CROP PRODUCTION

Photograph by Marina Coetzee

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Table of Contents

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Preface

It is with great pleasure, gratitude and pride that the JPC presents this production manual.

After years of deliberations, careful planning, and a lot of dedication the NAMIBIA AGRICULTURAL UNION and the NAMIBIA NATIONAL FARMERS' UNION jointly embarked on the EMERGING COMMERCIAL FARMERS' SUPPORT PROGRAMME. This programme resulted from the realisation that the new group of emerging commercial farmers who, having been previously disadvantaged and mostly coming from the background of communal farming, were in dire need of basic (sophisticated) skills training to manage modern farming techniques. The planning phase entailed, amongst others, a need assessment way back in 2004/5, which clearly identified the areas of assistance required. After having analysed all the relevant data, the two unions set about structuring a two-year programme which would address the challenges faced by new farmers so that ultimately they would be able to deal with the daunting task of becoming successful commercial farmers. Besides a dedicated programme of lectures, training courses, study tours and mentoring, it was decided to also produce and publish a set of eight PRODUCTION MANUALS which would serve as valuable training guides with technical details, but would also be a source of reference for future everyday practical farming in Namibia.

It is with gratitude that we acknowledge the unrelenting support of many individuals, too numerous to name, and certain institutions which supported and still support the whole Emerging Commercial Farmers' Support Programme.

We sincerely hope that this initiative will make a lasting contribution to sustainable agricultural land utilisation and to the goals of land reform in Namibia.

On behalf of the JPC,

Raimar Von Hase
(President, Namibia Agricultural Union)

Pintile Davids
(President, Namibia National Farmers Union)

Windhoek, December 2007

Foreword

Agriculture as the backbone of Namibia's economy has a major role to play in achieving Vision 2030. However, to be able to make a significant contribution towards the growth of the economy and thus wealth creation, agricultural production/output has to increase manifold. For the realisation of such an increase the following crucial issues have to be addressed. Subsistence farming should become commercialised, e.g. landownership in some form or other should be allocated to individuals, under-utilised areas should be developed and put into production and the problem of bush encroachment should be addressed and solved at national level.

Food production at competitive and affordable prices for the consumer is the biggest challenge that farmers worldwide have to face. With input costs increasing at a higher rate than the increase in prices realised for produce from the farm, it is clear that productivity and the production capacity on farms have to improve continuously. This also applies to Namibia's agricultural sector.

Furthermore, if we want to participate in international trade with our export commodities, which currently are beef, mutton, Karakul pelts and grapes, we have to be able to compete worldwide with all the countries exporting the same commodities. Apart from being price competitive we also have to be competitive in satisfying the needs of the sophisticated consumer in terms of quality, health issues, traceability, animal welfare and other ethical production norms, e.g. personnel management, conservation of biodiversity/ecology (fauna, flora and water resources), etc.

Agricultural production is no longer just a matter of producing whatever the farmer is able and willing to produce and then expecting to achieve good prices for the product.

Farmers have to become more involved in the value chain, and should become much more market orientated by being sensitive to the needs and preferences of the consumer whom they want to serve. In addition they have to adhere to international trading rules and regulations as prescribed by the World Trade Organisation (WTO), and also comply with the Sanitary and Phytosanitary (SPS) requirements of the various countries with which they want to trade. Norway, for instance, has a zero tolerance for salmonella in beef/mutton that is imported into that country, thus making it very difficult to serve this lucrative market.

It is obvious that survival and growth in the agricultural sector can only be achieved if the farmer in future pays ***greater attention*** *to the world around him, as has been the case in the past.*

Skills development and training of farmers and their employees are becoming imperative, and are of national interest.

Being a farmer and thus the owner of agricultural land in Namibia should be regarded as a privilege. Not every citizen in Namibia, as in countries all over the world, can own agricultural land. There is just not enough land. Therefore every farmer has a responsibility to use his piece of land in a productive but also a sustainable way. Productive means exploiting the full production potential of the farm, furthermore contributing towards job creation in the primary and secondary sector, towards food production on national and international level and towards revenue for Government in terms of taxes paid. Sustainable means preserving and even improving the production potential, so that the generations to come can still make a living from that land. It should be the aim of every landowner to leave behind a farm that is in a better condition than the one he started off with, including production capacity, infrastructure and natural resources, e.g. underground water, fauna (game) and flora (plants).

Commercial farmers in general are often perceived as being wealthy, which, however, is not the case. Becoming a successful farmer in Namibia may take years and even generations, and requires love for and dedication towards farming, hard work, good management skills, financial discipline, persistency and a positive attitude.

Climate (rainfall) and other external unforeseen events can have a major influence on the progress made on the farm, and can ruin achievements made over years within a matter of time.

To get an indication of the current gross/net income on a cattle farm, the following indicators could serve as a guideline.

The average stocking rate on cattle farms in Namibia is ± 25 kg biomass (live mass) per ha. In old terms this meant ± 14 ha for every animal on the farm. In a cow/ox production system the production of beef (live mass) should be about 35 % of the stocking rate.

This means that if no herd building takes place, the farmer has 25 kg x 35 % = 8,75 kg live mass/ha available for sale every year.

At an average selling price (cows, oxen, heifers combined) of N$9.00/kg live mass he/she would be able to generate a gross income of N$9.00 x 8,75 kg = N$78.75/ha (± N$80.00).

The operational costs will be at least around 50 % of the gross income, which leaves a net income of N$80.00 x 50 % = N$40.00/ha.

On a 5 000 ha cattle farm the gross income will thus be ± N$400 000 and the net income, if operational expenditure is well managed, ± N$200 000. This amount is available for interest and capital repayments (Agribank), new improvements/replacements on the farm and private expenditures.

These indicators clearly show that a 5 000 ha cattle farm will not enable a farmer to become wealthy overnight. To the contrary, for the sake of survival those farmers often either create additional income with employment elsewhere, or they venture into diversification on the farm e.g. guest farms, hunting, crop, hay, olive and charcoal production, etc.

It is advisable not to diversify as long as the main production line is not well managed and exploited to its full potential.

Although the commercial farmer functions in isolation on his property and to a great extent depends on himself concerning the day-to-day activities and progress on the farm, it is still important to establish and maintain good relationships with the neighbours. The control of stock theft and illegal hunting, predator control and the maintenance of border fences, etc., require good and open communication with and trust in the neighbours.

In conclusion, farming should be a constant process of learning. Even farmers with formal agricultural qualifications still have to keep in touch with the latest developments concerning farming practices, market requirements, consumer preferences, etc. It is advisable to make use of every opportunity to improve their own knowledge and skills, to enable them to adjust and therefore survive and prosper in an ever-changing world. Farmers' days, study groups and established successful farmers can be a good source of knowledge and new ideas and are often stimulation to creative thinking.

INTRODUCTION

Crop production is the oldest form of agricultural activity. It originated about 9 000 years ago on the banks of the Euphrates and the Tigris River where the first cereal grains are said to have been cultivated. Plant production is an exceptional art of utilising nature's gifts to the benefit of human beings and their environment. However, in Namibia this production line is challenged by a number of factors that need to be considered before the first spade can be picked up.

Markets

Although Namibian markets are undersupplied for most commodities, the biggest challenge to local crop producers is to identify and utilise the competitive advantage against imported goods. This is possible with the seasonal production cycle, as determined by the Namibian climate. South African producers produce for a much longer season and sometimes even all year round, thereby ensuring an almost continuous supply. This is why local dealers are reluctant to buy locally. Namibians will have to exploit the niches when, due to our warmer climate, we can produce a certain crop two or three weeks earlier (or even later) than our southern neighbours. Watermelons and grapes are good examples in this regard.

Long transportation distances

Most production requirements like seeds, fertiliser and equipment come from South Africa. These need to be transported over long distances to the production area from where the produce must again be transported back to the markets. Transport is expensive and so is the product that needs to be transported. The local market is limited and therefore it remains the crop producers' responsibility to scientifically investigate, develop and exploit new markets, locally as well as regionally and overseas.

High production costs

Long transportation distances have been mentioned. Another challenge is the high cost of energy – electricity and diesel fuel – in Namibia. Particularly the high-potential crop production areas of northeastern Namibia are far removed from almost everything. Scientifically proven low-cost production systems are the only answer to this problem.

Suitable dry land and GM (genetically modified) cultivars

High-production cultivars and hybrids are developed in South Africa for South African circumstances. These are used in Namibia as well because locally developed cultivars, which could possibly make a difference in our drier and warmer production areas, are still lacking. Another challenge is the investigation of the possible planting of seeds, which have been genetically modified. If this proves to be safe, Namibian producers could possibly save on losses due to pests and weeds, as well as on pesticides and herbicides. Presently there is a moratorium by the Government of Namibia on the use of GMO's in Namibia. Namibia therefore maintains a GMO-free status, until the Biosafety Act of 2006 (Act no 7 of 2006) and the regulations to support the Act, are implemented.

Before any investments are undertaken to purchase equipment or to prepare a piece of land for crop production, a few questions should be answered:

Do I have sufficient water to consider plant production?
Vegetables need up to 7 000 m^3 of water per hectare per plant cycle.

What do I want to produce – agronomic or horticultural products?
Rain-fed agronomy requires a long-term average of about 500 mm per season.

What kind of system would be appropriate?

- **Rain-fed agronomy in northern Namibia**
  This system ranges from small-scale, one to five hectare mahangu plots in the northern communal areas up to large-scale grain and cotton farms of several hundreds of hectares in the Otavi–Tsumeb–Grootfontein triangle. It is important to define a bench mark (a goal) of what the prospective farmer intends to achieve. This will determine the equipment he needs, whether it is an animal-drawn cultivator or a tractor and a plough with several ploughshares.
- **Irrigated horticulture**
  Irrigation in Namibia takes place mainly along the perennial rivers of Namibia as part of the Green Scheme Project, on the banks of some of our ephemeral rivers, like the Swakop and the Omaruru River or in the area of the Stampriet subartesian water carrier. In this case, the water must be shallow and plenty, otherwise any irrigation project is doomed to failure. The Hardap scheme, which places about 2 000 ha of mainly lucerne and grains under irrigation, is an exceptional and highly specific situation.
- **Irrigation under plastic tunnels**
  This is usually a relatively small but highly advanced and intensive production system. Surely, a very different approach would be considered if one compares this system with the targets of large-scale agronomy.

Other factors like the availability and quality of soils, soil depth, climatic circumstances, distance to markets, availability of storage facilities, electricity and other existing infrastructure determine the choice of production system.

After these have been investigated, it is important to define achievable targets, which could be the following:

- I would like to deliver a one-ton bakkie load of fresh vegetables to my closest village every Friday.
- I would like to put 50 ha maize under rain-fed production and I should achieve an average of 3 t/ha/year.
- I would like to become a member of the Green Scheme Project to produce export grapes of the best achievable quality.

Once these targets have been set, one should start studying the particular field of interest as thoroughly as possible. This manual should not be considered the alpha and omega of crop production. It would be impossible to include each and every available crop with all the different cultivars and varieties. It would be even more impossible to describe each and every agricultural implement that is available, but one should be able to find a few answers to burning questions. Furthermore, this manual will hopefully stimulate our interest to study more literature and eventually to save hundreds or even thousands of dollars in "school fees" just by using the knowledge others have made available to our upcoming farming community.

Remember one thing:

CROP PRODUCTION NEEDS A LOT OF WATER!

Good luck.

CHAPTER 1
Soil Science

After studying this chapter the reader should understand the following:

- the basic principles of plant nutrition and the difference between macronutrients and micronutrients;
- the major function of the most important nutrients and how deficiencies of particular nutrients are visible in the deficient plant;
- the principle of optimum soil values and the measurement of soil nutrients in ppm and mg/kg;
- the difference between acidity and alkalinity and the pH scale;
- the difference between silt, clay and sandy soils, and taking a soil sample for analysis by the soil laboratory.

1. Plant nutrient requirements

Plants are made up of more or less ninety different chemical elements. However, not all of these are important for the purpose of this chapter. Table 1 lists the sixteen most important elements in plant nutrition, which are called **essential elements**. The atmosphere provides the first three of these, and the others are provided by the soil. The following three, the **macronutrients**, are needed in large quantities and are also known as major or primary nutrients. The next three are known as **secondary nutrients**, as they are also needed in relatively large quantities (but less than the macronutrients). The last seven nutrients are only needed in very small quantities and are known as trace elements or **micronutrients**.

Table 1. The 16 essential nutrients for plant production

Provided by atmosphere	Chemical abbreviation
carbon oxygen hydrogen	C O H
Macronutrients	
nitrogen phosphorus potassium	N P K
Secondary nutrients	
calcium magnesium sulphur	Ca Mg S
Micronutrients	
iron copper zinc manganese boron molybdenum chlorine	Fe Cu Zn Mn B Mo Cl

An important distinction must be made between the total amount of nutrients present in the soil and the amount available to the plant. For many nutrients relatively large quantities may be present in the soil, but may be unavailable to the plant. Phosphorus, for example, may be present in large quantities as iron phosphate or aluminium phosphate, but as these compounds are virtually insoluble, the phosphorus is not available to the plant.

Some elements are easily transported by the plant from one of its parts to the other, while others cannot be moved once they are fixed to make up the structure of the plant. This is important, as poor, older plant leaves might be an indication of a deficiency of one or more transportable elements, while very poor, young leaves could be an indication of a deficiency of non-transportable elements.

Nitrogen is taken up by the plant, mostly in the form of nitrate. It plays a major role in the process of photosynthesis and is therefore important for plant growth. The most noticeable effect of nitrogen is the characteristic green colour of leaves. This element is able to move easily within the plant. Nitrogen deficiency is noticed in yellowish leaves.

Phosphorus is largely taken up in the form of phosphate and plays an important role in photosynthesis and plant growth. It is equally important for root development, respiration, flowering and fruit maturation. Phosphorus deficiency causes a purplish colouration at the seedling stage with later yellowing, stunted growth and delayed maturity. Only 25 % of all phosphorus added as fertiliser is taken up, the remainder is fixed in unavailable chemical compounds in the soil.

Potassium is not found in plant structures as such but only in cell fluids. It is essential in all cell metabolic processes and also in the opening and closing of leaf pores (stomata). Furthermore, this macronutrient plays a major role in root development and therefore in the uptake of other elements as well. Potassium affects both respiration and transpiration. It also promotes the synthesis and translocation of carbohydrates, strengthening of plant fibre and wall strength. A deficiency causes yellowing of leaf tips and margins.

Calcium forms part of the cell wall structure and is necessary for the growth of cell tissue. It increases the resistance of roots to toxic conditions in acid soils. A deficiency leads to malformation of the growing parts, but symptoms are seldom recognised in the field. Deficiencies are first visible in new and young leaves, due to the relative immobility of calcium in the plant.

Magnesium is crucial to the green colour of plant leaves, without which photosynthesis cannot take place. Shortages can be expected in sandy, acid soils. A deficiency causes discolouration and premature defoliation of the plants. The first deficiency symptoms occur in the older leaves.

Sulphur makes up a part of some amino acids, which build up proteins. It promotes the formation of chlorophyll (leaf green) as well as root nodules on legumes.

Iron plays a role in oxidation-reduction processes and in chlorophyll formation. It is found in enzymes and certain proteins. It is not very mobile in the plant. Deficiencies occur in alkaline soils.

Copper is found in seeds and growing parts of plants and plays a regulating role in certain plant processes, such as chlorophyll functions and the uptake of iron.

Zinc activates enzymes, regulates the pH of the cell solution, plays a role in chlorophyll and growth hormones and serves as a catalyst in certain plant reactions. Zinc deficiencies can be induced by high soil pH or high soil phosphorus levels. Deficiencies reduce the size, structure and development of plant cells. Zinc is not very mobile in plants.

Manganese plays a role in photosynthesis and in oxidation-reduction processes in the plant. It assists in the uptake of nitrates and enzyme activity. Manganese is not very mobile in the plant.

Boron is essential in pollination and the formation of flowers and fruits. It also plays a role in the uptake of other elements, the synthesis of proteins and in carbohydrate and water metabolism. Boron deficiency can be expected in leached sandy soils with extremely high or low pH values.

Molybdenum plays an important role in the process of photosynthesis as well as protein formation. Furthermore it is vital to nodule development for the functioning of nitrogen, fixing bacteria in the roots of legumes. Deficiency symptoms may occur in leached and acid soils.

Chlorine is responsible for regulating the osmotic pressure in plants. A deficiency gives a wilting appearance and “bronzing” of leaves.

2. Optimum soil values for a variety of crops

The soil content of any nutrient or element is expressed as **parts per million (ppm)**, which means the same as milligram per kilogram **(mg/kg)**. If the calcium content is, for example, 250 ppm, it means that 1 kilogram of soil contains 250 milligrams of calcium.

Phosphorus

Namibian soils are very poor in plant-available phosphorus with typical values of 1 to 5 ppm. It is almost invariably necessary to apply phosphorus when establishing a new crop. The phosphorus should be incorporated into the soil at the determined depth before planting the crops. Phosphorus is not very mobile in soil and subsequent applications should also be applied as close to the roots as possible. If there is too much calcium in the soil one should use mono-ammonium phosphate or di-ammonium phosphate rather than superphosphate as a source of phosphate.

Calcium, magnesium and potassium

Most Namibian soils have more than enough calcium, but may lack magnesium and potassium. These can be applied in the form of dolomitic lime or magnesium sulphate, and potassium chloride, sulphate or nitrate. Apart from the absolute concentrations of soil nutrients, their relative proportions are also important. It may turn out that the soil has enough magnesium and potassium in absolute terms, but the calcium concentration is so high that it interferes with the plant’s assimilation of these nutrients.

Table 2. Optimum soil phosphorus, potassium, calcium and magnesium values for a variety of crops in ppm.

Crop	Phosphate (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)
Grains	15–35	80–160	300–2000	80–300
Vegetables	40–90	120–140	400–2500	100–400
Potatoes	40–90	120–140	400–2500	100–400
Citrus	30–60	200–500		
Bananas	30–60	120–300		
Avocados	30–60	150–120		
Mangoes	60–120	80–200		
Pecan nuts	25–45	70–150		
Macadamia nuts	25–45	60–160		
Granadillas	25–45	200–320		
Coffee	25–45	80–200		
Litchis	15–30	60–120		
Pineapples	15–30	250–300		

3. Acidity and pH

Soils can be acid or alkaline. Soils in the higher rainfall areas (above 600 mm per year) would rather develop acid characteristics, while alkaline soils occur largely in the lower rainfall areas. This would be the common tendency but it is not always the case as more factors, other than rainfall, might determine soil pH. The soil pH expresses the degree of soil acidity on a scale from 1 (highest acidity) through 7 (neutrality) to 14 (highest alkalinity) as indicated in Figure 1.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ACIDIC					NEUTRAL			ALKALINE					

Figure 1: The pH scale *(© Ministry of Agriculture, Water and Rural Development. 1996)*

Soil pH is of utmost importance in plant growth as it influences nutrient availability, toxicities and the activity of soil organisms. Acidification of soils results in a gradual decline in yields. Some plants are tolerant to acidic soils, e.g. rice and tea, but most of them grow better in neutral or slightly alkaline soils. The level of acidity that plants can tolerate is influenced by the supply of available nutrients and moisture.

