepared, with a level, fine surface. Deep working of the soil to a depth of at least 30 cm is important to allow good root development. Ensure that compacted layers are broken up, and like in other crops also take care against over-working of the soil, since this can also cause compaction and possible surface capping, which seriously affects the emergence and root development of plants.

4. Production guidelines

a. Sowing times

Untimely bolting is a serious problem in crops such as carrots, beetroot, onions and cabbage. The problems of bolting experienced with crops like carrots and beetroot can be rectified by sowing at recommended times for a specific region.

Table 1. Sowing times for carrots

Cold areas (heavy frost)	August-March
Warm areas (light frost)	January-November
Hot areas (no frost)	February-September

b. Seeding rates

One of the major problems confronting most carrot growers is to achieve the correct plant population. Where the population is too low, roots tend to become large, are generally subject to more splitting and cracking, and marketable yields are negatively affected. However, if the population is excessive, roots tend to become smaller, and are often twisted around one another, giving poorer quality root, and marketable yields of good quality may also be affected. Dense planting could be thinned out, but one needs to take into consideration that this is costly, time-consuming and requires labour, which may be a problem when grown on a commercial scale.

One aspect that needs to be taken into consideration with the planting of carrots is the very large differences in seed sizes found amongst the different varieties. Large seed may have 400 000 seeds per kg while small seeds may have over 1 500 000. The germination capacity and vigour of seed lots also differ, and germination may vary from 80% to 100%. This aspect must be taken into account when deciding upon the seed rate.

A **"field factor"** [1] that can be applied taking into consideration the prevailing climate, soil and other conditions is:

- Good soil and poor tilth: probability of 50% germination
- Average conditions: 60%
- Good conditions: 70%
- Ideal conditions: 80%

With this in mind the following recommendation can be followed[2]:

- ✓ *Large roots or early harvest:* 75-120 plants/m^2
- ✓ *Medium – large roots:* 250 plants/m^2
- ✓ *Fine roots*: 500-1000 plants/m^2

The amount of seed required for sowing to give the desired population is calculated as follows:

$$\text{Seed required (kg/ha)} = \frac{\text{1000 x Number of plants desired/m}^2\text{ of planted area}}{\text{No. of seeds/g x germination\% x field factor}}$$

Example

Number of plants desired: 80/m^2
Number of seed per g: 800
Germination %: 90
Field factor (good): 0.7

Calculation:
Seed requirement (kg/ha) = (1000 x 80/m^2) ÷ (800 x 90 x 0.7)
= 1.59 kg/ha

Activity

Activity 1

Calculate the seed required for a specific field with the following information.
No of plants desired: 125
No seeds per g: 500
Germination %: 90
Field factor (average): 0.6

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c. Seeding

Normally carrot seeds tend to germinate irregularly and seedlings are delicate and cannot push through a dry or deep covering of soil. The seed should be covered to a uniform depth of 10-25 mm, and should be kept moist until plants are well established. In loose, sandy soil seeds can be planted 40 mm deep. On heavier soil, in colder months when the soil temperature is lower and growth is slow, shallow planting is preferred. In summer, when the soil dries out quickly, slightly deeper planting can be beneficial.

In order to make weed control easier, seed is sown in rows rather than broadcast in fields or in beds. Rows are generally spaced at 200-400 mm. Where double or triple rows are used, the width between sets of rows varies from 400-600 mm. For the production of baby carrots, rows may be as close as 100 mm.

In case of furrow irrigation:

- ✓ The seed is sown in small furrows approximately 7.5 cm deep and covered 20-30 mm deep with soil.
- ✓ After the seed has germinated, the furrows serve as irrigation furrows. Water must be applied to the furrows before seeding to ensure a moist seedbed.

Normally seed is treated before sowing. The reason for treatment is to control the following diseases:

- Root rot
- Collapse disease
- Soil fungi

d. Tillage

Soil cultivation between the rows is aimed at weed control at an early stage. Weeds must not be allowed to compete with the crop for soil water. The availability of herbicides, make tillage for weed control irrelevant. Growers usually make use of tillage to prevent that soils cap after heavy rains. This practice loosen heavy, compacted soil and some farmers prefer to use a light hoe between the rows in order to cover the shoulders of the young carrots with a thin layer of soil to prevent greening of the shoulders.

5. Crop rotation

Crop rotation is important as discussed earlier, and the following crops can be used for rotation: cabbage, cauliflower, lettuce and tomatoes.

It is imperative that kraal manure and other forms of organic manure have adequate time to decompose before carrots are planted, since organic fertilisers are often used for crops in a rotational system. Leguminous crops such as peas and beans can also be used in crop rotation with carrots.

Recommendation: carrots should not be cultivated more than once in three years on the same soil to avoid soil borne diseases.

6. Fertilizing[1,2]

Fertilise according to soil analysis. Soil analysis will not only lead to more appropriate fertilisation levels, but can also significantly limit unnecessary fertilisation costs. Carrots require a fertile soil as illustrated in Table 2:

Table 2. Approximate absorption of the major nutrients by a crop of 56 ton per hectare

Nutrient absorption (kg/ha)			
Plant part	**N**	**P**	**K**
Root	80	20	200
Top	65	5	145

a. Nitrogen (N)

Good yields are possible with applications as little as 80 kg N per hectare. However, up to 130 kg N per hectare may be applied, particularly where the soil phosphorous and potassium status is high and perhaps where excessive leaching on sandy soils occurs. High rates of nitrogen should be avoided, as this stimulates leaf growth at the expense of root development and yield.

b. Phosphorous (P)

Phosphorous is an important element for root crops since it stimulates root development. Where the phosphorous status of soils is adequate, 40 kg of applied phosphorous should be enough for a good crop.

c. Potassium (K)

Carrots have a particularly high potassium requirement as illustrated in Table 2 and sufficient K must be applied to meet the crop needs. High potassium levels ensure better quality-crisper and better coloured roots. Since carrots are usually grown on lighter texture soils, where leaching is more prevalent, about half of the potassium is required as a side-dressing during growth (4-8 weeks after planting), and a late dressing can also be supplied to enhance colour, if it should be a problem.

When taking into account the figures illustrated in Table 2, one ton of carrots will remove 2.6 kg N, 0.44 kg P and 6.1 kg K from the soil.

Example

Expected yield: 30 t/ha
N: 2.6 kg x 30 t/ha = 78 kg/ha
P: 0.44 kg x 30 t/ha = 13.2 kg/ha
K: 6.1 kg/ha x 30 t/ha = 183 kg/ha

Activity

Activity 2

1. Determine the amount of N, P and K in kilogram needed per hectare for the production of 40t carrots/ha.

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7. Cultivars[3,4]

Many varieties are available from the seed trade. Depending on the specific market, a grower can decide on:

- *Chantenay types*: used for processing and include varieties like Chantenay Karoo, Chantenay Royal, Chantenay Red Core. These types are round (spherical) types very popular for the fresh produce market
- *Nantes types:* long cylindrical types with a blunt point and also suited for fresh produce market.
- *Persian heart types:* oval in shape and generally cultivated on heavier soil types. Not very popular and only cultivated on a small scale.
- *Kuroda types*: much the same shape as Chantenay types but are generally longer and more tapered in shape. Varieties include Kuroda, Roda 249.
- *Berlicum types:* thick carrots and are similar to the Chantenay types, but are longer. Varieties include Cape market, Nabo, Rona and Fina.
- *Flakkee types:* large, long, slim and fairly high yielding carrots. Varieties include Regol, Prospector, Grossa.
- *Imperator types*: also known as "horse" carrots and are very slim, long, crisp and tender carrots. Varieties include Imperator Long, Orlando Gold.

**Specific guidelines obtainable from seed representative*

8. Irrigation

The principle with application of irrigation is that the soil should never be allowed to dry out. This is of critical importance from planting until the plants have emerged and become well-established, in order to achieve a good stand. The top 30-40 mm of the soil, in which the seeds are planted and the early root development occurs, may dry out rapidly under hot conditions, especially if ridge planting is used. Frequent light irrigations may be necessary, even though the lower soil layers have enough soil water. The soil water content should be maintained at above 50% of the readily available soil water content throughout the growing period.

Table 3 indicates the approximate amount of irrigation water required for different climate regions. Carrots require more irrigation water during hot seasons and in drier climates than during cold seasons and in humid climates. Effective rain indicates the contribution to total water requirement of the crop that rainfall could make under average irrigation management. Peak requirement is the amount of water that a crop requires during the month of highest requirement. Consult an irrigation specialist for specific irrigation advice.

Table 3. Approximate irrigation requirements of carrots planted in different climate regions on a loam soil under a centre pivot irrigation (SAPWAT)

Area / Planting season	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm) for month
Spring plant			
Dry, cold, summer rain, (Karoo), 15 Oct, peak Dec	32	538	225
Dry, cold, winter rain, 15 Oct, peak Dec	24	440	185
Dry, hot, west, (North Cape), 15 Sep, peak Nov	41	419	190
Dry, hot, east, (Dry Bushveld), 15 Sep, peak Nov	100	312	116
Humid, hot summers, (Wet Lowveld), 15 Sep, peak Sep	153	129	55
Humid, warm summers, summer rain, (Highveld), 15 Oct, peak Dec	140	246	78
Humid, warm summers, winter rain, 15 Oct, peak Dec	47	365	155
Summer plant			
Dry, cold, summer rain, (Karoo), 15 Dec, peak Feb	61	402	150
Dry, cold, winter rain, 15 Dec, peak Feb	13	382	149
Humid, warm summers, summer rain, (Highveld), 15 Dec, peak Feb	135	236	74
Humid, warm summers, winter rain, 15 Dec, peak Feb	39	338	131
Autumn plant			
Dry, cold, summer rain, (Karoo), 15 Mar, peak May	41	197	52
Dry, cold, winter rain, 15 Mar, peak Mar	71	107	32
Dry, hot, west, (North Cape), 15 Mar, peak May	43	229	71
Dry, hot, east, (Dry Bushveld), 15 Mar, peak May	37	259	89
Humid, hot summers, (Wet Lowveld), 15 Mar, peak Jun	63	188	60
Humid, warm summers, summer rain, (Highveld), 15 Mar, peak Jun	45	222	73
Humid, warm summers, winter rain, 15 Mar, peak Mar	96	71	36
Winter plant			
Dry, hot, west, (North Cape), 15 Jul, peak Oct	29	369	164
Dry, hot, east, (Dry Bushveld), 15 Jul, peak Oct	37	340	144
Humid, hot summers, (Wet Lowveld), 15 Jul, peak Sep	92	227	82

9. Weed control

Carrots are small and rather vulnerable during the early stages of growth. Weeds are efficient competitors for available nutrients, water and sunlight. It is therefore important that weeds be controlled in the early stages of crop development, because early competition can adversely affect plant growth and result in the lowering of crop yields.

Weed control can be achieved mechanically, by hand, chemically or by a combination of these methods. Chemical control of weeds, supplemented with mechanical and/or hand weeding is a general practice. It is important to use registered herbicides for the controlling of broadleaf weeds and grasses (annual and perennial).

10. Insects and diseases[1]

No chemicals are registered for specific use on carrots to control insect pests. Nematodes are often prevalent on lighter soils, and various fumigations may be required before planting to control it. Soil insects like cutworm, wireworm and millipedes sometimes cause problems by damaging the roots. Earlier harvesting is then justified to avoid damage that occurs later during growth. The use of bait and frequent working of the soil should also reduce pest incidence.

