Manual for Vegetable Production in Botswana

Horticultural Research Program

Vision: What we want to be

We at the Department of Agricutlural Research, commit ourselves to be a center of excellence in adapting and developing appropriate and environmentally-friendly agricultural technologies and conservation of agricultural resources in support of sustainable and competitive agriculture in partnership with stakeholders.

Mission: Why we exist

Our mission is to identify, adapt and develop innovative technologies that will enable our customers to optimize productivity through:

- *Effective and efficient utilization of agricultural resources*
- *Conservation of genetic resources*
- *Good agricultural management practices*

We will achieve this mission through teamwork, collaborative effort, dedication, motivation and a well-resourced research environment.

Values: What we believe in

Customer - *Customers are our reason for being. We show concern for our customers through continuous consultation and feedback, and constant improvement of service delivery.*

Staff - *Our staff is key to providing high quality service. we commit to develop, manage and grow our staff in order to instill a high standard of work ethics and improve their job competences and performance.*

Sevice - *We exist to provide customer focused service. We pledge to deliver high quality service in a timely, effective and efficient manner.*

Conduct - *We cherish high standards of work ethics. Our customers are quaranteed courtesy respect, selflessness, fairness, sensivity and intergrity.*

Innovation - *We shall own the future by being innovative. We commit ourselves to being innovative and proactive in order to match the requirement of the future.*

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Stakeholders - *Stakeholders are valued partmners in agricultural development. We believe in involving stakeholders in planning and implementing process in order to promote a viable and sustaible agricultural sector.*

Gender - *We recognize gender sensitivity as very important in agricultural development. We commit to develop and support gender sensitive policies and programmes.*

GOVERNMENT OF BOTSWANA

MINISTRY OF AGRICULTURE

Manual for vegetable production in Botswana

PREPARED BY
THE HORTICULTURAL RESEARCH PROGRAM

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FOREWORD

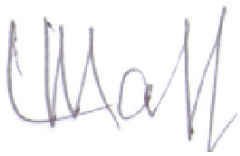
This manual is intended to be a guide to the horticultural extension personnel, horticultural producers as well as agricultural institutions in their endeavour to improve productivity in the horticultural sub-sector.

Botswana currently imports substantial quantities of vegetables from neighbouring countries amounting to millions of Pula annually. This is partly owing to the fact that the necessary information on vegetable production locally is not readily available to assist producers in their production.

This manual is therefore designed to provide guidelines on seedling production and management, plant spacing, cropping programme, soil fertility, crop protection as well as marketing aspects.

The National Master Plan for Agricultural Development identified vegetable production as one of the priority areas with potential for development in Botswana. I hope, therefore, that this manual will contribute modestly to the goal of improving vegetable production in the country.

A good number of staff of the Department of Agricultural Research were involved in conceptualisation, writing, reviewing, editing, and production of this manual. Their valuable contributions are hereby gratefully acknowledged.



Dr L. M. Mazhani
Director, Department of Agricultural Research
MAY 2003

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The contents of this manual remains largely the same as in the previous edition. I therefore would like to thank all those who contributed towards the first edition for the work well done. The overwhelming demand for the manual from farmers, lecturers, and students is a testimony that the information contained in it is very useful. This has been the driving force in persuading management to foot the bill for this edition, an investment also appreciated. I thank our Public Relations office, in particular, Mr. B. J. Mmusi for acting as our 'mouth piece' in dealing with management in that regard.

I also want to thank those who used the first edition, for the encouragement and coming up with suggestions to 'fine-tune' this edition. I am grateful to Mr. G. Mcleod at TCE for devoting his time to reviewing the first edition and bringing our attention to the numerous mistakes made in that issue. The contribution from my collegue Dr. G. Wiles which came just when the manual was about to be taken for printing is very much appreciated. Lastly I want to record my appreciation to Ms. M. Moamogwe for making my life easier, particularly in putting together contributions from different people and doing the final editing.

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INTRODUCTION

Vegetables are a complex group of a wide variety of different types of crops. Most vegetables are annuals or biennuals, completing their life-cycle in one or two years, respectively. They have diverse forms of propagation: by seed or vegetative parts. They may be herbaceous, viny, shrubby or tree-like in growth habit. They differ in growth requirements. Many vegetables can be grown under a wide range of conditions, while others have more specific requirements for water, temperature and light. Thus in one place several species can be grown only during certain times of the year. The importance of vegetables as a source of numerous essential nutrients in the diet need not be over-emphasized. With increasing demand for farm-fresh produce and new alternative specialty crops, vegetables also play a major role in improving the income of small farmers in particular. It is estimated that local horticultural production accounts for only about 20% of the national demand, the rest of the requirement being met from imports. This shows that there is potential for increasing production of horticultural crops by local farmers. The production of most vegetables in the country is seasonal, which is mainly attributable to the variation in climatic conditions during the year.

Role of vegetables in nutrition

Vegetables as a group constitute an important component in a human diet. They are the most important sources of minerals in addition to being excellent sources of Vitamin A, C and B complex. These elements are essential for the proper functioning of different organs of the body and hence their deficiency in the diet have an adverse effect on the physiology of the human body. Examples include inability of the eye to see normally in dim light caused by deficiency of vitamin A, and development of weak bones resulting from lack of calcium. Shortage of iron in the diet also causes a condition known as anaemia. Some vegetables can be good sources of energy particularly root crops. Legumes and leafy vegetables are generally rich in protein.

The contribution of vegetables as a source of fibre is very important, especially where low fibre diet is consumed. Although edible fibre is not considered a nutrient and is not absorbed by the body, it is the component of vegetables that assist in moving food through the alimentary canal by aiding the muscular action of the intestines, thus preventing constipation. It also helps to satisfy the appetite.

Economic role of vegetables

We are all aware of the nutritional importance of vegetables. But equally significant are the opportunities for employment and family income generated by vegetable production. Vegetable production is labour intensive and can generate 3 - 10 times the employment and income per hectare of land compared to that of cereals like maize. Vegetables also create a number of job opportunities in complementary businesses that arises such as marketing, processing and transportation. The demand for horticultural products is projected to grow significantly in the coming decades, due to an increase in the awareness of their nutritional importance and the resultant increase in their consumption. This offers an opportunity to absorb an ever-increasing unemployed labour force.

PLANNING PRODUCTION FOR THE MARKET

Due to the perishable nature of vegetables, farmers have to be informed about the crops they want to grow as well as the market requirements to aid them in planning their production. One of the biggest frustrations growers encounter is raising a beautiful crop only to see it rot in the field because there is no market for it. Much of this can be eliminated by planning production in accordance with, the market needs, in-terms of the vegetable type, and quantities required. Once the grower has determined how much he/she can sell, then he/she should work out a production plan to supply the desired quantities of each vegetable. In order to do this, information on the following is needed:

(a) How long does it take for the crops to reach maturity? This will tell one when to plant, to harvest at a given time.
(b) How long can you continue harvesting once a crop is mature? This will tell one how often to plant to ensure continuous production.
(c) Expected yield: how much will you harvest from a given area? This will tell one how much to plant to satisfy customers.

A production plan is a very important management tool. Management as a factor of production aims to organize the limited resources such as land, water, and labour, and use them to obtain the highest continuous possible net return. Most vegetables are of short duration growth and operations must be programmed to maximize the use of the land resources, water and manpower. Thus establishing the priority and sequence of vegetable crops and the timing of the farm activities well ahead of time are very essential in achieving a profitable vegetable production. Knowing what and when to plant, a farmer can ensure that all his inputs i.e. seeds, fertilizers, pesticides are available at the right time. A well-planned cropping programme will ensure that the workers are fully engaged throughout the year. This is very important because the permanent staff are paid in full even when there is very little work to do and less income is generated.

If one is interested in growing vegetables, it is advisable to start production on a small scale and build up from there as experience is gained and markets established. The growing of a large area of one kind of vegetable in anticipation of high prices should be avoided. This minimizes the risk associated with problems such as price fluctuations, spread of diseases and pest infestations. This leads to management problems and consequently crop failures.

Generally winter is the best time for planting most vegetables in Botswana, because of the low incidence of diseases favoured by wet conditions and low pest pressure. Frost sensitive crops, such as tomatoes and green peppers cannot be grown in winter, unless grown in a protected environment. It is important to note that times of high market prices do not usually coincide with times when large amounts of a particular vegetable are harvested. However, good prices may be obtained when vegetables are harvested out of season.

VEGETABLE SEEDLING PRODUCTION AND NURSERY MANAGEMENT

The first step in successful vegetable production is to raise healthy vigorous seedlings. Young plants whether propagated from seed or vegetatively require a lot of care particularly during the early stages of growth. They have to be protected from adverse temperatures, heavy rains, drought, wind and a variety of pests and diseases. If small seeded vegetables are sown directly in the field, germination is often poor and the young plants grow very slowly and require a long time to mature. Also the season may be too short for full development in the field. To overcome these problems many vegetable crops are grown in nurseries before being transplanted in the field. A vegetable nursery is a place where plants are cared for during the early stages of growth, providing optimum conditions for germination and subsequent growth until they are strong enough to be planted out in their permanent place. A nursery can be as simple as a raised bed in an open field or sophisticated as a glass-house with micro-sprinklers and an automatic temperature control system. Although raising seedlings in a nursery has advantages, some vegetables do not transplant well, particularly root crops, and must be sown directly in the field for optimum results. It has to be noted, however, that transplanting seedlings interrupts their growth, which has the potential to reduce their vigor.

Advantages of growing seedlings in nursery beds.
Although many vegetable seeds can be sown directly in the field, experience has shown that raising seedlings in a nursery has a number of advantages as discussed below.

1. Intensive care - Seedlings receive better care and protection (from animals, weeds and pests) in the nursery. The average garden soil is not an ideal medium for raising seedlings especially from the point of view of soil tilth. At an early stage of development most vegetable crops require special attention that is not possible in the main field.

2. Reduction of costs - Fewer seeds are used for raising seedlings in the nursery than for sowing directly in the field,because in the latter seedlings have to be thinned to one, which is wasteful. When expensive hybrid seeds are used, transplants therefore become more economically attractive. Pesticides and labour are also reduced under nursery conditions as compared to planting directly in the field.

3. Opportunity for selection - Raising seedlings in a nursery affords the grower an opportunity to select well grown, vigorous, uniform and disease free seedlings.

4. Extend a short growing season for late maturing crops - Seedlings can be raised in a nursery under a protected environment before conditions outside become suitable for growth and transplanted into the field when conditions allow, thus reducing the amount of time spent in the field.

5. Forced vegetable production for an early market - Generally prices of horticultural produce are attractive when production or supply is low. Vegetables can be grown 'out-of-season' in a nursery when conditions are not yet favourable. Such crops will thus mature earlier after transplanting and hence stand to fetch a higher price in the market.

Choosing a vegetable nursery site

A number of important aspects must be considered in choosing a site for the establishment of a nursery if the outlay on seed, fertilizer, and labour is to show profitable returns. These factors are broadly grouped into the following:

1. **Environmental factors**

This refers to natural features of the land, which may greatly influence the cost of operation and facilitate management of the nursery.

a) Proximity to planting site (main field)

Some of the advantages of locating a nursery as close as possible to the main field are:

i) Cost of transporting the seedlings to the field is minimized.

ii) Less risk of loss of seedlings during transportation, and seedling failure after transplanting.

iii) Reducing the chances of transmitting or redistributing soil-borne pathogens through seedling roots or earth balls over long distances. When, however, particular diseases occur in the nursery area it may of course be advantageous to raise the seedlings outside the affected area in order to initiate new plantings with disease-free seedling materials.

b) Land gradient (steepness of the land)

It is desirable to have the nursery on a level ground with good drainage. This will reduce the cost of establishing the nursery considerably. If the nursery is to be located on a sloping land, soil conservation measures are required, such as constructing terraces across the slope to conserve soil and moisture.

c) Nursery soils

Favourable soil conditions (good drainage, absence of toxicity, fertile, etc.) are indispensable for the success of a nursery. When nursery plants are raised in pots, polybags, seedboxes or trays, it may not be necessary for soils on the nursery site to be fertile. But in this case, a source of high quality soil must be as close to a nursery site as possible in order to lower the cost of soil transportation.

d) Water supply

A nursery should be located where a reliable, abundant and inexpensive supply of uncontaminated water is available. Water supply could be from wells, boreholes, natural streams or irrigation channels.

2. Proximity to services

a) Labour supply

Nursery operations are labour intensive, therefore, it is very important that nurseries are sited in areas where a dependable and regular supply of experienced labour can be easily obtained.

b) Markets

The nearness of nursery sites to potential buyers is very important to commercial nurseries intending to raise seedlings for sale to growers. Such a nursery should be located as close as possible to these growers.

c) Supplies

It is desirable to have a nursery located close to sources of inputs (equipments or tools, and consumables such as seeds, pesticides, fertilizers).

d) Services

It can be advantageous to have a nursery located in an area where the services of agricultural experts (horticulturists, crop protection specialists, soil scientists, etc) can be obtained easily. Other aspects of services are the availability of good roads necessary for the transportation of supplies, seedlings and workers.

Types of nursery facilities

There are three main facilities normally used for raising seedlings in a nursery. The choice of a particular one will depend on the available resources and prevailing environmental conditions.

* Greenhouses - environment fully controlled
* Nethouse - environment partially modified
* Open field - where climatic conditions are normally favourable for the crops grown.