If the pH is too low, i.e. the soil is too acidic, lime could be applied under irrigation circumstances. With dry-land production, this investment is not worth it and one should rather find a crop that tolerates the low pH. If the pH is too high, i.e. the soil is too alkaline, acidifying fertilisers such as ammonium sulphate, ammonium nitrate, MAP or acidifying improvers such as compost made of pine needles should be applied.

4. Salinity and alkalinity – sodicity

Soluble salts are found in all soils and natural waters. However, sometimes these salts accumulate in soils to such an extent that they can impair proper plant growth. Salts accumulate in soils largely as a result of infiltration of the runoff of irrigation water, together with evapotranspiration, which concentrates these waters. The salts are mainly chlorides, bicarbonates, sulphates of sodium, potassium, calcium and magnesium.

The salt concentration of soils is measured by electric conductivity (EC) and the unit with which the EC is expressed in soil analysis results is mS/cm (millisiemens per centimetre).

Alkaline (sodic) soils are associated with high sodium content and a high pH in the absence of surplus soluble salts. The EC is generally less than 4 mS/cm and the pH is 8,5 or more.

Plant growth is negatively affected by sodic conditions because of :

- high pH that leads to nutritional imbalances;
- toxicity of specific ions such as carbonates, sodium and molybdenum; and
- poor drainage and aeration because of the soil forming a crust.

Reclamation of sodic soils essentially requires extensive leaching of the sodium salts in the soil and replacing these with calcium salts like gypsum or acidifying agents like sulphuric acid or iron sulphate. Manure or compost will improve the soil structure and therefore the tolerance of crops to sodic soils will be improved due to better aeration as well.

Under dry-land conditions it is advisable to opt for a crop that can tolerate the given soil conditions rather than try to change the soil. Rather opt not to plant at all.

5. Soil texture

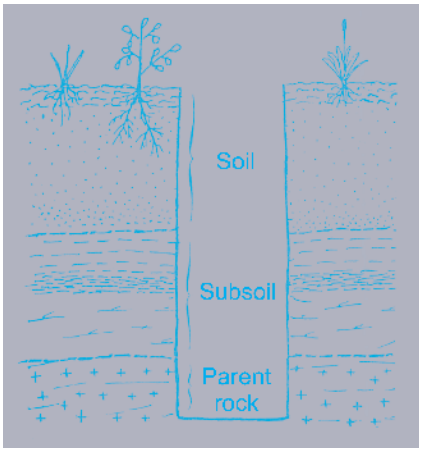


Figure 2: Soil texture *(© Ministry of Agriculture, Water and Rural Development. 1996)*

Soil particles are initially divided into two sizes: those larger than 2 mm in diameter, usually called gravel, and those smaller than 2 mm in diameter, called fine earth. Soil texture can be defined as the relative proportions of sand, silt and clay within the fine earth.

Sand particles can be seen individually with the naked eye. Sandy soils are well aerated and have good drainage, but will not hold water or nutrients very well.

Silt particles can be seen by using a microscope. Silt contains less silica than sand and has better nutrient-holding characteristics than sand.

Clay particles can only be seen by using a microscope. Clay particles (or colloids) are important because they can hold nutrients on their surface in a form which is readily available to plants. They can also hold water better than sand. On the negative side, clay soils have a tendency to become waterlogged in the rainy season, causing poor aeration and subsequently, poor root development. Clay is sticky when wet and may form very hard clods when dry.

Sand, silt and clay percentages are obtained by carrying out a particle size analysis of a sample in the laboratory.

Farmers often describe clay soils as “heavy” and sandy soils as “light”. This does not refer to their weight, but to their ease of working. A heavy soil requires much more effort to cultivate than a light soil. Medium textured soils (such as loam, clay loam, sandy clay loam, silty clay loam, sandy loam and silt loam) are best for most plants. Organic matter (compost and kraal manure) should be incorporated into the soil to improve the soil texture.

6. Soil fertility evaluation

6.1 Soil sampling

The analysis is no better than the sample. This means that sampling must be done very carefully to ensure that the sample taken is typical of what it is meant to represent. Nowadays, laboratory procedures for soil analysis are relatively standardised and accurate, and the main source of error often comes from the initial sampling of the soil. No effort or careful laboratory work is of any use at all if the sample is not properly taken.

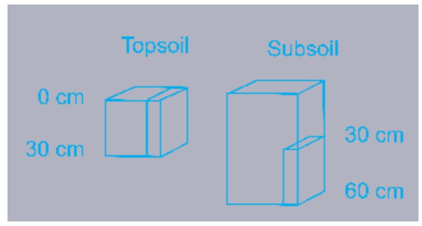


Figure 3: Soil sampling *(© Ministry of Agriculture, Water and Rural Development. 1996)*

The area to be sampled has to be fairly uniform as regards slope, drainage, soil colour and texture, and past history of cropping and fertiliser use. If a field includes obviously different areas it must be subdivided for sampling purposes. The soil is sampled from at least 10 to 20 sites per subdivision.

All these samples are then thoroughly mixed to form one big composite sample. Out of this big sample one representative sample of about 1 kg is taken and sent to the laboratory.

For sampling purposes, soil is generally subdivided into the topsoil (0-30 cm deep) and the subsoil (30-60 cm deep). For deep-rooted crops, a representative subsoil (which is once again a composite of 10 to 20 subsoil samples) should be taken and sent as such to the laboratory as well.

To describe the exact step-by-step procedures of soil sampling as required by the agricultural laboratory would be too long for the purpose of this manual, but it can be obtained directly from the laboratory at the following address:

ADDRESS OF THE AGRICULTURAL LABORATORY

Government Office Park
Private Bag 13184
WINDHOEK

Tel.: 061-202-2079 or 202-2080 (Soil Science)

6.2 Soil analysis interpretation and fertiliser application

Once a soil sample has been analysed by the agricultural laboratory in Windhoek, soil analysis results will be returned to the applicant. Depending on the request by the applicant, these will include the respective concentrations of individual nutrients in the soil as well as pH and soil texture percentages of sand, silt and clay. Only the features as indicated on the application form will be analysed.

As soon as the soil analysis results are available, fertiliser recommendations can be made. This is a highly specialised task, which requires a lot of experience and knowledge. In practice most farmers would be expected to consult experts before expensive fertilisers are purchased and applied in noticeable quantities.

CHAPTER 2
General Crop Production

The purpose of this chapter is to introduce the reader to the basics of crop production with the emphasis on horticulture. The reason for this is that many smallholders start their crop production with vegetables before they decide to go bigger. However, certain choices will have to be considered right from the beginning and this chapter should help the reader to make the following decisions:

- He should be supported to decide which crops to produce and which seeds to use.
- He should be able to choose the right site and to prepare the planting site properly.
- He should be able to differentiate between different fertilisers and their application.
- He should be well aware of the importance of intercropping and crop rotation.
- He will be supported to decide about the most appropriate irrigation system and when and how often to irrigate.
- He will be introduced to the important practices of proper packaging and storage of his produce.
- Finally he will be introduced to the different role-players in marketing, the principles of supply and demand (as major price regulator) as well as calculating profit-orientated price schedules.

1. Choosing which crop to grow

Besides the various grain crops like maize and pearl millet, there are several groups of vegetable crops to choose from. These are the following:

- **Leafy vegetables**
  Plants with edible leaves, e.g. cabbage, spinach and Swiss chard.
- **Fruit vegetables**
  Plants with edible fruit, e.g. tomatoes, peppers and melons.
- **Root vegetables**
  Plants that store food in their own roots or in their tubers underground, e.g. carrots, beetroot and sweet potatoes.
- **Legumes**
  Plants that produce pods with edible seeds, e.g. cowpeas and green beans.
- **Bulb vegetables**
  Plants that store food in swollen leaves at the base of their stem, e.g. onions.

It is advisable to grow crops from each group. It provides the farmer with a variety of products so that he will have something to eat and sell throughout the year.

2. Selection of seeds

Improved cultivars for most crops are widely available in Namibia. Most of the more expensive seeds on the market are hybrids with the following distinctive advantages above home-produced, open-pollinated seeds.

Hybrids usually:

- germinate better;
- produce a higher yield;
- have key resistance or tolerance to diseases and some insects; and
- possess other desirable characteristics such as better size, shape, colour, heat tolerance and resistance to injury during purchasing.

Seed companies are continuously improving varieties. Therefore the best variety to choose will change as time passes. Furthermore, companies generally do not guarantee the germination percentage of low-cost varieties.

It should generally be recognised that using the best seeds available is the wisest decision. Yields will, on average, be higher and costs of pest management should be lower. A higher marketable or consumable yield will make the extra expense of good seeds pay for itself.

3. Seedbed preparation and planting of crops

3.1 Seedbed preparation

A seedbed is a special area where the soil is carefully prepared to help the germination of seeds. The process of seedbed preparation is called tillage. Young plants grow best in soil that has been broken up into small crumbs; such soil is described as having a fine tilth. In a seedbed, it is possible to carefully control the depth of and distance between seeds.

A seedbed should be deep, even and firm. The objectives of tillage are:

- to modify the soil structure. A granular structure is desirable to allow rapid infiltration and good retention of rainfall, whereas finer particles are considered advantageous in the vicinity of seeds;
- to control weeds;
- to incorporate plant residues into the soil;
- to minimise soil erosion by following practices like contour tillage and proper placement of plant residues;
- to establish specific surface configurations for planting, irrigation, drainage and harvesting operations;
- to incorporate and mix fertilisers and pesticides into the soil.

Tillage operations are classified as **primary** and **secondary** tillage. Implements used for this purpose can be divided into primary and secondary implements. **Primary implements** are basic implements used to loosen the soil and sometimes inverting it with the objective of improving structure and countering compaction. These implements include mouldboard ploughs, disc ploughs, chisel ploughs and rippers.

Secondary implements include cultivators, discs and harrows, and are used for the final seedbed preparation, weed control and breaking of surface crusts.

In recent years there has been an increasing interest in minimum-tillage systems as a means of reducing row-crop production costs and minimising soil compaction by repeated heavy tractor driving on the field. In some minimum-tillage systems, till-and-plant combination units follow ploughing, chiselling or other primary tillage, with narrow strips receiving shallow secondary tillage just ahead of the planter. Other types of combination units perform zone or strip tillage just ahead of the planters in untilled soil or in soil that was ploughed during the previous fall. Several arrangements of combination units that will perform minimum-tillage and planting operations are commercially available.

Primary tillage implements

(© Alibaba.com)

Mouldboard plough

This implement is used to turn soil up to 300 mm deep and is particularly useful in heavier soils. The mouldboard plough is not recommended for sandy soil, because the already poor soil structure may be destroyed, which again promotes wind erosion.

(© Andrag)

Chisel plough

Chisel ploughs are used to loosen soil to a limited depth of 250 mm. Mainly recommended for relatively dry and sandy soils.

(© Alibaba.com)

Disc plough

The disc plough has a slicing action with the main advantage that better water penetration is obtained. It is also very effective on land with large amounts of plant residues, because it promotes rapid breakdown of soil structure. This implement is therefore useful for hard, dry soils but not recommended for sandy soils.

(© Andrag)

Ripper plough

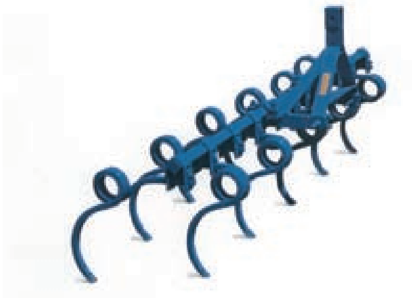
Rippers are used when deep cultivation of up to 400 mm is necessary and turning of the soil is undesirable. If soils are tilled annually to the same depth, a plough-sole develops. This compacted layer prevents infiltration and root development. To ensure better drainage and utilisation of water, it is essential to break this layer regularly.

Secondary tillage implements

Secondary tillage implements include a variety of implements like cultivators and harrows.

Harrows are mainly used to level the seed-bed and for breaking larger surface crusts.

(© Wikipedia.com)



(© Andrag)

Cultivators are mainly used to control young weeds but are also used for breaking surface crusts. The tilling depth is seldom more than 100 mm. These implements are only effective for moist soils and are often used for seedbed preparation.

3.2 Sowing of crops directly in the field

Crop planting operations may involve placing seeds or tubers (such as potatoes) in the soil at a predetermined depth. This can be done by hand or with machines. With appropriate planting equipment, seeds may be distributed according to any of the following methods or patterns:

- Broadcasting (random scattering of seeds over the surface of the field).
- Drill seeding (random dropping and covering of seeds in furrows to give definite rows).
- Precision planting (accurate placing of single seeds at approximately equal intervals in rows).
- Hill dropping (placing groups of seeds at approximately equal intervals in rows).

Planting may be done on the flat surface of a field, in furrows or in beds, as illustrated below. **Furrow planting** is widely practised under semiarid conditions for row crops such as maize and mahangu. This method places the seed in moist soil and protects the young plants from wind and blowing soils. **Bed planting** is often practised in high-rainfall areas to improve surface drainage. **Flat planting** generally predominates where natural moisture conditions are favourable.

A variation of bed planting provides a flat plateau, perhaps 7,5 cm high and 25 cm wide in the bottom of the furrow. Bed planting is common for certain types of row crops in irrigated areas. With closely spaced row crops such as sugar beet, lettuce and other vegetables, two or more rows are sometimes planted close together in a single bed, thereby leaving more width in the spaces between beds for the operation of equipment.

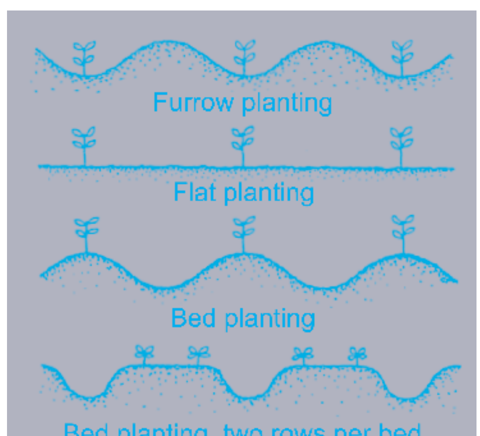


Figure 4: Surface profiles for row-crop planting
(© Kepner, R.A., Bainer, R. and Barger, E.L. 1978)

4. Nursery site selection, sowing and transplanting

The stage between sowing and the appearance of the first true leaves is crucial and many seedlings are lost if conditions are not favourable. Many crops are sown directly in the field of production as described above, while others are sown in **nursery beds** and transplanted to the garden later on.

The following table shows which crops should be sown in nurseries and which should be sown directly in the garden or field.

Table 3. Methods of sowing and sowing depth for some crops

Crop type	Crop	Sowing method		Sowing depth
		Nursery	Direct	
1. Leafy	Cabbage	x		1 cm
	Cauliflower	x		1 cm
	Onions	x		1 cm
2. Root	Carrots		x	1 cm
	Beetroot		x	2–3 cm
	Potatoes		x	7–10 cm
	Sweet potatoes		x	cuttings
3. Fruit	Tomatoes	x		1 cm
	Peppers	x		1 cm
	Eggplant	x		1 cm
	Swiss chard		x	2 cm
	Pumpkins		x	3–4 cm
	Melons		x	2–3 cm
4. Legume	Beans		x	5 cm
	Peas		x	5 cm
	Cowpeas		x	3 cm
5. No group	Maize		x	4–5 cm
	Local vegetables		x	1 cm

For crops that are sown in nursery beds and then transplanted, a nursery should:

- have good soil, improved with compost, kraal manure and inorganic fertilisers;
- have a reliable water supply (small nurseries can be watered with a watering can);
- have shade netting or a home-made shade roof;
- be close enough to the garden that transportation of seedlings will be easy.

4.1 Preparation of nursery beds

There are many methods of preparing a seedbed for the nursery, but the following are recommended:

- The seedbeds should be dug very deep with a spade. Fork the ground over lightly to break the big lumps of soil.
- Raise the level of the seedbed by about 20 cm. This is done by taking soil from around the seedbed, leaving a small trench. Raising the beds improves drainage.
- Make the seed bed about 1 m x 1,5 m, so that one can easily reach the middle.

- Organic matter and inorganic fertiliser should be added. Apply 60 g of compound fertiliser, (2:3:2) per square metre. Work the fertiliser into the upper 10 cm of the soil. The organic matter and the inorganic fertiliser will supply nutrients to the growing seedlings. Remove any large lumps of soil or stones.
- At this stage the seedbeds should be watered properly and two weeks should pass for weeds to emerge. If this waiting period is omitted, more weeding will be necessary while the seedlings are developing.
- Before sowing, the seedbed is raked carefully so that it is level and has a fine tilth. This ensures that seeds are in close contact with the soil particles that hold the water they need.

4.2 Sowing in nursery beds

- Make seed drills (or furrows) with a small stick. Use a tight line to keep them straight.
- The depth of the furrow should be about five (5) times the diameter of the seed to be sown (see Table 3 on the previous page).
- The distance between rows should not be more that 15 cm. This is enough because the seedlings will be transplanted before they are big enough to start shading each other.
- It is best to sow thinly with about 5 cm between each two seeds to ensure a good stand.
- Cover the seeds and press down the soil lightly by hand. A slight compaction may be needed in order to get good contact between soil and seed.
- Water the seedbed using a can with a fine nozzle or use a tin can with small holes pierced in the bottom. The soil should be kept humid at all times until the seeds have emerged. This usually means daily watering. When proper growth has begun, watering may be reduced.
- About three weeks after germination, excess seedlings should be removed to allow proper root development for the remaining well-spaced plants. Single plants are easier to transplant without damaging the root system.
- Keep the area around the seedbeds free of weeds, as weeds can be hosts of insect pests. It is anyway important to keep good watch for insects that can damage the seedlings overnight. Grasshoppers, cutworms and caterpillars should be picked off or sprayed if necessary.