No chemicals are registered for the control of important diseases that occur with carrot production (Table 4).

Table 4. Symptoms and control of important diseases in the production of carrots

Disease	Altenaria Leaf Blight *(Altenaria dauci)*
Symptoms	Occurs during wet weather in summer, with prolonged heavy dews.
Control	• Sow tolerant cultivars • Ensure seed is disease free (certified seed) • In areas where blight is a problem, avoid carrot planting in fields where foliage will not dry quickly after rain or dew • Practice a strict crop rotation programme
Disease	Bacterial Blight *(Xanthomonas carotae)*
Symptoms	Favoured by warm, wet weather. Symptoms can easily be confused with Altenaria blight, but the disease is less common. Irregular brown spots on the leaves and brown, elongated, horizontal lesions.
Control	• Disease free and certified seed is recommended
Disease	White Mould *(Sclerotinia sclerotiorum)*
Symptoms	Carrots should preferably not be planted in a field with a known history of the disease. It is common in lush, dense plantings and will often start where plants have been trampled or otherwise injured. A white cottony growth develops on above-ground parts of the plant. The affected plant tissue turns soft and watery.
Control	• Practice a three year rotation with non-susceptible crops. • Deep working (ploughing) to invert the soil to a depth of 250mm or more hinders the germination of sclerotinia and hastens their decomposition. • Remove and destroy infected crop residues

11. Harvesting[1]

Although there are some varietal differences, the crop is usually ready for the market within 3-3½ months, although it may take about a month longer during cold months. The roots are harvested when they reach the desired size but are still tender and succulent. The market prefers roots that have reached a diameter of 20 mm or more, but can be earlier where a specific market prefers more slender carrots for pre-packaging or for "baby carrots".

A proportion of carrots are marketed by being bunched, with leaves attached. Bunches vary in size from about 5-10 or more roots. The freshness and quality of the leaf is an important criteria used by buyers, as it gives an indication of the freshness of the product, especially at the retail outlet.

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Module 9g

Cole crops

(Brassicas)

1. Introduction

This group of crops belong to the family *Cruciferae*, and the commercially important crops all belong to the genus *Brassica*. Hence, the reference to the *Brassica* crops or simply the brassicas.

- Cabbage: *B. oleracea capitata*
- Cauliflower: *B. oleracea botrytis*
- Brussels sprouts*: B. oleracea gemmifera*
- Sprouting broccoli: *B. oleracea italic*

Some other vegetables in the same family include horseradish, Chinese cabbage, kohlrabi, various mustards, radish, turnip, swede as well as a number of lesser known vegetables. Important is that these cole-crops have similar climatic requirements, and are also attacked by similar range of pests and diseases.

Cabbage is one the most important vegetable crops in South Africa and has a high nutritional value for human consumption. Another reason for the popularity of cabbage is the relative low input cost for the income generated.

2. Growth requirements

a. Temperature

Cole crops may all be classified as cool season plants, they grow best growth under cool, moist conditions.

Cabbage: minimum temperatures down to -3ºC are possible without any loss or damage to the plant as long as differences between day and night temperatures are not too high. The optimum mean temperature is about 17ºC, with an average maximum of 24ºC, and an average minimum of 4-5ºC. Mature heads and young plants, are more sensitive to cold when temperature differences between day and night are large.

Cauliflower: has very similar temperature and moisture requirements to that of cabbage for optimum growth and development, but is less adapted to extremes of heat and cold. Growth is poorer at mean temperatures of less than 7ºC.

Broccoli: this crop also can not withstand the same degree of extreme temperatures than cabbage can, but will do much better than cauliflower when variation of conditions occurs. Under high temperatures broccoli has the tendency to abscission (shedding) or partial abscission of buds leading the condition known as “brown bud’

Brussels sprouts: this crop can withstand colder conditions than cabbage, but is probably more sensitive to high temperatures than cauliflower. Under high temperatures, most varieties produce loose, open sprouts, which have no value.

b. Soil requirements

Brassicas are fairly heavy feeders and will grow well on soils with high organic matter content. They are adapted to a great variety of soils, varying from sand to fairly heavy clay, provided that the soil is fertile and suitably drained. The best results are achieved by planting on soils that perform the best during certain seasons, e.g. early crops grow better on light soils whereas later crops grow better on heavier soils.
Cabbages are relatively tolerant to brackish conditions. Red cabbages are more sensitive to brackish conditions, and a pH index of 8 will cause an 80% reduction in yield. Optimum pH for brassicas is between 6 and 7. On low pH soils crop rotation is required to control club root.

3. Production guidelines

a. Seedbeds and seeding

The common practice that is followed is to make use of well-prepared seedbeds and to transplant the seedlings when they are sufficiently developed. Soils which tend to cap or compact should be avoided and seedbeds should not be made on any site where crucifers (pumpkins, butternuts, etc.) have been grown over the past three years.
An alternative to the open seedbeds that most commercial and many small-scale farmers use is to either produce their plants in styrofoam or similar trays, or purchase plants from specialised nurseries that use this system. This system has advantages for those growers who cannot produce seedlings well in open seedbeds. There is also a saving in seed cost, and seedlings transplant more successfully from trays, and perform better than do seedlings raised from open seedbeds.

Transplanting of well-hardened, young, stocky plants should apply. Weak plants with symptoms of abnormalities, like double-stem, no growing point or diseased root system, should be avoided.

Irrigation from seeding till transplant is very important and the following guidelines apply:

- Keep the seedlings moist and growing strongly for 3-6 weeks or until they are 7-10 cm tall. Then reduce irrigation over the last 7-10 days (but do not allow the plants to wilt) in order to harden them to withstand the shock of transplanting.

- Give the seedbeds a proper irrigation before transplanting in order to restore a good water regime in the seedlings, and to facilitate the lifting of the plants to minimise root damage.

b. Spacing

Spacing and plant population affect the head size, head shape and yield. The grower should take into account the demand of the market. For larger heads, a wider spacing is recommended. With the exception of Brussels sprouts where individual sprout size is not affected by spacing, the growers should concentrate in their planning to the plant spacing to determine the exact plant density required (Table 1).

Table 1. Plant spacing and densities for various cole crops recommended [1]

	Spacing	Plant density (plants/ha)
Cabbages		
Large headed types	500-600 mm x 400 mm	40 000-45 000
Medium headed types	500-600 mm x 300 mm	55 000-65 000
Baby cabbages	300-350 mm x 350 mm	80 000-100 000
Cauliflowers		
Large framed varieties	750-900 mm x 500 mm	22 000
Small framed varieties	600-750 mm x 400 mm	35 000
Broccoli		
Large framed varieties	600-750 mm x 400 mm	33 000
Small framed varieties	600-750 mm x 300 mm	45 000
Brussels sprouts		
All	900-1000 mm x 450 mm	22 000

c. Sowing dates

The following sowing dates apply for the various production areas (Table 2).

Table 2. Sowing dates of various cole crops

	Cold areas (heavy frost)	Warmer areas (Light frost)	Hot areas (No frost)	Growing period (days) (Plant-harvest)
Cabbage	Sept-Feb	All year	Feb-Jun/Jul	100-120
Cauliflower	Dec-Feb/Mar Aug-Sept	Jan-Apr Jul-Sept	Feb-Mar/Apr	85 days: early varieties 150 days: late varieties
Broccoli	Sept-Jan	Jan - Sept	Feb-Jun/Jul	100-120
Brussels sprouts	Nov/Dec - Feb	Jan-Mar	Feb-Apr	120

d. Rotation cropping

A three or four year rotation system is recommended, mainly to reduce the risk of diseases.

e. Fertilizing[1,2]

Due to the high risks involved with vegetable production, care must be taken so that the risk of losses can be reduced. Fertilise according to soil analysis. Soil analysis will not only lead to more appropriate fertilisation levels, but can also significantly limit unnecessary fertilisation costs. Cole crops have a high nutritional requirement and these crops can respond very well to organic manure. Brassicas in general are sensitive to soil acidity. Soils of low pH values usually contain high levels of Al and Mg, which adversely affect growth and yield. The recommended pH for cole crops is above 6.5_{H2OI} or an acid saturation below 2%. The following approximate absorption of nutrients by cole crops give an indication of the N, P and K requirements of this group of crops (Table 3).

Table 3. Approximate absorption of the major nutrients by a good crop of broccoli, Brussels sprouts and cabbage

Vegetable	Yield (t/ha)	Nutrient absorption (kg/ha)		
		N	P	K
Cabbage	30	120	20	100
Broccoli	11	185	11	235
Brussels sprouts	18	263	32	273

- **Nitrogen (N)**

The nitrogen requirements of cole crops are relatively high. Cabbages and cole crops with relative long growing seasons like Brussels sprouts or late maturing cauliflower varieties require approximately 200-250 kg N per hectare. Broccoli and early maturing cauliflower on the other hand require 150-200 kg N per hectare for good yields. Half to 2/3 of the recommended nitrogen is applied during planting, while the rest is applied as a side dressing, usually at 2-3 weeks after planting and again about 3 and 6 weeks later.

- **Phosphorous (P)**

Phosphorous is an important element for root development and ensures a vigorous growth. Phosphorous deficiency retards growth and the leaves can become dull green to intense dark green. Where the phosphorous status of soils is adequate, 40 kg of applied phosphorous should be enough for a good crop.

- **Potassium (K)**

Cole crops have a very high potassium requirement as illustrated in Table 3 and sufficient K must be applied to meet the crop needs. Plant analyses indicate that cole crops need as much potassium as they need nitrogen and although total yield may perhaps not be affected, the quality of the crop is reduced. Heads tend to be softer and looser. Very high rates of potassium can increase the incidence of cracking cabbages and may also increase tip-burn and calcium and manganese deficiencies[3].

- **Secondary and micro elements**

✓ **Calcium (Ca)**

Cole crops have a high calcium requirement and deficiencies may occur on acid soils, on soils with very high potassium, or even on very dry soil where the calcium uptake can be reduced. Deficiencies cause a condition known as tip-burn, where the tips and the margins of the leaves become paler and paper thin and eventually die back.

✓ **Magnesium (Mg)**

Magnesium deficiencies occur mainly on acidic soils, or on soils subject to high leaching. It can be corrected by a foliar spraying.

✓ **Molybdenum (Mo)**

Cole crops are very susceptible to a molybdenum deficiency, with cauliflower accepted as being a very good indicator plant for such deficiencies. The first symptom is the yellowing of the foliage, very similar to nitrogen deficiencies. Young leaves become distorted. This is particular in cauliflower, showing symptoms of “whiptail”- where the mid rib of the leaf develops normally, but the blade does not fill out properly resulting in narrow, distorted leaves.

✓ **Manganese (Mn)**

Deficiencies may occur on soils where the pH is high ($pH>6.5_{H_2O}$). This deficiency may be corrected by foliar spraying.

f. Cultivars[3]

There are a number of cultivars available in the seed trade, with new ones continually being developed. A good practice is to keep in regular touch with the seed representative to get the latest recommendations on cultivars suited to the local conditions and the planned planting dates.

Cabbage: the most popular commercial cultivars are all hybrids and show some tolerance against black rot. They include: Conquistador, Green Coronet, Green Crown, Grand Slam and Star 3306 for production during the cool season. Cultivars with greater heat tolerance include the well known Hercules, Green Star as well as well Centauro and various Star cultivars.