Media for raising seedlings

Soil is the major medium for germinating seeds and growing seedlings, although it is not the best. There are artificial media made of perlite, vermiculite and peat moss, which are used as soil substitutes. For best results, a growth/rooting medium should posses the following qualities:

- sufficiently firm enough and dense to hold seeds in place during germination.
- sufficiently porous to let excess water drain away
- have a high water holding capacity.
- free from weed seeds, nematodes and other pathogens.
- high cation exchange capacity so that it can provide nutrients
- able to withstand sterilization treatment without being altered.
- not be toxic to plants

Since it may not be possible for one medium to have all these characteristics, different media are normally mixed together to obtain a 'near' ideal mixture. Materials found in the locality may also be used. Some media may becontaminated, therefore it may be necessary to sterilize them before they are used, to kill weed seeds, insects and numerous soil pathogens. This treatment includes the use of heat and/or chemicals. Steam sterilization and solarization are used in the heat treatment to kill all pathogens in the media. One of the advantages of this treatment is that the media can be used sooner after treatment and the treatment can be applied to the dry, wet or even cold media.

There is, however, a risk of the media structure or composition being modified by the heat. Chemical treatment which is also referred to as fumigation involves the use of insecticides which may be specific to certain pathogens or broad spectrum (controls a wide range of pests). These chemicals should be handled with caution as most of them are toxic to both humans and animals. Some of the commonly used chemicals are, chloropicrim and vapam.

Seedling management

1) Watering. The seedbed or seedbox should be watered carefully with a fine stream of water. After the plants are well established, watering should be done thoroughly but not too often. It is advisable to irrigate seedlings in the morning and not in the afternoon as the latter leaves the soil surface moist overnight, a condition favouring damping off.

2) Shading. Shading should be done to protect the young seedlings from high heat intensity in sunny areas and also from from heavy rain. Shade can be provided by polythene nets or even grass. The shade should be removed some days before transplanting to allow the seedlings to acclimatize to field conditions.

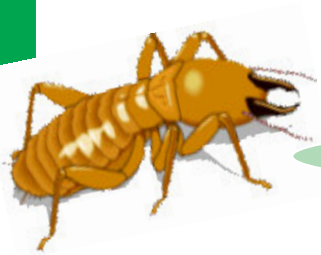
3) Thinning. This is a way of regulating plant density in rows and in holes. During thinning, weak, diseased plants are pulled out to allow healthy seedlings to grow well. It is normally done when seedlings have formed a few true leaves.

4) Insect pest and disease control. This is a continuous process from seedling emergence to transplanting. It is normally done by physical means but chemicals can also be used if the need arises.

5) Weeding. This is done by physical means when weeds emerge.

6) Hardening-off. Transplants must be 'hardened-off' so that they can withstand the transition from a relatively sheltered and protected environment to a sometimes harsh open situation. Generally, hardening is imposed from about 1 to 2 weeks prior to transplanting seedlings, by gradually exposing them to higher (or lower) temperature and the higher light intensity prevailing in the field. It should, however, not involve any treatment that may reduce the rate of photosynthesis, such as nutrient stress. Care should be taken not to over-harden plants, as this may delay maturity and in some instances even reduce crop yields.

7) Transplanting. This refers to the operation of lifting the seedlings from the seedbeds or containers and transferring them to the field where they will grow and mature. The main aim during transplanting should be to interrupt growth as little as possible, and if the operation is not carried out properly it can severely check growth or in extreme cases cause death of transplants. Most vegetable seedlings are ready to be moved 4-8 weeks after sowing. The seedbed should be given a thorough soaking about 6-12 hours before the plants are moved to ensure that they are fully turgid and that the roots retain plenty of soil when the plants are lifted. The main field should also be irrigated at the same time so that the planting holes can be opened up easily and the plants easily 'firmed'. The best time to carry out transplanting is in the late afternoon or early evening, as this allows the plants some time to get partially re-established before having to face heat stress during the day. A cool cloudy weather is ideal for transplanting. It is always wise to raise about 30% more seedlings than are actually required so that the weak ones can be discarded and any casualties replaced. The adaptability of vegetables to transplanting varies widely between crops. Transplanting success depends on how rapidly a plant is able to regenerate those parts of the root system that were lost/damaged during transplanting.



PESTS AND DISEASE MANAGEMENT

Pests and diseases are very important in crop production in general as they can pose a serious problem to farmers. These organisms can greatly reduce yield and quality of the produce and consequently the produce will fetch a lower price in the market and give lower returns to the farmer. These two problems are important in that money has to be spent in buying chemicals or resources such as labour ehngaged/diverted to combat them and this constitute a financial loss to the farmer. Good husbandry practices are essential if good yields are to be achieved. The problem should be fully understood so that the most appropriate method(s) to effect satisfactory and economical control can be chosen. It has to be noted that the use of chemicals to fight diseases and pests should be employed as a last alternative as their effect can often pose a more serious long-term threat to the survival of humans and the environment. Good husbandry and the use of resistant varieties can often reduce or eliminate the need for chemical control. If only slight damage is done to the crop, then it may not be necessary or economic to use chemicals. As a precautionary measure to prevent losses that can be due to pests and diseases, the following husbandry practices are necessary to be undertaken:

- Cultivation - plough deeply to destroy and bury residues of previous crops on which pests and diseases may over-winter. These residues may also be burnt.
- Hand picking - Large insects like locust and corn crickets may be controlled in this way while their population is still low.
- Adaptable cultivars - Select varieties to suit local conditions and where available varieties resistant to pests and diseases prevalent in the area.
- Early planted crops matures before a heavy build up of pests and diseases which occurs later in the season.
- Good sanitation - Keep a weed-free field as weeds harbour pests and diseases and they also compete with crops for light, air and nutrients.
- Practice crop rotation to help prevent a build-up of pest and disease populations in the soil. This will also ensure an efficient use of the soil nutrients as crops have different nutrient requirements and root depth.
- Use certified seeds which are disease-free, this will ensure disease-free seedlings.
- Chemical control - If pests and/or diseases persist despite the above management techniques, then treatment with chemicals may be the only way to save the crop. For the correct use of chemicals, it is absolutely necessary that all label instructions are strictly adhered to. Generally, the risk of disease development is high during hot and humid weather. A table in the appendix of this manual (Table A3) outlines common pests and diseases which are a problem to farmers in Botswana. Where possible, the active ingredient (a.i) of a chemical is also provided for ease of reference. Pesticides can be dangerous if handled carelessly, so when applying them the safety of other people should be considered. The safe period of the pesticides (the time from application to when the produce can be consumed without the risk of getting poisoned) should also be observed to reduce the risk of consuming excessive amounts of harmful chemicals before the active ingredient is degraded (oral toxicity).
- Biological control - This control measure involves the use of living organisms, (normally natural parasites of a pest dealt with) to control pests as an alternative to chemical control, thereby avoiding the possible harmful effects of the latter to beneficial insects as well as the environment. Care should however be taken in using this method to avoid a situation whereby the parasites become a problem (pest) after eliminating the main pest.

VEGETABLE CROPS

1. CRUCIFERAE

This family includes cabbage, Kale, rape and Cauliflower among others. These vegetables are usually eaten boiled, although cabbage can be eaten raw as a salad.

CABBAGE (*Brassica oleracea* var capitata)

Table 1. Descriptions of recommemnded cultivars

Cultivar	Black rot resistance	Cold tolerance	Heat tolerance	Maturity (days from transplanting)	Head size (kg)	Expected yield (t/ha)
Star 3301	Tolerant	Tolerant	Tolerant	60 - 80	2 - 2.3	86
Big cropper	Fair	Very tolerant	Tolerant	90 - 140	2 - 2.3	86
Tenacity	Tolerant	Tolerant	Tolerant	approx. 80	1.7 - 2.0	74
Grandslam	Susceptible	Very tolerant	Susceptible	85 - 140	2.0 - 2.3	86
Gloria	Susceptible	Very tolerant	Susceptible	approx. 80	1.7 - 2.0	74
Hercules	Tolerant	Fair	Fair	85 - 140	1.7 - 2.0	74
Transmark	Susceptible	Tolerant	Susceptible	75 - 130	1.9 - 2.2	82
Greenstar	Tolerant	Tolerant	Tolerant	approx. 80	1.9 - 2.2	82
Riana	Tolerant	Tolerant	Tolerant	approx. 80	1.6 - 1.9	70
K. K. Cross	Fair	Fair	Tolerant	approx. 80	1.7 - 2.0	74

Climatic requirements

Cabbage grows best under cool moist conditions and performs well at altitudes of 700 meters or more. The optimum temperature for growth is 18 °C with an average maximum of 24 °C and a minimum of 15 °C. Generally, young plants will withstand extreme temperatures better than older ones.

Soil and fertilizer requirement

Cabbage will grow on most types of soils, but are best suited to a well-drained loam or sandy loam, with a good organic status. Haevy clay soils may easily become waterlogged after heavy rain and thus encourage the serious diseases such as blackrot and soft rot. Optimum pH is 6.8, soils with a pH below 5.5 should be limed. Cabbage responds very well to nitrogen and should receive regular top-dressings to ensure good growth. The amount of fertilizer required will depend to a large extent on the fertility status of the soil (Table 2). If available, kraal manure should be applied at the rate of 50 tons/ha (=500 kg/100m^2= 2 x 15 litre buckets/3 m^2 (approx)). Organic matter should be incorporated into the soil to a depth of 30-40 cm.

Table 2: Fertilizer requirement for cabbage

Soil type	Basal dressing (kg/ha)	Top dressing (kg/ha)
Sandy to loamy sand (low fertility)	63 nitrogen 94 phosphorus 63 Potasium	70 nitrogen at 4 and 8 weeks after transplanting
Sandy loam (moderate fertility)	47 nitrogen 71 phosphorus 47 potasium	as above
loam (Fertile soil)	32 nitrogen 47 phosphorus 32 potasium	as above

NB. *Amounts given in elemental weight basis. These rates are based on a compound fertilizer 2:3:2.Refer to appendix for the calculations of actual fertilizer rates.*

Sowing and transplanting

Cabbage can be sown all year round if suitable varieties are chosen. 300 grams of seed is adequate to plant 1 hectare of cabbage. Seed should be sown thinly in 1 cm deep furrows spaced 15 cm apart in seedbeds. Usually these furrows run across a seed bed which should be 1 meter wide. Seedlings should be transplanted when they have developed two pairs of true leaves and are about 15 cm high (usually 4 - 5 weeks after sowing). It is best to transplant in late afternoon if temperature is too high. It is advisable to bring the soil to field capacity before transplanting and irrigate again immediately after planting. The roots must not be allowed to dry out. A spacing of 50 cm x 40 cm or 40 cm x 40 cm is recommended for early maturing cultivars, while all others can be planted 50 cm x 50 cm apart. Spacing can also be varied depending on the head size required, narrow spacing for small heads and wider spacing for bigger heads.

Irrigation

Soil must be kept moist to a minimum depth of 45 cm. The amount of water required depends on the time of the year and the stage of crop growth. As a general rule, water must be applied more often on sandy soils and when evapo-transpiration is high. The soil moisture content should be brought to field capacity before transplanting. During the 1st week after transplanting it is critical that the soil is kept moist all the time especially in summer and on sandy soils. Seedlings should not be left to get dry at this stage because their roots are not yet fully developed hence,can only get water from a limited soil volume. The general water requirement for cabbage is 23.4 mm applied at intervals of 6 days and 2 days during winter and summer respectively.

Harvesting

This varies according to planting date and temperature during the growing season. The crop matures early in summer exposure to cold weather during growth delays maturity. Heads can be harvested as soon as they are firm. Once cabbage is mature, the heads will stand in the field from 2 (summer) to four (4) weeks (winter) before splitting. However, some varieties are prone to splitting and cannot be left for such a long time. The cultivars 'Hercules' and 'Big Cropper' are susceptible to splitting after maturity and therefore should be harvested as soon as possible. When harvesting, a few outside leaves on the head should be left to protect it during transport. Split, rotten and insect damaged heads should be removed before the crop is marketed. Cabbage is usually packaged in green net pockets with a capacity of holding 25 - 30 kg of produce.

KALE AND RAPE

Recommended variety descriptions

Kale *(Brassica oleracea* var acephala*)*

1. **Chou moellier**

Tall growing non-branching kale with thick fleshy stem, large plain leaves.

2. **Thousand - headed**

Similar to choumoellier but branched and stem not thickened, plain leaves, cold tolerant.

Rape *(Brassica napus)*

Giant Essex is more productive than **Dwarf Essex** and does not bolt (early production of seed, resulting in deterioration in quality of the consumable part). The plant is branching and is not as tall as kale. Leaves may be damaged by hard frost as it has softer texture than kale. The cultivar **English Giant** is also adapted to local conditions and is also widely marketed locally.

Climatic requirements

Both crops prefer cool weather but kale is more cold tolerant, able to withstand temperatures of up to – 10oC. Young rape leaves may be damaged by sharp frost. Nevertheless both kale and rape can withstand high summer temperatures if water supply is adequate.

Soil and fertilizer requirements

These crops grow well on a wide range of soils. On sandy soils organic matter should be added. pH should be in the range 5.5 to 7.0. Basal fertilizer application should be the same as for cabbage. Because these crops are harvested continuously they should receive top dressings of 42 kg/ha nitrogen three weeks after transplanting and then every three weeks as long as picking continues.

Where black rot is a problem, do not plant kale, rape or other brassicas on the same land more than once every three years.

Sowing

Kale and rape may be sown all year round but optimum sowing dates are:
Cool areas (Southern District, Southern Kgalagadi) - December/January
Mild areas (Gaborone, Central district, Francistown, Ghanzi) - January to March.
Warm areas (Maun, Chobe, Northern Tuli Block) February to April.