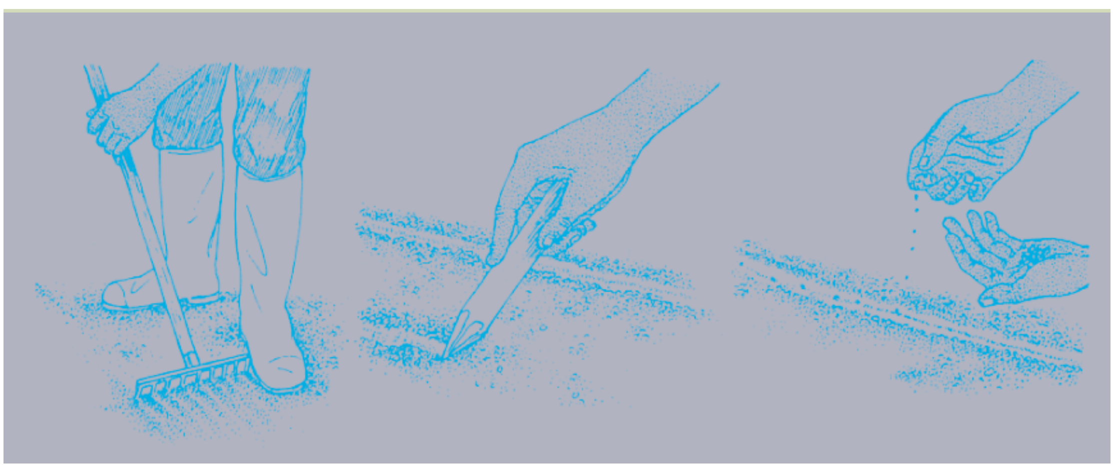


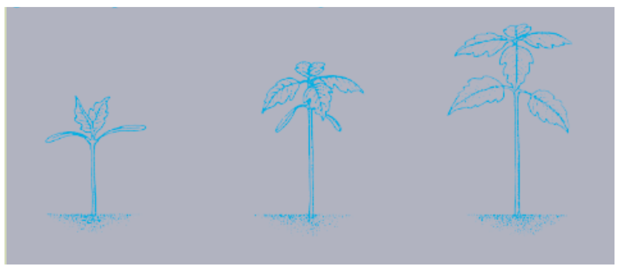
Figure 5: Sowing in nursery beds: Rake the soil, mark out drills, sow the seed carefully, lightly cover with earth and firm down
(© Ministry of Agriculture, Water and Rural Development. 1996)

4.3 Preparing the growing beds

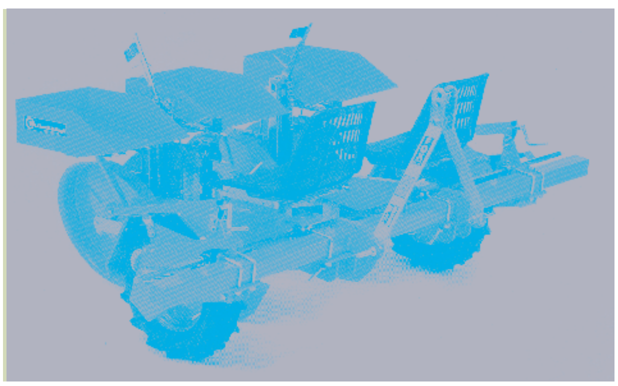
At least six weeks before transplanting prepare the beds as follows:

- Cut down the large weeds and put them on a compost heap.
- Spread manure or compost on the ground (about one wheelbarrow load to four square metres). This will improve the soil structure and make it more fertile.
- Apply lime if the soil needs it. This will depend on the soil pH determined through soil analysis. The lime will rectify the soil acidity, improve the soil structure and supply calcium. Remember that lime is a fine powder, so apply it when there is no wind.
- Dig the manure and the lime into the soil. Make sure that the manure and the lime are thoroughly covered.
- Try to bury smaller weeds at the same time. Turn them upside down into a trench. This kills the weeds and adds humus to the soil.
- After digging, leave the soil alone for a while. The manure will rot and the lime will start to work. Air and water can now penetrate easily. They are both needed for the growth of roots and of soil organisms. Soil water contains dissolved plant nutrients, which the roots absorb.

4.4 Hardening off and transplanting



The seed on the right is ready to plant



Mechanical transplanter for young plants
(© Checchi and Magli)

- A week before the plants are ready for transplanting, reduce the frequency of watering and shade in order to harden off the plants. This hardening off will reduce the transplanting shock.
- Transplanting must take place on a wet and cloudy day or late in the afternoon, for the seedlings to get a cool environment in which they can recover from the transplanting.
- Water the nursery beds some hours before the seedlings are dug out. This will soften the soil and give plants the opportunity to take up water before transplanting.
- Seedlings are carefully dug out of the soil one by one and placed in a basket or tray. They are then transported to the garden that is ready to receive them. Do not dig out too many seedlings at once, since they start wilting as soon as they have been dug out.
- Place one seedling in each planting hole. Follow the correct transplanting depth for each crop.
- Water the plants after transplanting. Provide a little shade for each plant if small branches are available. The seedlings must have some shade during the first week after transplanting. After about one week the shade must be removed.
- It is important to water regularly and keep good watch over the seedlings for the next few days, when the plants are in a delicate stage.

5. Increasing soil fertility

5.1 General soil fertility

Plants need many nutrients for good growth. Roots take up these elements from the soil water as soluble salts. A good farmer makes sure that plants have enough nutrients for the entire growth period. If one or more nutrients are missing, the plants will suffer or may even die. The elements needed are usually divided into two groups:

- major elements that are needed in large quantities; and
- trace elements that are required in very small quantities.

Major elements

The major elements are nitrogen (N), phosphorus (P) and potassium (K).

Nitrogen (N)
Nitrogen promotes vegetative growth and is essential in protein formation and photosynthesis. Nitrogen deficiency leads to slow growth and pale foliage. Too much nitrogen will give soft and excessively fast growth or delayed flowering and fruit setting. Nitrogen moves easily in soils and can therefore be leached by rain or irrigation water.

Phosphorus (P)
Phosphorus facilitates vigorous root formation. It is especially important, therefore, for vegetables that are transplanted. It speeds up crop maturity and does not easily move in soils.

Potassium (K)
Potassium is linked with nitrogen in several plant processes, including protein formation. Adequate supplies of potash are important for the growth of root and tuber crops. Potassium is very mobile in soils and is therefore easily leached.

Trace Elements

Important trace elements are boron (B), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), sulphur (S) and zinc (Zn).

These trace elements are required by plants in very small quantities. They are often available in clay soils but may have to be added in sandy soils. Some commercial fertilisers contain trace elements in addition to N, P and K. In such cases it will be indicated accordingly on the fertiliser bag. The trace elements can also be applied to plants separately through foliar sprays onto the plant leaves. The term "trace elements" only indicates the quantity needed. They are as important for the plant as the major elements.

Plant nutrients can come from five sources. These are the inherent soil fertility (fertility already present in the soil), manure (organic), compost (organic), inorganic (chemical) fertilisers and foliar sprays (trace elements).

5.2 Kraal manure

Kraal manure is very important for maintaining and improving soil fertility. Manure provides some food for plants, as it contains fair amounts of nitrogen, phosphorus, potassium and trace elements. However, these elements are sometimes in unbalanced ratios to each other and some additions might be necessary. It is a good idea to have the available kraal manure analysed in the agricultural laboratory from time to time for further recommendations.

Manure from cattle, donkeys, horses, chickens and pigs is well suited. Small stock manure (sheep and goats) should be excluded due to a high risk of containing nematodes. Even 30-year-old small stock dung can still contain nematodes, which are extremely harmful to the roots of most crops.

Kraal manure should:

- be broadcasted and worked into the soil before establishing a crop;
- not be used for root crops, as it promotes vegetative growth and disfigured roots;
- not be used near seedlings when it is fresh, because fumes of ammonia gas may scorch them.

5.3 Compost

Compost is a very important organic material. Composting is the process whereby plant residues, straw and other organic materials are partly decomposed before being dug into the soil. Composting happens everywhere in nature where materials decay, but placing compost on a heap can speed up the process.

It is difficult to produce enough compost for the fields, but farmers can always make enough compost for small vegetable gardens. Composting should be done under well-controlled conditions, preferably in a compost hole or on a compost heap. The process requires nitrogen, oxygen and water.

The heap is built with 30 cm thick layers of plant material, separated by thin layers of an activator, which usually is a nitrogen fertiliser or some manure. Lime or ash is sometimes added to reduce acidity. Do not use lime together with sulphate of ammonia as this may lead to nitrogen loss. Make sure to include enough moisture so that microorganisms can do their work.

The choice of plant materials will depend on what is easily available and on the activator. Most common materials are grass, lawn and hedge cuttings, cereal stalks, etc. The woodier the material, (mahangu stalks, etc.) the longer it will take to make the compost.

The better the compost is protected from drying out the better the end product will be. Place the compost in good shade to prevent overheating and drying out. It can even be covered with plastic sheeting, old fodder bags or a lot of raw plant material like grass. Remember to remove the seeds from perennial grasses or weeds before using them to prevent the spreading of unwanted weeds.

The heap should be turned over completely a few times during the composting period. Outer layers are thus placed in the centre so that they will decompose as well. The heap must be lightly watered during dry conditions.

After 10 to 20 weeks, the material should be ready for use in the garden.

5.4 Chemical fertilisers

Chemical fertilisers are also called inorganic or "artificial" fertilisers to differentiate them from manure and compost. The main function of chemical fertilisers is to provide major elements. However, they do not improve the soil condition as compost does. Manure and compost on the other hand, will not supply enough of the major elements for proper plant production.

Example of mechanical row planter and chemical applicator *(© Kuhn Metasa)*

Trace elements are usually applied directly on the plant leaves in the form of foliar sprays.

Nitrogen (N) fertilisers

- **Ammonium sulphate (21 % N)**
  Ammonium sulphate is a very common N-fertiliser. The nitrogen is in the ammonium form, which must be converted to nitrate before the plants can utilise it. Thus, the sulphate of ammonia reacts more slowly than other nitrogenous fertilisers. The 21 % refers to the total content of nitrogen in the fertiliser.

  If sulphate of ammonia is used regularly on the same land, it will increase soil acidity. This effect is used to reduce the soil pH in alkaline soils.

- **Limestone ammonium nitrate (LAN) (28 % N)**
  LAN is also called calcium ammonium nitrate (CAN) in some countries. Half of its nitrogen is in ammonium form; the other half is in nitrate form. This combines the fast reaction of nitrate with the slower and longer-lasting reaction of ammonium. LAN contains so much calcium that it does not acidify the soil. This makes limestone ammonium nitrate very useful in acidic soils.

- **Urea (46 % N)**
  Nitrogen in urea is available in the form of amide. It is as commonly available on the market as sulphate of ammonia. Sometimes, urea is cheaper than other nitrogen fertilisers. Urea is a very concentrated fertiliser and it can be difficult to apply it in the small quantities that are needed. Sometimes people mix it with dry sand in order to apply it evenly.

  Urea is usually available both as a crystal and as "prills". If prills are used, there is usually little danger of scorching the plant leaves, as the prills bounce off the plants and fall to the soil.

While the plants are growing, the basic fertiliser is often supplemented with some additional N-fertilisers. This fertiliser is placed in a line along the rows of plants and is called top dressing or side dressing.

Phosphate fertilisers

- **Superphosphate (10,5 % P)**
  In some literature, superphosphate (SSP) is mentioned with a content of 18 to 19% phosphate, but nowadays only the water-soluble content of 10,5 % is used. It is, however, still the same material.

  Superphosphate is made by treating raw rock phosphate with sulphuric acid to make it more water-soluble. As it contains about 50 % calcium sulphate (gypsum), it will normally not increase soil acidity.

- **Phosphate from bones**
  Bone meal can be used to provide phosphorus to plants. The bone meal is worked into the soil and will slowly release P to the plants.

Potassium fertilisers

Potassium fertilisers are seldom used in pure form because of the widespread use of compound fertilisers. They can, however, be used in advanced fertiliser programmes.

- **Nitrate of potash (KNO_3)**
  Nitrate of potash is readily available and is most commonly used when potassium is needed.

Compound fertilisers (NPK)

Compound fertilisers contain all the major elements, N, P and K, but do not contain trace elements unless it is specifically indicated on the bags.

- Compound fertilisers describe the ratio of nutrients in the sequence N:P:K. The total percentage of all nutrients added is given in brackets, for example 2:1:2 (26) has 10,4 % nitrogen, 5,2 % phosphorus and 10,4 % potassium. (The total content is 26 %, because 2 + 1 + 2 = 5, two fifths of the 26 % is nitrogen; $\frac{2}{5}$ x 26 = 10,4 %, etc.)

- For vegetable crops NPK 2:1:2, NPK 2:3:4 and NPK 2:3:2, should be used. Compound fertilisers are usually applied as a base dressing before planting or sowing. Later on, a side dressing or top dressing of nitrogen fertiliser is added. Due to leaching problems in sandy soils in Namibia, top dressing should often be given as a small amount, e.g. 4 to 5 times during the growing season.

- Mono ammonium phosphate (MAP) + Zn is a compound fertiliser of nitrogen, phosphate and zinc and is commonly used in Namibia.

Foliar sprays

Trace elements are usually applied to plants as foliar sprays. Before using trace elements, it is important to identify the lacking nutrients correctly. In some cases leaf symptoms are clear indications of nutrient deficiency, while in other cases one would need a laboratory test first.

The trace elements that are sold usually include copper, zinc, molybdenum, manganese, iron and boron. The instructions on the package should be followed carefully in order to achieve good results.

5.5 Intercropping and crop rotation

In vegetable production it is important to rotate crops. This means growing different crops on a certain piece of land every season. This is done for two reasons:

- Different crops are hosts to different insect pests, diseases and weeds. By changing crops every season, there is a lower risk of a build-up of insect pests, diseases and weeds on a particular piece of land.

- Different crops use different nutrients. By changing crops every season, depletion of certain nutrients from the soil is avoided. This is especially important where soil fertility is low; and little or no fertiliser is used.

> The following crop rotation list shows which crops belong to a certain group. Do not grow a crop from the same rotation group on the same piece of land the following season. Choose a crop from the next group. Once Group 4 is reached, go back to Group 1 and start again.

- **Group 1: Leafy vegetables**
  Cabbage, cauliflower, Chinese cabbage, broccoli, Brussels sprouts, kale, leeks and celery. These are heavy feeders. They must therefore have plenty of kraal manure, compost or inorganic fertilisers.

- **Group 2: Root vegetables**
  Carrots, beetroot, sweet potatoes, turnips, kohlrabi and onions. Manure should not be applied near to the planting time for these crops, as this often leads to the forking of roots. Similarly, if too much nitrogen fertiliser is applied, the crops may produce many leaves and fewer roots and tubers.

- **Group 3: Fruit vegetables**
  Tomatoes, potatoes, peppers, eggplant, lettuce and Swiss chard. Lettuce and Swiss chard are formally leafy vegetables but are placed here due to their sensitivity to nematodes, which is as high as that of the first four crops. Therefore vegetables in this group should not be planted consecutively into the same bed in subsequent seasons.

- **Group 4: Legumes**
  Beans, peas and cowpeas. Legumes are not very demanding as regards nutrient requirements. It is very important to know that legumes, due to a symbiotic coexistence with Rhizobium bacteria in their roots, have the ability to take nitrogen out of the air for their own use and also for crops planted together with them or in rotation the next year.

- **No group**
  Cucumbers, pumpkins, squashes, melons, watermelons, okra, sugar maize and radishes. These vegetables are not included in any group because they have few borne diseases. They can be used anywhere in the rotation as long as they are not grown in the same bed for more than one consecutive season.

Practical use of crop rotation

The easiest way to use crop rotation is to divide the garden into four equal plots and then grow one or more crops of each group in every plot. "No group" crops may be planted in beds outside the crop rotation or placed in the rotation beds as long as they are rotated every season. If cabbages were well fertilised with manure then carrots would not need to (and should not) be fertilised with manure if they are planted after the cabbage. Legumes like cowpeas are also not very demanding on nitrogen and would therefore not need to be fertilised with manure if planted after a well-fertilised tomato crop.

Below is an example showing a crop rotation plan for tomatoes, cabbage, carrots and cowpeas. The crops in this example are rotated anti-clockwise.

1st season	Leaf CABBAGE	Root CARROTS
	Legume COWPEAS	Fruit TOMATOES
2nd season	Root CARROTS	Fruit TOMATOES
	Leaf CABBAGE	Legume COWPEAS

6. Irrigation systems

Many different ways to irrigate fields have been developed and there is no "best" method for all soils, field sizes and crops. The best system at any location will be the one that:

- can adequately irrigate the fields without wasting water;
- the farmer can understand and use effectively;
- is reliable and can be rectified easily if something goes wrong.

Throughout the world, many irrigation schemes can never pay back the costs of their installation. For the inexperienced beginner it is therefore advisable to start small and cheap so that knowledge and experience are gained before making a big investment.

Site selection

In addition to soil fertility, depth and location in relation to market and homestead, there are a few more considerations:

- Water source
  The nearer the field is to the water source, the easier it will be to irrigate.
- Topography
  If the farmer will use a surface method of irrigation, a uniform, gently sloping site would be preferable. This can greatly reduce the preparation needed to make channels, beds, etc.
- Drainage
  The most important factor to be considered when choosing a site is that it should have good subsurface drainage. Installation of irrigation schemes without good drainage has been responsible for damaging large areas of good land throughout the world. The reason for this is that in hot countries with high evaporation rates, water tends to rise in the soil

to evaporate from the surface. This process can bring up large quantities of salts, which are deposited in the topsoil and reduce plant growth.

The only solution is to ensure that there is a net downward movement of water through the soil to wash down or leach the salts. Where there is inadequate drainage, applying extra water will cause the soil to become waterlogged and it will become unsuitable for crop production.

6.1 Manual

Watering manually with watering cans and hosepipes is best suited for small basins or beds so that water can infiltrate evenly across the bed. With widely spaced crops, a small basin can be prepared around each plant. Watering manually is, however, extremely labour-intensive and therefore unsuitable for larger fields.

6.2 Flood

Flood or surface irrigation systems are cheap and easy to construct but usually require a lot of water, particularly in sandy soils.

- **Basins or beds**
  A flat area of land surrounded by a bank to retain water. It is important that the area is completely level to ensure that the water is distributed evenly. An easy way to check that the basin is level is to fill it with water before planting. The water should distribute itself evenly over the whole area with no parts being deeper or shallower than others.

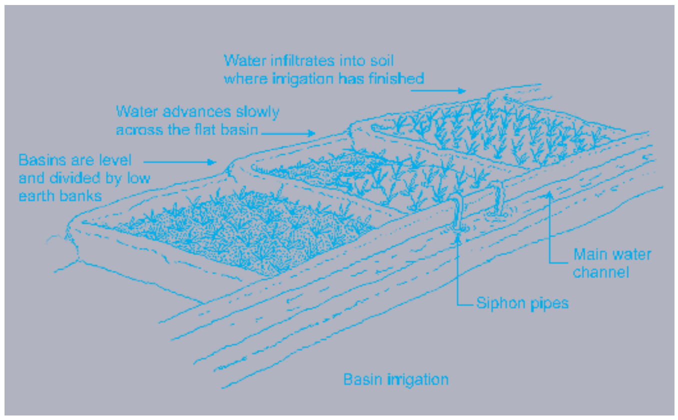


Figure 6: Basin or bed irrigation *(© Ministry of Agriculture, Water and Rural Development. 1996)*

- **Furrows**
  A ridge-and-furrow system can be prepared easily by using oxen or a tractor and ploughing equipment. It is an effective way to irrigate crops in rows on gently sloping land and reduces time needed for land preparation.

  Water flows into the furrow at the top of the slope and goes to the bottom end. The supply of water must be controlled so that water does not overflow at the bottom end of the furrow.

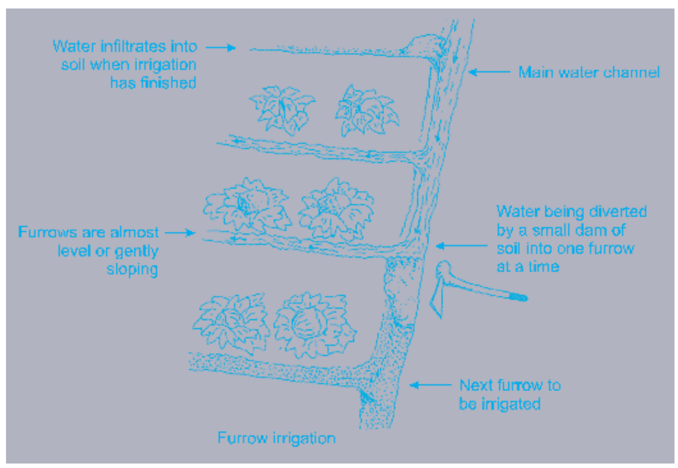


Figure 7: Furrow irrigation *(© Ministry of Agriculture, Water and Rural Development. 1996)*

  Crops are grown in rows on the tops or sides of the ridges, and the water infiltrates sideways and downwards into the soil during irrigation. The spacing of furrows can be matched to the spacing required by the crop.