Cauliflower: popular cultivars include Glacier, Arizona, Star 4403, Star 4405 and Tenere

Broccoli: Green valiant is possibly the most popular.

Brussels sprouts: Long Island is grown in home gardens and various commercial cultivars like Amarosa, Jade Cross and Prince Marrel are available.

g. Succession of crops

The selection of herbicides where chemical weed control is applied should be considered when rotational cropping programme is planned. For example, the earlier use of residual herbicides like atrazine may for instance be detrimental for a following cole crop. The use of triluralin on cabbages could affect the growth and production of following crops that are sensitive to this chemical.

h. Irrigation

Brassicas cannot be produced without at least supplementary irrigation. The aver age water loss of a cabbage crop is about 4 mm per day or 300 ml/day for a young plant or 400 ml for an adult plant[2] .The following recommendations apply:

- ✓ Until the seedlings are well-established after transplanting, they should be kept under ideal moisture conditions, no more than 25% of available water used before irrigation is application.
- ✓ Up to about the halfway growth stage no more than 40% depletion of avalaible water should be allowed.
- ✓ Thereafter the soil may be allowed to dry a little more, but irrigation should however take place as soon as 50% depletion of available water is recorded.
- ✓ It is important, when plants are reaching maturity that the amount of irrigation can be reduced since too much irrigation can cause cabbage heads to crack.

Table 4. Approximate irrigation requirements of cole crops planted in different climate regions on a loam soil under a centre pivot (SAPWAT)

Crop	Area / Planting season	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm) for month
Cabbage	Spring planting				
	Dry, cold, summer rain (Karoo), 15 Sep, peak Dec	100	79	475	175
	Dry, cold, winter rain, 15 Sep, peak Dec	58	49	534	205
	Humid, warm summers, summer rain, (Highveld), 15 Sep, peak Dec	276	166	350	108
	Humid, warm summers, (winter rain), 15 Sep, peak Dec	118	73	437	175
	Summer planting				
	Dry, cold, summer rain (Karoo), 15 Feb, peak Feb	130	81	252	80

	Dry, cold, winter rain, 15 Feb, peak Feb	79	57	306	99
	Dry, hot, west (North Cape), 15 Feb, peak Feb	150	75	322	102
	Dry, hot, east (dry bushveld), 15 Feb, peak Apr	150	81	291	95
	Humid, hot summers (wet lowveld), 15 Feb, peak Feb	223	104	173	48
	Humid, warm summers, summer rain, (Highveld), 15 Feb, peak Feb	171	93	262	79
	Humid, warm summers, (winter rain), 15 Feb, peak Feb	135	94	228	101
	Autumn planting				
	Dry, hot, west (North Cape), 15 Apr, peak Jul	52	26	323	101
	Dry, hot, east (dry bushveld), 15 Apr, peak Jul	44	29	355	108
	Humid, hot summers (wet lowveld), 15 Apr, peak Jul	64	36	284	80
Cauliflower	**Spring planting**				
	Dry, cold, summer rain (Karoo), 15 Sep, peak Nov	80	46	407	142
	Dry, cold, winter rain, 15 Sep, peak Nov	50	34	432	172
	Humid, warm summers, summer rain, (Highveld), 15 Sep, peak Nov	235	102	358	103
	Humid, warm summers, (winter rain), 15 Sep, peak Nov	113	50	401	146
	Summer planting				
	Dry, cold, summer rain (Karoo), 15 Feb, peak Feb	131	67	301	83
	Dry, cold, winter rain, 15 Feb, peak Mar	83	48	358	106
	Humid, warm summers, summer rain, (Highveld), 15 Feb, peak Feb	171	93	262	79
	Humid, warm summers, (winter rain), 15 Feb, peak May	172	77	313	82
	Autumn planting				
	Dry, hot, west (North Cape), 15 Mar, peak Mar	105	39	358	99
	Dry, hot, east (dry bushveld), 15 Mar, peak Jun	94	41	377	100
	Humid, hot summers (wet lowveld), 15 Mar, peak Jun	130	55	279	86
Broccoli	**Spring planting**				
	Dry, cold, summer rain (Karoo), 15 Sep, peak Nov	56	31	318	135
	Dry, cold, winter rain, 15 Sep, peak Nov	40	28	329	153
	Humid, warm summers, summer rain, (Highveld), 15 Sep, peak Nov	166	70	271	94
	Humid, warm summers, (winter rain), 15 Sep, peak Sep	113	50	401	146
	Summer planting				
	Dry, cold, summer rain (Karoo), 15 Feb, peak Jan	124	59	298	110
	Dry, cold, winter rain, 15 Feb, peak Jan	26	12	401	140
	Humid, warm summers, summer rain, (Highveld), 15 Feb, peak Feb	223	86	264	94
	Humid, warm summers, (winter rain), 15 Feb, peak Mar	172	77	313	82
	Autumn planting				
	Dry, hot, west (North Cape), 15 May, peak Jul	17	9	239	84
	Dry, hot, east (dry bushveld), 15 May, peak Jul	16	12	278	101
	Humid, hot summers (wet lowveld), 15 May, peak Jul	30	12	224	78
Brussels sprouts	**Spring planting**				
	Dry, cold, summer rain (Karoo), 31 Oct, peak Nov	173	80	694	185
	Dry, cold, winter rain, 31 Oct, peak Jan	52	23	852	226
	Humid, warm summers, summer rain, (Highveld), 31 Oct, peak Nov	406	155	539	142
	Humid, warm summers, (winter rain), 31 Oct, peak Jan	98	43	749	201
	Summer planting				
	Dry, cold, summer rain (Karoo), 15 Feb, peak Mar	140	70	393	121
	Dry, cold, winter rain, 15 Feb, peak Mar	110	56	428	159
	Humid, warm summers, summer rain, (Highveld), 15 Feb, peak Mar	173	73	417	115
	Humid, warm summers, (winter rain), 15 Feb, peak Mar	207	91	349	140
	Autumn planting				
	Dry, hot, west (North Cape), 31 Mar peak Apr	74	24	445	145
	Dry, hot, east (dry bushveld), 31 Mar, peak Apr	68	32	493	152

i. Weed control[1,3]

Weeds need to be controlled since they are efficient competitors for sunlight, nutrients and water. The specific weeds causing the major problems should be identified in order to select the most appropriate herbicide and method of control. Many of the weeds that occur are cruciferous weeds, which often host diseases and pest of cole crops. It is important that weeds are controlled at an early stage of crop development, because they adversely affect plant growth and result in lowering crop yields. Weed control can be done mechanically, by hand, chemically or by a combination of these methods.

Cole crops respond well to a cultivation of loosening the soil surface should this become crusted after heavy rain. The first cultivation/hoeing is usually done 2 or 3 weeks after transplanting. Caution should be exercised not to cultivate too deeply, nor too close to the plant.

There are several herbicides registered for the use on cole crops. Consult a professional when in doubt.

j. Insects and diseases[1]

Cole crops are often attacked by many insects and diseases. The severity of occurrence varies from place to place and from season to season. Before planting, find out which diseases and pests are likely to occur locally and, whenever possible, review records of disease and pest incidence in the field to be planted. Choose cultural practices and crop cultivars that reduce the impact of key pests and diseases. The use of disease free seed and adequate treatment can avoid the occurrence and introduction to new fields. The following are the most important pests and diseases found on cabbage (Table 5).

Table 5. Most important pests found on cabbage [1, 2]

Pest	American bollworm
Symptoms	Major pest on many crops, including brassicas. Larvae damage on the leaves and a cause a lot of damage to cabbage and brussels sprouts, where the edible product consists of leaves. Damage in early stage of these crops is often severe, and the growing point can be destroyed. Characteristic to bollworm are the dirty white stripes along each side with very distinctive spiracles. Use registered pesticide for control.
Pest	Bagrada bug *(Bagrada hilaris)*
Symptoms	The bagrada shield the growing point, causing the plant to form numerous heads of lesser quality. Bugs suck on young leaves causing them to dry and die. Also damage the young growing point, causing the plant to form numerous heads of lesser quality. Use registered pesticide to control the problem.
Pest	Aphids (Aphidea) (family)
Symptoms	Various aphids attack cole crops, the most common being the grey cabbage *(Brevicoryne brassicae)* aphid and the green peach aphid *(Myzus persicae*). Aphids cause damage by sucking the sap, and are serious pests since they contaminate the edible product. Control by using a registered pesticide.
Pest	Cutworms *(Agrotis spp.)*
Symptoms	Cutworm larvae cause damage to some lower leaves where they touch the ground. However, the main damage is caused when the stem of seedlings are cut off close to ground level. Cutworms usually feed at night, and it can be controlled by using of bait.

Pest	Diamond back moths *(Plutella xylostella)*
Symptoms	A small green caterpillar feeds on the underside of the leaf making small window-like holes, leaving a wax layer. It spins its cocoon which is attached to the leaf or stem, and pupate within. Adult moths are small and slender, greyish or brownish in colour. Folded, the wings of the male moths display three distinctive diamond shaped markings on their backs, hence the name "diamond back moth'.

Table 6. Major diseases commonly found on cabbage[1,2]

Disease	Damping off
Can be caused by numerous factors: • Blackleg: the stem goes woody and hard • *Altenaria spp.:* Stem goes black and rots • *Rhizoctonia solani:* stem goes woody and rots leaving a white mycelium • *Pythium spp:* lateral roots disappear, only tap roots stay • Cutworms: cause damage which places seedlings under stress and they damp off • Waterlogging: cabbages are sensitive to waterlogging • Fertiliser burn: nitrogen given as topdressing ringbarks the stem of fair-sized seedlings.	
Symptoms	Typical symptoms are wilted plants and at a later stage purple leaves. Plants eventually die, and no lateral shoots are visible. Only the tap roots stay.
Control	• Use seed treated with a suitable fungicide • Avoid planting when soil is cold • Prepare good seedbed, which stimulates quick germination • Ensure residues are thoroughly decomposed before planting. Practice good water and fertiliser management

Disease	Club root
	A waterborne fungus that is very destructive and is favoured by acidic soils with adequate soil water. It disperses from field to field by the movement of infected plants, especially transplanting. The higher the temperature the heavier the attack, optimum development temperatures between 25ºC and 30ºC
Symptoms	Plants are initially stunted and start to wilt since the water supply to the rest of the plant is disturbed. Leaves show lead-grey to purple colour. Roots are also affected; they swell and eventually fuse into a single large club.
Control	Once in the soil, there is no economical way to control the disease. Some cultivars are more resistant to some strains of the fungus. Once the fungus is in the soil, avoid planting cole crops on that specific field. The spores can survive 20 years in the soil, and crop rotation cannot combat the problem.
Disease	Black rot
Symptoms	The bacterial disease can be destructive under rainy conditions, particularly in relatively warm areas. Optimum temperatures are around 30ºC and bacteria starts to develop at 20ºC. The summer crops are more susceptible, and the most serious losses occur in Brussels sprouts and cabbages.
Control	• Always use clean seed. Keep good control of insects in the seedbed. • Remove all debris in susceptible areas and also control weeds effectively. • Crop rotation is a must in warm areas where the disease is prevalent.