For winter production in cold areas Kale should be used instead of rape. For transplanting, sow 2 g of seed on a square meter seedbed to plant 50 m^2 field of Kale or rape. They may also be direct sown at a rate of 3 - 5 kg seed per hectare and thinned after establishment. The crop should be transplanted or thinned when seedlings are 15 cm high. Care of the crop is generally similar to that of cabbage. The seedlings for rape and the cultivar 'Thousand-headed' of kale should be planted at a spacing of 60 cm between rows and 40 cm between plants, while for 'Chomoullier' 40 cm x 40 cm is adequate.

Harvesting

Leaves are picked as they become mature starting with the lower ones, by pushing them downwards and snapping them off. For marketing they are tied in bundles or packaged in plastic bags (18 x 39.8 cm). Each bundle normally weighs 0.5 - 1 kg. Only healthy newly-matured leaves should be used. Old and yellowing leaves must be discarded. Harvesting starts four to six weeks after transplanting and continues for three to four months.

Yield

Provided pest control is satisfactory, a yield of 50 - 75 tons/ha can be expected over a four - month picking period. Because of high pest levels in summer, the picking period may be shorter and lower yields will be obtained.

Diseases affecting brassicas

1. Downy Mildew

Casual Agent: *Peronospora parasitica* (fungus)

Symptoms

Most serious on seedbeds and appears as small leaf spots which first are yellow later turn brown with bluish black lace-like markings. The disease is promoted by wet-weather and low to mild temperature. In moist weather, a white mold develops on the under side of the leaf spots.

Transmission

The causal fungus overwinters on seed, in crucifer weeds and perhaps in soil.

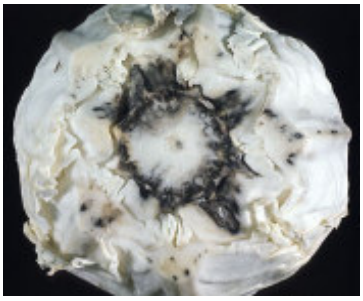
Control: Spraying with Mancozeb, Copper oxychloride, Zineb or Apron C at two-week intervals.
Sanitation - and seedbed rotation.

2. Black rot

Causal agent: Bacterium *(Xanthomonas campestris)*

Symptoms

Affects young as well as mature plants. Seedling stem infections may start in cotyledons. Dwarfing or one sided growth is common in leaves and entire plants. Infected lower leaves of cabbage and cauliflower turn yellow or brown and drop early. On older plants yellow wedge shaped areas appear at leaf margins and expand towards the centre of the leaf, affected areas later turn brown and dry out. In cross-section the vascular tissue is black in veins within affected areas.



Cross section of cabbage base showing black vascular bundles

Black rot is prevalent during summer rainfall period. Research has shown that its incidence is related to high leaf manganese concentrations., which in turn is related to low pH soils, hence it can be reduced by liming.

Characteristic wedge-shaped yellowing on cabbage leaves

Transmission

The black rot bacterium overwinters on seed and in residue from diseased plants, it persists in residue for 1 to 2 years. It is seed-borne and is spread on seedlings and by movement of contaminated water.

Control: Cultural - proper sanitation is important
2 year crop rotation
Use of resistant varieties

3. Bacterial soft rot

Causal Agent: Bacterium (*Erwinia carotovora)*

Symptoms

Affected areas appear to be water soaked, develop a soft decay and have a foul distinctive odour. Affected cabbage and cauliflower heads decay rapidly and turn dark brown to black. This disease often occurs together with black rot.

Transmission
The bacteria usually infect plants through surface areas injured by insects, cold or mechanical means. Warm wet weather conditions promote disease development.

Control: Good sanitation

Insect pests of brassicas

1. Diamond Back moth, *Plutella xylostella* (L) (Lepidoptera: Yponomeutidae)

The diamond back moth is a world wide and major pest of cruciferous crops in Southern Africa.

Characteristics
The adult moth is small with a wing span of about 15mm. It is about 8 mm long slender with three pale triangular marking on the inner edge of each forewing that form a diamond pattern when wings are folded from which it derives its name. The caterpillar is light green and sometimes has irregular dark markings on the head which turn light yellow when mature. The prolegs have a complete ring of crotchets. Pupae are found in flimsy cocoons on the lower surface of the leaves and are yellow-white to green in colour.

An adult Diamond Black Moth

Damage
The caterpillars chew the underside of the leave leaving only a thin transparent sheath. These 'window-like' holes later breaks as the leave grows, to form holes. Severe attacks may leave only the veins.

'DBM' caterpillers and the charecteristic window-like damage on leaves

Control
Chemical control of DBM has become difficult because of its ability to develop resistance to most chemical pesticides. However, Malathion, Carbofuran, Chlorpyrifos, Endosulfan, Methomyl, Dichlorvos, as well as pyrethroids may be used. Microbial control using *Bacillus thuringiensis* is the most effective method of control. For details on the formulations of *B. thuringiensis* consult *Aguide to the use of pesticides and fungicides* published by South African Department of Agriculture. Natural populations are suppressed by natural enemies like parasitic wasps, *Diadegma eucerophaga, Apantelles plutellae* and *Hyracella collaris* in areas where they are established.

Damage caused by DBM on cabbage

2. Cabbage Aphid (*Brevicoryne brassicae* (Homoptera: Aphididae))

The cabbage aphid (*'Ngadule'*in the local language)attacks many Crucifers like cabbage, rape brussel sprout and cauliflower.

Aphids on a cabbage leaf

Characteristics

It is a soft bodied insect, greyish - green in colour and the body is covered with a fine powdery wax.It is about 3 mm long. Winged and unwinged adults females occurs. Each adult produces up to 60 nymphs which develop and reproduce in a short span of time. A life cycle is completed in 8-10 days. Cabbage aphid is common on winter crops, but other aphids (*Myzus persieae*) may attack brassicas.

Damage

Aphids suck plant sap from the lower side of leaves, stems and flowers and form large compact colonies. High infestation may result in stunted plant and yield reduction. The leaf tips curl and turn yellow or white in colour. If not controlled, it results in mottled and crinkled leaves.

Control

Coccinellidae (lady bird beetle) adults and syrphid larvae are natural enemies of cabbage aphid. Insecticide control, using chemicals like Dichlorvos, Chlorpyrifos, endosulfan, methomyl, parathion, Phorate, Gamma-BHC and Demeton-S- methyl are effective.

3) Bagrada bug, *Bagrada cruciferarum*. (Kirkadly) (Hemiptera:Pentatomidae)

Bagrada bug (*'Podile'*) is one of the most serious pest of crucifers. It occurs everywhere in Botswana where crucifers are grown.

Characteristics

The adults are winged, about 6 mm long and usually found in pairs. They are black with orange and yellow spots. The adult lay 100 or more pale yellow-white eggs on foliage or on the soil. The eggs darken and hatch in about 1 week. There are 5 moults and the insect matures in 2-3 weeks. There are several generations each year.

Damage

Bagrada bugs causes damage to cabbage by sucking juice from young leaves and growing point. In years of severe infestation, feeding results in stunted plants, leaves turning yellow with a rough texture, and death of the growing point. Excessive feeding of growing point results in plants producing two or more small unmarketable heads instead of a large central head.

Control

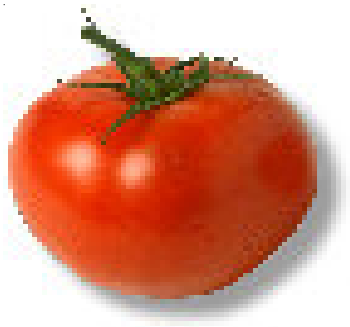
Because eggs are laid in the soil, they are readily killed by cultivation, so frequent cultivation of vegetable beds will help greatly in control of this pest. Several insecticides may be used to control Bagrada bugs when infestations are high. Young seedlings may be dusted with Bexadust. Plants at all stages of growth may be sprayed with Gamma BHC. Carbofuran, Parathion and Phorate are also effective.

Bagrada bug on cabbage leaf

2. SOLANACEAE

TOMATO

(Lycopersicon lycopersicum)



Recommended cultivar descriptions

1. Moneymaker

- Open pollinated
- Round firm fruits

Moneymaker is an indeterminate (producing tall plants) variety requiring staking. Harvesting commences in 80 days and yield averages 62 t/ha with a mean fruit weight of 70 g. It is a prolific fruit bearer although the fruits are small.

2. Expresso

- Hybrid
- Round to flat fruits

It is a semi-determinate variety producing firm fruits. Harvesting can be done from 80 days after transplanting. The variety has a mean yield potential of 65 t/ha and fruit weight of 125 g.

3. Heinz 1370

- Open pollinated
- Flat and fairly firm fruits
- Determinate (producing short bushy plants)

This cultivar has a mean yield of 60 t/ha and fruits weighing on average 100g. Harvesting commences in about 85 days after transplanting.

4. Zeal

- Hybrid
- Round firm fruits
- Good quality fruits
- Root Knot Nematodes resistance

Has a determinate growth habit and the fruits are round and firm. Fruits are ready for picking from 90 days. Mean yield is 66 t/ha with fruits weighing 132g.

5. Zest

- o Hybrid
- Round and firm fruits
- Uniform fruits
- High yield potential

Zest has semi-determinate growth habit and should be staked for better results. Harvesting commences in 90 days. The variety has a mean potential yield of 75 t/ha with fruit weight of 125 g.

6. Sixpack

- Open pollinated
- Early maturing
- Round and fairly firm fruits

Its growth habit is determinate. Harvesting commences in about 80 days and gives a mean yield of 60 t/ha with fruit weight of 100 gram.

Climatic requirements

Tomato is a summer crop that is easily damaged by frost. However, where weather conditions are favourable like some parts of Ngamiland and Chobe production can be done throughout the year. The best growing temperatures are 21 - 24°C, at these temperatures good quality

seed will take about 7 days to germinate. Temperature affects flowering and pollination - when the weather is very hot and dry, flowers may dry out and pollination does not occur. All year production in other parts of the country is possible under protected environment such as in tunnels and greenhouses. Under very wet conditions tomatoes suffer badly from disease and fruit fails to ripen.

Soil and Fertilizer requirement

Tomatoes will grow best on a well-drained sandy loam soil. Soil depth should be a minimum of 60 cm. Soils with a pH lower than 5.5 should be limed (1 - 2 Kg per square meter). Kraal manure or compost at a rate of 3 – 10kg/m^2 and 6 g/m^2 N, 9 g/m^2 P, and 6 g/m^2 K fertilizer should be applied prior to planting. Top-dressing with a nitrogenous fertilizer should be done at 2 weeks and 4 weeks after planting at a rate of 2.8 g/m^2 N.

Soil and cultural practice

Five (5) grams of seed will produce 700 seedlings, which is enough to plant 250 m^2. For a continuous supply of tomatoes from October through May, protected sowing should be made in mid-June followed by outdoor sowing every 2 months until early February. In frost free areas sowing can be made every 2 months. The production of tomato without protection from the heat during the hottest months (December- January) can be costly due to high pest pressure, particularly red spider mites.

From protected sowing made in early June, planting begins as early as the danger of frost is past in mid-August. Fruit from this planting is ready for picking in about 80 days while that from September – January planting is harvested in 60 – 70 days. The crop is usually grown in double rows at a spacing of 1.2 m between rows and 40 cm between plants. Row spacing can vary depending on other operations and/or equipment.

Mulching

Grass mulching will help control Bacterial Wilt disease and help prevent water loss from the soil.

Supports

Trellising helps improve the quality and quantity of marketable fruit. Bush varieties grown during winter in frost free areas can be produced without support. Training tomatoes also reduces incideences of fungal diseases as they promote air circulation through the crop. There are different types of training but a parallel wire system is common in Botswana.

Pruning

This consists of removing side shoots when they are 5 cm long by gently breaking off shoot between finger and thumb. This can be done up to one meter or the full height of the plant. Bush varieties should not be pruned. Pruning makes the control of diseases particularly during wet periods easier. Although this practice has some advantages, if not done properly or over-done, it can result in yield reduction. This practice is desirable for protected cultivation.

Irrigation

Tomatoes require approximately 500 mm of water per season. Soil must be kept moist to a minimum depth of 45 cm. To satisfy an average tomato crop water requirement, an amount of 16.2 mm should be applied at each irrigation with an interval of 1.5 days and 4 days during summer and winter (cool) season, respectively.

Table 3: Irrigation programme for tomato

Period from transplanting	Amount to apply in summer (mm/day)	Amount to apply during cool season (mm/day)
Up to 4th week	7.5	3.0
4th - 12 th week	11.0	3.9
12th - harvesting	9.5	3.5

Poor fruit formation

This is mainly a result of poor management or growing conditions although the genetic make-up of the crop may also contribute towards these conditions.

- Cat-Face
  Physiological malformation normally occurring at the base of the fruit (holes or scars), found particularly in some cultivars with large fruit.

Tomato fruits suffering from blossom end rot

- Blossom End Rot
  Appears as a dark brown or black area at the base of the fruit. This condition is normally caused by lack of calcium (lime) in the soil. It can also be caused by poor irrigation practices.

- Hollow Fruit
  When the seed inside the fruit is not surrounded by jelly. The fruit goes puffy and shrivels quickly. This can be due to picking green fruit too early. It may also occur when poor conditions for pollination occur, or may be due to lack of potassium.

- Blotchy Ripening
  Yellow or orange patches on the fruit. Caused by very fast growth, high temperatures and in some cases a lack of lime or potassium..

- Green Back
  Fruit remains green around the stalk end while the rest of the fruit turns red, seed inside the fruit usually remain green. Caused by excess sunlight or lack of potassium.

- Cracked Fruit
  Fruit develops cracks on the skin, in most cases running from top end to the fruit base. The main cause of cracked fruit is bad irrigation practices, particularly if the crop is heavily watered when the soil is very dry.