In order to achieve good water distribution with surface irrigation, basins are restricted to a maximum of 50 m² (for example 5 m wide by 10 m long) and furrows to a maximum of 100 metres in length.

6.3 Sprinklers

Sprinklers apply water slowly over several hours and as the rate of application is slower than the rate of infiltration into the soil, there is less need for special land forming. Sprinklers must operate with pressurised water from a piped supply with a controlled pressure pump or from a high-up situated reservoir. This requires additional investments in terms of larger pumps and stronger pipes than required by other systems. However, due to its improved effectiveness compared to surface irrigation systems, this could be a worthwhile consideration for the more progressive farmer.

6.4 Drip irrigation

Drip irrigation is currently the most advanced irrigation method. Several different systems are available on the market. They are made up of various thin plastic pipes with extremely small holes, spaced at prescribed distances from each other over the length of the pipe. These holes can be 30 cm to 1 m apart. Water drips from each hole at pre-calculated rates to irrigate one or two individual plants at a time.

Drip irrigation systems are more expensive than other systems but can easily save up to 30 % water. Drip irrigation should therefore at all times be recommended in Namibia where farmers are able to afford them. This is the ideal system for a small start to gain experience if expansion is considered once reasonable success has been achieved.

7. Irrigation frequency and quantities

7.1 Crop water requirements

The amount of water that a plant needs is dependent on many factors: type of crop, age of crop, temperature, humidity, amount of direct sunlight and speed of wind. The amount is normally expressed as depth of water in units of mm/day and includes the amount used by the plant and that which evaporates from the soil around the plant. For any location it is possible to look at climate records and make an estimate of crop water use, e.g.

Table 4. Average amount of water used for vegetables in mm/day at different locations in Namibia

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rundu	5,0	4,1	4,4	4,0	3,5	2,8	3,1	4,0	5,0	5,8	5,4	5,3
Okahandja	6,3	6,1	4,8	4,0	3,6	2,9	3,3	4,3	5,3	6,6	6,5	7,0
Mariental	6,9	5,3	4,9	3,5	2,7	2,1	2,3	3,1	4,1	5,7	6,6	7,3
Keetmanshoop	8,7	6,6	6,2	4,8	4,1	3,5	3,8	4,9	5,8	7,7	8,4	9,2

These figures can be used as a guide for any crop in mid-season growing under normal weather conditions. The following situations, however, need to be taken into consideration:

- If the weather is unusually hot, windy or dry, the crop will use more water.
- If the weather is unusually cool, damp or cloudy, the crop will use less water.
- A young crop may use only half this amount of water.
- A maturing crop may use this amount multiplied by 1,25.

To calculate the volume of water needed in a field, use the following formula:

Volume (litres) = Depth (mm) x Area (m^2)

Example: In March a field of tomatoes 10 metres by 5 metres growing near Rundu needs 4,4 mm per day; so volume needed = 4,4 mm x 50 m^2 = 220 litres.

When using this method to calculate water requirements, it is advisable to make a small overestimation from the figures given above. This can account for errors in deciding whether you have "normal" weather and for losing some irrigation water due to leaks or inefficient application methods.

7.2 How often to irrigate

The roots of a plant need both water and air and will only grow properly if both are available. If the topsoil is always moist, most plants will spread roots laterally to use this water instead of developing deep roots. If water is not easily available in the topsoil, the roots will grow deeper in search of water. Dry-land crops and trees that grow well in Namibia are those that:

- develop deep roots to find water in the soil;
- are very efficient at absorbing water from the soil.

For healthy growth, vegetables can be encouraged to develop deep roots so that they can extract water from deeper layers of the soil. Some typical rooting depths of crops under optimal conditions are shown in Table 5.

Table 5. Typical root depths for some crops grown under optimal conditions

maize	1,0 m	tomatoes	1,2 m
beans	1,0 m	lettuce	0,3 m
cabbage	0,5 m	onions	0,3 m
carrots	0,4 m	potatoes	1,0 m
melons	1,2 m		

If crops grow in good, deep soil and do not develop fine roots to the depths shown above, it is probably a sign that water is applied too often.

Before watering, one can use the "sausage test" to check if watering is required. Dig down to the bottom of the root system. Take some soil from the bottom of the hole and squeeze it in your hands. If the soil stays together like a sausage after squeezing, the soil is still wet and watering is not yet required (see illustration). If the soil falls apart it is time to water. After watering, dig another hole and do the same test to see if the plants have received enough water.

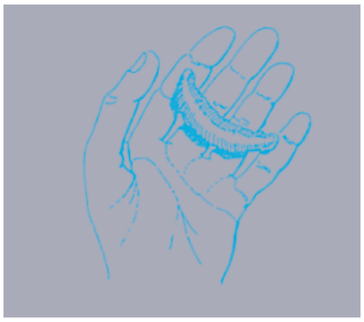


Figure 8: Sausage test
(© MAWRD. 1996)

Using the previous example, it is best to add up the 4,7 mm(or 235 litres) of water needed per day and water about once every three to four days. This will ensure that the water reaches the deeper soil layers without losing excessively to evaporation, which would have been the case if a little bit were supplied every day. On the other hand, only very little water is lost to the ground in unreachable, deep layers.

An additional benefit of deep watering is that the topsoil is allowed to dry between irrigations, which can interrupt the breeding cycles of many insects. Seedlings must, however, be irrigated every day.

7.3 When to irrigate

It is normally recommended to irrigate either early in the morning or late in the afternoon. There are two reasons for this:

- When water is applied so that the whole plant is wet, small drops can remain on the leaves for several hours. In bright sunlight, these drops can act as a magnifying glass and concentrate the heat of the sun, causing damage to leaves. This is mostly seen on cabbage plants.

- Evaporation rates are always highest in the middle of the day and a greater proportion of the water applied at this time will be lost to evaporation. If water is applied so that the whole plant is wet, the wet surface area is greatly increased and so the evaporative loss is much higher. One exception is tomatoes: a shower on the leaves during the hottest part of the day will decrease leaf temperature and increase growth.

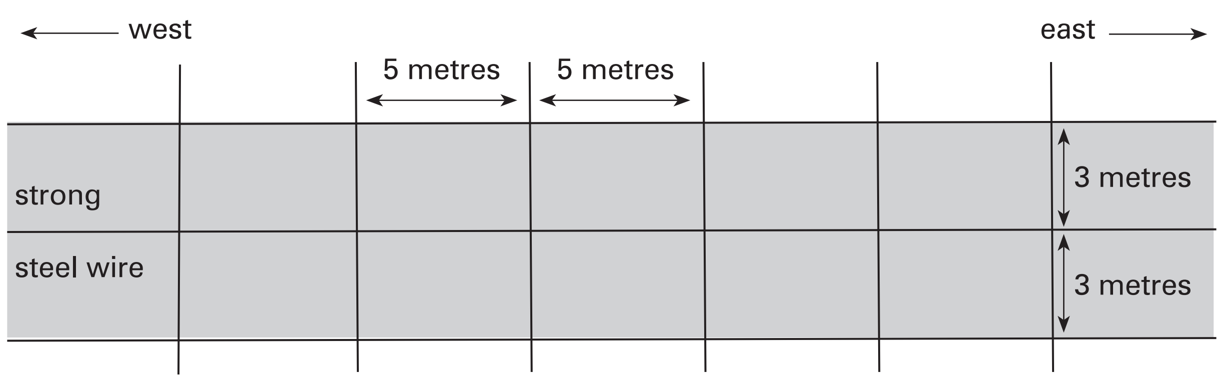
8. Shading vegetables

The climate in Namibia is often so warm that shade netting will increase the production of most vegetables. It is expensive to use shade netting over the entire garden, so it is advisable to use it over parts of the garden only. The quality of most seedlings and some crops, such as green pepper and Swiss chard, improves remarkably when grown under shade. Other crops, for instance onions and garlic, grow better without shade.

Shade netting is produced in many colours and qualities. For farming purposes, it is advisable to use 40 % shade cloth in green or black. A detailed drawing should be done before budgeting and ordering materials. A whole roll of shade netting measures 3 m x 50 m. Plan the nursery so that it fits the size of complete rolls of shade netting in order to avoid sewing the rolls together or cutting the material. Use special nylon twine for sewing the net to the construction. All other types of nylon string will wear down due to damage from sunlight.

Place the support poles so that they fit the double width of a roll, i.e. 6 m between poles across the nursery. Lengthwise, the distance between poles should be 5 m.

Consider the height of the "roof". Two metres is suitable to fix the shade netting but this is too low if an ordinary tractor is to be used under the netting. Make sure all supporting poles are properly anchored, so that wind will not damage the construction.



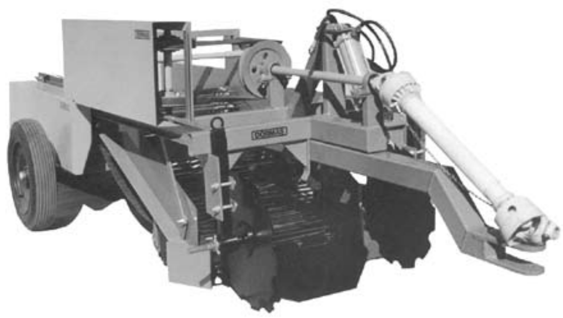
A well-illustrated leaflet on shade netting constructions can be obtained from the main importers in Namibia: *ALNET* or *Southern Cross Services*, Windhoek. They can also provide information on design and prices.

Other shading methods

Plastic shade netting is relatively expensive, but farmers can build their own small nurseries with a roof made of dry grass, reeds or other materials. One can also plant shade trees like leucaena (*wonderboom*) in rows or alleys. Spacing between rows should be approximately 6 m and the direction of rows should be north-south.

9. Harvesting, packaging and storage

Fresh fruit and vegetables are living tissues that continue to change after harvesting. Sometimes the changes are good, such as the ripening of bananas. But very often they are not desirable. The problem is that the changes cannot be stopped; they can only be slowed down. When a horticultural product is harvested it is cut off from its source of nutrition and water. Without them and considering the changes that continue to take place after harvesting it is difficult to keep the products in a good condition.



Mechanical potato harvester
(© Dormas)

Various harvested horticultural products are very different in shape and structure. Some are roots; others are stems, leaves, flowers or fruits. The needs of each are different after harvesting in order to keep them in the best possible condition. There are at least four important biological considerations in this regard:

- **Transpiration**
  Transpiration is evaporation of water from any plant. Fruit and vegetables are high in water content and will continue to transpire after harvesting in an attempt to keep themselves cool. During this process the plant will lose water (and weight) and will wilt and shrivel, which will give it a deteriorated appearance.

- **Respiration**
  Respiration is the process all living organisms use to produce energy for their own needs. It is natural for a plant part after it has been harvested, to continue to respire, thereby depleting its stored energy reserves like starch, sugars and fats. This is detrimental to the quality of the product. The solution is to keep the products cool in order to slow down this process as far as possible.

- **Diseases**
  Bacteria and fungi will attack, damage and destroy any fruit or vegetable after harvesting. Normally this process is remarkably faster at higher temperatures. The best solution once again would be to keep the products cool.

- **Ethylene**
  Ethylene is a gas that is produced naturally by all plants. It functions as a plant growth and ripening hormone and can artificially be used very effectively to ripen bananas, tomatoes and oranges in controlled ripening chambers. However, some vegetables are so sensitive to ethylene, that they should not be stored together with those that have a higher natural ethylene production. Table 6 indicates which groups of vegetables and fruit can be stored together due to their rate of ethylene production.

Table 6. Classification of some horticultural products according to their ethylene production rates

Class (ethylene production rate)	Product
Very low	Asparagus, cauliflower, citrus, grapes, strawberries, leafy vegetables, root vegetables, potatoes, most cut flowers
Low	Cucumbers, eggplant, okra, peppers, pineapples, pumpkins, water-melons
Moderate	Bananas, guavas, honeydew melons, mangoes, tomatoes
High	Apples, avocados, sweet melons, papayas, peaches, pears, plums
Very high	Passion fruit (granadillas)

Keeping sensitive products cool will help solve the problem to a large degree, but the bad effects of ethylene will continue at a slower rate.

9.1 Quality

People who consume fruit and vegetables regularly expect to get certain characteristics in the product they choose. Those characteristics together are called quality. An example will be helpful. A tomato of good or high quality that is ready to eat has:

- the colour (usually red) that people expect;
- the size they want;
- little or no disease, insects or other damage;
- the taste people want;
- the firmness, shape and internal colour they expect.

The desire of consumers must be taken as first priority. But others involved in the handling and marketing of horticultural products have needs as well. Shippers want products that are not damaged easily by handling. Retailers and wholesalers want products that last on the shelf for a long time. They also want products that appeal to their customers and will induce them to buy.

It is therefore the responsibility of the farmer to know what consumers, shippers, wholesalers and retailers want and then try to provide them with that quality. Sometimes it is difficult to provide that quality and at the same time grow varieties that produce well.

9.2 Maturity and ripeness

Maturity

Horticultural products should only be harvested when they are mature. That does not necessarily mean that they are ready to be eaten or used. That means that, even though they may not be ripe, they are ready for harvest. Mature means that the product has developed enough so that it will continue to develop or ripen even after harvesting until it is ready for use.

If the product is harvested before it is mature, it will not properly develop all the characteristics of quality that people want. Similarly, if the product is harvested too late, it will already have ripened and may even have gone past the proper stage of ripeness that people want. It is therefore, important to harvest at the right stage.

Ripeness

Ripeness means that the fruit or vegetable is ready for consumption or use. If it is also of a high quality, it has the characteristics that people want.

Horticultural products should be harvested after they have become mature but before they are ready for consumption. This is because:

- there is usually a delay between harvesting and consumption. The delay is caused by the time that is needed to grade, transport and sell the product. For home consumption, fruit can be left on the plant until they are ripe, because they will be used immediately.
- horticultural products are softer if they are already ripe. Handling or transporting them when they are soft causes more damage.
- horticultural products take longer to become rotten if they are harvested before they are ripe.

9.3 Handling and transportation

As mentioned earlier, people who consume fruit and vegetables want quality. It is essential that the producer and those who handle the products keep them in the best condition possible. The following are some guidelines for handling horticultural products:

- Do not drop or throw vegetables. A drop of even 10 or 15 centimetres can bruise a tomato, a mango or even a potato.
- Package horticultural products properly so that they do not bruise each other during transportation.
- Do not stack bags or containers of fruit or vegetables too high, as the products at the bottom will have to carry all the weight of those above. It is advisable to use containers that can be stacked without putting weight on the product. The weight should be carried by the sides of the container and not by the product itself.
- Do not overfill containers since this will cause pressure on the product or prevent the container from carrying the weight of the stack.
- Use a proper container that was designed for the particular product.
- Get the product to the market as quickly as possible to ensure the highest possible freshness.
- Remember the high ethylene production rates of tomatoes, melons and fruit. Do not package them together with leafy or root vegetables.
- Too much air movement around the products can cause them to lose water and, consequently, weight and appearance.

9.4 Cleaning and grading

Buyers of horticultural products are willing to pay more for high quality. Products presented for sale should therefore be clean and graded. When cleaning, dirt and damaged parts must be removed. Carrots, sweet potatoes, leafy vegetables, tomatoes, melons and cabbages can all be washed for short-term storage and sale. Do not wash products if they are to be stored for a long period. Wait until after storage to wash it.

It is important to establish a reputation for having good quality to achieve high prices and to encourage buyers to buy repeatedly. Therefore all farming products are graded. Grading is a process of sorting and classifying. Some products will be removed as culls because they are damaged, badly shaped or of the wrong size. Governments establish the criteria for grades, which are available from the Agronomic Board. It is highly recommendable for producers to acquaint themselves with the grading systems of their products in order to deliberately produce what the markets desire.

9.5 Cooling

After harvesting it is important to cool down the produce as soon as possible to delay the rotting process. If refrigeration is not available, the following precautionary measures should be taken to cool down the produce:

- **Use of cold water**
  The easiest way is to simply immerse the products in cool or cold water for a few minutes. This can, however, not be done with vegetables such as green beans, potatoes, carrots or onions.
- **Early morning harvesting**
  Harvesting before sunrise is the most effective way of ensuring a naturally cooled product.
- **Removal from the sun**
  If harvesting is done during the day, fruit and vegetables should all be removed from the sun immediately. Put them in the shade or in a cool building.

10. Marketing of produce

In agriculture, marketing begins on the farm with the planning of production to meet specific demands and market prospects. It includes the following steps that occur until the sale of fresh or processed products to consumers:

- The producer can **sell directly to consumers**. Consumers can come to the farm or the producer can take the produce to a market and sell it directly to the consumer.
- The producer may **sell to a wholesaler** who sells to retail markets, which sell to the consumer.
- Some farmers **use an agent or agency** to do the marketing.

The following are examples of marketing agencies:

- **Individuals**
  Private persons sometimes make a business of selling products for others.
- **Cooperatives**
  Farmers often make agreements with each other to establish an organisation that they own in a cooperative way (not as shareholders). Those doing the selling are usually employees.
- **Associations**
  Farmers may agree to share the duties of marketing among themselves. They charge themselves a fee to cover marketing costs like telephone costs, packaging and transport.
- **Companies**
  These are businesses that do the marketing for producers and charge a fee for their work.

10.1 Role of governments and marketing boards

In a free market economy, governments should not enter into the actual mechanics of marketing. They do, however, legislate the marketing board through direct representation by one or more government officials serving on its Board of Directors.

Marketing boards have the following powers and functions. They:

- set prices;
- set grading standards;
- regulate sales in markets;
- collect levies;
- advise government on promulgation of laws and by-laws;

- educate and train;
- collect and publish information concerning the specific product;
- promote the product to the public.

The Agronomic Board of Namibia has established a database of all agronomic producers concerning the type of crop and size of area regarding what is planted every year. This information is available to every farmer and should be used, particularly when one needs to take a decision of what to grow and when to plant.

10.2 Price fluctuations

It is very important for farmers to understand that it is normal for market prices to fluctuate from season to season or even from week to week. In the marketing world the reason for this is called the "changes of demand and supply".

Demand: **is the quantity of products buyers would like to buy at a reasonable price.**

Supply: **is the quantity of products sellers would like to sell at a reasonable price.**

If demand is high, i.e. if there are many interested buyers, the price will go up as long as the supply is smaller than or equal to the demand. As soon as everybody produces the specific crop, the markets might get oversupplied (or saturated) and prices will go down. A typical example is the supply of water-melons towards the end of each year. Normally the first water-melons on the market achieve very high prices but as the season proceeds and more and more water-melons reach the market, prices go down. Farmers eventually give them away at dumping prices. It is therefore a good idea to make sure to be the first or the very last one in the market with any particular product.

10.3 Estimating costs

Demand largely sets the highest price that producers can charge for their produce while producer costs set the minimum price to be asked. Producers want to charge a price that covers their costs of production, distribution and marketing, and include a fair return (profit) for their efforts.