Disease	Sclerotinia rot (White mould) (*Sclerotinia sclerotiorum*)
Symptoms	Cool, wet conditions favour disease development. Disease is spread by spores shot into the air by sclerotia left over from the previous crop. White/grey fungus infecting lower leaves of the cabbage against the stem are visible.
Control	Same treatment as black leg. Seeds must be sterilised.
Disease	Downy mildew
	Common disease on cole crops during cool, moist weather. The economic damage often occurs on seedlings, where the infection can cause huge damage.
Symptoms	Pale green spots on the upper surface of cabbage leaves which enlarge to big yellow to white areas. Typical mildew growth can be found under the leaves.
Control	• Fungicidal treatment of the seedlings is recommended where infections usually occur. • Good water management can reduce the incidence of the disease • Good seedbed preparation and practices, to allow aeration and drying • Prevent over-lapping of plantings and plough in old crops as soon as harvesting has been completed.
Disease	Black leg (*Phoma lingam)*
Symptoms	The fungus causes many symptoms on cole crops such as seed rot, damping off, root and stem rots, and leaf sessions. Usually stem rots start at or below the ground level. Black leg damages roots and lower stem, so affected plants are often wilted and small. The most distinctive symptom that occurs is found on the basal part of the stem below the soil surface.
Control	• Rotate infected fields out of cole crops for at least two years • Used disease free seed • Fumigate seedbeds • Plough infected debris under

k. Harvesting[1,2]

Cabbages are harvested as soon as the heads are sufficiently hard and large enough. When the heads are quite solid, they will no longer increase in size and must then be harvested. The heads should be cut off in such a way that a few of the large, open wrapped leaves are retained for the protection around the heads.

When sent to the fresh produce market they are tightly packed into an open mesh bag, which hold between 25-30 kg of cabbages, depending the clients' requirements. It is a very popular crops sought by hawkers, who usually buy it directly from the farmers and sell it loose.

References

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Module 9h

Cucurbits

1. Introduction

This group of crops includes pumpkins, squashes, vegetable marrows, cucumbers, musk and sweet melon, and water melons.

Cucurbits originated in the tropics and do well at temperatures above 25°C. They are frost sensitive.

2. Growth requirements

a. Soil temperature

Soil temperature influences germination and root growth. The minimum soil temperature for good field germination is approximately 18°C and the maximum 30°C. At temperatures between these limits seedlings should emerge within 7 days. If the soil temperature is below 16°C seed will germinate poorly and no germination will take place below 10°C. Compared with other cucurbits, pumpkins and squash seed are more resistant to injurious effects of low temperatures.

b. Soil requirements

The producer should first establish whether the specific field is suitable for production of cucurbits. Best results are obtained on sandy loam to loam soils, with a clay content of 15% to 30%. The minimum soil depth is 450 mm, while the ideal soil depth is 900 mm and deeper. The highest concentration of roots is found in the top 300 mm of the soil. As far as soil acidity is concerned, good results are obtained on soils with pH 6.5_{H2O} and higher. If lime is required it should be ploughed in four weeks before planting.

3. Production guidelines

a. Soil cultivation

The land should first be inspected for suitability and for impervious soil layers shallower than 450 mm. If these layers occur, a ripper should be used to break it. Following this, the seedbed should be prepared by ploughing to a depth of 200 mm to 300 mm. Ensure that the seedbed is level.

b. Cultivars, types and growing season

Trailing type	Popular Cultivars	Time to first harvest (days)	Harvesting period (months)
Pumpkins	Flat White Boer, Crown Prince, star 7001, Star 7052 (grey)	110-130	1
Hubbards	Green, Green Chicago Warted, Golden	100-120	1
Butternut squash	Waltham	90-110	1
Gem squash	Rolet	80-95	1-2
Table Queen squash	Table Queen	85-95	1-2

Bush type	Caserta, Ambassador, Aristocrat, Diplomat, Long White marrow and Zucchini :all uses for baby marrows	30-50 days as baby marrows 10-20 days longer to full size	1-3

c. Planting dates

Cucurbits do not transplant easily, therefore direct planting is usually the practised. Often 2- 4 seeds are planted at each site and excess plants are later thinned out. Occasionally, seedlings are used, especially for squashes and marrows, when early crops are wanted in cooler areas[2].

Planting in cooler areas should be delayed till after the last frost, and when the soil has warmed up to at least 18°C.

Table 1. Planting dates for cucurbits

Cool areas (moderate frost)	Sept-Dec/Jan
Warm areas (light frost)	Aug- Jan/Feb
Hot areas (no frost)	Mar-May Jul -Oct

d. Plant spacing and seeding rates

Cucurbits are planted 30-40 mm deep, and under ideal conditions the field should be irrigated before planting. The soil should make good contact with the seed, and irrigation should not be applied until emergence to prevent the formation of a soil crust.

Table 2. Plant spacing and seeding rate for cucurbits

Crop	Plant spacing	Seeding rate/ha (kg)
Pumpkins Hubbards	500 mm x 2 m x 2.7 m	4-6
Butternuts Gems Table Queen	300-500 mm x 1.2 m x 1.8 m	2-3
Cucumbers	300 mm x 1.2 m x 1.5 m	2-3
Melons	300 mm x 1.5 m x 2 m	3-4
Watermelon	500 mm x 1.8 m x 2.5 m	3-4
Bush types	300-500 mm x 1.2 m x 1.5 m	4-6

4. Potential yield (t/ha)

Table 3. Potential production yields for various cucurbits

Crop	Conservative yield	Moderate yield	Good yield
Pumpkins and hubbards	12-15	18-20	30
Butternut and gems	12	15-18	25-30
Cucumbers	12	15-18	25-30
Sweet melon	12	15-18	25
Water melon	12-15	20	30
Marrows, (large)	12	15-18	25-30
Marrows (baby)	7-8	12	15-20

5. Crop rotation

Crop rotation is important to prevent diseases caused by harmful organisms living in the soil. A severe *Fusarium* infection can for instance result in a total crop loss.

Before a field is planted one should make sure that no cucurbit was planted on the field during the previous 3 years.

6. Fertilizing[1,2,3]

Fertilise according to soil analysis. The following recommendations therefore merely serve as a general guide:

Soils with a low pH ($_{KCl}$) lower than 5 should be limed. Pumpkins and squashes react favourably to high-organic matter content in the soil. Soils having a poor structure and a generally, low organic-matter content, are unsuitable. If kraal manure or compost is available, 20-40 m^3 per ha should be worked into the soil.

The general fertiliser requirements of these crops are not particularly high, and the nitrogen requirement is about 70-100 kg N/ha. Phosphorous (with a minimum of 40 kg) and potassium dressings are adjusted according the soil analysis figures:

- 2 weeks before plant: 1/2 - 2/3 of nitrogen and all phosphorous and potassium should be applied.
- Topdressing: 3-4 weeks after emergence, remaining nitrogen. On sandy soils the topdressing can be split into two dressings, one at three weeks and the other at 6 weeks. Additional fertilising after flowering is not recommended.

Molybdenum deficiencies: Where Mo is deficient, the required seed per hectare is soaked for 4-6 hours in a solution of sodium or ammonium molybdate (15-20 g sodium or ammonium molybdate in 5 ℓ water). The soaking also stimulates rapid germination. The deficiency can also be corrected by spraying of plants once or twice after emergence with a solution of 120 g sodium molybdate in 500 ℓ water.

7. Irrigation

The principle with application of irrigation is that the soil should never be allowed to dry out. This is of critical importance from planting until the plants have emerged and become well-established in order to achieve a good stand. The top 30-40 mm of the soil, in which the seeds are planted and the early root development occurs, may dry out rapidly under hot conditions. Frequent light irrigations may be necessary, even though the lower soil layers have enough soil water. The soil water content should be maintained at above 50% of the readily available soil water content throughout the growing period.

Table 4 indicates the approximate amount of irrigation water required for different climate regions. Effective rain indicates the contribution to total water requirement of the crop that rainfall could make under average irrigation management. Peak requirement is the amount of irrigation water that a crop requires during the month of highest requirement. Consult an irrigation specialist for specific irrigation advice.

To encourage deep rooting, the effective root zone (approximately 300 mm) should be wet during the first third of the growing period. Thereafter, allow a depletion of 50% before irrigating the soil. Adequate irrigation from flowering onward is very important.

Table 4. Approximate irrigation requirements of cucurbits planted in different climate regions on a loam soil under a centre pivot (SAPWAT)

Type / Area		Seasonal rain (mm)	Effective rain (mm)	Irrigation require-ment (mm)	Peak require quire-ment (mm)
Medium growers (100-120 days)	Dry, cold, summer rain, (Karoo), 15 Oct, peak Jan	162	140	432	140
	Dry, cold, winter rain, 15 Oct, peak Jan	58	48	571	180
	Dry, hot, west, (North Cape), 15 Jan, peak Mar	197	130	342	95
	Dry, hot, west, (North Cape), 15 Sep, peak Dec	114	88	576	191
	Dry, hot, east, (dry Bushveld), 15 Jan, peak Apr	256	171	264	81
	Dry, hot, east, (dry Bushveld), 15 Sep, peak Dec	313	237	276	72
	Humid, hot summers, (wet Lowveld), 15 Jan, peak Apr	377	175	118	39
	Humid, hot summers, (wet Lowveld), 15 Sep, peak Sep	435	244	110	43
	Humid, warm summers, summer rain, (Highveld), 15 Oct, peak Jan	401	280	236	69
	Humid, warm summers, winter rain, 15 Nov, peak Jan	115	91	476	160
Short growers (80-100 days)	Dry, cold, summer rain, (Karoo), 15 Oct, peak Dec	96	85	317	156
	Dry, cold, winter rain, 15 Oct, peak Dec	41	35	391	187
	Dry, hot, west, (North Cape), 15 Jan, peak Mar	160	107	278	108
	Dry, hot, west, (North Cape), 15 Sep, peak Nov	69	57	370	171
	Dry, hot, east, (dry Bushveld), 15 Jan, peak Mar	220	142	191	82
	Dry, hot, east, (dry Bushveld), 15 Sep, peak Nov	199	148	219	75
	Humid, hot summers, (wet Lowveld), 15 Jan, peak Jan	338	151	70	36
	Humid, hot summers, (wet Lowveld), 15 Sep, peak Sep	158	109	104	38
	Humid, warm summers, summer rain, (Highveld), 15 Oct, peak Dec	273	202	161	81
	Humid, warm summers, winter rain, 15 Nov, peak Dec	86	64	311	158
Bush types(40-60 days)	Dry, cold, summer rain, (Karoo), 15 Oct, peak Dec	66	42	285	156
	Dry, cold, winter rain, 15 Oct, peak Dec	37	33	303	141
	Dry, hot, west, (North Cape), 15 Jan, peak Jan	99	58	221	98
	Dry, hot, west, (North Cape), 15 Sep, peak Oct	31	25	216	112
	Dry, hot, east, (dry Bushveld), 15 Jan, peak Jan	163	95	139	63
	Dry, hot, east, (dry Bushveld), 15 Sep, peak Sep	90	70	161	80
	Humid, hot summers, (wet Lowveld), 15 Jan, peak Jan	263	102	57	41
	Humid, hot summers, (wet Lowveld), 15 Sep, peak Sep	128	80	85	59
	Humid, warm summers, summer rain, (Highveld), 15 Oct, peak Oct	217	148	129	58
	Humid, warm summers, winter rain, 15 Nov, peak Dec	80	58	240	119

8. Weed control[1,2]

The herbicides that are registered for chemical weed control only control annual and perennial grasses. No chemical herbicide is registered for the control of broad leaved weeds in cucurbits. Mechanical weed control is practised during the early stages (5-6 weeks) of growth, and then only hand weeding is possible thereafter.