Harvesting

Determinate (bush) and indeterminate (tall) varieties start fruiting at the same time, but the tall varieties continue bearing over a longer period. Production is generally slow at first, and builts up to a peak then rapidly declines. Therefore overlap between plantings is necessary to even out fluctuation in production. Tomatoes spoil very quickly, so harvesting, handling and packing must be done without delay and with care. Picking

should be done in the morning or late afternoon when the fruit is cool. Tomato fruits can be harvested at different ripening stages as follows:

Pale Green Stage
When the fruit has reached the correct pale green stage the sections of the tomato which contains the seeds are surrounded by jelly. Tomatoes picked when pale green are for distant markets where it may take 10 - 14 days before they are sold.

First Light Red Stage
The fruit shows a slight pink colour at the base of the fruit. Fruit at this stage can be sent to nearby markets for sale within 10 days.

Light Red Stage
Most tomatoes are picked at this stage for sale to local markets. Picking should be done every 3 days.

Red or Fully Ripe Stage
Fruit at this stage is ready for immediate sale and may need picking daily.

Common diseases of tomato

1. Early Blight

Causal agent: Fungus *Alternaria solani*

Symptoms

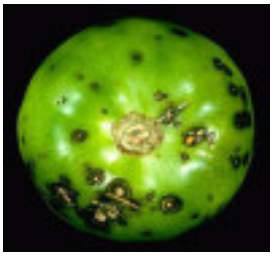
Can affect seedlings but generally is observed on older plants. On seedlings, dark spots develop on cotyledons, stems and true leaves. On older plants, dark brown spots with dark concentric rings develop on oldest leaves. Spotted leaves may die prematurely, resulting in substantial early defoliation. Fruits have sunscald and poor fruit colour.

Early blight lessions on leaves

Transmission

The disease causing fungus survives in infected leaf or stem tissues on or in the soil. This fungus can be easily carried by air currents, windblown soil, splashing rain, and irrigation water. The disease is promoted by heavy dews and rainfall and is severe on plants of poor vigor caused by poor nutrition, drought, or other pests.

Management:
Good sanitation
Crop rotation, involving small grains, corn or legumes
Use cultivars with greater resistance to early bligh
Spraying with Mancozeb or Copper oxychloride is recommended.
Maintain soil fertility at optimum levels



Tomato fruits with spots (left) and dark leathery sunken lessions (blossom end rot) caused by early blight

2. Wilts

a. Verticillium Wilt

Causal Agent: *Verticillium* spp.

Symptoms

Causes a restricted flow of water through out the plant, resulting in wilting. Leaf symptoms appear on oldest leaves first and later develop on younger leaves. Leaves of infected plants or parts of the infected plants loose turgidity, turn yellow, then brown and die. Wilted leaves may be flat or curled. A cross section of infected stems and twigs shows a complete or interupted ring consisting of discoloured brownish coloured water vessels.

Tomato plant suffering from verticillium wilt

Transmission

Disease fungus is soil borne but can persist for many years. Disease is more prevalent in cool weather than in warm weather.

Control: Crop Rotation and good sanitation.
Resistant varieties such as Rodade, Zest, Sixpack

b. Bacterial Wilt

Causal agent: Bacterium *Pseudomonas solanacearum*

Symptoms

Sudden plant wilting without leaf yellowing. Later turn brown and sometimes become water soaked and with hollow veins and stems.

Transmission

The bacterium over-winters in cold-frame and green house soil and in field soils. The disease can be serious if transplants are infected.

Control: Crop rotation
Destruction of infected crop residues
Use of resistant cultivars

Common pests of tomato

1. Red Spidermite (Tetranynchus Spp)

Various species of red spider mites attack crops in Botswana. The most commonly found being *T. urticae* and *T.Cinnabarinus*. *T. urticae* differs from *T. Cinnabarinus* by its green to yellow - brown colour in summer, and dark patches on the sides of the abdomen.

Characteristic

Small red coloured oval shaped mites about 0.5 mm in length. They usually live on the uderside of leaves and hence may not be easily seen.

Damage

Mites suck sap from the lower surface of leaves. The damage appears initially on the underside of leaves as small white/yellow spots which become enlarged due to continued feeding. The spots later become brown or bronze in colour, later dry out and wither.

a tomato branch heavily infested with red spider mites

Ripe fruits may also have orange/bronze patches. Secondary damage occurs when the webs are spun all over the plant leaves, preventing the leaves from opening properly. In cucumber and tomatoes growth becomes hardened and stunted. Attacks most common during hot, dry weather.

Control

Blanket use of insecticides reduces or kills natural enemies which results in an increase in the number of spidermites. Insecticide application should be based on careful population monitoring of spidermite before and after spraying. *Tetranyncus* spp are able to develop resistance to one pesticide after the other, sometimes very rapidly because of their short life cycle. A repeated (if necessary) full cover spray with chemicals such as Dicofol, Abamectin and Propargite maybe used. Alternating these chemicals reduces the chances of developing resistance by the pest. *Phytoseulus similis* has been shown to be effective as a biological control agent in the greenhouse tomato production.

2. Semi loopers (*Plusia* spp (Lepidoptera: Noctuidae))

Various species of semi-looper occur in Botswana. These are light-green caterpillars found feeding on young and mature tomato fruits. The loopers are characterised by their peculiar way of walking, looping the body with every forward movement. The moths are migratory and attacks can be quite sudden, severe and localized. Yield losses can be reduced by the use of insecticides.

3. American bollworm (*Helicoverpa armigera* (Lepidoptera: Noctuidae))

Because of its wide distribution and very catholic taste in food plants, prefering flower buds, flowers and developing fruits, the American bollworm is one of the most injurious pests of agriculture and home gardens.

Bollworm eating a tomato fruit

Characteristics

The adults are greenish or brownish moths some 15-20 mm long. The young larvae is almost black in colour, and changing to brownish, green or even pink with time. The underside is dirty white and cream white strips running along the sides with very distinct spiracles. The adult female lay eggs singly on upper leaf surface. They are shining white in colour when first laid, turning brownish when they are about to hatch 3-5 days later. The newly hatched caterpillar feed on foliage first and then descend and feed on tomato fruit. The caterpillar feeds inside the fruit where it undergoes 5-6 instars in 2-4 weeks before it is fully grown and are then about 40 mm long. The fully grown caterpillar walks down the ground and enters a crack in the soil or digs its own tunnel into the soil where it pupate for 10-12 days. Foliar feeding on tomato by newly hatched larvae does not cause any significant damage, but fruit boring may results in yield loss of up to 70%.

Control

H. armigera has been reported to develop resistance to most commonly used insecticides. However in Botswana, there is no evidence yet to show that it has developed resistance to synthetic pyrethroid. The use of Cypermethrin, Chlorpyrifos, Endosulfan, Methomyl, and Permethrin, among others give effective control against bollworm.

4. Root knot nematodes (*Meloidogyne spp*)

Charcteristic

Root knot nematodes cause charcteristic galls on roots. Galls may be up to 2.5 cm in diameter but are usually smaller. These galls interfere with the flow of water and nutrients to the plant resulting in plants growing less vigorously, yellowing, being prone to wilting in hot weather (even when well-watered) and responding poorly to fertilizers. Damage in the field usually appear as irregular patches and are frequently associated with light-textured soils.

Control

The following control measures can help reduce root knot nematodes load in the soil:

- use of resistant varieties
- rotation with non-host crops
- fumigation of the soil with chemicals like nemacur
- Plant mary-gold flowers in plots side-by-side with the crop.

Tomato plant roots infested by root knot nematodes

GREEN PEPPER (*Capsicum annuum*)

Some recommended varieties descriptions

1. California Wonder

- Dark green and smooth skin fruits.
- The fruit is mainly 3 or 4 lobed
- Can be picked at 60 to 70 days after transplanting.

2. California Wonder 300

- Open pollinated
- Matures in about 70 days from transplanting
- Dark green fruits turning red
- Fruit size of about 11 x 10 cm

3. Florida Resistant Giant

- Thick fleshy walls
- Dark green fruits turning red
- Tall bush plant type
- Ready for harvesting in 75 days from transplanting
- Blocky bell fruits measuring about 10 x 11 cm

Climatic Requirements

Peppers thrive well in warm conditions and have a long growing season. The plants require a warmer climate than tomatoes and are more sensitive to frost. Temperatures between 5°C and 15°C result in poor growth. Temperatures around 24°C are optimum for most green pepper varieties.

Despite the need for warm conditions the plant is sensitive to higher temperatures. Above 32°C the flowers are inclined to fall-off and few fruits if any, set at temperatures above 35°C especially when these temperatures are coupled with dry winds. Fruits that do form at such high temperatures are normally malformed. The fruit is also very prone to sunburn.

Soil Requirements

Like most other plants, green peppers can be grown successfully on a wide range of soils, but they prefer sandy - loam and loamy soils. Green pepper requires soil pH of between 5.5 and 7.0. The soil must drain well with good water holding capacity. It should also contain a adequate amounts of humus and be deeper than 40 cm.

Kraal manure or compost at 3 - 10 Kg per m^2, should be ploughed in preferably 4 - 6 weeks before planting. Plants require a high level of potassium, phosphorus and nitrogen in the soil. Base dressing of 60 kg/ha N, 90 kg/ha P and 60 kg/ha K fertilizer. On formation of the first fruits, a top dressing of 46 Kg/ha N should be given to keep the plants growing vigorously. Plants should be kept under observation for nitrogen deficiencies, and second topdressing, of the same quantity, should be given when necessary.

Sowing

The seeds are sown in the same way as tomatoes, i.e., in shallow furrows made across the seed-beds; about a hundred seeds are sown in each metre - long furrow. Half a kilogram of seed will give sufficient plants for one hectare. Under severe dry or warm conditions a light grass mulch will help retain the moisture and as soon as the seedlings appear the grass should be removed. In areas that normally experience frost, sowing can commence as soon as the danger of frost has past, and ground and air temperatures are favourable. The use of seed trays for seedling production is also encouraged.

Green pepper takes 7 to 8 weeks from sowing to transplanting. Should a flower form at the tip of the plant at transplanting it should be removed. Seedlings should be handled with care when transplanting. Transplanting is done the same way as with tomatoes and preferably on cool days or in the late afternoon. Irrigation should immediately follow transplanting. Single rows 60 cm apart, with the plants 60 cm apart in the rows, make harvesting easier than closer spacing and prevent the plants from being broken in the process.

Irrigation

Effective irrigation is essential to obtain the best yields of fruit of the right size. The soil must be kept moist to a minimum depth of 45 cm. During the first two weeks after transplanting, the plants should be irrigated twice or three times per week for the transplants to become established, thereafter, once or twice per week depending on climatic conditions and soil type. The water requirement for green pepper is 23.8 mm, which should be applied at an interval of 6 days and 2 days during winter and summer respectively.

Harvesting

A yield of 30 to 70 tons per hectare is considered to be good. Peppers are mainly picked when full-grown but still green. Peppers can be allowed to become red or yellow depending on the consumer preferences. During harvesting, grading and packing, the fruit should be handled with care. It bruises easily and this should be avoided as it promotes rotting.

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POTATO (*Solanum tuberosum*)

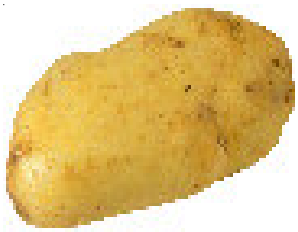


Table 4: Descriptions of recommended potato varieties

Variety Characteristic	BP1	Up-to-Date	Montclare	Van der Plank
Appearance	Flesh and skin white, shallow eyes. Few malformed tubers. Sprouts blue.	Flesh and skin white, shallow eyes. Tubers medium to large, round to oval, liable to produce malformed tubers.	White skin, white flesh, tubers oval flat to pear shape with no internal defects.	Fesh and skin white. Eyes very shallow. Tubers large to very large and pear shape.
Time from planting to maturity	120 days	120 days	120-135 days	90-115 days
Disease Resistance	Moderately susceptible to late blight; very susceptible to scab	Very susceptible to late blight; only moderately susceptible to scab.	Resistant to late blight.	Moderately susceptible to late blight; very susceptible to scab.
Advantages	Strong grower and good yield.	Strong grower and good yield.	Heavy yield and resistance to late blight.	Large tubers; long dormancy period, tubers do not start to sprout in the ground.
Disadvantages	Large tubers incline to hollow heart; very susceptible to scab.	Not suitable for Jan/Feb planting because of late blight susceptibility; poor heat tolerance, giving low yield and malformed tubers in hot weather.	Quick sprouting with tubers liable to secondary growth, therefore not suitable for spring planting.	Not drought tolerant; requires good conditions to yield well; very susceptible to Fusarium.
Adaptability	Suitable for all plantings except where scab is a problem.	Recommended only for winter planting due to blight susceptibility and poor tuber formation in hot weather.	For planting mid-Jan to mid-Feb in Southern District.	Suitable for spring planting in Southern District; when tuber quality is superior to other varieties.

Climatic requirements

Potato prefers a cool temperate climate but it can also thrive under warm day temperatures provided night temperatures are cool, otherwise tuber formation will be poor. However, potatoes are susceptible to frost, though young plants which have not started to form tubers can recover from frost damage. The mean optimum temperature for tuber formation lies between 15 to 20°C. Above 32°C tuber formation and development is very poor. High soil temperatures at planting time can cause the seed to rot in the soil and lead to poor emergence.

In Botswana only a few areas are suitable for potato production. In frost-free areas (Chobe, Tuli Block) potatoes can be planted from April to mid-July (optimum mid-April to end of June). In the Southern District potatoes can be planted from the end of January to mid-February and from the end of July to mid-August. Other areas tend to be too cold in winter and too hot in summer for economic production.