Types of costs:

- Fixed costs
  Fixed costs are costs that do not vary with production. That means they have to be paid irrespective of the production level. An example would be the repayment of the farm purchase loan. Agribank must be paid, whether one plants a crop or not.
- Variable costs
  Variable costs vary directly with the level of production. As production goes up, the costs go up as well; e.g. more water must be pumped as more land is being irrigated.
- Total costs
  Total costs are the total of variable costs plus fixed costs for any given level of production. For sound business, producers should charge prices that will cover their total production costs plus a reasonable profit at a given level of production.

To achieve the highest price per unit you have to be either the first or the very last one in the market.

CHAPTER 3
Pest and Weed Control

The purpose of this chapter is to introduce the reader to the basic principles of pest and weed control and to present a few alternatives. After studying this chapter, the reader should be able to:

- choose the most appropriate way of pest control for his circumstances;
- select the most suitable application technique for the pesticide to be used;
- apply the relevant safety measures when working with pesticides;
- apply the necessary first aid treatment in case of pesticide poisoning;
- control weeds in an environment-friendly and sustainable way.

As soon as a farmer starts planting any crop, it will be either attacked by some pest or other, or a number of weeds will take advantage and compete for the improved soil and water conditions that the farmer has created for his/her little plant. As long as the cultivated land is relatively new and small, pest and weed control can in most cases be done by hand or by mechanical means. However, as the enterprise grows bigger, other methods become necessary, of which chemical control is often the last choice. Chemical control is expensive and – if not applied properly – can place a threat on people and on the environment as well as on animals that might feed on plant residues.

1. Pest management

1.1 Introduction

Good pest management practices should be aimed at reducing risks related to both pest and pesticide damage for pesticide users, foodstuffs, consumers and the environment.

Guiding principles

Always:

- try to manage pests in order to keep them from reaching damaging levels, instead of killing pests as well as natural enemies;
- try to apply pesticides in a way that will avoid pesticide resistance developing in the pest population.

This can be achieved by:

- changing between pesticide products of different groups or combining biological control methods with chemical control methods.
- never overdosing. Calculate the recommended doses for the specific spraying technique.
- improving the production methods using what is known as Integrated Pest Management.

> ***Integrated Pest Management (IPM)***
> *IPM is the integration of available techniques to reduce pest populations and maintain them below the levels that cause economic injury in a way that will avoid harmful side effects.*

Misuse of pesticides leads to:

- elimination of beneficial natural enemies. As a result of this, pest problems will increase continuously.
- resistance to pesticides. This leads to increasing the concentration of pesticides or loss of the control potential of pesticides.
- increased expenditure. Pesticides are expensive.
- illness or death. Pesticides are highly toxic. Residues of pesticides on produce also affect the health of consumers, damage the environment and contaminate water sources.

1.2 Main features of integrated pest management (IPM) instruments

The main groups of IPM instruments are the following:

- Cropping, cultivation and plant breeding methods
  Effect: Yield increases, pest pressure decreases, control measures become economically viable.
- Mechanical and physical control methods
  Effect: Yield stabilisation, risk reduction.
- Biological plant protection methods, natural insecticides
  Effect: Yield stabilisation, risk reduction.
- Chemical methods
  Effect: Yield stabilisation, risk reduction.

Cropping, cultivation and plant breeding methods

The right crop for the right site
Favourable environmental conditions like soil, climate and locality will promote healthy crop development and a lower sensitivity to insect pests.

Soil tillage
Soil tillage is a highly effective measure against soil-borne pests and pathogens. For instance, eggs of locusts and grasshoppers as well as a large variety of caterpillars are destroyed through tillage.

Choice of resistant varieties
It is important to choose crop varieties that are resistant to some of the local pests and diseases. Each variety has advantages and disadvantages. For risk reduction, choose a combination of different varieties.

Application of fertiliser to promote plant resistance
In general, well-nourished plants can more quickly pass through growing stages during which they are vulnerable to pests. Availability of potassium, especially, will enhance plant resistance.

Crop rotation
Since different crops are sensitive to different pests, a properly designed crop rotation system will contribute to prevent the build-up of soil-borne pathogens. The greater the variety of crops, the greater the stability of the field.

Harvesting date and method
Harvest as early as possible and shorten the time between harvesting and storage. Reduce the storage time to prevent storage pests from building up.

Trap and border crops
Insects show preferences for certain plants to hide or live in. This knowledge is used to control insect pests selectively with "trap plants" and to promote natural enemies. For instance, including some rows of tobacco or maize in a cotton field acts as a trap for African bollworms. The bollworms are then managed within the trap crops. In the same manner, the migration of armoured bush crickets can be controlled by selective spraying of the bushes surrounding the field where they rest during daytime.

Phytosanitary measures to reduce pest infestation
Crop residues help pests to survive unfavourable climatic conditions. By destroying crop residues, the African bollworm in cotton and the stem borer in maize and sorghum can be reduced considerably. By putting the crop residues together in heaps as feed for animals and by ploughing the leftovers after harvesting one destroys those niches. In vegetable production areas, the compost heap should be at least 30 m away from the fields to avoid "air-borne" fungi contamination through the wind. Check major wind direction before determining the compost-making spot. In order to avoid early contamination, never use residues of tomatoes, potatoes and cabbage to make compost.

Never use home-harvested seeds. They may already be contaminated with pathogens.

Mechanical and physical control methods

For resource-poor farmers and those whose crops are affected by low levels, mechanical methods are as a rule most effective. However, these are very labour-intensive and are recommended for small-scale farming only.

Physical collection and destroying of caterpillars, armyworms, armoured crickets and creeping locusts are relatively easy and should be done as soon as they are observed. Furthermore, the cutting and removal of afflicted plant parts can help to temporarily mitigate the infestation.

Biological control methods

Living organisms
Under biological control we understand the use of living organisms to reduce certain pests. Successful biological control has the following basic advantages over chemical methods:

- It is specific. The control measure is directed against only one pest.
- It is non-toxic.
- It is permanent where natural enemies are introduced.
- It is a financially attractive option. Only the initial costs are high.
- It is compatible even with chemical ones, provided a selective action of the chosen chemical is known.

Natural pesticides

The most common natural pesticide, a plant extract, can be made from the *Melia* tree (*Melia azedarach*) and/or the *Neem* tree. *Melia* (Cape syringa) is widespread in Namibia. The *Neem* tree has been established at several places at Ogongo College and Omahenene Research Station. In small vegetable production, neem or melia plant extracts are highly efficient.

Processing is as follows:

- Harvest the fruit in March. They should be slightly yellowish in colour.
- For the production of extract suspension, they should be dried and afterwards crushed in a mortar.
- Mix the crushed *Neem* or *Melia* fruit with water (500 g crushed seeds in 10 litres of water). Use the solution after 24 hours to control a large number of vegetable pests as well as armyworms and locusts.

Melia can be mixed with mahangu meal (10:1) as bait against the armoured cricket.

> *Melia (Melia azedarach) belongs to toxicity class III (Table 7, p. 44). For processing and application, one has to take appropriate protective measures. Neem has no human toxicity and can be used without any safety measures.*

Chemical control methods

The following steps should be taken before the application of pesticides:

Selecting the pesticide (or active ingredient):

- If and where possible, use an active ingredient which is selective to the main pest.
- Where the control measure needs to be repeated, change pesticides out of different groups for the replication to avoid pesticide resistance.
- Give preference to an active ingredient of lower toxicity over one of higher toxicity (LD 50 %).
- Select the active ingredient which breaks down fastest in soil and water.
- Observe the necessary preharvest interval.
- Check whether the pesticide has systemic (will be translocated to other parts of the plant) or contact effects, i.e. the killing effect is reached by contact, no ingestion is necessary.

Selecting the formulation:

- Determine where the pesticide should act (on the leaf, in the fruit, in the stem, in the soil), check what application equipment is available.
- Ascertain whether there are problems obtaining water.
- Find out whether granules can be used.

Selecting the application method:

- Decide how the application is to be carried out.
- Determine what concentration is necessary.
- Ascertain whether water application rate (high-volume spraying) or oil application (ultra-low volume spraying) is to be used.
- Check whether a spot-spraying method can be applied.

- Determine what application equipment is appropriate to given requirements.
- Ensure that the necessary care and maintenance can be guaranteed for the equipment to be used.
- Ensure that the necessary protective measures can be taken before, during and after application.

Selecting the time of spraying:

- Establish that the control threshold has been reached.
- Ensure that the pests are at their most vulnerable stage of development.
- Make sure that weather conditions are favourable.
- Select the appropriate time of the day.

1.3 Control threshold level for migratory pests

For most migratory pests, a "control threshold level" has been determined by the Ministry of Agriculture, Water and Forestry. In the case of locusts and armyworm, the number of individuals per square metre is to be counted and a decision is to be taken thereafter. In the case of Quela birds, the number of birds per 500 m^2 determines the need of control action. In most cases the damage is done by the pests after four days. Therefore immediate action is advisable. Agricultural Extension Officers should be able to assist with the mode of operation in case of migratory pests.

2. Criteria for choosing pesticides

2.1 Classification of pesticides by hazards

Toxicity values of formulated products are a guide to the toxic effects of pesticides on humans. The active ingredient (a.i.) toxicity does not reflect the hazard associated with exposure to the pesticide. An example may illustrate this:

The a.i. in a product may be categorised as "very toxic" to humans but presents a low to moderate hazard to the user due to low concentration and marketing as a solid formulation, e.g. granules, or low volatility. On the other hand, a product containing an a.i. with low toxicity may present an increased hazard for the user because it is marketed as a liquid formulation containing solvents that accelerate skin penetration.

The formulation together with the amount of the active ingredient of the product gives the right hazard level.

Table 7. Classification of pesticides by hazards

Toxicity Class (incl. Pictogram)	[c]**LD50 for the rat (mg/kg body mass)** harmful only by wrong use				**Poisoning Indicators** when wrongly used	
	Oral (mouth)		Dermal (skin)		Eye Effects	Skin Effects
	[a]Solids	[a]Liquids	[a]Solids	[a]Liquids		
Ia Extremely hazardous **VERY TOXIC** [b]*red coloured-coded band*	5 or less	20 or less	10 or less	40 or less	Corrosive cornea opacity not reversible in 7 days	Corrosive
Ib Highly hazardous **TOXIC** [b]*red colour-coded band*	5–50	20–200	10–100	40–400	Corrosive cornea opacity not reversible in 7 days	Corrosive
II Moderately hazardous **HARMFUL** [b]*yellow colour-coded band*	50–500	200–2000	100–1000	400–4000	Cornea opacity reversible in 7 days	Severe irritation for 72 hours
III Slightly hazardous **CAUTION** [b]*blue colour-coded band*	over 500	over 2000	over 1000	over 4000	No cornea opacity	Moderate irritation for 72 hours
IV Acute hazard **unlikely by normal use** [b]*green colour-coded band*	over 2000	over 3000			No irritation	Mild or slight irritation for 72 hours

[a] The terms "solids" and "liquids" refer to the physical state of the product of formulation being classified.
[b] A colour-coded band, stretching across at least the bottom of the sales panel of the label.
[c] LD50 = Measurement of the acute toxicity due to a single dose of exposure to chemical, oral (stomach uptake) , dermal (skin absorption) or through inhalation.

100 mg corresponds to a pinch; 1 mg corresponds to a drip; 2 g corresponds to a filled crown cork.

2.2 Classification of pesticides by formulation

A single active ingredient, the component of a pesticide that kills the target, is often sold in several kinds of formulations. One has to choose the formulation that will be best for each need.

The amount of active ingredient and its formulation is always listed on the label. For instance, a 50 WP (wettable powder) contains 50 % by weight of the active ingredient. Liquid formulations indicate the amount of active ingredient in gram per litre. For instance, a 300 EC means 300 gram per litre of active ingredient and the formulation is an emulsifiable concentrate.

When choosing a formulation, consider the following:

- The plant or surface to be protected. High pesticide concentration may lead to injuries on vegetation. This is specific to different types of plants.
- Application equipment available and best suited for the job.
- Hazard of drift and runoff.
- Safety to applicator, helpers or other humans or animals to be exposed.
- Habits and growth patterns of the pest (bait versus broadcast spray, granular versus foliar spray).
- Cost.
- Type of environment in which the application must be made (plant production, pasture, aquatic, forest, urban, etc).

Common formulations are as described in Table 8 below.

Table 8. Classification of pesticides by formulation

Suffix	Meaning	Description	Advantage	Disadvantage
EC or E	Emulsifiable concentrate	Liquid formulation containing the a.i. and an emulsifier to mix it with water.	• relatively low price • easy handling • little visible residues on fresh vegetables	• high concentration is easily overdosed or underdosed (phytotoxicity i.e. sensitivity to high pesticide concentration) • easily absorbed through the skin
WP or W	Wettable powder	The a.i. is combined with a finely ground carrier that enhances the ability of the powder to suspend in water.	• relatively low price • easy handling; lower phytotoxicity hazard than other liquid formulations (ECs) • easily measured and mixed • less skin and eye absorption than ECs	• inhalation hazard while pouring and mixing the powder • requires good and constant agitation in the spray tank • abrasive to pumps and nozzles
FL or F	Flowables	Liquid formulation consisting of a finely ground a.i., should be mixed with water.	• easy to handle and apply • seldom clogs nozzles	• requires moderate agitation • leaves visible residues
D	Dust	Low percentage of a.i. on a very fine dry inert carrier like talc or chalk. Ready to use.	• no water needed • simple application equipment (cotton sack with a stick)	• danger of drift • severe inhalation hazard
G	Granular	The a.i. is coated or absorbed onto coarse particles like clay, often used for soil application.	• ready to use, no mixing • poor drift hazard • simple application equipment	• doesn't stick to foliage • expensive • may need to be incorporated into soil • may need soil moisture
ULV	Ultra low volume concentrate	An oil-based liquid formulation which has to be applied with specialised equipment as is or diluted with a small amount of diesel oil. Designed to apply only ± 2 L/ha.	• mostly ready to use • no water is needed • less time-consuming application process	• wind condition should be stable • severe hazard of inhalation due to high concentration • expensive application equipment needed

3. Application techniques

With the term application techniques, reference is made to the techniques by which plant protection agents are applied. The exact dosages and distribution of the spray mixtures are as important for successful plant protection as the product itself, and as decisive as the right timing of its application. Mixing and application instructions are always written on the label of the product container and should be followed with great care.

Water as a vehicle

Water is not necessary for the biological action of a plant protection product. It serves only as a vehicle. Successful spraying depends on the ratio of water to the pesticide. Hence, if too much water is used, a large percentage of the product runs off the plant. It is also uneconomical to transport large amounts of water out into the field. New technologies allow the reduction of the need of large volumes of water per hectare effectively. Ultra-low volume equipment is quite effective in this regard. With this technology, water can be replaced by diesel as a vehicle, and the need for liquid per hectare can go down to two litres.

It is not the chemical that limits the success of the "less water technique" but the equipment available.

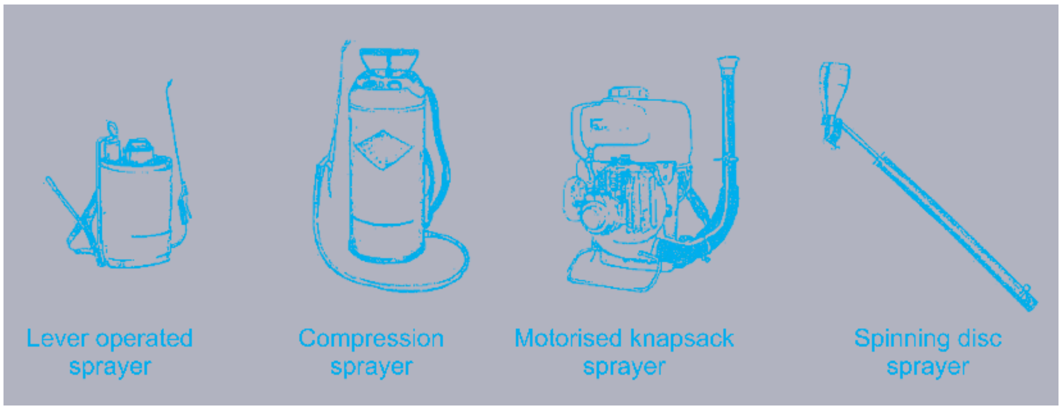


Figure 9: Hand sprayers for pesticide application *(© Ministry of Agriculture, Water and Rural Development. 1996)*

Characteristics of different hand sprayers

Lever-operated sprayer

Lever-operated sprayers are suited for low-volume (LV) and high-volume (HV) applications, but not for ultra-low volume (ULV) applications. They are often used in large orchards but are very well suited for the small-scale farmer too.

With lever-operated knapsack sprayers pressure is generated continuously during spraying by a manual pump action. An air chamber equalises the pressure to maintain a constant nozzle pressure supply.

Compression sprayers

The advantage of compression sprayers is that pumping is not necessary during spraying. This facilitates working on uneven terrain or with crops that must possibly be held with the other hand while spraying. Fill the sprayer not more than $^2/_3$ or up to the manufacturer's mark. Then pressurise it to (usually) 5 bar and commence spraying. Concerning volume application rates, compression sprayers fall into the same category as lever-operated sprayers. They are very well suited for small-scale farmers as well.

Motorised knapsack sprayer

Motorised knapsack sprayers are very well suited for LV and ULV applications. The engine drives a centrifugal blower which delivers a high-speed/low-volume air stream. A separate line from the tank feeds the spray liquid directly into the air outlet. In order to ensure sufficient breakup of the spray liquid into smaller particles (atomisation), the engine must always run at full throttle.

The advantage of motorised knapsack sprayers is that no pumping is required and trees can be treated very easily. The work rate is about five times higher with a suitable ULV attachment. With a good wind prevailing, the work rate is 20 times higher than with the two sprayers mentioned before. This makes motorised knapsack sprayers very useful for migratory pest control. A swath width of more than 20 m can be achieved. When held upwards, a swath of 50 m and a vertical throw of up to 10 m can be obtained. The application volume can be reduced to 2,5 L/ha by using undiluted ready-to-use oil-based ULV formulations.

For field crops, keep the air discharge tube slightly downwards. In order to avoid self-contamination, do not swing the air discharge tube left and right.