9. Insects[1,2]

Nematodes, bollworm and pumpkin flies are the major pests. When implementing a spray programme, ensure that the bees are not harmed, as they are essential for pollination.

Table 5. Symptoms and control of important pests in the production of cucurbits[1,2]

Pest	Cutworm
Symptoms	Grey to black worm active during the night when it severs the stems of young plants at or just above the soil surface
Control	• Clean cultivation about 6 weeks before planting • Cutworm bait
Pest	Pumpkin fly *(Dacus ciliates)*
Symptoms	Brownish fly which closely resembles a small wasp is characterised by yellow stripes or spots on its body. When laying eggs the female stings into the young fruit and this give rise to characteristic lesions on the fruit. White maggots will be found inside the fruit at a later stage.
Control	Control programme must be initiated as soon as the first flowers open and continued till the fruits are mature. The pest can be controlled either by spraying or applying of a bait on the leaves.
Pest	Bollworm *(Heliothus armigera)*
Symptoms	Young bolworm are hairy and almost black. With each moult they become lighter until brown to green in colour. A clear yellowish stripe runs along either side of the body. The larvae feed on flowers and young fruit.
Control	An insecticide should be applied before the larvae are 5 mm long.
Pest	Aphids
Symptoms	Black or green colonies found sucking the sap of young growth.
Control	Spray with a registered insecticide as soon as it is noticed. The treatment must be repeated when necessary.

10. Diseases[4,1]

Powdery mildew in warm, dry weather; downy mildew under moisture conditions and various virus diseases are the major diseases. A number of fungicides are registered for the control of either powdery mildew or downy mildew, as well as the other diseases.

11. Harvesting[2]

The fruit should be cut from the plant, and not simply pulled off. A short section of the stem is usually retained on the fruit to reduce the incidence of fruit rot at the stem end.

- Pumpkins, hubbards and butternuts are harvested when fully sized, and when the skin has hardened. If well ripened, they may be stored for several months
- Gems and Table Queens are picked when fully sized, but preferably before the skins harden.
- Mature marrows are harvested at the similar stage. Baby marrows are picked when very immature, often before the blossom is shed, usually at a 20-30 mm diameter, and a length of 100-200 mm.

References

1. ARC, Vegetable and Ornamental Plant Institute, 1998. The production of cucurbits. National Department of Agriculture, Pretoria
2. KwaZulu-Natal Department of Agriculture and Environmental Affairs, 2001. Vegetable production in KwaZulu-Natal, Pietermaritzburg.
3. Starke Ayres Pty (Ltd), 2009. Cultivar selection.
4. Hygrotech, 2000. The production of cucurbits. Hygrotech, Silverton, Pretoria.

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Module 9i

Green beans

(Paseolus vulgaris)

1. Introduction

Green beans belong to the family known as *Fabaceae* or legumes. Green beans are very popular and are present in most home gardens and community gardens where vegetables are planted. Green beans can be produced in South Africa wherever irrigation is present in sufficient quantities. The frost free Lowveld (Mpumalanga), KwaZulu-Natal, Western Cape, Eastern Cape (especially Gamtoos Valley and areas around Port Elizabeth) and Limpopo are important production areas in the country.

2. Growth requirements

To produce high yields of good quality, it is essential that green beans are cultivated under suitable climatic and soil conditions.

a. Temperature

The optimum temperatures for growth and development are 16-24ºC, since all green bean cultivars have been developed from species found in natural habitats in Central America. Green beans are very sensitive to frost. Exposure to only a few degrees below freezing point will usually cause serious damage to plants. Temperatures above 35ºC, especially when accompanied by dry winds, may cause the flowers and the tender pods to abort, resulting in poor yields.

Successive night temperatures of 5ºC and lower will result in a large percentage of opaque pods. This means that flowers do not abort, the pods develop well but are husky and contain no or a small number of seed. This is also the cause of short and malformed pods.

In the frost free areas of the Lowveld green beans are cultivated during the winter. However, relative frost freedom of a particular area does not necessarily mean an area is suitable for green bean production, since night temperatures may still not be adequate for normal development of pods.

b. Rainfall

Apart from temperature the occurrence of rainfall has an appreciable influence on the cultivation of the crop. Wet conditions during the growing period will promote the development of halo blight, pod rotting caused by botrytis and anthracnose. Wet conditions also hamper the harvesting process. On the other hand, drought conditions, especially on sandy soil, will have deleterious effects on the quality and the yield of the crop.

c. Wind

Wind also plays an important role in the production of beans. Especially in the case of runner beans, extensive damage can be caused by strong winds, and these do not only ruin the leaves and pods but also wreaks havoc upon the training systems. Dry winds can also adversely affect pollination and in consequence the yield.

d. Soil requirements

Green beans can grow on a wide range of soil types, ranging from sandy soils to relatively heavy clay soils; provided it is well drained to at least 400 mm. Sandy-loam to loam soils are preferred. Soils which are characterised by crusting should be avoided, because they may seriously reduce emergence, as well as detrimentally affect subsequent growth. Green beans are amongst the most sensitive vegetables to brackish conditions and to high boron content in the soil. The optimal $pH_{(water)}$ value for green beans varies between 6-6.5. Soils above $pH_{(water)}$ of 6.8, particularly strong alkaline soils may cause manganese deficiency and must be avoided. Acidic soils ($pH_{(water)}$ lower than 5.5) can only be used provided they are well limed prior planting.

3. Production guidelines

a. Land preparation

Prepare the land to a good depth. Take care not to over work and pulverise the soil, because this can cause crusting. When soil conditions are favourable for the development of roots, it can develop up to a depth of 1200 mm. Poor seedbed preparation does not only impede the penetration and branching of the root system, but also reduce the plant's resistance to the drought conditions and root diseases.

When only rotavators are used for the cultivating of soil, the soil under the cultivated part can become compacted. A ripper could be used for the breaking of these compacted soil layers.

b. Seedbeds and seeding

A great variety of planters can be used and the tendency is to make use of precision planters, especially where mechanical harvesting is applied. On a small scale, the seeds may be planted in drills or small furrows which have previously been soaked with water. After planting, the dry soil on the ridges is raked over the planted seed.
During planting the following aspects should be kept in mind:

- For optimum germination, all seed must be placed at the same depth, not deeper than 50mm. In order to obtain uniformity in germination and eventually ripening process of the plants, it is essential to plant at a constant depth, especially if mechanical harvesting is to be applied.
- Care must be taken not to damage the seed during the planting process. Bean seed is very brittle and readily damaged by some types of mechanical planters.
- As seed is very expensive, it should be used sparingly, and the optimum spacing of the seed in the rows should be adhered to as accurately as possible.

The following plant spacing and populations are recommended:[1,2,3]

- *Factory crops (freezing, canning or dehydration):* generally drilled in rows drawn about 200 mm apart. In wet, humid areas the aim is generally to achieve a density of 35-45 plants/m^2. In drier areas, under irrigation, a density of 50-60 plants/m^2 is used and, under ideal conditions, a population of about 100 plants/m^2 give best results for a once-over harvest.

- *Fresh market:* Rows are generally 600 mm apart, and it is preferable to plant two rows, spaced 200 mm apart, with 600 mm wide access paths between sets of double rows. Seeds are planted about 50 mm apart in the rows. This will provide 33 seeds/m^2 for single rows, and 50 seeds/m^2 for double rows. Under poor and average conditions, only 50-70% of these seeds will produce bearing plants with 65-90% under good growing conditions.

c. Time of planting

The following planting dates apply for the various production areas (Table 1).

Table 1. Planting dates for green beans

	Cold area (heavy frost)	Warmer areas (Light frost)	Hot areas (No frost)	Growing period (days) (Plant – harvest)
Green beans	Sept-Jan	Middle Aug-Feb/Mar	Feb-Sept*	Bush beans: 50-60 days Runner beans: 60-74 days

**Discontinue the planting of runner beans one month earlier due to their relative longer growing period.*

d. Rotation cropping

Green beans like other legumes are valuable rotational crops in a vegetable growing program. Especially where kraal manure and compost are hard to get, crops with a high nutritive requirements like cabbage and tomatoes, will give the best results if planted just after green beans in a rotational system. As much as possible of the crop residues should therefore be worked into the soil. Because diseases like bacterial blight, fussarium wilt-disease and anthracnose can be transmitted in the soil, green beans should not be planted more than once in three years in the same field.

e. Yields (t/ha)

	Conservative	Average	Good
Bush beans	5	8	12-15
Runner beans	7	10	15-20

4. Fertilizing[1]

Fertilise according to soil analyses. Soil analysis will not only lead to more appropriate fertilisation levels, but can also significantly limit unnecessary fertilisation costs. The nutrients must be readily available for the uptake by the plant roots. The placement in the soil, soil moisture, pH and many other factors influence the utilisation of nutrients by the plant. A general fertilisation program can only serve as a guide, and for proper recommendations a detailed soil analysis is required.

The following withdrawal norms in kg per ton product for green beans apply as illustrated in Table 2.

Table 2. Approximate withdrawal of the major nutrients in kg per ton product of green beans[1]

Nutrient absorption (kg/ha)			
Green beans (yield)	N	P	K
1 t/ha	13.6	1.45	9.09

Bearing in mind that leguminous crops fix some of its own nitrogen requirements and those plants are almost invariably ploughed back into the soil after harvest, it is clear that fertiliser requirements are relatively low. For runner beans, the fertiliser rates can be increased by 25%.

Example

To calculate the approximate withdrawal of N, P and K for a relatively good crop of 11 t/ha of bush beans that is grown in the Limpopo area, use the figures that is illustrated in Table 2.

Answer*:*

N: 11 x 13.6 = 149.6 kg/ha (150 kg/ha)

P: 11 tons x 1.45 kg/ha = 15.95 kg/ha (16 kg/ha)

K: 11 tons x 9.09 kg/ha = 99.99 kg/ha (100kg/ha)

- **Secondary elements**

A deficiency of trace elements in green beans occurs fairly generally. Due to the short growth season, the deficiency cannot be rectified after its symptoms have made their appearance, but in the case of future plantings it should be borne in mind.

5. Cultivars[3]

There are a number of cultivars available in the seed trade, with new ones continually being developed. A good practice is to keep in regular touch with the seed representative to get the latest recommendations on cultivars possibly suited to the local conditions and the planned planting times.

Popular cultivars

- *Bush (dwarf):* Contendor, Endurance, Espada, Paulitsa, Nelson, Newton, Champ, Espada, Clyde, Provider, Wintergreen and Star 2001.
- *Runner beans:* Lazy Housewife, Witsa. These require trellising and are more popular in home gardens than as a commercial crop.

6. Irrigation

The success of green bean production depends on continuity of growth and no interruptions must occur. For this reason, effective irrigation management is of great importance in the cultivation of the crop.

Before planting: The effective root zone of green beans can be taken as 450 mm, and therefore the soil should be wet to a depth of 450 mm before planting. The amount of irrigation required for this will depend on the type of soil (texture). After planting: the first irrigation after planting can be postponed to at least a week after the plants have emerged. The precise amount will once again depend on the soil type and climatic conditions. From the flowering stage onwards, green beans are very sensitive to moisture deficiency, and precise irrigation is required until the pods have been harvested.

The soil water content should be maintained at above 50% of the readily available soil water content throughout the growing period.