Soil and fertilizer requirement

Potatoes prefer a well-drained sandy loam or sandy clay loam with good water-holding capacity. Heavy soils cause uneven shaped tubers and it is difficult to remove soil from tubers at harvest. Soils must be at least 60 cm deep. Unlike most vegetables, potatoes can do well in acidic soils with a pH range of 4.2 to 5.8 with an optimum of 5.0 to 5.5 preferred.

Where available kraal manure can be applied at about 50 tons per hectare. The following fertilizer rate should give reasonable yields under most conditions:

Base Dressing: 63 Kg/ha N, 94 kg/ha P and 63 kg/ha K. e.g. A single application of 1000kg/ha 2:3:2(22) will provide these quantities.

Top Dressing: 106 Kg/ha N

Apply top dressing about 4 weeks after emergence, to coincide with the first ridging. If a soil analysis report is available these rates should be modified accordingly. Potatoes are heavy feeders and inadequate fertilization will result in poor yields.

Sowing and cultural practices/management

Potato Seed

Although potato is normally grown from potato tubers, true potato seed (tps) can now be used but they are still not popular. To ensure a healthy crop it is important that only clean disease-free seed is used. Currently, such material is obtained from South Africa and Zimbabwe.

Seed treatment

Seed tubers have a natural dormancy period of 1 to 3 months after lifting, depending on variety and conditions of storage. The seed tuber should be placed in shallow trays to sprout before planting. The seed tubers can be covered with damp straw to start sprouting, and if necessary gibberellin can be used to induce dormant tubers to sprout. Sprouts should be about 6 mm long at planting. If planting has to be delayed, the sprouts should be exposed to light to prevent further growth. To treat and prevent the transmission of diseases such as common scab andfusarium dry rot, seed tubers should be dipped in Mancozeb after lifting and before sprouting.

Seed rate

The following table gives the seed requirement at various spacing when 28 – 140 g seed is used. For different seed tuber sizes at a given spacing the seed requirement can be estimated as follows:

$$\text{Requirement (30 Kg bags/ha)} = \frac{\text{Average seed wt. (g)}}{70} \times \text{Requirement}$$

The inter-row spacing is largely determined by the cultivation implements used, but the closer spacing is preferred. Different seed sizes can be used for different intra-row spacing as indicated in table 5. Seed tuber over 140 g can be cut; but this is not advisable for January/February plantings as the seed is liable to rot. Cut the seed longitudinally so that each piece has a similar number of equally developed sprouts.

Table 5: Number of 30 Kg pockets of seed tuber (28 – 140 g) required to plant 1 ha under different spacing

Within row spacing (cm)	Between row spacing (cm)			Seed size (g)
	74	85	95	
25	125	111	99	28
30	104	92	82	56
35	90	79	71	84
40	78	69	62	112
45	69	62	55	140

Potato planters are available which apply fertilizer, plant the seed tubers and cover them in one operation. A ridger can be used to open furrows at the required distance. Fertilizer is placed in the bottom of the furrow and soil from the ridge is used to cover it. If sprinkler irrigation is used the land can be levelled after planting. If furrow irrigation is used, the initial furrow can be made deeper and a shallow remains after covering the seed which can be used for irrigation. Seed should be planted about 10 cm deep. Do not let seed come into contact with fertilizer when planting, as it will burn the seed.

Cultivation

About four weeks after emergence top-dressing with a nitrogenous fertilizer is done and the first ridging carried out. This should give reasonable weed control.

Irrigation

Typical water requirements are given below for different regions. These estimates assume the soil is brought to field capacity after planting. More frequent applications of smaller amounts of water should be applied on sandy soils. The idea is to maintain adequate moisture in the top 60 cm of soil, which is the normal rooting depth for potatoes. The plants must not be allowed to dry out, particularly after tuber initiation has started as this will seriously reduce yield and quality of the crop.

Harvesting

Time to maturity and harvest period

Potatoes take approximately 4 months (120 days) from planting to harvest. February/March planting mature slightly quicker (about 100 days) but harvesting of this crop can be spread over two months after maturity. Winter and Spring crops (especially the latter) must be harvested and marketed as soon as they become ready. Potatoes can be harvested when the skin becomes firm and does not rub off easily. If harvested earlier, they are liable to discolour, shrivel and not store well. The tubers can be dug by hand, using a fork, or a mechanical digger. It is not recommended to store potatoes after lifting under Botswana conditions. However, lifting of the February planted crop can be spread over 2 to 3 months to increase the marketing season, as the soil temperatures are cool at this time of year. If left too long in the ground some varieties will sprout or rot because of high temperatures.

Table 6: Irrigation requirements (mm/wk) for a potato crop grown in different regions

Time planting planting (weeks)	February-planted crop in Southern district	May-planted crop in Tuli Block	August-planted crop in Southern district
0 - 2	11.7	6.7	7.5
2 - 5	20.3	11.6	15.0
5 - 7	29.9	15.4	32.0
7 - 9	35.5	19.9	42.1
9 - 12	33.6	24.5	56.7
12 - 15	28.5	29.7	55.8
15 - 17	27.3	31.3	55.8

Yield

Yield up to 30 tons/ha can be obtained from winter planted crops. However 15 to 24 tons/ha is a reasonable yield.

Diseases of potato

1. Common Scab

Casual agent: *Streptomyces scabies*

Symptoms

Shallow scab consists of a superficial roughened area sometimes raised above, often slight below the surface of a healthy skin. Deep scab consists of lesions 1 - 3 mm deep darker than shallow llesions.

Potato tubers suffering from common scab

Control: Potato seed treatment with Mancozeb
Good sanitation
Crop rotation

2. Virus diseases

Causal Agent: Viruses (Potato Y and X potyvirus)

Symptoms

Various combinations of mild to severe leaf mottling, mosaic, vein-clearing, leaf strapping,feathery mottling, stunting, puckering, distortion ,necrosis and death. For the leaf roll virus upward rolling of leaf margins which progresses toward the midrib is observed. Retarded growth with rigid leaf tissue and dwarfed plants.

Transmission

The viruses are sap transmissible and also by white flies and aphids.

Control: Use of virus-free material from tissue cultures.
Use insecticides to control the vectors.

3. Early and late blights

Refer to section on tomato for symptoms, transmission and disease management/control

3. ALLIACEAE

ONION

Allium cepa)

Table 7: Descriptions of recommended onion cultivars

Characteristic/ trait	Cultivar			
	Granex 33 (H)	Pyramid (O)	Texas grano 502 PRR (O)	Bon accord (O)
Bulb shape	flat top, slightly tapered below	flat	flat top tappered below	globe
Bulb size	145 g	135 g	150 g	135 g
Storage	poor	fair	poor	good
Bolting	slightly susceptible	slightly susceptible	slightly susceptible	moderately susceptible
Yield	69 t/ha	64 t/ha	71 t/ha	64 t/ha
Early planting	suitable	suitable	not suitable	not suitable

NB: H - hybrid O - open pollinated

Climatic requirements

Cool temperatures are required during the first part of the growing season. When the plants start to form bulbs and especially during harvesting, warmer temperatures are preferable. Onion varieties are very sensitive to day length and temperature. Care must therefore be taken in the choice of suitable varieties. For example Australian Brown, a very popular variety in South Africa, is not suitable for production in Botswana as our summer days are too short to allow this variety to form bulbs.

Soils and fertilizer requirement

Onions can be grown on nearly all types of soils, ranging from sandy loam to clay soil. The best results are obtained from a sandy loam soil. Clays soils are not satisfactory unless well supplied with humus to loosen them up. Soil should be well drained and have a minimum depth of 60 cm. The pH of the soil should be within the range of 5.0 to 6.5. The onion plant is very sensitive to both high acidity and salinity and as such yields can vary over a fairly narrow range of soil pH. Soils that are more acid should be limed and the amount of lime to be applied must be determined after soil analysis. The lime must be ploughed in at least four weeks before the onions are planted. 63 kg/ha N, 94 kg/ha P and 63 kg/ha K (eg. 2:3:2 (22) + 1% Zn at the rate of 1000 kg/ha) should be applied as an initial pre-planting application. The plants should be top-dressed with a nitrogenous fertilizer at a rate of 64 Kg/ha, 4 to 6 weeks after transplanting or 12 weeks after direct sowing.

Sowing and cultural practices

Soil Preparation

Whatever method of production is to be used, the soil must be prepared thoroughly. The seedbed or the plot must be in good tilth and as level as possible.

Method of Production

(a) Direct drilling

800 grams of seed will be required for 1000m^2 of land for thin line sowing in rows 30 cm apart. The seed should be sown 1 cm deep. Direct drilling is not advisable where fine tilth cannot be effectively done, particularly in heavy soils. Soil should be raked by hand or a spike tooth harrow used for final cultivation. The period from sowing to harvest of direct drilled crops is 3 - 4 weeks shorter than for transplanted crops.

(b) Transplanted crop
8 grams of seed per square meter will be required for thin line sowing in rows 10 cm apart in seedbed. 3 Kg of seed sown in seedbeds will give sufficient seedlings for one hectare. The seedbed should be raised to provide easy drainage. Three year rotation should be practised if a permanent seedbed area is used. Seedlings will take 60 - 65 days from sowing to pencil thickness, when they are ready for transplanting. In the field only the white part of the stem should be covered with soil as in the seedbed.

(c) Setts
The term "sett" is applied to any small dry onion bulb about 1 – 2.5 cm in diameter. The seed for production of sets is sown at the end of August or early September. The seed rate for set production is 10 - 13.5 gm/m^2. 1m^2 of seedbed sown at this rate will produce enough sets to plant out a 12m^2 plot. The plants are not thinned in the seedbed. By the end of August, the days start lengthening and the plants immediately form bulbs before they put on more leaves. This together with high plant population result in very small bulbs. Fertilizer should be applied at a rate of 32 Kg/ha N, 48 kg/ha P and 32 kg/ha K at the time of sowing. The small bulbs will be ready to be harvested by the end of December.

After harvest the set should be dried off and stored in a dry, well-ventilated place until February when they are ready to be planted out in furrows 1 to 2.5 cm deep. Onions from sets can be harvested from the end of May to the end of July.

Plant spacing
An appropriate spacing is 5 - 10 cm and 30-45 cm intra- and inter-row, respectively. Under furrow irrigation, the width of the furrow should be 60 - 90 cm and two rows should be planted on each side of the furrow.

Time of planting
It might be necessary from the producer's point of view, to plant as early as possible in order to market the crop when the prices are high. But early sowing generally increases bolting (flower stalk production), thick necks and double bulbs, whereas late sowing reduces these defects but also reduces bulb size and yield.

(a) Setts
Sets should be planted from the middle to the end of February. Sets should not be planted later than that because the other two cheaper methods can be used.

(b) Direct drilled onions
The best yield is obtained when seed is sown from the middle of March to the end of March. However Pyramid and Granex can be sown as early as from 1st March.

c) Transplants
Pyramid and Granex 33 can be sown in the seedbed as early as from 1st March to the middle of April, whereas Texas Grano 502 PRR and Bon Accord should be sown from the middle of March up to the middle of April as they are likely to bolt if sown too early.

Weeding and cultivation
For the successful growing of onions, weed control is essential, especially during their early development. Onion seedlings are poor competitors with weeds. The removal of weed by hand between the plants is the cheapest method if labour is available. However, because of large plant population the effectiveness of hand or mechanical weeding is a problem, especially for the direct sown crops. Herbicides such as Dacthal w75 (pre-emergence herbicide), can be used.

Irrigation

Onions are a shallow-rooted crop and require frequent light irrigation. A rooting depth of 30 cm can be assumed, and soil in this zone must be kept moist. For the first 6 weeks after direct drilling and for the first week after transplanting, watering must be very frequent (every 1 - 2 days) to establish the crop. After the crop is established watering should be as follows:

0 to 8 weeks	12 mm/wk
9 - 12 weeks	15 mm/wk
13 - 16 weeks	20 mm/wk
17 - 20 weeks	27 mm/wk

These are actual water requirements of the crop and allowance should be made for irrigation efficiency when deciding how much water will be required (70% efficiently with sprinklers, 50 - 60% furrow). These figures are for the Gaborone region. In warmer parts of the country (Ngamiland, Tuli Block) more water is required to compensate for higher evapo-transpiration.

On sandy soils watering should be more frequent whereas on heavy soils less frequent. Onions are very sensitive to salinity and saline water should not be used for irrigation. If a crust is formed by irrigation on the surface of the soil, it should be broken as soon as possible and with a minimum injury to the plants.

Harvesting

Time to Maturity

Because onions are day-length and temperature sensitive only a limited sowing period is possible. The harvesting period can be extended by the use of different planting methods (i.e. setts, direct sowing, transplants). Use of sets has not been successful in Tuli block and Ngamiland regions, but in Gaborone region it gives bulbs for June - August harvesting from a February planting. From March sowings transplants take 180 days (Ngamiland and Tuli Block), 200 days (Gaborone region) and 215 days (Southern region) to maturity. Direct sown onions usually mature 3 to 4 weeks before transplants sown at the same date.

Harvest Period

Onion leaves fall over when the bulbs are mature and ready for harvest. Once onions are mature they should be harvested. The marketing season can be extended by storage for up to three months after harvesting. On good soils yields of over 60/ha are possible. However, 40t/ha is more typical. Onion setts generally give lower yields of about 30t/ha. Yields are substantially reduced if sowing is delayed. Onions can be harvested at different growth stages for marketing as follows:

- Green onions

Harvesting usually begins when 10 - 25% of the plants (leaves) have fallen over. They are made into bundles with leaves on and are the first to be marketed.