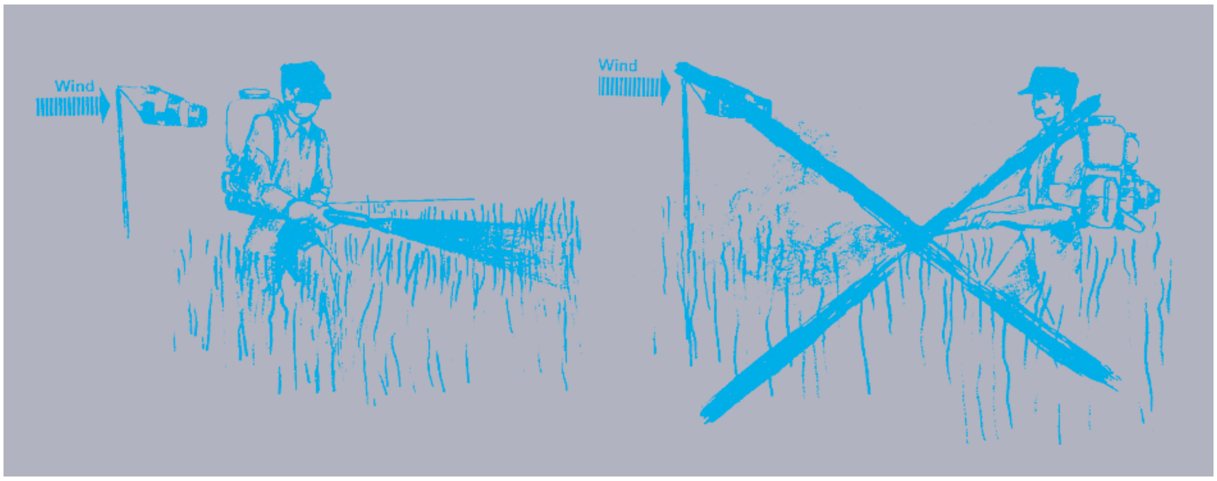


Figure 10: Correct use of pesticide sprayers
(© Ministry of Agriculture, Water and Rural Development. 1996)

- make use of crosswind condition
- do not spray without proper personal protection
- spray sideways
- do not spray upwind

Spinning disc sprayer

The volume applied per ha is only 1 to 5 L/ha of undiluted product. That is why they are also called Micro ULV Insecticide sprayers. The insecticide flows from the ½ litre product bottle onto the rotor or spinning disc, which is driven by an (6 torch battery operated) electric motor at a speed of 11 000 revolutions per minute. Wind is used to carry the spray droplets to the target. Minimum wind speed of 1 metre per second is required for effective spraying. According to wind speed and height of release, the point of their deposition can be predicted with reasonable accuracy.

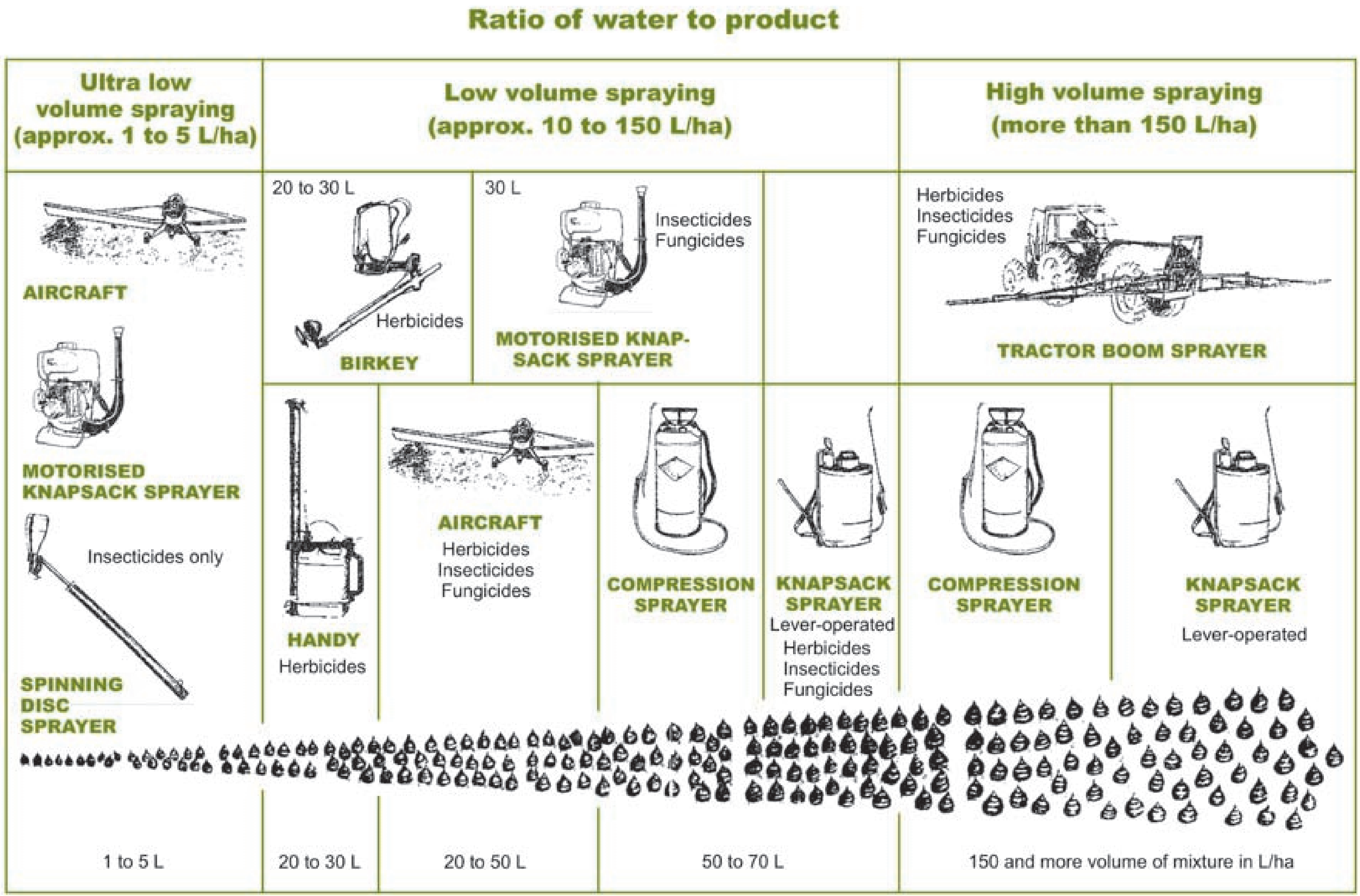


Figure 11: Classification of pesticide sprayers *(© Ministry of Agriculture, Water and Rural Development. 1996)*

4. Safety measures for pesticide application

4.1 Protective clothing

With the use of any pesticide protective clothing is a must. Remember, pesticides are toxic!

The following protective clothes are recommended, but these recommendations do not replace label instructions.

Overall	A thick cotton overall should be used by anyone who handles pesticides.
Boots	Boots made of latex with an outside PVC coating should be used by anyone who handles pesticides.
Gloves	Gloves made of Nitrile or Neoprene should be used by anyone who handles pesticides. Latex or PVC gloves are too porous.
Aprons	Aprons made of natural rubber and PVC coated rubber should be worn when cleaning spray equipment and when mixing and loading pesticides.
Respirator with gas/ vapour/dust filter	A respirator should be worn if this protection is specified on the label, if the product has to be applied in confined spaces (warehouses, silos, greenhouses), if preparing a spray mixture with volatile product in rooms, if applying a product as a mist, aerosol or dust, e.g. with mist blowers or spinning disc sprayers in irregular, windy conditions.
Mouth and nose mask	To avoid touching mouth and nose while handling pesticides a mask should cover the nose and mouth.
Goggles or face shield	The cornea is most sensitive for dermal take-up of pesticides; therefore goggles should always be worn while handling pesticides. For people with glasses special goggles are available.
Hat	The sun heat increases the dermal take up of pesticide and the most sun-exposed body part is the head; therefore a brimmed hat should always be worn.

Maintenance and storage of protective clothing

- Wash items with soap after each preparation of spray mixture or application round.
- Have a spare set of cotton overalls available if the spraying takes longer than a day.
- Store the clothing well away from pesticides and application equipment.

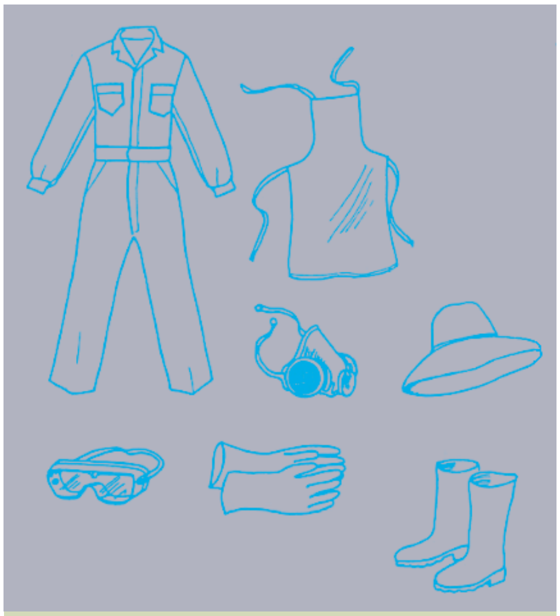


Figure 12: Examples of protective clothing
(© Ministry of Agriculture, Water and Rural Development. 1996)

4.2 Hygiene and First aid treatment

There is only one simple requirement that a farmer must offer if working with pesticides is intended. ***Fresh water and soap!***

Excellent personal hygiene includes washing all parts of the body or protective clothing that have been exposed to the pesticide immediately after work, and not eating, drinking or smoking while working.

Emergency Measures in Case of Pesticide Poisoning

How can pesticide poisoning be recognised?

Figure 13: Signs of pesticide poisoning *(© Ministry of Agriculture, Water and Rural Development. 1996)*

First aid treatment

> *In case of severe poisoning, observe patient's breathing closely and prepare to administer artificial respiration.*

The following are the first aid steps to be followed in cases of pesticide poisoning:

I Pesticide has been swallowed

Induced vomiting is only recommended if a highly toxic pesticide has been swallowed (toxicity class 1a or 1b).

Step 1: Find out which product(s) caused the poisoning. Refer to the product label to see whether or not vomiting is to be induced. To induce vomiting tickle the back of the persons throat with the finger. Ensure that your finger is not bitten.

Step 2: If vomiting should not or cannot be induced, administer activated medicinal charcoal to absorb pesticide. Dosage is 3 tablespoons of activated medicinal charcoal in half a glass of water. Repeat this as often as possible.

Step 3: Obtain medical assistance. In case of an organophosphate or carbamate, atropine sulphate is the antidote for the poisoning (injection, do not overdose).

II Pesticide on the skin

Step 1: Remove clothing and wash exposed skin with plenty of water and soap as quickly as possible to reduce the amount of poison that can penetrate through the skin. For quick action the operator must make sure always to have 200 litres of water and soap available at the application sites.

Step 2: Dry the skin and put on clean clothing.

Step 3: In case of heavy and widespread skin exposure to products of toxicity class 1 or 2, obtain medical assistance. In case of an organophosphate or carbamate, atropine sulphate is the antidote for the poisoning (injection, do not overdose).

III Pesticide splashes in the eye

The highest risk one is exposed to is at the time of putting the concentrate into the water for mixing. Avoid splashing!

The human eye is a very vulnerable organ; the speed with which first aid measures are taken is, therefore, crucial.

Step 1: Rinse the eye with a gentle stream of water, keeping the eyelid open. Do this for fifteen minutes or more. Fifteen minutes may seem a rather long time, but only by adhering to this recommendation, can the pesticide be removed.

Step 2: Cover the eye with a clean piece of cloth.

IV Pesticide has been inhaled

Immediately take the person away from the workplace into fresh air. Loosen the clothing to ease breathing.

5. Weed control

5.1 Importance

A weed is any plant that is undesirable, or that is growing in the wrong place at the wrong time.

> *Research has shown that under heavily encroached conditions it was more cost-effective in terms of increased production to control the weeds rather than to add artificial fertiliser.*

Weeds have the following negative effects:

- Weeds compete with crops for water, nutrients and sunlight.
- Weeds can lower the quality of crops, for example by seed contamination.
- Some weeds are poisonous.
- Weeds can be alternative hosts for insect pests and diseases.
- Sometimes it is expensive to control weeds.

Weeds have the following positive effects:

- Weeds provide shelter for beneficial insects/animals.
- Some weeds are sources of food for man.

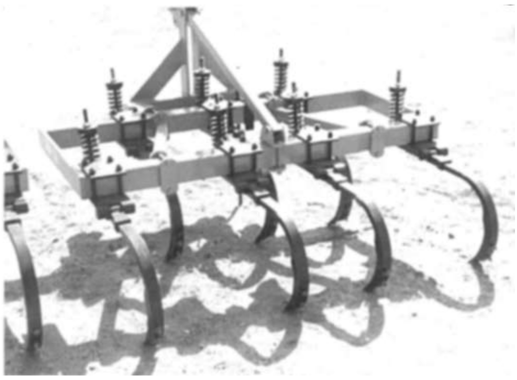
5.2 Controlling techniques

Since chemical weed control is rather expensive and demands expert advice it is considered to be too elaborate for the purpose of this manual. It is recommended that specialist advice be used before using any kind of chemical weed control.

Ploughing (primary tillage)

Ploughing may bury some weeds or bring out underground parts of weeds to dry out. Ploughing may, on the other hand, also bring out weed seeds to the surface where they can more easily germinate.

The tiller plough is used for seedbed preparation and mechanical weeding



Tiller plough *(© BP Implements)*

Harrowing/cultivating (secondary tillage)

The harrow or cultivator is used to destroy seedlings that have emerged since ploughing. The tillage depth should not be more than 10 to15 cm.

Manual weeding

Early weeding is important. Most crops will benefit from early weeding, so that they are not forced to compete with weeds. It is especially important that the following crops are free from weeds in the early stages of their growth: maize, cotton, groundnuts, beans and sweet potatoes.

During the season, most weeds are traditionally destroyed by pulling them out or cutting them with a hoe. Uprooted weeds are left on the soil to protect it from the sun or rain and to add to the organic matter content of the soil. Thinning and gap filling of the crop are sometimes done at the same time as weeding. Hand hoeing is cheap in terms of the cost of tools but it is very labour-intensive. Weeding during the season is usually the most important factor limiting the area of land that a farmer can put under crop production.

Mechanical weeding is only possible where crops are planted in rows. Secondary tillage implements like harrows and cultivators are generally recommended for mechanical weed control. The tine harrow is particularly suited for this activity.

The cost of implements can be very high if tractors are used. Cheap donkey- or ox-drawn cultivators are readily available in Namibia. Combined with sowing in rows, these cultivators can help overcome the weeding problem at a price that smallholders can afford, and so enable cultivated areas to be expanded.

In order to use animal-drawn cultivators, furrows should be at least 80 to 90 cm wide to allow for the passage of the cultivators. Narrower furrows demand very well-trained animals and experienced users. It has been estimated from on-farm trials that on average, weeding done with a cultivator using a donkey is ten times faster than using a hoe. Weeding done with a cultivator using an ox is twenty times faster than using a hoe. Weeding with a hand hoe is still needed to eradicate weeds between the crops in the rows.

CHAPTER 4
Specific Crops and Vegetables

Throughout the world and even in Namibia, there are an uncountable number of crops, which are cultivated for some use or other. These range from plants like the prickly pear, over vegetables and herbs, citrus, olives, grapes, subtropical fruit, to cereal grains and fodder plants like lucerne and old man salt bush. It is impossible to compile a manual that describes every crop with all its available sub-types or cultivars. It is, however, important to mention that for most crops a number of cultivars are available on the market and that the particular cultivar can "make or break" the success of the enterprise. A producer will have to realise that no single cultivar will comply with all the requirements as set by prevailing circumstances with respect to climate, soil, water, diseases and pests. One should therefore select the best option from the available range or even try out a few different cultivars, and then identify the best-producing ones over several seasons. The following should be considered when seeds are purchased:

- the growth period of the cultivar;
- adaptability to specific soil conditions;
- adaptability to prevailing climatic conditions;
- susceptibility to disease;
- planting date;
- marketing time, which will enable the producer to enjoy the earliest possible markets;
- the purpose for which the crop is planted, e.g. home consumption would require a long-season cultivar, but when selling the produce it could be more desirable to have enough available at the earliest possible time.

A very short overview is given below of some of the more common horticultural crops. A few grain products were included as well, but any farmer who intends to go bigger should use this manual as a basic guideline only. For the prospective farmer, a list of references for further studies is included at the end of this book. Additional consultation is also recommended before major costs are undertaken for extensive agronomic production.

It is strongly recommended to seek expert advice for any fertiliser recommendations. The figures given below are examples only and cannot be used under all different circumstances.

1. Pearl millet/mahangu (*Pennisetum glaucum*)

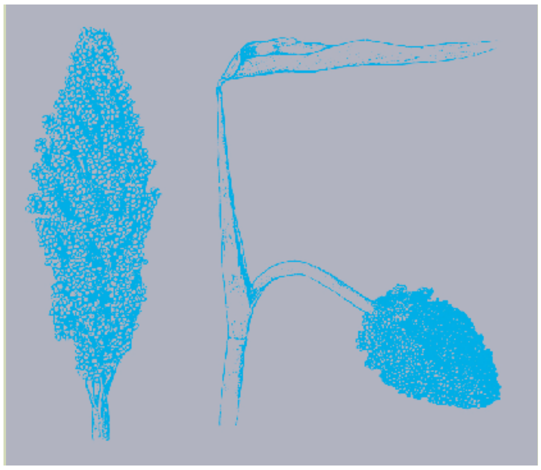
Pearl millet is the major food cereal in the northern communal areas and is popularly known as mahangu. Pearl millet is normally reserved for those areas where maize and sorghum fail to grow because of low rainfall or adverse soil factors. Generally, pearl millet is considered to be more efficient in its utilisation of moisture and appears to have a higher level of heat tolerance than sorghum or maize.

(© Ministry of Agriculture, Water and Rural Development. 1996)

Annual rainfall requirements	300–700 mm
Soil preferences	Tolerates a wide range of soils but performs best on well drained, deep and lightly textured soils. Tolerates soils with less than 10 % clay but does not tolerate waterlogging. High tolerance to salinity.
pH preferences	Neutral
Root system	Extremely profuse root system that may penetrate to great depths of up to 5 m.
Minimum growing season	80–100 days, depending on variety.
Average grain yield	200–400 kg/ha/year.
Fertiliser requirements (dependent on soil analysis)	Basal fertiliser (before planting): 6–12 t/ha kraal manure plus 100 kg 2:3:2 (30) + Zn. Top dressing: 40 kg/ha LAN.
Intercropping/ crop rotation	Intercropping with cowpeas improves soil fertility, increases yield and reduces disease and pest intensity.
Sowing time	October/November (after three consecutive rainy days with an accumulated rainfall of at least 20 mm).
Sowing depth	30–40 mm
Resowing	After six days all seeds in moist soil should have emerged. If emergence is poor, gap filling must be done as early as possible.
Thinning	Seedlings must be thinned 2–3 weeks after sowing, at maximum height of 150 mm.
Weeding	First weeding together with thinning and four weeks later again.
Diseases and pests	Very low disease intensity. Migrant pests (locusts, armyworm, *quelea* bird) and armoured cricket.
Harvesting	Mature, dry heads are cut and placed on an elevated platform to dry further for threshing.
Storage	Store in traditional baskets.

2. Sorghum (*Sorghum bicolor*)

Sorghum is a traditional staple food throughout the semi-arid areas of Africa. It is a crop of multiple uses. Its grain is widely used for human food, as fodder for farm animals and as raw materials for starch and alcohol production. Sorghum is classified according to the economic use of its species into grain sugar, broom and pasture sorghum.