Table 3 indicates the approximate amount of irrigation water required for different climate regions. Green beans require more irrigation water during hot seasons and in drier climates than during cold seasons and in humid climates. Effective rain indicates the contribution to total water requirement of the crop that rainfall could make under average irrigation management. Peak requirement is the amount of water that a crop requires during the month of highest requirement. Consult an irrigation specialist for specific irrigation advice.

Table 3. Approximate irrigation water requirements of green beans grown in different climatic regions (SAPWAT).

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement for month (mm)
Spring plant				
Dry, cold, summer rain, (Karoo), 15 Sep, peak Nov	37	30	276	148
Dry, cold, winter rain, 15 Sep, peak Nov	38	34	216	126
Dry, hot, west, (North Cape), 15 Sep, peak Nov	42	32	289	157
Dry, hot, east, (dry Bushveld), 15 Sep, peak Nov	108	84	209	94
Humid, hot summers, (wet Lowveld), 15 Sep, peak Sep	232	133	67	28
Humid, warm summers, summer rain, (Highveld), 15 Sep, peak Nov	173	112	131	56
Humid, warm summers, winter rain, 15 Sep, peak Nov	90	64	156	100
Summer plant				
Dry, cold, summer rain, (Karoo), 15 Dec, peak Jan	59	46	329	160
Dry, cold, winter rain, 15 Dec, peak Jan	23	13	304	139
Dry, hot, west, (North Cape), 15 Jan peak Mar	130	81	227	105
Dry, hot, east, (dry Bushveld), 15 Jan, peak Mar	225	110	177	82
Humid, hot summers, (wet Lowveld), 15 Jan, peak Mar	378	149	55	26
Humid, warm summers, summer rain, (Highveld), 15 Dec, peak Feb	258	136	118	56
Humid, warm summers, winter rain, 15 Dec, peak Feb	41	29	257	120

7. Weed control

A few herbicides are registered for use in green bean cultivation. These herbicides differ regarding the stage and method of application and the spectrum of weeds they control. Before deciding on a particular herbicide or combination of herbicides, producers must ascertain the weed spectrum that will occur during the production season. It is advisable to contact the technical advisor of chemical firms marketing herbicides.

8. Insects and diseases[1]

Green beans are often attacked by nematodes (controlled by soil fumigation), red spider mites, bean fly, stinkbugs and also by less common pests like aphids, thrips, CMR beetles etc.

The major diseases that are commonly found on green beans are rust, bacterial blight, damping off, Sclerotinia rot, antrachnose and virus diseases. Copper based fungicides are used to control bacterial blight, which is favoured by prolonged wet growing conditions. The spread of bacteria and viruses is by rain splatter, and the use of quality seed, free of bacteria and viruses reduced the problem. A number of preventative fungicides are registered for the control of rust, which usually gain importance during late summer and autumn.

9. Harvesting

Harvesting usually starts when the pods are well developed but before the seed have developed appreciably. Frequent picking, about twice a week under warm conditions, ensures that a better quality and a higher yield is obtained than when picking is less frequent.

References

1. ARC, Vegetable and Ornamental Plant Institute, 1998. The production of green beans. National Department of Agriculture, Pretoria

2. Department of Agriculture and Environmental Affairs KwaZulu-Natal, 2001. Vegetable production in KwaZulu-Natal. Pietermaritzburg.

3. Starke Ayres Pty (Ltd), 2009. Cultivar selection.

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- Dr P Reid

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Module 9j

Tomatoes

(Lycopersicon esculentum)

1. Introduction

The tomato belongs to the family Solanaceae, which also include members like the sweet pepper, chilli, gooseberry, eggplant and potato. Several important weeds such as thorn apple ("stinkblaar"), the wild gooseberry and bugweed also belong to this family.

The tomato is a very important vegetable crop in South Africa and is very popular in household food gardens. The fruit is mainly sold fresh, but large quantities are also processed.

2. Growth requirements

To produce high yields of good quality, it is essential that tomatoes are cultivated under suitable climatic and soil conditions.

a. Temperature

The tomato is a warm-season annual plant, which is very sensitive to daily temperatures. Temperatures a few degrees above freezing may cause severe damage to both plant and fruit. The optimum growing temperature for growth, yield and fruit quality of tomatoes is an average daily mean of 20ºC to 24ºC. At temperatures below 12ºC and above 35ºC, flowers are often shed. This leads to poor fruit set, and the quality of the fruit produced under such conditions may be detrimentally affected.

Best soil temperature for germination of tomato seed is between 15ºC and 30ºC.At such temperatures germination occurs in about 7-10 days. Germination is negatively affected at soil temperatures above 35ºC. Hot, dry winds may cause excessive flower drop, even when soil is moist. Wind can also cause severe mechanical damage.

Continuous moist and rainy conditions promote the occurrence and spreading of leaf diseases, and also make control more difficult. For the best results, tomatoes should be grown in relatively dry areas under irrigation (preferably drip irrigation)

b. Soil requirements

Tomatoes should ideally be grown in deep, fertile and humus-rich soils that are well drained. Sandy-loam to clay-loam soils, with clay content between 15% and 35% are the most suitable. Sandy and gravel soils are acceptable, provided that the soil moisture content can be kept at a desired level. Heavy clay soils should not be considered because of the slower drainage, which can cause waterlogging problems during prolonged rainfall periods.

The greatest concentration of roots is found in the top 60 cm of the soil, which is also considered to be the effective rooting zone dept of tomatoes.

3. Production guidelines

a. Land preparation

Prepare the land to a good depth. Take care not to over-work and pulverise the soil, because this can cause soil crusting. When soil conditions are favourable for the development of roots, it can develop up to a depth of 1200 mm. Poor seedbed preparation does not only impede the penetration and branching of the root system, but also reduces the plant's resistance to drought conditions and root diseases.

b. Seedbeds and seeding

The site for seedbeds should not be exposed to strong winds, but good air movement and exposure to full sunlight is required to reduce disease incidence. It should also be isolated from existing tomato fields, as these are a possible source of pests and diseases.

A three-year rotation system should be practised. In many cases soil fumigation with registered compounds may be required for the control of nematodes. Beds are usually made about 1 m wide and 150 mm higher than the pathway between them to facilitate drainage. The beds should be level across their width, with no high spots (too dry) and low spots (too wet). Seed is sown thinly in shallow furrows, drawn 100-150 mm apart, and covered to a depth of 10-15 mm. Frequent light irrigations are necessary to prevent the drying out of the top of the soil in which the seed is planted. Gradually increase the irrigation as the plant grows. Approximately 250 g of seed, sown on 100-150 m^2 of seedbed, should provide sufficient plants for one hectare.

Hardened seedlings of 100-150 mm tall can be transplanted. Under warm conditions, tomato seedlings may require 30 days to reach the transplanting stage, but it may take up to 60 days under colder conditions. Younger seedlings of the required size usually perform better than older ones. Plant seedlings into a moist soil and set the plants slightly deeper than they were in the seedbed. Firm the soil around the roots and irrigate as soon as possible after transplanting.

c. Sowing time

The following sowing dates apply for the various production areas (Table 1).

Table 1. Sowing dates for tomatoes

	Cold area (heavy frost)	Warmer areas (Light frost)	Hot areas (No frost)
Tomatoes	Sept-Nov	Aug-Dec	Dec- Mar Jul-Sept

d. Rotation cropping

A three or even a four-year rotational cropping system should be followed to reduce the risk of disease build-up. Related crops, such as potatoes, chilli, eggplant, sweet pepper, Cape gooseberry and tobacco should not be included in this rotation, as they often host some of the important tomato diseases and pests.

e. Spacing and plant populations

Tomatoes that are planted for processing purposes are seldom trellised and row widths are determined by the span of the tractor and spray-rig, as well as the vigour of the cultivar used. A plant spacing of 300-500 mm in the rows drawn 1.2 m apart will provide a plant population between 16 000 and 28 000 plants per hectare.

For household and fresh produce market purposes plants are invariably trellised. The seedlings should be planted on ridges 1.4-2.0 m apart, with plant spacing of 300 - 500 mm in the row. This will ensure a plant population of approximately 10 000 - 16 000 plants/ha. The row spacing is usually determined by factors like the size of the tractor and equipment used for cultivation. Trellising usually helps to improve the marketable yield and quality of the tomatoes. Trellising is expensive (material and labour), but the cost there-of must be offset against a bigger marketable yield, ease of harvesting and less disease and pest problems.

The training methods mostly used by producers of fresh table tomatoes are the following:

- Poles 2-2.5 m long and 50 mm to 70 mm in diameter are planted in rows to a depth of 600 mm, usually at a spacing of about 3 m. Poles at the end may be slightly larger, and should be well supported or anchored to prevent their being pulled over later in the season by the weight of the vine growth.

- When plants are 300-400 mm tall, wire is stretched on either side of the plants down the row, at a height of about 300 mm. These two wires are attached to the inner poles and as the plants grow, additional pairs of wires are stretched along the rows and attached higher up the poles at intervals of about 300-400 mm. Four to seven wires may be needed, depending on the vigour and height of the plant.

4. Fertilizing[1]

Most cultivars have the potential to produce yields in excess of 100 tons per hectare and have a fairly high nutritional requirement. Tomatoes in general respond fairly well to organic fertilisers. In order to achieve satisfactory yields of an acceptable quality, a balanced fertiliser program is very important. Fertilise according to soil analysis. Soil analysis will not only lead to more appropriate fertilisation levels, but can also significantly limit unnecessary fertilisation costs. The nutrients must be readily available for uptake by the plant roots. The placement in the soil, soil moisture, pH and many other factors influence the utilisation of nutrients by the plant. A general fertilisation program can only serve as a guide. A detailed soil analysis is required for proper recommendations.

Soil pH

Tomatoes are very sensitive to high soil acidity, and soils of low pH often contain high levels of soluble manganese and aluminium, both of which can reach toxic levels that will affect crop growth and yield. Under such conditions soil phosphorous may be immobilised, rendering it unavailable to the plant. Calcium, magnesium, nitrogen, potassium, sulphur and molybdenum become less available under very acid soil conditions.

Tomatoes prefer a pH_{KCl} ranging from about 5-6, to slightly alkaline. If the pH of the soil is unsuitable, it should be corrected by adequate liming before planting.

The withdrawal norms in kg per ton product for tomatoes apply as illustrated in Table 2.

Table 2. Approximate withdrawal of the major nutrients in kg per 67 ton fruit[3]

Nutrient absorption (kg/ha)			
Tomatoes	**N**	**P**	**K**
67t/ha	202	24	314

Nitrogen (N)

The nitrogen requirements of tomatoes are generally considered to be moderately high, as illustrated in Table 1. Usually about 120-150 kg N/ha is required for target yield of 35 t/ha. About a quarter of the nitrogen is applied at planting. The remainder is applied after the first 6-8 weeks of growth, followed by applications at 2-3 week intervals. In order to maintain a balance with potassium (K), the use of potassium nitrate for some of the side dressings is recommended.

Phosphorous (P)

Where the phosphorous status of a soil has been built up over several years, 40-60 kg P/ha is adequate for a target yield of 35t/ha. On a relative acid soil, the best results are obtained by banding the P fertiliser. An early symptom of P deficiency in tomatoes is the development of a purplish colour on the underside of the leaves.