- Partly mature crop

The bulbs are lifted and left to dry for about a week. This is usually done when 50 to 75% of the leaves have fallen over. The tops are cut off in the field and bulbs marketed in 10 Kg orange pockets.

- Stored crops

These must be thoroughly dried, usually on the land where they have been grown. Up to 10 rows can be drawn together in one wind-row so the leaves of the onion protect the bulb from the direct sunlight. Sun burnt bulbs will not store well; hence it is not advisable to use late (November and December) harvested crops for storage.

For bulk storage, trim stems when bulbs are dry and lay them 1 - 1.5 meters deep on a wire mesh floor. For good storage bulbs must be kept dry and adequate ventilation ensured. An open-walled shed or crib is recommended.

Stored onions should be inspected from time to time for development of storage disease. The most common are bacterial soft rot (a watery rot of the bulbs) and a black fungal growth on the scales caused by *Aspergillus niger*. These diseases can spread very rapidly, therefore infected bulbs should be removed.

If the right variety is chosen and storage conditions are good, onions can be kept in store from September till March or April. If stored longer than this onions are likely to sprout with the onset of cooler weather.

Diseases of Onions

1. Downy mildew

Causal Agent: Fungus *(Peronospora destructor)*

Symptoms

A white purplish mould develops on leaves during cool moist weather. The leaves then shrivel from the tips and then turn yellow, and may droop.

Transmission

The downy mildew fungus overwinters in onion bulbs and sets and in residue from diseased plants. Fungus spores are spread by air currents. Cool moist weather promotes disease development.

Control: Downy mildew can be controlled by spraying with Mancozeb. However, if it is only a problem on crops grown from setts, hot water treatment is effective and spraying is not needed.

2. Botrytis Leaf Blight

Causal agent: Fungus *(Botrytis* spp.)

Symptoms

Appear first as numerous white specks on the leaves, as spots expand, the leaves die from the tips and turn brown. Plant tops may be killed and topple over within a week all plants in the field may be affected.

Transmission

Botrytis are present in the fields where plants are grown. Fungus spores are spread by air currents.

Control: Spray with Mancoze or Apron C.
Good Sanitation.

3. Purple Blotch

Causal Agent: *Alternaria porri*

Symptoms

Begins as water soaked spots which later turn brown. These spots later become purplish with a darker margin surrounded by a yellow zone. In moist weather the spots become covered with a brown mold.

Transmission

The fungus overwinters in residue from diseased plants. Long periods of rain or heavy dew promote disease development.

Control: Seed treatment with thiram.
Spray with Mancozeb.
Crop rotation.

Common pests of onion

1. Thrips *(Thrips tabaci)* (Thysanoptera: Thripidae)

This is cosmopolitan species that occurs on many crops. The adult is pale yellow to brownish. The adult is only about 1 mm in length. The eggs are inserted singly into the tissue of the leaf and the thrips feed on the leaves of plants. They crawl between the appressed leaves of onions where their numbers may build up, and they may even kill all onion plants. They feed on the plant sap on the leaf, resulting in whitish or silvery patches. The leaves eventually curl up and wilt.

Onion plant infested by thrips

Control:

Several insecticides are available for the control of onion thrips. The use of Endosalfan, Gamma-BHC, Phorate, Mercaptothion as well as pyrethroids (Deltamethrin, cypermethrin, parathion etc) is recommended.

4. CHENOPODIACEAE

BEETROOT (*Beta vulgaris* - Crassa group)

Table 8 : Description of recommended varieties of beetroot

Variety	Characteristic / Trait					
	Maturity in summer (days)	Maturity in winter (days)	Flesh colour	White rings	Root shape	Use
Crimson globe	60 - 70	100 - 120	Red	Fair	Globe	Fresh market
Detroit Dark red	60 - 70	100 - 120	Blood red	Few	Globe	Processing and fresh market

Climatic Requirements

A cool weather crop grows best during spring and autumn. The plants are not killed by frost, but cold weather will cause a thick tap-root and the development of many fine root hairs. Over-wintered crops of some varieties will also produce seeds. Although beetroots are more tolerant to high temperatures than most root crops, production during the period October -January is limited to the Southern region.

Soil and Fertilizer requirements

A well-drained sandy loam which has received manure with the previous crop is the best. Soils must not be acidic, a pH of 5.8 - 8.0 is best. Heavy clay soils are not suitable for this crop, as they restrict root development. Fertilizer should be applied as follows:

Base Dressing: 50 kg/ha N, 75 kg/ha P and 50 kg/ha K

Top Dressing: 52 kg/ha N applied at four and eight weeks

Sowing

Seeds should be placed at a depth of 2.5 cm in the soil. An inter-row spacing of 25 – 40 cm is recommended with the plants later thinned to an intra-row spacing of 8 - 12 cm. For good germination, maintain the moisture in the seedbed by applying a light grass mulch, which should be removed once germination has occurred. Successive sowings at 4-6 week intervals throughout the year only possible in the Southern region, as problems are experienced with germination due to high soil temperatures and rapid drying of seedbeds during the months of October to January in other regions.

Table 9: Best sowing times for beetroot in different regions

Regions	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Southern	--	X	X	X	--	--	--	X	X	--	--	--
Gaborone		--	X	X	X	--	--	X	--			
Central & Nothern		--	X	X	X	--	--	X	--			
Ngamiland			--	X	X	X	X	X	--			

Sowing chart key : *X - recommended sowing time* *-- - acceptable sowing time*

Irrigation

Bring the soil to field capacity before sowing. Irrigate daily after sowing until seedlings are 3 cm high (approx. 3-4 weeks). Then irrigate every 2-3 days till after thinning at a rate of 10 mm per application. A water requirement for beetroot is 14.6 mm and this should be applied at an interval of 4 days in winter and daily in summer.

Harvesting

Time to maturity is 14 - 16 weeks depending on variety and time of year. Harvest when roots are 6 - 8 cm in diameter. Larger roots maybe fibrous with a poor flavour. When lifting take care not to damage the roots. Beetroots are normally bundled, with their leaves, in bunches of 4-7 depending on size. The average weight of a bunch should be 1 kg while 20 t/ha is a reasonable yield.

SWISS CHARD (*Beta vulgaris* - Cicla group)

Recommended Varieties Description

Recommended cultivars

1. Fordhook Giant large, dark green, crumpled leaves with broad glossy, white ribs. They can be harvested continuously from the 8th week after sowing if well manured.
It is prefered for its dark green leaves.

2. Lucullus

Large, light green, crumpled leaves with slender, cream coloured ribs. As with Fordhood Giant, it can be harvested from the 8th week after sowing.

Both Fordhook giant and Lucullus can be produced all year around in Southern and Gaborone Regions. For details on the other Regions, see the Sowing Chart in the appendix.

Climatic Requirements

Swiss chard prefers cool weather with temperatures ranging from 10°C - 30°C; optimum monthly temperatures of 15°C - 18°C, not exceeding 24°C. It is damaged by light frost.

Soil and fertilizer requirement

Will grow on a wide range of soils, preferably a sandy loam soil. Good yields will not be obtained on soils with low fertility levels as it is a heavy feeder. If a prolonged harvesting period is desired, heavy applications of organic matter will be required. Swiss chard prefers a slightly acid soil with a pH of 6.0 to 6.8. A general fertilizer recommendation for swiss chard is as follows:

Base Dressing

Suitable for most soil types. Add kraal manure at the rate of 5 - 8 Kg/m^2 or add chicken manure at 2 - 4 Kg/m^2. A basal dressing of 55 kg/ha N, 80 kg/ha P and 55 kg/ha K should also be applied in addition to the manure.

Top Dressing:

Swiss chard has a high nitrogen requirement and should recieve applications of nitrogen at a rate of 42 kg/ha at 21 day intervals.

Cultural practices

Sowing

Seed is direct sown but may also be transplanted. About 14 kg is sufficient to cover a hectare using an intra-row spacing of 20 cm and a recommended inter-row space of 50 cm.

Thinning

Thinning should be done 3 - 4 weeks after sowing for all types of swiss chard when seedlings are 5 - 7 cm high. Weak plants should be removed leaving only strong ones at the spacing stated in the `sowing `section. Irrigate to settle plants back into the soil after thinning.

Cultivation

Keep soil free of weeds, use shallow cultivations at all stages of growth.

Irrigation

Swiss chard has a high salt tolerance therefore suitable for situations where brack conditions occur. The soil should be brought to capacity 2-3 days before sowing and irrigated at 2-days interval until germination. To a mature crop apply 25 – 31 mm every week in winter and the same amount every three days during summer.

Harvesting and packaging

Harvesting commences between 8 weeks after sowing for all types of swiss chard, by removing outer leaves or stems at regular intervals. The leaves should be cut with a sharp knife about 4 cm above the soil surface without injuring new buds.

Leaves are tied into 500 g bunches for marketing. Plastic wrapping may be used to keep leaves or stems in a fresh state for a period of time. To prevent bundles of swiss chard leaves from wilting, they can be placed upright in 5 - 8 cm of water in an upright container. Another method which can also be used is to cover the bundles with damp sacks. Normally this will retain the leaves in a turgid/good condition for 12 - 24 hours.

Yield

Average yield ranges from 7.5 - 16 tons/ha depending on the length of the cropping season and the level of fertilization. Average weekly yields per square metre will be in the region of 75 - 150 grams, assuming a 4 month cropping season and that 66% of the total area is cropped.

2. Leaf Spot of swiss chard and beetroot

Causal agent: fungus *(Cercospora)*

Symptoms

Small light brown spots with reddish or purple edges. Later may become so numerous as to give the leaves a scorched appearance.

Transmission

The causal fungus is carried on seed and possibly survives one season in residue from diseased plants. Disease development is promoted by prolonged periods of warm wet conditions.

Control: Dust with captan
Spray Dithane M45.

Common pests of swiss chard

1.Root knot Nematodes

Nematodes results in galls forming on roots, thereby restricting water absorption by the plant. Affected plants are usually stunted. Affected plants are normally in patches, rather than uniformly spread through out the field.

5. UMBELLIFERAE

CARROT (*Daucus carota*)

Table 10: Recommended varieties description

Cultivar	Characteristic / trait				
	Colour	Days to maturity	Tolerance to alternaria	Leaf growth	Uses
Chantenay	Very good	70 (90)*	Fair to Poor	Strong/high	Home & marktet
Cape market	Very good	75 (100)	Fairly good	Strong/high	Home, market & canning
Nantes	Fair	70 (80)	Fair to poor	strong/high	Home & pre-pack
Oxheart	Poor	70 (80)	Poor	Medium to small	Home

** figures in parenthesis are for winter production*

Climatic requirements

Carrot is a cool season crop which attains best growth at temperature range of 15 - 20 °C. Exposure of the crop to temperatures above 20 °C during development results in shorter fibrous root. This also leads to poor root colour development, a phenomena which can also occur when the crop is growing under low temperature conditions (below 15 °C).

Soil and fertilizer requirements

The crop is best suited to a deep, loose, well-drained, sandy loam which is slightly acid. Heavy clay soils are not suitable for this crop as they restrict root growth resulting in irregular shaped roots. In soils with high organic matter levels carrots tend to produce excessive leaf growth and form forked roots. **General recommendations where soil tests have not been carried out are listed below. Top dressing is done when plants are about 5 - 7 cm high.**

Base Dressing: 50 kg/ha N, 75 kg/ha P and 50 kg/ha K

Top Dressing: 52 kg/ha N applied at four and eight weeks

Sowing and cultural practices/management

Carrots are a direct sown crop. Seeds should be sown in a moist soil at a depth of 1 cm. For good germination maintain moisture to this depth. A light grass mulch will help in maintaining the optimum moisture level. Sow the seeds in rows for better weed control. An inter-row spacing of 30 – 45 cm is recommended. About 4.5 kg seed is adequate to cover 1ha. Carrots seedlings are delicate and should be thinned early, to a spacing of about 5 cm apart. For a continuous supply of carrots to the market, make successive sowing every 4 - 6 weeks during the season.

Table 11: Suggested sowing months for carrot production in different regions

Regions	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Southern	--	X	X	X	--	--	--	--	X	--	--	--
Gaborone		--	X	X	X	--	--	X	X	--		
Central		--	X	X	X	--	--	X	--			
North east		--	X	X	X	--	--	X	--			
Ngamiland			--	X	X	X	X	X	--			

Sowing chart key : *X - recommended sowing time* *-- - acceptable sowing time*

Cultivation and weed control

Never allow weeds to compete with your crop. Soil cultivation between the rows can be carried out as soon as seedlings are clearly visible (1 - 2 cm high). A wheel hoe or a light hand hoe can be used between the rows to control weeds and also to cover the shoulders of maturing carrots with a thin layer of soil. Earthing up prevents greening of the carrots root shoulders. For those producing carrots on a larger scale herbicides may be necessary.

Irrigation

As a general guide carrots require 300 - 350 mm of water from sowing to harvest assuming 12 - 14 weeks to maturity of the crop. Irrigation during winter should be done by applying about 16 mm water at an interval of 4 days, whereas in summer it should be done daily or at two days interval.

It is important to maintain the soil moisture to a depth of 60 cm to ensure good quality carrots. Moisture content of the soil influences the form and colour of carrots as follows:

- shortage of soil moisture results in a longer carrot.
- very wet conditions produce shorter and thicker carrots, with a lighter colour.
- variations in soil moisture levels can cause splitting of carrots.