(© Ministry of Agriculture, Water and Rural Development. 1996)

Annual rainfall requirements	300–400 mm (highly drought resistant).
Soil preferences	None. Produces best in fertile, well-drained, well-structured soils of medium texture. Very high tolerance to salinity.
pH preferences	Neutral
Root system	Twice as many secondary roots as maize.
Minimum growing season	90–160 days, depending on the variety.
Average grain yield	200–750 kg/ha/year. 1 500 kg/ha/year can be achieved.
Fertiliser requirements (dependent on soil analysis)	Basal fertiliser (before planting): 6 t kraal manure/ha plus 50 kg/ha superphosphate. Top dressing: 50 kg/ha LAN.
Intercropping/ crop rotation	Intercrop with cowpeas and beans and rotate with pearl millet, cotton and sunflowers. Return to the same field after three years.
Sowing time	October/November
Sowing depth	2–3 cm in clay soils; 5–6 cm in sandy soils.
Weeding	Very important not later than four weeks after sowing.
Diseases	Downy mildew, a fungal leaf disease, only controlled by destroying infected plants and by crop rotation. Four different smuts may attack sorghum heads and contaminate grain with black spores. Remove infected plants carefully. Do not shed during removal and burn to destroy spores.
Pests	Shoot fly lays eggs on leaves of seedlings. Larvae destroy growing points and thereby greatly reduce number of grain heads. Control with tadosulfur 35 % (2,5 L/ha). Stem borers tunnel into plant stalks, causing breakage. Control with vetox 85 (1 kg/ha). Midge, a tiny insect, attacks heads during flowering – no grain is formed. Spray during early flowering with sevin, vetox or dimethoate.
Harvesting	Harvest at complete ripeness; thresh by beating with stick/thresher.
Storage	Attacked by rice weevil and angoumois grain moth. Clean and remove all old grain from storage structures before storing new produce.

3. Maize (*Zea mays*)

Maize, like pearl millet and sorghum, belongs to the grass family *Graminae*. It is an annual summer crop with a large number of cultivars including dented maize, flint maize, sweet corn, popcorn bread maize and pod maize. Maize is cross-pollinated. The kernel is a fruit with one seed and in mature stage consists of three main parts: the teats (or pericarp), the starchy endosperm and the embryo (germ) that gives rise to the new plant.

(© Ministry of Agriculture, Water and Rural Development. 1996)

Annual rainfall requirements	500–900 mm Critical period 30 days before pollination, when warm weather and 100–125 mm rain is needed.
Soil preferences	Tolerates wide range of soils but best on well-drained, well-aerated, deep (60 cm) loams and silt loams.
pH preferences	Tolerates 5–8; optimum is 6–7.
Average annual grain yield	Dry land: 1 000–3 500 kg/ha Irrigation: 5 000–12 000 kg/ha
Fertiliser requirements (dependent on yield expectations and soil analysis)	(This example: 7000 kg yield/ha under flood irrigation) Basal fertiliser (before planting): 5 t of kraal manure/ha. Heavy feeder. At planting: 400 kg 2:3:2 (30) +Zn/ha. Top dressing: 300 kg urea three weeks after emerging divided into six applications of 50 kg/week/ha plus two times 25 kg $MgSO_4$ and 60 kg KCl (six applications of 10 kg each) and 10 kg K_2SO_4.
Intercropping	Intercrop with legumes like cowpeas. Sunflower is a suitable catch crop for witchweed.
Sowing time	Mid-December to mid-February (after the first 20–25 mm of rain).
Sowing depth	7,5 cm in sandy soils, 5 cm in clay soils.
Plant population	45 000–55 000 plants/ha. This is about 10–12,5 kg seeds/ha.
Plant spacing	Dry land: 200 cm between rows; 25 cm within rows.
Weeding	15 days after sowing at time of thinning. 2nd time when plant is 50 cm high. Witchweed is a serious problem.
Diseases	Diplodia, leaf spot, rust, root rot, leaf blight, yellow leaf wilt, anthracnose, tassel smut, stem rot, fusarium, cob rot, sugar-cane mosaic and dwarf mosaic virus. Control is through treated maize seed, rotational cropping with broadleaved crops, management of insects that spread diseases and planting resistant varieties.
Insect pests	Brown locust, Red locust, armyworm, stalk borers and maize weevils.
Harvesting	Harvest as soon as maize is dry to avoid damage by rodents, termites, weevils and grain moths in the field.
Storage	Grain should be treated to control damage while in storage with Pirimiphos-methyl 2D (*Actellic dust*) at 40 g/90 kg of grain.

Cultivar choice is an important aspect in the maize production process. Due to the wide diversity of conditions under which maize is produced in Namibia, it is essential that cultivars are adapted to specific production conditions. Certain cultivars are better adapted to drier, warmer production areas and therefore perform better under low-yield potential (dry-land conditions). Cultivars that perform better in situations with a higher potential are thus better adapted to wet conditions or irrigation. White maize is usually used for human consumption, while yellow maize is produced as animal fodder. Seed providers constantly develop new hybrids and new breeds. The prospective farmer should discuss his target production level with his seed supplier, who will advise him which seed to use. It is advisable, however, to start with a few different cultivars to gather own experience and to be able to make own decisions on the long term.

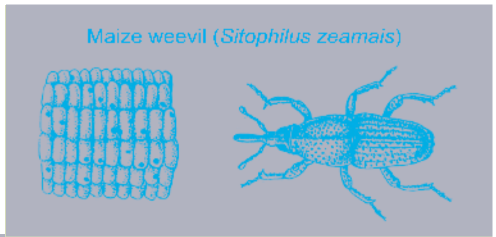


Figure 14: Maize insect pests *(© Ministry of Agriculture, Water and Rural Development. 1996)*

4. Cowpeas (*Vigna unguiculata*)

Cowpeas, like other legumes, are able to fix nitrogen in their roots with the help of bacteria, thereby increasing soil fertility. It is an ideal crop for Namibia as it tolerates heat and relatively dry weather conditions. Furthermore, it is a very good source of protein for humans and farm animals.

(© Ministry of Agriculture, Water and Rural Development. 1996)

Annual rainfall requirements	500 mm/year
Soil preferences	Sandy topsoil with 5–10 % clay and sandy loam and underneath with 10–20 % clay content. Needs 1,2 m deep soils.
pH preferences	Does not tolerate alkaline (pH ≥ 8) or acid (pH ≤ 4,5) soils.
Root system	Long, deep roots.
Average annual grain yield	Soils with high fertility produce a lot of vegetative growth; marginal soils produce high grain yields.
Fertiliser require-ments (dependent on soil analysis)	Basal fertiliser (before planting): 30–60 kg/ha MAP (33 + Zn). Cowpea is a legume and needs no N-fertilisers. Top dressing: none.
Intercropping	Great value as intercrop with millet, sorghum, maize and cotton.
Sowing time	Since cowpeas are cold-sensitive they should be planted early in the season, as soon as the first rains are expected.
Sowing depth	5–10 cm in sandy soils, 3–7 cm in heavy soils.
Plant spacing	50–100 cm between rows and 15–45 cm in the rows.
Weeding	Weed as long as plants are still very small.
Diseases and pests	Bruchid weevil
Harvesting	For human consumption, pods can be picked when they ripen i.e. when the colour starts to change from green to purplish or cream.
Storage	If not sold or consumed immediately, pods with seeds should be sun-dried properly and then threshed and stored.

5. Groundnuts (*Arachis hypogea*)

Groundnuts are a good source of protein and energy. Because it is a legume, it will improve soil fertility when grown in rotation with other crops like maize or pearl millet.

(© Ministry of Agriculture, Water and Rural Development. 1996)

Annual rainfall requirements	450–600 mm
Soil preferences	Light sandy, loamy soil with good structure and a clay content of 8–10 %.
pH preferences	Neutral to acid soils but not lower than pH of 5 is ideal.
Root system	Deep root system of 1,2–2,1 m with the groundnuts themselves produced underground on the roots.
Fertiliser requirements (dependent on soil analysis)	Basal fertiliser (before planting): 95 kg/ha Superphosphate (10,5 %). Top-dressing: 35 kg/ha LAN OR Basal fertiliser (before planting): 30 kg MAP (33) + 0,75 % Zn. Top dressing: 15 kg/ha MAP (33) + 0,75 % Zn. Groundnuts are sensitive to Ca and Zn deficiency.
Intercropping	Can be intercropped with any crop like millet, sorghum or maize.
Seed treatment	Seeds must be treated with fungicide before nodular bacteria are inoculated.
Sowing time	Mid-November to mid-December in very wet soil.
Sowing depth	5–7 cm
Plant spacing	0,9 m between rows x 0,2 m within rows.
Resowing	Gap filling during the first week after germination.
Weeding	Extremely important as early as weeds are visible.
Diseases and pests	Aspergillus and Rhizopus attack seeds. Symptom is wilting seedlings. Treat seeds with Thiulin (120 g/100 kg seeds) one day before planting Rosette, a viral disease transferred by aphids. Control aphids by sound planting techniques and healthy plants. Cercospora and Phoma; fungal diseases that cause dark spots and yellow leaves. Control carefully with registered fungicides.
Harvesting	Pods may be lifted with a spade or by shallow ploughing just underneath the pods. The whole plant is then pulled over a frame, covered with wire mesh. The pods fall through the mesh and should be picked up immediately and dried on a platform for two days after which they are placed in hessian bags for storage.

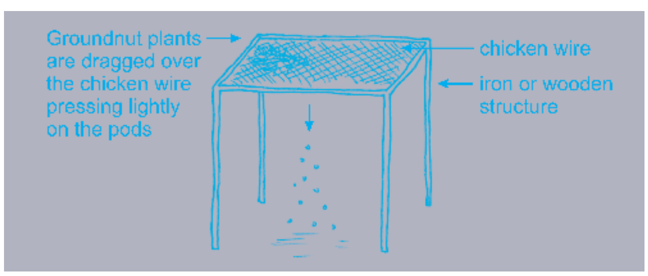
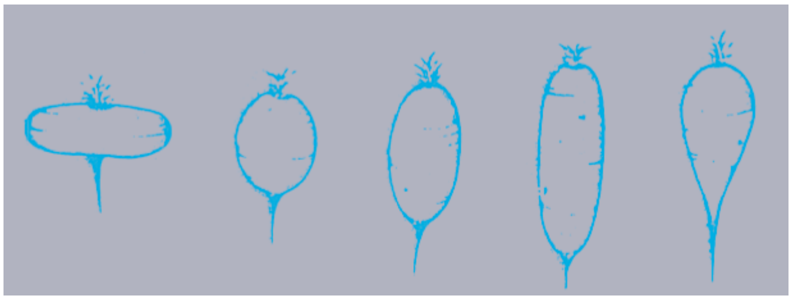


Figure 15: Pod picker or separator *(© Ministry of Agric. Water and Rural Development. 1996)*

6. Beetroot (*Beta vulgaris* var. *conditiva*)

Beetroot originated in Asia and Europe. It is therefore a cool-weather crop; nevertheless, it will produce most of the year in Namibia.



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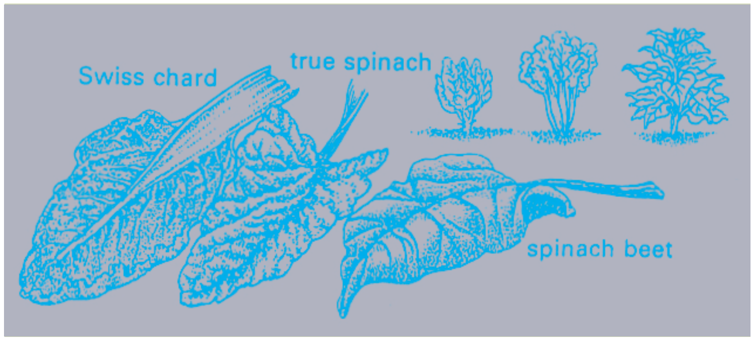
Soil preferences	Deep, fertile soils; pH 6–8.
Root system	Root crop with tubers.
Fertiliser requirements (dependent on soil analysis)	Basal fertiliser (before planting): This is a root crop; do not use manure! 60 g NPK 2:3:4/m² (= 600 kg NPK 2:3:4/ha). Top dressing: 15 g LAN or 10 g urea/metre of row.
Sowing time	February to April and August to October.
Sowing depth	2–3 cm
Seed rate	80–100 g/100 m².
Plant spacing	30 cm between rows x 5 cm within rows.
Thinning	Thin early to one plant per station (at each sowing spot).
Diseases and pests	Highly sensitive to nematodes – rotate with non-sensitive crops. Cutworm caterpillars bite the plant stems at ground level at night. Bait the ground around the plant with cutworm bait or use Aldrin or Dieldrin. The worms will eat the bait and die.
Harvesting	Summer: 60–80 days; winter 100–130 days, when tubers are 5–6 cm in diameter, leave small ones in ground to grow bigger.
Main cultivars	Detroit Dark Red, Crimson Globe.

7. Spinach (*Beta vulgaris* var. *cicla*)

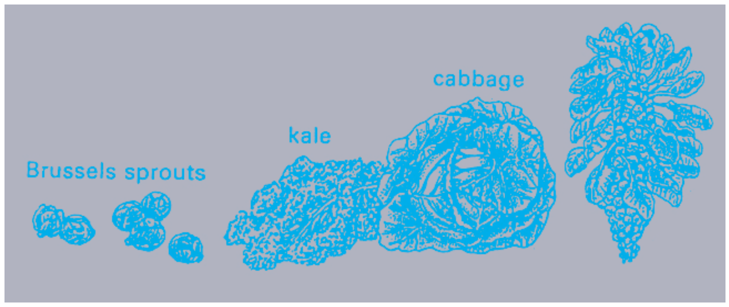
Swiss chard (spinach) is closely related to beetroot (*Beta vulgaris*). This crop is easy to grow but it does not store well and should be eaten soon after picking. Once the plant is established, the picking can go on for up to a year. Yields are quite high and the leaves are rich in calcium and carotene.



Soil preferences	Heavy feeder. Deep, fertile soils, pH 6–7.
Irrigation requirements	Irrigate regularly, otherwise leaves collapse and the plants wither.
Fertiliser requirements (dependent on soil analysis)	Basal fertiliser (before planting): Heavy feeder. 60 g NPK 2:3:4/m²/supply plenty of kraal manure. Top dressing: 15 g LAN or 10 g urea/metre of row.
Sowing time	April to August
Sowing depth	1–2 cm
Seed rate	50 g/100 m² plot.
Plant spacing	40 cm x 25 cm
Thinning	Each seed makes 2–3 plants, therefore thinning is important.
Diseases and pests	Extremely sensitive to nematodes – crop rotation is very important! Caterpillars: Control with home-made tobacco extracts, Malathion, Ripcord or Bulldock. See also cutworms under beetroot.
Harvesting	Harvest every week when the crop is about eight weeks old. The crop can produce for many months.
Main cultivars	Monstrous Viroflay.

8. Cabbage (*Brassica oleracea* var. *capitata*)

Cabbage is a cool-season crop, but new varieties are extending the geographical and seasonal ranges in which it can be grown successfully. It is very popular and healthy and contains the vitamins A, B1, B2, C and fibre.



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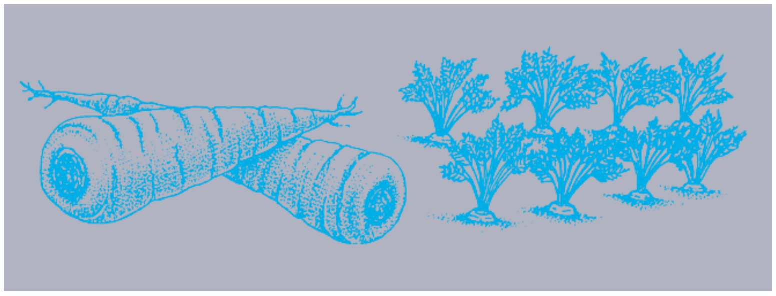
Soil preferences	Prefers a soil, rich in organic matter with good moisture holding properties. pH 6–6,8	
Fertiliser requirements (dependent on soil analysis)	Basal fertiliser (before planting): apply 5 t of kraal manure and 500 kg superfos/ha. At planting: (175 g seed), 400 kg 2:3:4 (38) + Zn/ha. Top dressing: three weeks after emergence: 100 kg UAS (urea ammonium sulphate), two weeks later 75 kg UAS/ha.	
Sowing time	Cool season crop, plant April to June.	
Sowing depth	1 cm	
Seed rate	3–4 g/100 m² plot.	
Plant spacing	50 cm x 50 cm	
Time to harvest	90–110 days	
Diseases and pests	Pest:	Chemical control:
	Aphids: Green or bluish-grey, covered with a waxy powder.	Mercaptotion, Malathion, Malasol, Chlorpyrifos, Diazinon (Abolish), Dimethoate (Kombat aphids), Endosulfan (Thiodan).
	Bagrada: Serious pest. Stink bug, mostly black with orange spots.	Lambda-cyhalothrin, Karate, Dichlorvos and Mercaptotion containing insecticides like Malathion and Malsol.
	Diamond-back moth larvae: Small, light-green caterpillars.	Chlorpyrifos, Baythroid, Cypermethrin, Deltamethrin, Dichlorvos, Endosulfan (Thiodan) and Mercaptotion containing insecticides like Malathion and Malsol.
	African bollworm.	Cypermethrin, Lambda-cyhalothrin, Karate, Chlorpyrifos, Endosulfan (Thiodan).
	Black rot: Serious bacterial disease. Forms yellow-brown patches, later black veins.	No chemical treatment available. Avoid wetting leaves, rotate crops and use resistant varieties: Star 3301, Green Star, Green Coronet and Genesis.
	Downy mildew: Pale green, later yellow, then brown spots develop on upper surface of leaves. Under the leaves, a white down develops.	Copper ammonium carbonate, Copper oxychloride, (Kombat Rust), Cupric hydroxide, Mancozeb (Sancozeb or Dithane M45).
	Bacterial spot.	Copper oxychloride.

	Alternaria leaf spot: (Fungus) Small dark spots appear first and enlarge to form large circular lesions.	Chlorothalomil (Bravo), Maneb/zinc oxide, (Trimangol), Zineb.
Harvesting	90–100 days after sowing, cut with a sharp knife when heads are firm and hard. Yield of more than 20 t/ha is possible.	
Main cultivars	Sugar Loaf, Prize Drumhead, Copenhagen Market, Glory of Enkhuizen.	

9. Carrots (*Daucus carota*)

The carrot is indigenous to Asia and Eastern Europe and is grown for its edible root, which can be eaten cooked or raw. Carrots contain vitamin A and can be stored for relatively long periods of time.



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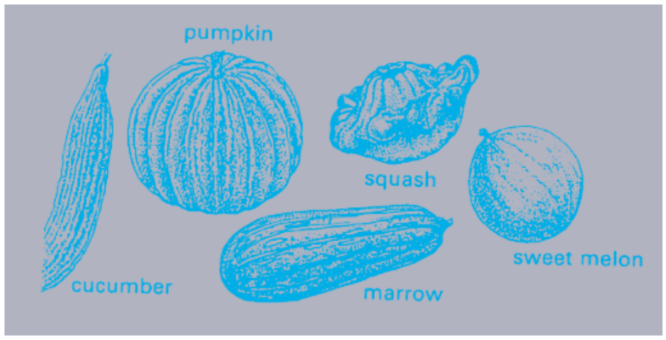
Soil preferences	Deep sandy loam with compost or manure. Avoid heavy compact soil. pH between 6–7
Fertiliser requirements (dependent on soil analysis)	Basal fertiliser (before planting): If compost or manure of the previous season is still in the soil this is ideal but it should not be applied directly before planting. Apply 70 g/m^2 of 2:3:2 (24) Top dressing: 10–20 g LAN/m^2 when plants are about 10 cm high.
Crop rotation	Rotate with cabbage, cauliflower and tomatoes.
Sowing time	All season crop – use different varieties for summer and winter.
Sowing depth	1–2 cm
Seed rate	40 g/100 m^2 plot (5,5 kg/ha).
Plant spacing	35 cm between rows x 5 cm within rows.
Thinning	Thin as soon as possible to a distance of 5 cm between plants.
Time to harvest	70–85 days after sowing.
Diseases and pests	Aphids: Usually green in colour, spray Malathion. Flea beetles: Malathion. Nematodes – controlled by crop rotation.
Main cultivars	Nantes, Chantenay, Cape Market.