Potassium (K)

The potassium requirements of tomatoes are high. Plant analyses indicate that plants take up about 50% more potassium than nitrogen. The major effect of potassium is its influence on fruit quality (colour, taste, firmness, sugars, acids, solids of the fruit). Chlorine tends to reduce the fruit quality, and it is therefore recommended to use chlorine-free fertilisers. A minimum of 130 kg K/ha should be applied for a target yield of 35t/ha, depending on the potassium status of the soil.

Secondary elements

The following secondary and micronutrients are essential for satisfactory yields.

- Calcium (Ca)
- Magnesium (Mg)
- Sulphur (S)
- Boron (B)
- Iron (Fe)
- Copper (Cu)
- Zinc (Zn)
- Manganese (Mn)
- Molybdenum (Mo)

5. Cultivars[3]

There are a number of cultivars available in the seed trade, with new ones continually being developed. A good practice is to keep in regular touch with the seed representative to get the latest recommendations on suitable cultivars. Test any new recommended cultivar on a small scale, alongside a proven one for comparison purposes

The following characteristics of tomato cultivars are very important and should be kept in mind:

- Susceptibility to various diseases and nematodes: Many of the popular cultivars recommended have some resistance and/or tolerance to some diseases or nematodes. This is a very important factor to take into consideration because at the end of the day it affects costs of production and the potential profit that could be generated.
- Fruit quality and especially the specific needs of the market to be met. Here factors like firmness; size, shape, colour and uniformity are important.
- Adaptability and reliability of the cultivar: This determines the yield of a good quality that could be expected, even under slightly less favourable growing conditions.
- Plant growth habit: A determinate growth habit indicates that the growing points of the plant terminate in a florescence, this restricts

further growth. Such cultivars do not grow as tall as indeterminate types, where the growth restriction does not occur. These cultivar types bear fruit simultaneously and harvesting is done with one or two passes through the field. An indeterminate cultivar produces fruit continuously, usually until killed off by frost or some other factor.

- Planting time: certain cultivars do better than others at particular times of the year. There is also a tendency that relatively good adapted cultivars may produce defects, like cat face, under cool, moist conditions.
- Specific market requirements: processing tomatoes require certain qualities like high solid contents, while table tomato preferences include characteristics like firmness, flavour, colour and shape.

The cultivar selection is influenced by the requirements of the specific market the tomatoes will be produced for (Table 3)

Table 3. Cultivar selection according to various types of tomatoes

Fresh market	Flororade, Karino, Rodade Star 9001, Star 9003, Star 9056, Zeal are all very popular cultivars. New longshelf tomatoes that become very popular include Blockbuster, Baldo, and Shirley.
Jam or preserving tomatoes	Star 9056F, Rossol, Letago, HTX 14, RomaVF, Sun 6216, UC82B, Nema 1400
Cherry tomatoes	Bamby, Josephine, Cherry Star, Sweetie
Tunnel tomatoes	Altetico, Daniella, Gabriella, Diego,
Truss tomatoes[4]	Aranca F1, Campari F1, Furore F1

6. Irrigation

Tomatoes are usually grown under irrigation and the total water usage will vary depending on the prevailing climate conditions during growth. Under hot and relative dry conditions, between 400-750 mm of irrigation is required. In cooler, high humidity regions, the requirement of a summer crop may vary between 300-600 mm of irrigation.

The following guidelines apply:

- It is important to keep the effective root-zone moist throughout the growing season. During the first two or three weeks after transplanting, the soil should be wetted to a depth of approximately 400 mm as soon as 25% depletion of the readily available soil water has been reached. Thereafter a depletion of 50% readily available water is an acceptable level before the next irrigation.
- Lateral spread of roots can be 1 m or more, and therefore the irrigation of the entire soil area is advisable, except during the month after transplanting when the plants are relatively small and the roots have not yet spread to their full extent.
- When mechanical harvesting is used, it is critical to ensure that the last irrigation should be applied at 40% red fruit on heavier clay soils, and 50-60% on lighter sandy soils[3]

Table 4. Approximate irrigation requirements of tomatoes planted in different climate regions on a loam soil under drip irrigation (SAPWAT).

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm)
Table				
Dry, cold, summer rain, (Karoo), 15 Oct, peak Jan	195	150	515	145
Dry, cold, winter rain, 15 Oct, peak Jan	65	40	680	190
Dry, hot, west, (North Cape), 15 Sep, peak Dec	150	85	740	215
Dry, hot, east, (dry Bushveld), 15 Sep, peak Jan	385	235	420	115
Humid, hot summers, (wet Lowveld), 15 Sep, peak Jan	560	260	195	50
Humid, warm summers, summer rain, (Highveld), 15 Nov, peak Feb	420	240	360	95
Humid, warm summers, winter rain, 15 Nov, peak Jan	125	80	600	160
Canning				
Dry, cold, summer rain, (Karoo), 15 Oct, peak Feb	135	105	450	165
Dry, cold, winter rain, 15 Oct, peak Dec	50	30	555	185
Dry, hot, west, (North Cape), 15 Sep, peak Nov	95	60	550	195
Dry, hot, east, (dry Bushveld), 15 Sep, peak Nov	270	175	320	105
Humid, hot summers, (wet Lowveld), 15 Sep, peak Nov	385	200	155	50
Humid, warm summers, summer rain, (Highveld), 15 Nov, peak Jan	365	215	300	100
Humid, warm summers, winter rain, 15 Nov, peak Jan	85	60	490	165

7. Weed control[2]

A few herbicides are registered for use in tomato cultivation since weeds are effective competitors with the crop for nutrients, water and sunlight. Some of these weeds may host pests and diseases of tomatoes, and therefore it is important to effectively control weeds in the early stages of crop development.

Weeds can be controlled by means of mechanical and chemical methods. Mechanical control of weeds includes hand cultivation, but it is important that these actions start timeously before any damage to the crop results from competition. Row spacing selected, especially in larger plantings, is often such that mechanical weed control through hand hoeing or hand pulling can be practised in the inter-row area during the initial growth stages. However, as soon as the tomato plant is well established, mechanical cultivation should preferably be discontinued since the tomato feeding roots are wide spread and relatively shallow. Contact your chemical representative for advice.

8. Insects and diseases[1]

Tomatoes are attacked by a wide variety of pests and diseases. This necessitates an effective pest and disease control plan for every planting. Select cultivars or cultural practices that reduce the impact of diseases and pests. The chemical control of many pests and diseases are essential. Most of these chemicals have only a preventative action, and cannot cure the infected plant. A routine preventative spray programme to control diseases like early and light blight, as well as certain bacterial diseases, is generally advisable.

9. Harvesting, grading and packing

The stage of maturity at which the fruit is picked, as well as the intervals between picking is determined by the following factors:

- Distance between the farm and the market- if there is great time delay fruit should be picked at a less mature stage
- When fruit is harvested under relative high temperatures – pick at a less mature stage
- Market preference plays an important role: processors and certain consumers prefer fully coloured fruit.

The fruit is usually graded according to size, colour and quality. First grade fruits must be sound with no signs of disease and cracks. Foreign matter must not be included in the packaging. The tomatoes must be free of spray residues, must be well shaped and uniform in size.

Marketing is one of the most important aspects of production and sales, and yet with many fresh producing farmers it receives the least attention. Market research is essential for successful marketing.

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3. Starke Ayres Pty (Ltd), 2009. Cultivar selection.
4. Hygrotech Seed Pty Ltd, Silverton, Pretoria
5. Boelema, BH, 1975. The cultivation of vegetables in South Africa. HT: tomato diseases. Farming in South Africa.

My notes...........

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Developer: Dr Joe Stevens

Authenticator: Mr P van Heerden

Module 9k

Amadumbi

(Colocasia esculenta)

1. Introduction

Amadumbi (or Madumbies) is a perennial crop, tuberous plant with large heart shaped leaves variable in size and colour. The corms and cormels are rich in starch and can be eaten similar to potatoes after being boiled, baked, roasted or fried in oil. The crop is widely spread throughout the tropics and is grown commercially in Egypt.

The composition of the flesh is relatively high in carbohydrates, protein and vitamins. Most cultivars contain oxalic acid (0.1-0.4% fresh weight) mainly in the form of bundles of needle–shaped crystals of calcium oxalate embedded in the tissues. These exert an irritant, which is removed by boiling. The leaves and petioles can be utilized as vegetables and are useful sources of vitamin A and C.

2. Growth requirements

This tropical, subtropical crop requires areas with long frost-free periods.

a. Temperature and humidity

The optimum temperature ranges from 21-27^{0}C. . When grown in temperate regions there must be a frost period of 6-7 months. High humidity is preferred, with well-distributed rainfall of 1 000 mm or more or supplementary irrigation.

b. Soil requirements

Amadumbies grow on most soil types, but prefer deep, well drained, fertile, and sandy-loam to loam soils with a fairly high level of water table. Amadumbies are often planted along stream banks, but are also tolerant of upland conditions.

3. Production guidelines

a. Land preparation

Prepare the land to a good depth like for other tuberous vegetables (sweet potatoes).

b. Planting material and plant spacing

The tubers formed on the side are used for propagation as also the top portion of the main tuber. Amadumbi is propagated vegetative by the use of pieces of tubers, or stem cutting, which consist of the tuber tip (0.6 cm) and the lower 15-25 cm of the petioles. Stem cuttings form parent tubers usually give the best results. It is important to ensure that the plant material is taken from a healthy growing plant and that the best plants are kept for replanting the next season.

Plant amadumbies in furrows to give 50-80 mm soil depth after covering. If the water table is high (e.g. on stream banks), amadumbies may be planted on ridges, which would assist with the harvesting. It is recommended to ridge plants slightly after topdressing.

The seeding rate for sprouted corms or cornels is 25-75 g weight or a total of 1.5 t/ha. The plants should be spaced 60 cm – 1 m between rows, and 30-60 cm within the rows, resulting a plant population of 20 000-40 000 plants/ha.

c. Time of planting

In cool areas it is the best to plant amadumbies from September till October, while in warmer areas planting is possible from August till November. In hot areas, planting can start in July till October.

d. Growth period

The maturation period is influenced by factors like cultivar and planting date, temperature during the growing season and soil type. The growth period is approximately 6 to 10 months, while in South Africa the crop matures in 200-270 days from planting.

e. Yields (t/ha)

The yields vary according to the cultivar, crop duration and the cultural conditions.

Conservative (t/ha)	Average (t/ha)	Good (t/ha)
5	6-10	15+

4. Fertilizing

If a soil analysis is available fertilise according to it. Amadumbies prefer high organic content soils with an optimum pH $_{KCl}$ of 5.5-6.5. Heavy dressings of organic material (compost, matured kraal manure) can be given three weeks before planting. Nitrogen, potassium and phosphorous appear to effect both the number of cornels produced per plant as well as the total yield. The calcium requirements of the plant are relatively high.

If no soil analysis is available, broadcast lime before final soil preparation. At planting apply 1000 kg 2:3:2 (22) /ha on the row, and top-dress on 14 weeks with 175 kg 1:0:1 (36) /ha.

5. Cultivars

There are several cultivars available in the world, but in South Africa growers store a portion of their own crop for replanting, and no seed corm industry currently exist to provide certified planting material to growers.

6. Irrigation

In high rainfall areas irrigation is either not necessary or only supplementary irrigation is applied. In lower rainfall areas irrigation is provided for vegetative growth and leaf development and the use of furrow and sprinkler irrigation is very popular. In the mature stage the plants need abundant continuous supply of water for optimum growth.