Harvesting and marketing

Depending on the variety and the season the crop is usually ready for marketing within 12 - 14 weeks after sowing. Carrots are harvested when they have reached a diameter of at least 2cm. When lifting use a fork taking care not to damage the roots. Carrots can be harvested over a period of 4 - 6 weeks once they are ready. For a fresh market, carrots can be bundled with their leaves in bunches of 6 - 9. The average weight of a bunch should be 1 Kg. For distant markets carrots are sold without leaves in 14 Kg net plastic or hessian bags.

Yields

Typical optimum carrots yields are 30 - 50t/ha (with leaves) or 20 - 30t/ha (root only).

Pests affecting carrot

1. Root knot nematode

Causal agents: *Meloidogyne incognita* and *Meloidogyne javanica*

Symptoms

Infected carrots may have forked roots and irregular round galls and spindle shaped enlargements on the top and side roots. Plants exhibiting stunted growth usually occur in patches of non-uniform growth rather than spreading evenly in the entire field.

Control: Nemacur
Rotation with non host crops
Sanitation - weed control to eliminate alternate hosts.

Malformation in carrot probably caused by nematodes but application of fresh mature also has the same effects

6. CONVOLVULACEAE

SWEETPOTATO (*Ipomoea batatas*)

Recommended varieties

1. Blesbok

- Skin colour: purple-red with cream white flesh
- Size: medium to larg
- Shape: long elliptic
- Resistant to cracking
- Early tuber formation
- Low tuber dry matter

2. Ribbok

- Skin colour: whitish with pink tinge, flesh creamy-white
- Size: Medium
- Shape: short and fat, oval
- Fairly resistant to cracking
- Foliage growth vigorous

3. IITA TIS 3290

- Skin colour : pale pink skin with white/cream flesh
- Size: medium to large
- Shape: elongated oval to cylindrical
- Fairly resistant to cracking
- Foliage growth very vigorous

4. Mafutha

- Skin colour: pale light pink with cream orange spots
- Size: small to medium
- Shape: round elliptic
- Resistant to cracking
- Early tuber formation
- High tuber dry matter content

5. Impala

- Skin colour: deep pink, flesh cream with orange specks.
- Size: small to medium
- Shape: elongated, tapered cylinder
- Resistant to cracking
- Foliage growth only moderate

6.Kenya / SPN/O

- Skin colour: white to cream-white skin and flesh
- Size: large to very large tubers
- Shape: elongated tapered cylinder
- High tuber dry matter
- A very vigorous growing cultivar which establishes quickly

Climatic requirements

Sweetpotatoes require warm conditions for growth and cool cloudy conditions, and cold nights (less than 8°C) retard crop development. Foliage is killed by frost, therefore, the growing season of 4 - 5 months must be completed before night temperatures drop sharply (usually early May in Gaborone).

Soil and Fertilizer requirements

Sweetpotatoes prefer sandy to sandy-loam soils with pH 5.1 to 6.3. Soils must be well drained. Heavy soils lead to poorly shaped tubers, and because of their tendency to crack on drying, favours weevil attack. If available apply kraal manure at 20 - 40m^3/ha. Apply Nitrogen at 32 kg/ha, Phosphorus at 47 kg/ha and Potassium at 32 kg/ha, before planting and top-dress with 31.5 kg/ha N six weeks after planting. If a soil analysis is available these rates can be modified accordingly.

Planting and cultural practices

Sweetpotatoes are propagated vegetatively using stem cuttings, which should be taken from healthy virus-free plants. A plot for producing cuttings can be established in February in areas with light frost. Irrigation should be stopped when the vines are killed by frost and resumed as the tubers start sprouting (August/September). Cuttings will be ready for use in November/December. In frost-free areas over-wintered vines can be cut and used as planting material in August/September. Tubers will sprout and produce a second crop of cuttings in November/December. Plants that show symptoms of yellowing, mottling or lack of vigour should not be used for cuttings as they are likely to transmit disease to the subsequent crop.

Preparation of cuttings for planting

Cuttings of 30 - 40 cm long should be used for planting. Vines from mother plants are cut into suitable pieces and leaves removed from the lower two-thirds of each cutting to prepare it for planting. Cuttings taken from the tips of stems are the best but other sections of the stem may also be used. Cuttings may be kept for 1 - 2 days before planting in wet hessian sacks or buckets of water. Tuber may also be stored and re-planted in July/August to produce cuttings for October/Novemer planting.

Land preparation and planting

After ploughing and incorporation of kraal manure ridges should be made 1 metre apart in the land. Fertilizer (2:3:2) should be banded along the base of the ridges and mixed with the soil. If there is no rain land should be irrigated to field capacity before planting. Cuttings should be planted 40 cm apart along the ridges. The lower 1/2-2/3 of the cutting is covered with soil and the land irrigated again after planting.

Cultivation

Weeding should be done until the vines cover the soil. The vines will then be able to suppress weeds. When top dressing is done more soil can be brought up around the ridges when covering the fertilizer, to ensure that when tubers develop they are well covered by soil. This (hilling) will also ensure that soil cracks are filled up hence weevil damage to tubers will be reduced.

Irrigation

Sweetpotato is deep-rooted and fairly drought tolerant. However, moisture stress, especially during tuber initiation (about 45 to 60 days after planting) should be avoided. Frequent watering is also recommended until the cuttings are established. Watering should be continued until 2 - 3 weeks before lifting. Too much water at this stage may result in rotting, and in cracking of the tubers. Unlike most vegetables, sweetpotatoes requires less irrigation and can tolerate long dry periods. In areas where rainfall is over 500 mm, they may be grown successfully without irrigation.

Crop rotation

To avoid build-up of pests and diseases, sweetpotatoes should not be planted on the same land more than once every three years.

Harvesting and marketing

The crop can be lifted from 4 months after planting, but will continue to bulk up until the onset of cold weather if left on the ground. Remove vines before harvesting, then lift with a digging fork taking care not to break or damage the roots. Vines may be used as stock-feed and have high nutritional value. Except in very cold areas the crop can be left in the ground until required for marketing. However, do not water after growth has ceased as this may cause tubers to rot.

If post-harvest storage is required the tubers should be cured at 25 - 30°C and high (85 - 90%) humidity (e.g. on wet sacks) for 5 to 7 days after harvest. An underground cellar is recommended for this purpose. After curing tubers may be stored in cool conditions (12 - 15°C) for several months. Only healthy, mature sweetpotatoes free from damage should be stored.

Yield

Depending on time of planting and the harvesting date, yields of 20 - 40 t/ha be obtained. Especially in cooler areas early plantings (November) will give the best yield. Yields will be low if planted less than four months before the onset of cool winter weather.

Diseases of sweetpotato

1. Mosaic virus

Causal Agent: virus

Symptoms

Plants grow slowly and are stunted. Small leaves with yellow patches with a rough/crumpled textures. Yield of affetced plants is drastically reduced.

Transmission

The disease may be carried from one season's crop to the next through the planting material.

Control

There is no control for the disease but infected plants should be removed from the field. The use of 'clean' planting material is very important. Insects such as white-flies, which transmit the virus from infected plants to healthy ones through the sap, should be controlled.

Pests of sweetpotato

1. Sweetpotato weevils

Larvae feed and tunnel into the stems and tubers. Adult weevils feed on the tender buds, leaves, stems as well as storage roots, leaving tunnels filled with debris. Hot dry weather favours weevil development.

Control

Effective control measures include:

- Hilling-up of soil around the base of the plant and filling of soil cracks.
- Applying sufficient irrigation to prevent or reduce soil cracks.
- Timely planting and prompt harvesting to avoid a dry period.

A sweetpotato weevil

7. CUCURBITACEAE

PUMPKINS, SQUASHES AND WATERMELONS

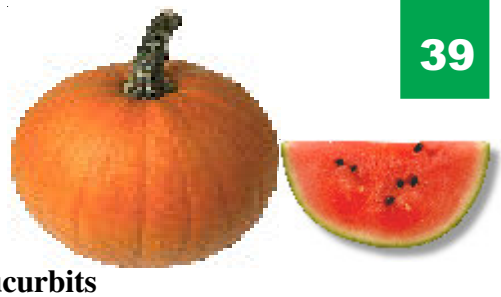


Table 12: Description of recommended varieties of cucurbits

Type	Variety	Shape	Size	Skin colour	Flesh colour	Days to maturity
Pumpkin	Flat White Boer A	Flattened with scalloped edge	3-6 Kg	Cream white	Orange	100-120 days
	Flat White Boer Ford	Flattened with scalloped edge	4-8 Kg	Cream white	Orange	110-130 days
	Queensland Blue	Ribbed drum narrowing to flower end	3-4 Kg	Grey-green	Orange	100-120 days
Squash	Green Hubbard	Flask shaped, tapering to stalk end, rough skin	3-4 Kg	Dark green with lighter streaks	Yellow	100-120 days
	Green Hubbard Chicago Warted	Flask shaped tapering to stalk end, skin warty	3.5 -4.5 Kg	Very dark green with lighter streaks	Yellow	100-120 days
	Little Gem	Round, tennis-ball shape	150-200 g	Green, becoming yellow when over ripe	Yellow-green	60-80 days
	Rolet	As for Little Gem	200-250 g	Dark green	Creamy yellow	60-80 days
	Butternut	Thick neck swollen ball at flower end	1 Kg	Buff	Orange	80-100 days
	Table Queen	Ribbed "acorn" squash, tapering to flower end	400-700 g	Dark green	Yellow	80-100 days
Watermelon	Sugar baby	Round	3-5 Kg	Dark green, with darker stripes	Bright red with dark brown seeds	85 days
	Black Diamond	Nearly round	up to 18 Kg	Dark green	Bright red, with black seeds	95-105 days
	Charston Gray	Oblong or obvate	up to 13 Kg	Light grey-green	Bright red, with dark brown seeds	85-90 days
	Congo	Oblong or obvate	up to17 Kg	Alternate dark and mid-green stripes	Light red, with buff-coloured seeds	85-95 days

Climatic Requirements

Cucubits perform best in warm weather with optimum temperature for pumpkin being 18 - 25° C while squash and watermelon do well at 21 - 30°C. Cucurbits are damaged by frost and pollination is poor below 13°C. Pumpkins and squashes require a soil temperature of at least 11°C for germination while watermelons require at least 20°C. At low temperatures more female flowers are produced and at high temperatures more male flowers are produced. Very high temperatures may lead to poor fruit set of pumpkin and squash (especially Flat White Boer). Abortion of female flowers is common. Prolonged humid weather leads to outbreaks of leaf diseases.

Soil and Fertilizer Requirements

A deep well-drained soil is preferred (at-least 60 cm) with a pH of 5.5. to 7.5. Sandy loam and loam soils give best results. If available, kraal manure should be applied at 30 - 50 tons/hectare and worked into the soil before planting. Superphosphate should also be applied at a rate of 700 kg/ha, before planting. The crop should be top-dressed with 3

5 Kg/ha N when plants start to produce runners. If pH is above 6.5 use 170 Kg/hectare ammonium sulphate instead of LAN. For closely planted crops (e.g. gem squash) the fertilizer may be broadcast. For widely spaced crops fertilizer should be banded in strips along the planting rows. However, do not concentrate the fertilizer in too small an area as it may damage the plant roots.

Sowing and cultural practices

The field should be clean cultivated about 6 - 8 weeks before planting to reduce cutworm population and allow decay of organic matter. The following planting methods may be used depending on the irrigation system and the size of the area to be planted.

Furrow planting (for use with furrow irrigation)

Make furrows at the recommended row spacing (see below). Sow seed on the side of the furrow, just above where the water reaches, at the desired spacing. Two seeds are sown at each station and thinned to one plant if both emerge. Plants are trained away from the irrigation furrow as they grow.

Flat planting (for use with sprinkler or drip irrigation)

After fertilizer has been incorporated, seed is sown in rows on the flat. A planter may be used (e.g. Planet Junior). If sowing is done by hand sow two seeds per hole and thin to one plant after emergence. This method is recommended for sandy soils.

Hill or Basin planting

This method is very labour intensive and can only be recommended for small areas. It is only appropriate for widely spaced crops (hubbards, pumpkins and watermelons). Hills are made 30 cm high and a basin made round each hill into which the irrigation furrow runs. Basins of about 90 cm diameter spaced 2m x 2m apart are recommended. Sow 4 seeds per hill thinning to two plants after emergence.

Time of Sowing

Pumpkin and squash can be sown as soon as frost danger is past. Watermelons should be sown 2 - 3 weeks later as they require a higher soil temperature for germination. In frost-free areas pumpkin and squash are best grown as winter crops. Best months for Sowing are as stated in the table below:

Table 13: Recommended sowing dates for different cucurbits

Crop	region	Month											
		J	F	M	A	M	J	J	A	S	O	N	D
Pumpkins and Squashes	1. cold areas (May- August)								–	*	*	–	–
	2. Mild areas (June-July)	–							*	*	–	–	–
	3. Frost-free areas		–	*	*	*	*	*	–				
Watermelons	1. Cold areas									*	*	*	–
	2. Mild areas	–								*	*	–	–

Table 14: Recommended planting space for cucurbits

Crop	Between rows	Between plants
Watermelon and pumpkin	2.4 metres	90 cm
Hubbard squash	2.4 metres	90 cm
Butternut, Table Queen	1.8 metres	90 cm
Little Gem, Rolet	1.2 metres	45 cm

Cultivation and Weeding

The soil should be kept free of weeds. Only shallow cultivation should be done in the root area to avoid damaging roots. Vines may be trained to leave paths between the rows in order to give access for pest and disease control operations.

Irrigation

Water requirement can be estimated from the following table.