10. Cucurbits (*Cucurbitaceae*)

This family of plants includes cucumber, sweet melons, water-melons, pumpkins, squashes, marrows, zucchini, gherkins, calabash and the loofah. Cucurbits are very useful vegetables; they have similar cultural requirements and generally suffer from the same diseases.



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Fertiliser requirements (dependent on soil analysis)	Basal fertiliser (before planting): Kraal manure and one tablespoon of double superphosphate per plant. Top dressing: One tablespoon of LAN/plant, four weeks after planting and the same again when plants start flowering.	
Intercropping	Pumpkins are often intercropped with mahangu, sorghum and maize. This reduces fruit-losses caused by flower-sucking insects such as melon flies.	
Sowing time	August to December	
Sowing depth	3–4 cm	
Plant spacing	Cucumber	90 cm x 60 cm
	Squash	90 cm x 60 cm
	Sweet melon	120 cm x 120 cm
	Water-melon	3 m x 2 m
	Pumpkin (trailing)	4 m x 4 m
	Pumpkin (bush)	120 cm x 120 cm
Time to harvest	Cucumber	6–8 weeks after sowing.
	Squash	6–10 weeks after sowing.
	Zucchini	As soon as fruit are 10–15 cm long.
	Sweet melons	3–5 months after sowing.
	Water-melon	Harvest when the white, lower portion starts getting yellow.
	Pumpkins	3–5 months after sowing.
Diseases and pests	Many diseases and pests attack cucurbits. Expert advice should be obtained as soon as symptoms are visible.	
Main cultivars	Cucumber	Palomar, London Long Green, Colorado.
	Pumpkin	White Boer Pumpkin, Queensland Blue.
	Sweet melon (*spanspek*)	Hale's Best, Honeydew, Galia.
	Watermelon	Sugar Baby, Charleston Grey, Black Diamond, Congo.
	Squashes	Green Hubbard, Little Gem, Rolet, Chargo Warted.

11. Green beans (*Phaseolus vulgaris*)

Green beans are warm-season annuals. Several species and many varieties are cultivated for their fruits (pods) that are eaten before physiological maturity when the seeds they contain are still non-viable and tender.

Beans are legumes and will fix nitrogen from the air if the appropriate Rhizobium species of bacteria is present (by inoculation or naturally).

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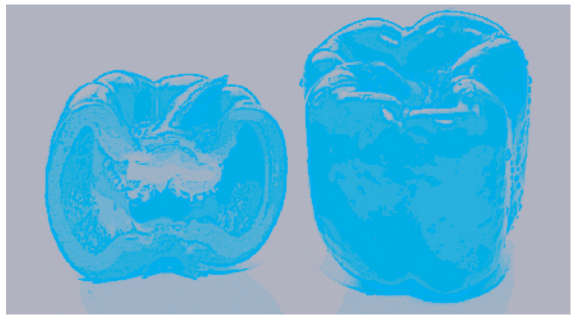
Soil preferences	Prefer soil that is well supplied with water. Clay loam and loam soils are the most productive. pH 5,5–7	
Fertiliser requirements (dependent on soil analysis)	Basal fertiliser (before planting): 60 g NPK (2:3:2 or 2:3:4)/m². Top dressing: not necessary.	
Crop management	Rhizobium inoculation is necessary if beans have not been planted on the site before. Order Rhizobium bacteria from seed supplier.	
Sowing time	From September to March (avoid frost).	
Sowing depth	2–10 cm	
Seed rate	200 to 1000 g/100 m² plot, depending on variety of beans.	
Plant spacing	Bush types: 50–90 cm between rows x 10 cm within rows. Poles: 90–120 cm between rows x 20 cm within rows.	
Time to harvest	45–80 days from sowing.	
Diseases and pests	Bean fly: Young plants that are attacked turn yellow and are stunted. Many plants die.	Chemical control with Carbaryl (Karbaspray), Mercaptotion (Malathion or Malasol).
	Banded blister beetles or CMR beetles: Black beetles, 20 to 25 cm long and two yellow bands across their backs and a yellow spot near the front.	Mercaptotion (Malathion, Malasol or Kombat Garden Insects).
	Aphids: Soft-bodied insects with long legs, usually black or green, with or without clear wings. Suck the sap of plants; cause twisting of the leaves.	Mercaptotion (Malathion, Malasol or Kombat Garden Insects). Dimethoate (Dimet or Kombat Aphids).
Harvesting	Harvest when pods are firm but seeds are still fine. High quality beans contain small seeds only. Too early harvested pods wilt very easily; pods harvested too late become hard, tough and stringy. Experience will teach the right stage.	
Main cultivars	Contender, Wintergreen, Seminole.	

12. Peppers and chillies (*Capsicum* spp.)

Peppers are small, bushy annuals or short-lived perennials with fruit usually red or green in colour. Sweet peppers are fruit vegetables, which can be eaten raw in salads or cooked, and added to stews and soups and other vegetables. Chillies are usually used as a seasoning or spice and are also used in home-prepared insect repellents and insecticides or elephant repellents on farms where these animals destroy infrastructure and field crops.

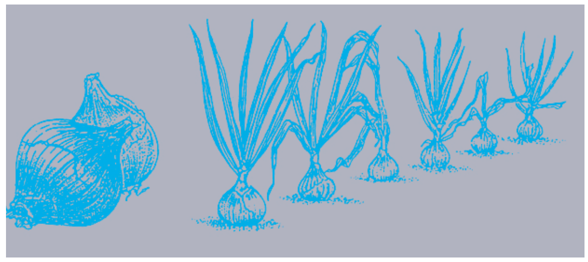


(© Polytechnic of Namibia, Horticulture Study Guide)

Soil preferences	Well-drained sandy or sandy loam soils with pH of 6–7.	
Fertiliser requirements (dependent on soil analysis)	Basal fertiliser (before planting): Give as much kraal manure as possible and apply 60 g of NPK 2:3:4 (38) per m^2 just before planting. Top dressing: 20 g of sulphate of ammonia per metre of row one month after transplanting and another 20 g sulphate of ammonia/m of row two months after transplanting.	
Crop rotation	Leafy vegetables, rotate with group 1 heavy feeders. Do not rotate with tobacco.	
Crop management	Seeds are sown in nursery beds and transplanted when they have grown to 10–15 cm tall and have 4–6 true leaves. This will normally be at 4–6 weeks after sowing. Smaller seedlings are left to grow in the nursery for later transplanting or filling blanks.	
Sowing time	September to March (avoid frost).	
Plant spacing	80–100 cm between; and 50–80 cm within rows.	
Time to harvest	2–3 months after transplanting.	
Diseases and pests	Aphids: see description of aphids under green beans.	Chemical control with Primicarb (Aphox), Dimethoate (Dimet) or Diazinon (Abolish).
	Thrips: Very tiny insects with four narrow, fringed wings. Nymphs are yellow. Adults are usually dark and very active. They rasp the plant surface, causing small silvery blotches on the leaves and fruit.	Control by crop rotation is very effective. Chemical control with Deltamethrin (Decis), Endosulfan (Thiodan), Lamda-cyhalothrin (Karate) or Mercaptothion (Malathion, Malasol).
	American leaf miners.	For control, refer to tomato section.
	Bacterial spot: Causes small tan-coloured spots with darker margins.	Copper oxychloride (Kombat Rust) or copper ammonium carbonate (copper Count N).
Harvesting	Green peppers are best harvested while fruits are still green or just turning red. Chillies – when turning red. Do not store green peppers longer than 24 hours. Chillies can be dried on a platform within 2–3 days and then stored and sold.	
Main cultivars	(Green peppers) Emerald Giant, California Wonder, Yolo Wonder.	

13. Onion (*Allium cepa*)

Onions are biennial herbs with bulbs formed at the base of the plant from thickened food-storage leaves. The hollow foliage leaves are produced from a flattened basal conical stem. Onions contain calcium, iron, fibre and vitamins B1, B2 and C.



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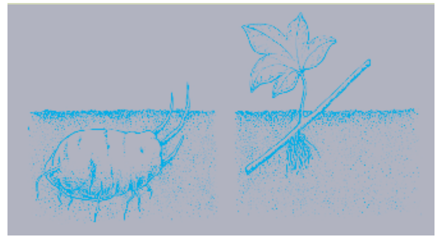
Soil preferences	Grows well in sandy or sandy loam soils but prefers a high level of organic matter. A pH of 6,8 is ideal.	
Fertiliser requirements (dependent on soil analysis)	Basal fertiliser (before planting): supply some kraal manure and then 50 g of NPK 2:3:4 (39) + Zn/m^2. Top dressing: 15 g LAN or 10 g urea/m of row or 20 g of sulphate of ammonia 4–6 weeks after emergence plus 5 g of KNO_3/m^2/week from week six to week 13 after emergence.	
Crop rotation	Rotation group: Root vegetables.	
Sowing time	February to May	
Sowing depth	1 cm	
Seed rate	In nursery beds as follows: 10 cm between and 5 cm within rows.	
Plant spacing	30–45 cm between and 8–10 cm within rows.	
Time to harvest	6–8 months	
Diseases and pests	Onion thrips: The leaves of plants become silvery and flecked. Heavy attacks lead to wilting of young plants.	Control by crop rotation is very effective. Chemical control with Deltamethrin (Decis), Endosulfan (Thiodan), Lamda-cyhalothrin (Karate) or Mercaptothion (Malathion, Malasol).
	Pink rot: Roots of seedlings and older plants turn pink and shrivelled. The plant does not die, but very small bulbs often result. The fungus exists in the soil for many years.	Dichlorophen (Xanbac D).
Main cultivars	Texas Grano, Early Cape Flat, De Wilt, Pyramid, Bon Accord.	

14. Sweet potatoes (*Ipomea batatas*)



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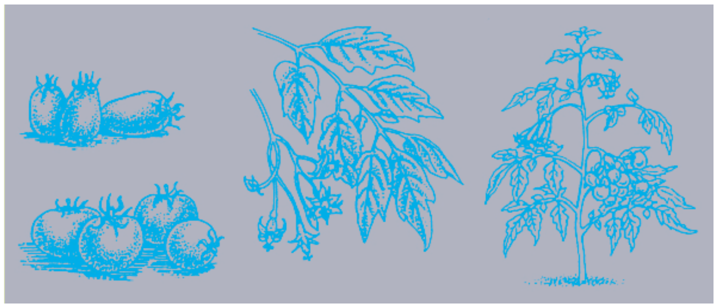
Sweet potatoes are an important food crop. The tubers are boiled or roasted and the young leaves are eaten as a vegetable. Sweet potato vines are a useful fodder crop, especially in the dry season. Most sweet potatoes are red in colour, but there is a yellowish variety as well.

Sweet potatoes are a warm-season crop and are propagated by means of cuttings or tubers as soon as the soil is fairly moist. Cuttings should be 30 to 40 cm long. They should be buried in the ground at an angle of 45° with about two thirds of the cutting in the soil. Tubers or parts of tubers are buried completely. It is important to make sure that cuttings and tubers are only taken from disease-free plants.

Annual irrigation requirements	750 mm	
Soil preferences	Wide range of soils below 25 % clay. Soil should be fertile and free of stones. Old cultivars such as the Yellow Borrie must not be planted in sandy soil, while new cultivars such as Ribbok grow very well in sandy soil.	
Root system	Shallow root system of tubers.	
Average seasonal yield	20 t/ha	
Fertiliser requirements	Basal fertiliser (before planting): Nitrogen is not recommended if sweet potatoes are grown for their tubers, because this will promote the growth of leaves at the expense of tubers. Kraal manure and compost should, however, be applied at a rate of not more than 100 kg/ha well before planting.	
Crop rotation	Important. Do not plant on same plot within four years.	
Planting time	August to November.	
Planting depth	5 cm (shallower in heavy soils, deeper in light soils).	
Plant spacing	30 cm within rows on ridges and 90 cm between ridges.	
Pests and control measures	Aphids (small insects which attack the leaves).	Spray with Dimethoate, Diazinon, Formothion or use garlic plants as a deterrent.
	Sweet potato weevils (larvae tunnel into tubers and roots).	Spray with Fenthion and Endosulfan. Burn all infested plants.
	Sweet potato moths lay eggs, which hatch into destructive large green caterpillars.	Spray with Dipterex or mix 3 to 4 ground-up chillies with a tablespoon of soap flakes in one litre of water and spray this on the leaves.
Diseases	Black rot.	Crop rotation.
	Sweet potato virus B.	No chemical to control viral diseases. Spray against white flies, which spread the virus.
Harvesting	Lift up with a fork to harvest from 3 to 5 months after planting, depending on the cultivar.	
Storage	Cannot be stored fresh for longer than a few days. Harvest when needed of store as dried chips in a dry and cool place.	
Main cultivars	Impala, Ribbok, Eland, Yellow Borrie.	

15. Tomatoes (*Lycopersicon esculentum*)

Tomatoes are sub-tropical plants, (therefore susceptible to frost) and related to potatoes, eggplant, peppers and tobacco plants. Tomatoes contain calcium, iron and vitamins A, B and C.



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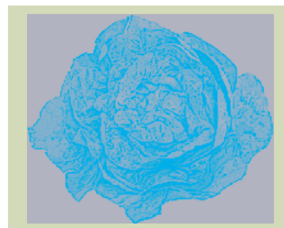
Soil preferences	Grow well on a range of soils from sandy loams to light clay. The best soils for tomatoes are fertile soils rich in organic matter, able to retain moisture, deep and well drained, not too acidic, with pH 5–7	
Fertiliser requirements (dependent on soil analysis and soil type)	See Appendix 1. Basal fertiliser (before planting): Heavy feeder. 800 kg NPK [2:3:4 (38) + Zn] /ha and supply plenty of kraal manure and 1000 kg of dolomitic lime in sandy soils. Top dressing: LAN: 25 kg in week two after transplant and again 75 kg in week eight after transplant. KNO_3: 62,5 kg in week three, 100 kg in week five, 137,5 kg in week seven, 75 kg in week nine and 12,5 kg every alternative week from week ten to week 18 after transplant. AS: 100 kg in week four and 75 kg in week six after transplant. $CaNO_3$: 5 kg/week from week five to week eight. $MgNO_3$: 5 kg/week from week two to week four .	
Average annual yield/ha	25–45 t (depending on irrigation method and frequency, soil type and fertiliser application).	
Sowing time	August–November.	
Sowing depth	1 cm	
Seed rate	Seedbed or nursery beds with 10–20 cm between rows, 2 cm apart in the row.	
Plant spacing	Transplant 45–120 cm between rows and 30–35 cm within rows.	
Weeding	Very important, four weeks after transplanting and four weeks later again.	
Time to harvest	3–4 months after transplanting.	
Diseases and pests: (Sensitive to numerous pests – only a few are mentioned here).	Nematodes	Control by recommended crop rotation.
	Tomato pinworms	Chemical control is difficult because insect quickly penetrates deep into the fruit.
	Red spider mite	Propargite (Comite or Omite) or Kelthane.
	Aphids	Dimethoate (Dimet) or Diazinon (Abolish), Mercaptothion (Malathion, Malasol).
	African bollworm	Bulldock, Ripcord, Lambda-cyhalothrin, (Karate).
	Green stinkbug	Endosulfan (Thiodan).
	Rust	Propargite (Comite or Omite).
	Leaf miners	Cyromazine (Patron) or Bifenthrin (Talstar).

Main cultivars	Tall-growing plants with large fruit.	Manapal AA, Mooketsi, Piersol, Homestead.
	Short-growing plants with medium large fruit.	Heintz 1370, Letaba, Urbana, Flora Dade.
	Tall-growing plants with small fruit.	Roodeplaat, Premier, Moneymaker.
	Short-growing plants with pear-shaped fruit for canning.	Roma, Roma V.F., Salati.

Crop management

Transplanting is done about one month after sowing or when the seedlings have four sets of leaves and are 10 to 15 cm high. Smaller seedlings may be left in the seedbed to grow further for later transplanting or filling of blanks.



16. Green salad (*Lactuca sativa*)

Irrigation requirements	440 mm/90 day season.
Soil preferences	Sand, sand loam, loamy sand, sand clay loam below 30 % clay.
pH preferences	4,8–8
Root system	Shallow to extremely shallow.
Average annual yield	20 t/ha
Fertiliser requirements (dependent on soil analysis)	Basal fertiliser (before planting): Heavy feeder. 60 g NPK 2:3:4 (38)/m²/supply plenty of kraal manure. Top dressing: 20 g of sulphate of ammonia per metre of row one month after planting and one month later again 15 g LAN or 10 g urea per metre of row.
Crop rotation	Rotate with tomatoes, onions and cucurbits.
Sowing time	All year but avoid frost and provide shade netting from Oct. to Feb.
Sowing depth	2 mm – sow in nursery beds and transplant three to four weeks later.
Plant spacing	30 x 30 cm
Plant population	80 000 plants/ha.
Weeding	Four weeks after transplanting.
Time to harvest	90 days
Diseases and pests	Cutworm, thrips, slugs, whitefly, leaf miner, botrytis, mildew, anthracnose.
Harvesting	Manual cutting only.
Storage	Store in cold room only.

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List of Figures

List of Tables

Appendix

Example of a fertiliser recommendation form for tomatoes on sandy soils as provided by professional consultant.

Client:	SMALL FARMERS
Irrig Syst:	SPRINKLER
Area (ha):	1
Crop:	TOMATOES
Yield (t/ha):	45 t
Soil:	SANDY

		N	P	K	Ca	Mg
TOTAL(kg/AREA):		227,2321	130,2935	253,1105	18,80588	1,35
	0					

TYPE:	234 (38) + 2 % Zn	LAN	KNO_3	AS	$CaNO_3$	$MgNO_3$
before plant	800	0	0	0	0	0
at planting	0	0	0	0	0	0
WK 2 after transplant	0	25	0	0	0	5
WK3	0	0	62,5	0	0	5
WK4	0	0	0	100	0	5
WK5	0	0	100	0	5	0
WK6	0	50	0	75	5	0
WK7	0	0	137,5	0	5	0
WK8	0	75	0	0	5	0
WK9	0	0	75	0	0	0
WK10	0	0	12,5	0	0	0
WK12	0	0	12,5	0	0	0
WK14	0	0	12,5	0	0	0
WK16	0	0	12,5	0	0	0
WK18	0	0	12,5	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
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0	0	0	0	0	0	0
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0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
Kg/AREA:	800	150	437,5	175	20	15
BAG UNITS:	kg	kg	kg	kg	kg	kg
BAG SIZE:	50	50	25	50	25	25
	1	1	1	1	1	1
TOTAL BAGS	16	3	17,5	3,5	0,8	0,6
TON/AREA:	1,5975					