Table 1. Approximate irrigation requirements of amadumbi planted in different climate regions on a loam soil under a centre pivot irrigation

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm)
Dry, hot, west, (North Cape), 15 Sep, peak Jan	310	220	1590	310
Dry, hot, east, (dry Bushveld), 15 Sep, peak Jan	570	415	1160	185
Humid, hot summers, (wet Lowveld), 15 Sep, peak May	825	480	625	115

7. Weed control

A weed-free seedbed followed by weed control for the first 6-8 weeks after planting is crucial. Most producers use hand hoeing, and the use of herbicides before weed or crop emergence is essential for good crop production. No herbicide is however registered specifically for amadumbi in South Africa.

8. Insects and diseases

Root-knot nematodes pose serious problems when planted in infested soils. Galls are produced on the roots, which often leads malformation of cornels. Leaf hoppers, thrips and aphids, sweet potato hawk moth, taro beetles can be troublesome, as well as red spider mite under dryland conditions.

The following diseases can also be troublesome:

- Leaf blight *(Phytopthera spp.):* usually when wet conditions prevail for a long period
- Soft rot *(Pythium spp.)*, tuber rot *(Sclerotium rolfi)*: stunts the growth of the plant and the corms at the base
- Leaf spot *(Cladosporium spp.):* usually severe in older leaves

The best control measure is the use of healthy plant material and apply crop rotation the same as applicable with the rest of the vegetables.

9. Harvesting and marketing

Taros are usually ready when the leaves begin to turn yellow and begin to wither. Harvesting can be delayed for some weeks during dry conditions without any deterioration of corms.

Normally the plants are lifted out of the soil by means of a fork or some producer's even use a 1.5-1.8 m pipe with a sharpened point to remove the corms. In large scale plantings the plants are removed mechanically. The soil should be soft during harvesting to prevent the breakage and skin damage of the cormels. When the corms are intended for immediate consumption the leaves and fibrous roots are removed and the corms washed. If it is to be stored the corms must be kept absolutely dry and free from mechanical damage. The optimum storage temperature is 11-13ºC. Corms can be stored successfully for a period exceeding 100 days.

References

1. Coertse AF & Alleman, J., 1996. Indigenous seed crops A4: Amadumbi. ARC, Roodeplaat Vegetable and Ornamental Plant Institute, Pretoria.

Developer: Joe Stevens
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Module 91

Cowpeas

(Vigna unguiculata)

1. Introduction

The cowpea is a traditional indigenous crop in South Africa. World production in 1981 showed that 16 African countries produced two thirds, while Nigeria and Niger produced almost half of the world production.

Low yields are recorded and are mainly attributed to diseases, insect damage and soil fertility problems. The small-scale production of cowpeas is mainly confined to Limpopo, Mpumalanga, North West and KwaZulu Natal. Cowpeas are relatively high in protein similar to that of edible legumes. Cowpea protein is like other food legumes relatively low in sulphur-containing amino acids, but tends to be slightly higher than dry bens.

2. Growth requirements

The crop can be successfully produced with minimum inputs as long as basic production principles are maintained.

a. Temperature

The cowpea is drought tolerant and high protein crop with lower soil fertility requirements than many other vegetable crops. This crop is well adapted to hot, marginal areas but also do well in the cooler, higher rainfall areas. Daily temperature of 8.5ºC is regarded, as the threshold for successful germination but temperatures above 21ºC is conducive for vegetative growth. Temperatures above 33ºC advance flowering time but can also promote flowering abscission if this coincides with moisture stress.

b. Soil requirements

Cowpeas are relatively sensitive to water-logging, and therefore the production is best on sandy or loam soils. Water logging causes loss of *Rhizobium* nodules and the ability of the plant to recover depends on the resumed root growth and renewed *Rhizobium* activity.

3. Production guidelines

a. Land preparation

Prepare the land to a good depth. Take care not to over work and pulverise the soil, because this can cause soil capping. Minimum tillage aimed at mulching to conserve soil properties and moisture produce equal or better results than conventional tillage.

b. Seedbeds and seeding

Seed propagates cowpeas and the following seeding rate is recommended:

- Vine types: 9-16 kg/ha
- Erect types: 12-20 kg/ha

Erect types perform better when denser spacing is applied eg: 900 mm x 100 mm with 111 000 plants per hectare or even denser provided that irrigation is available e.g. 450 mm x 100 mm with 220 000 plants per ha.
Semi vine types perform better with wider spacing than erect types, e.g.: 1.5 m x 100 mm with 66 000 plants/ha.

The spacing between the rows can be adapted according to the available implements such as planters and machines used for weed control and harvesting. Growers often use tramline spacing. Optimum planting depth is 40 mm for the seed.

c. Time of planting

The cultivars differ as far as their optimum planting time is concerned. The following planting dates apply for the various production areas (Table 1).

Table 1. Planting dates for cowpeas

	Cooler areas	Warmer areas
Cowpeas	mid November	mid December

The crop can also be planted at the beginning of October or late in January, but there are some risks to be taken. Too early plantings can lead to weak germination of the seed because temperatures are still low. Late planting in summer can lead to low yields due to weaker growth and early frost. Low temperatures also cause plants not to form pods resulting in very low grain yields.

d. Growth period

The growth period is influenced by factors like cultivar, planting date, temperature during the growing season, soil type and rainfall or irrigation. The following growing periods of cowpeas exist (Table 2).

Table 2. Growing periods for different cowpeas types

Growing stage	Cowpeas type	Growth period (days)
Planting-50% flowering	erect	50
	vine	60
Planting – harvesting	erect	120
	vine	140

e. Rotation cropping

The effect of crop rotation of legumes like cowpeas is well known. Studies showed that cowpeas could supply 27 kg N per hectare.

f. Yields (t/ha)

An average grain yield of 1 t/ha can be expected, while approximately 6t hay/ha can be produced.

4. Fertilizing

Fertilise according to soil analysis. In rotation with other vegetable crops, minimum fertilisation is necessary because the crop utilise the remaining fertilisers in the soil. Nitrogen applications should only take into consideration to prevent weak seedling development as a result of temporary nitrogen shortages.

Soils with a neutral pH, adequate P, K, S, Ca and Mg ensure optimum *Rhizobium* activity and nitrogen symbiosis. Cowpeas react moderately to phosphorous applications, but excessive application of phosphorus can lead to flower abscission under drought stress conditions. The application of K, Ca, Mg and S is only of importance where soils are deficient in these materials. The application of n is usually not necessary.

5. Cultivars

There are a number of cultivars available in the seed trade and are listed in Table 3.

Table 3. Cowpea cultivars and their distinctive characteristics

Cultivar	Growth habit	Growth period (days)	
		Plant-Flowering	Plant-Harvesting
Betsjoeana White	vine	60-70	120
Blue mixed	vine	60-70	120
Brahman	erect	55-60	120
Brown mixed	vine	60-70	120
Chappy	flat runner	70	120+
Dr Saunders	semi-erect	55-60	110
Glenda	semi-erect	55-60	110
Iron Grey	vine	60-70	120+
Mixture	vine	70+	20+
PAN 311	erect	50-55	90-110
PA 321	erect - semi-erect	45-50	90-110
PAN 325	erect - semi-erect	50-55	100-110
PAN 326	erect semi-erect	50-55	100-110
Rhino	erect semi-erect	45-55	100

6. Irrigation

It is important that over-irrigation and over-fertilisation must be avoided since too much vegetative growth of plants will occur which reduces grain production.

The cowpea has a deep taproot, deeper than groundnuts, mungbeans and soybeans. Soil water can be utilised at a depth that exceed 120cm and therefore the cowpea is considered to be drought tolerant. Because the crop is drought tolerant it requires less irrigation than other vegetable crops. For optimum production the plant must however never experience severe drought conditions.

The principle with application of irrigation is that the soil should never be allowed to dry out. This is of critical importance from planting until the plants have emerged and become well-established, in order to achieve a good stand. The top 30-40 mm of the soil, in which the seeds are planted and the early root development occurs, may dry out rapidly under hot conditions, especially if ridge planting is used. Frequent light irrigations may be necessary, even though the lower soil layers have enough soil water.

The following guidelines apply:

- Irrigation requirements of cowpea types with determinate grown habit decline rapidly and considerably after the flowering stage

- Indeterminate growth will use more irrigation water over a longer time

Table 2 indicates the approximate amount of irrigation water required for different climate regions. Effective rain indicates the contribution to total water requirement of the crop that rainfall could make under average irrigation management.

Peak requirement is the amount of irrigation water that a crop requires during the month of highest requirement.

Consult an irrigation specialist for specific irrigation advice.

Table 4. Approximate irrigation requirements of cowpeas planted in different climate regions on a loam soil under a centre pivot

Area	Seasonal rain (mm)	Effective rain (mm)	Irrigation requirement (mm)	Peak requirement (mm)
Dry, cold, summer rain, (Karoo), 15 Nov, peak Jan	120	105	370	175
Dry, cold, winter rain, 15 Nov, peak Jan	26	13	486	219
Dry, hot, west, (North Cape), 15 Dec, peak Feb	155	101	466	174
Dry, hot, east, (dry Bushveld), 15 Dec, peak Feb	288	195	289	199
Humid, hot summers, (wet Lowveld), 15 Dec, peak Feb	439	209	96	32
Humid, warm summers, summer rain, (Highveld), 15 Nov, peak Jan	301	210	215	101
Humid, warm summers, winter rain, 15 Nov, peak Jan	69	49	417	198

7. Weed control

A weed-free seedbed followed by weed control for the first 6-8 weeks after planting is crucial. Chemicals can be used, but the traditional mixed or intercropping poses a problem and therefore hand-hoeing is usually applied. Only a few herbicides are registered for the use on cowpeas. A pre-plant herbicide for the control of annual grasses and certain broadleaf weeds can be applied three weeks before planting.

8. Insects and diseases

Root-knot nematodes pose serious problems and although nematicides can be used, crop rotation with crops not susceptible offers the best long-term solutions.

Nectar glands of the flower bases make cowpeas very attractive to many insects. The most harmful insects are aphids and flowering pod- and seed-eating insects. Leaf eating insects threaten the vegetative growth. Chemical control can be applied only if the crop and its production is harmed. Intercropping has the advantage that the movement of the insects are restricted by the taller growing grain crops like maize, millet and sorghum.

There have been 12 viruses on cowpeas in South Africa identified which pose a serious threat to production in the first few weeks after emergence. The major fungus and bacterial diseases experienced are seedling damping-off (*Fusarium spp* and others), *Antrachnose spp*., brown blotch (*Colletotrichum spp.)* and *Altenaria* blight that can be prevalent during humid conditions. A disease like brown blotch can reduce seed yields by as much as 80%, while *Antrachnose* can reduce the yield by 50%.

The best control of these diseases is achieved by using varieties that are disease resistant or at least tolerant and the application of intercropping where the transmission of viral diseases can be restricted.

9. Harvesting

Harvesting starts when about 95% of the pods have dried off. During wet weather it is advantageous to postpone harvesting. To prevent seed losses as a result of the dehisce of pods, cowpeas are cut early in the morning and then threshed by hand or machines later during the day when they have dried off.

References

1) Coertse, AF & Venter, S., 1996. Indigenous seed crops A3: Cowpeas ARC, Roodeplaat Vegetable and Ornamental Plant Institute, Pretoria.

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