Table 15: Water requirements for cucurbits

Days from planting	Irrigation requirement (mm)	Winter Irrigation interval (days)	Summer Irrigation interval (days)
0 - 30	7.8	2	1
31 - 70	15.6	4	1 - 2
71 - 110	23.4	6	2
111 - maturity	31.2	8	3

Harvesting and packaging

1. Pumpkins (Flat White Boer, Queensland Blue)

Pumpkins must be allowed to become ripe before harvesting. The skin should be hard and not easily scratched with a finger nail. When harvested part of the stalk should be left on the fruit. If it is cut too close to the fruit, rots may set-in through the wound. The pumpkins are packed in green cabbage bags for marketing. For storage, only completely ripe fruit are suitable. Cure at 29° to 32°C for 2 weeks or a month at room temperature, then keep in a single layer (not stacked) in the shade. A cool well ventilated place is recommended, ideally 6 – 13°C. Fruit harvested in late autumn may be stored for 3 - 4 months. Remove any rotting fruit from the store.

2. Hubbard Squash

As for pumpkins, the fruits are harvested when the skin is no longer soft and the skin changes from bright to dull green. Packing and marketing is done as with pumpkins, but the skin is more tender and storage is not recommended.

3. Gem Squash (Little Gem, Rolet)

These are harvested at a "mature green" stage, i.e. while the skin and flesh are still green but the skin has started to harden, but can still be easily scratched with the finger nail. If harvested too young they wither rapidly after harvest, but if left too long the flesh becomes yellow and coarse and loses flavour. The skin of Little Gem turns yellow if it is left too long on the plant.Gem squashes are marketed in 10 Kg green bean bags. A short stem is left on the squash after harvest. The squashes are about the size of a tennis ball when ready.

4. Butternut and Table Queen

These are allowed to mature on the plant. The skin should be tough and not easily scratched. Butternut may be packed in orange pockets, or hessian potato bags. Table Queen is packed in green bean pockets. Both Butternut and Table Queen can be stored for several weeks after harvest, if picked when mature (Table Queen 4 - 6 weeks, Butternut 2 - 3 months). Storage conditions are as for pumpkins.

5. Watermelons

These are harvested when ripe. Ripeness can be determined as follows:

(a) Fruit tapped lightly with the finger gives a dull sound when ripe. Unripe fruit has a solid metallic sound.
(b) At the point of attachment of the fruit-stalk to the main vine there is a small tendril. When this tendril becomes dry the fruit is nearly ripe. When the next tendril, nearer to the tip of the vine, also becomes dry the fruit is ready for harvest.

Fruit should be harvested with a short stalk attached. They should not be left to become over-rip in the field as the texture and flavour deteriorates. Harvesting is best done in early morning. The fruit should be consumed as soon as possible after harvesting but can be kept for 2 - 3 weeks in cool weather (e. g. at 5 - 14°C). Watermelons are usually sold loose. Part of the fruit that rests on the soil turns whitish to yellow in colour. The flesh colour is often reddish but if harvesting is delayed it becomes pale.

Yields

Expected yields are as follows:

Pumpkins	18 - 22 tonnes/ha
Squash	11 - 16 tonnes/ha
Watermelons	9 - 11 tonnes/ha

Diseases associated with Cucurbits

1. Anthracnose:

Causal Agent: Fungus *(Colletotrichum lagenarium)*

Symptoms
Small, yellowish watery spots which enlarge rapidly and turn brown. Oblong lesion occur on the stem resulting in death of plant. On fruit round black sunken cankers occur.

Anthracnose on pumpkin leaves

Transmission
The fungus overwinters in seed and in residue from diseased plants and is spread by splashing water. Humid weather and frequent rains promote disease development and spread.
Control: Spray with Dithane M45.

2. Downy mildew (cucumber and muskmelon)

Casual agent**:** Fungus *Peronospora cubensis*

Symptoms
Irregularly shaped yellowish to brown spots appear on upper sides of leaves usually at the centre of plants. Under moist conditions a purplish mildew develops on the underside of leaf spots. Leaves die as spot increase in size**.**

Transmission:
Spread is rapid from the crown toward new growth. The fungus over winters in areas with relatively warm climate and can be introduced to other areas by wind. Moist conditions favour disease development.

Control: Spray with the following fungicides:
Apron C, Ridomil, Bravo 50, or Dithane M45.

3. Powdery mildew (Cucumber muskmelon, pumpkin and squash)

Causal agent: Fungus *Erysiphe cichracearum*

Symptoms
A white powdery growth on upper surface of the leaves. Crown leaves are affected first and may wither and die. In sever attacks, stems are affected, leaves finally turn yellow, dry out and become brown.

Transmission:
The fungus can be introduced on greenhouse grown plants or by wind from areas with relatively warm winter climate where the fungus can over winter on alternate hosts. High temperatures favour disease development.

Control: Spray with;
Benomyl, Sulphur, Copper oxychloride or Mancozeb.

4. Cucumber mosaic virus (CMV)

Causal Agent: Cucumovirus: *Cucumis sativas*

Symptoms
Mosaic infected plants are stunted, and new leaves are dwarfed, mottled and sometimes wrinkled. On cucumber mosaic virus infected muskmelons and cucumbers new leaves sometimes wilt and die, old crown leaves may turn yellow and dry up resulting in a slow decline of affected plants. Fruits may also be irregular in shape with knobs on their surface.

Transmission
Cucumber mosaic virus and water melon-2 over winter in some biennial and perennial plants and usually are carried to new plantings by aphids. Squash mosaic virus over-winters and is introduced to new plantings in infected seed. Cucumber mosaic virus is spread chiefly by aphids. Watermelon-2 spread by aphids and squash mosaic virus is spread by cucumber beetles and workers.

leaves of squash infected by CMV

Transmission
Not persistent in refuse, is more difficult to transmit by rubbing and usually is spread by aphids.

Control:

- Crop rotation
- Control of aphids
- Remaove weeds that may be host plants for aphids.
- Destroy infected plants

Pests affecting curcubits

1. Pumpkin fly (Dacus spp)

Characteristics and damage

Adult flies are cream coloured and up to 1 cm long, with brown and yellow bands or spots. The catapillers are cream coloured. Adult flies lay eggs in soft young fruit. The eggs hatch and larvae feed inside the fruit which rots and becomes soft. The fruit then turns yellow and later dries out becoming brown or black in colour.

Control

Spray the insecticide Fenthion soon after flower developmentor use Mercaptothion or Malathion as a bait at 15 grams, 500 grams sugar and 5 litres water. The bait is then applied on the leaves.

8. POACEAE

GREEN MEALIES *(Zea mays)*

Recommended cultivars

Maize iswidely consumed in the immature stage commonly referred to as green-mealies. When grown for this purpose, the seed is normally sown early after winter, therefore the crop has to be irrigated. Cobs may be up to 40 cm in length with each plant having 2 – 3 cobs. The following cultivars are just some of those that have been evaluated in Botswana and found to do well. All of them are hybrids, with the exception of Kalahari Early Pearl (KEP). It has to be noted also that these cultivars are also grown for grain under rainfed conditions.

Table 16. Perfomance of recommended green mealie cultivars

Cultivar	Yield (t/ha)	Cob weight (g)	Cultivar	Yield (t/ha)	Cob weight (g)
R 215	11.3	388	SR 52	8.6	444
R 201	11.1	414	KEP	7.7	329
SC 501	12.2	394	PNR 6463	7.3	325

Climatic and soil nutrient requirements

Green mealies does well in most soils but medium, well-drained loams with a high organic content are preferred. Soils can be applied with compost or manure and 2:3:2 fertilizer, at 500 kg/ha, before sowing, followed by two applications of ammonium sulphate (nitrogen) at 300 kg/ha, at two week-interval before flowering. Soil pH should be 5.5 – 6.8. Average temperature of 16 – 24°C favour growth.

Cultural practice

Seeds are sown in rows 60 - 90 cm apart with 30 – 45 cm between plants. Two seeds should be sown per hole and later thinned to one seedling after germination. Regular irrigation is essential, particularly from just before the silks develop. An approximate guide to the time of harvesting is about 20 days after 50 % of the crop has formed silk. A yield of 7 – 15 t/ha, depending on planting density, cultivar, and environment is normal.

Common Pests of green mealies

The most common pests in Botswana are Stalk borer and American bollworm. These can be controlled with the use of Endosulfan, Benomyl or pyrethroids.

9. LEGUMINOSAE

GREEN BEANS

(Phaseola vulgaris)

Table 17. Description of recommended cultivars

CULTIVAR	MATURITY (DAYS)	POD CHARACTERISTICS			SEED CHARACTERISTICS		REMARKS
		COLOUR	LENGTH (CM)	SHAPE	SIZE	COLOUR	
Bush type							
Contender	50	Light green	17	Oval, curved	Large	Pale brown	High yields. Stringless. Good resistance to blossom drop under high temperature. Resistant to bean mosaic virus. Fairly susceptible to bacterial blight.
Seminole	55	Medium green	14	Round, curved	Medium to large	Purple grey spotted	Very high yield. Stringless. Widely adaptable. Keeps well after picking. Resistant to bean mosaic virus.
Wintergreen	50	Medium green	16	Oval, fairly straight	Medium to large	Black	Excellent for winter production in frost-free areas. Also does well in cool areas in summer. Resistant to bean mosaic virus.
Runner type							
Lazy housewife	70	Medium green	17	Flat, strongly curved	Medium to large	Red	Bears continuously over an extended season. Pods have exceptional eating quality and flavour. Stringless.
Witsa	65	Medium green	16	Round, slightly curved	Small	White	Extremely heavy cropper. Vigorous. Good quality pods. Stringless.

Climatic requirements

Greenbeans grow best under fairly warm conditions. Temperatures a few degrees below freezing point usually cause severe damage to the plants. Optimum mean daily temperatures for best growth, yield and quality is between 16 - 21°C. Temperatures above 35°C usually cause the flowers and young pods to drop. Temperatures below 5°C cause poor pollination which results in hollow pods. Excessive rain causes flower drop and increases the incidence of disease.

Soils and fertilizer requirement

Can be grown on a wide range of soils but prefer a well drained medium loam with a pH of 6.0 to 7.5. Soils with poor drainage should not be used as standing water can injure the plants and will promote the development of halo blight, pod rotting caused by *Botrytis* and anthracnose diseases.

A basal dressing of 50 kg/ha N, 75 kg/ha P, 50 kg/ha K applied 7 days before planting is adequate to provide essential elements to the crop. Top dress between 3 - 4 weeks after planting with 56 kg/ha N.

Sowing and cultural practice/management

Green bean seeds are sown directly. Spacing for Dwarf beans is 45 - 60 cm between the rows and 10 cm within a row. Sowing depth should not be more than 5 cm or uneven germination will occur. For climbing or runner beans, plant in twin parallel rows 40 cm apart, with seed planted 10 cm apart along the rows. The double rows should be 90 cm apart. Seed rate varies with the size and germination percentages. For dwarf beans it can range from 8 - 12 Kg/1000 sq. m and about 4 - 6 Kg for climbing beans.

Table 18: Suggested planting dates for green beans

Regions	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Southern	--	X						--	X	X	--	--
Gaborone	--	X	X					X	X	X	--	
Central & Noth East		X	X	--			--	X	X	--		
Ngamiland			X	X	X	X	X	X				

x - Recommended sowing time *-- - Acceptable sowing time*

Note:Once beans have started to flower they become very sensitive to soil moisture deficit. Adequate irrigation at this time will reduce flower drop and increase yield.

Rotation cropping

- Do not plant beans on the same soil more than once in 3 years.
- Crops of high plant nutrient requirement such as cabbage or tomatoes will perform best when grown immediately after beans.

Cultivation

The soil should be cultivated to control weeds and break up the covering soil crust. This operation should not, however, be carried out too deep as this may injure the roots. It should also not be done when the plants are damp as diseases are easily spread amongst the leaves.

Irrigation

Maintain soil moisture to a depth of 45 cm before planting in order to achieve an even germination and growth during the crops initial period of development. This would require about 23.4 mm of irrigation over a two day period in summer and six days during winter.

Harvesting

For fresh market pick pods that are green and tender and about 10 cm long. Pods should snap easily when bent and without any sign of seeds. If harvesting is delayed, pods become fibrous. The pods should be picked early in the morning when it is cool. Sort out mal-formed and curved pods and pack selected quality beans in polythene bags. Use only perforated polythene bags or rapid rotting of the produce will occur.

Yield

Yield for fresh market is between 6 - 10 tons per hectare.

NUTRITIONAL DEFICIENCIES IN HORTICULTURAL CROPS

Plants require sixteen (16) elements in all for optimum growth. Three of these, namely, carbon, hydrogen and oxygen, are taken from the air while the remaining thirteen (13) must be supplied through the soil. Some elements such as calcium, phosphorus, potassium, nitrogen are needed in relatively large amounts hence referred to as macronutrients while others like magnesium, iron, boron, manganese, zinc, copper, molybdenum and chlorine are required in small amounts and are called trace elements or micro-nutrients. When the supply of these elements does not meet the plant's requirement for normal growth, the plant exhibits various deficiency symptoms of abnormality. The symptoms may appear on any or all organs of the plant, including leaves stems, roots, flowers, fruits and seeds. Deficiency symptoms can sometimes be confused with other complex field events, such as high water tables, salt damage, disease, drought, herbicide stress and varietal differences.

The kinds of symptoms produced by deficiency of a certain nutrient depend primarily on the functions of that particular element in the plant. These functions are simply impaired when the element or nutrient is lacking, which normally results in growth and yield and/or quality reduction. When the nutrient element is below a certain critical level, the plants develop acute and chronic symptoms and may even die. The prefered way to handle nutrient deficiencies is to identify annual crop needs with soil testing, perennial crop needs with plant analysis and to correct the deficiencies before crop establishement or deficiency symptoms appear. Deficiency symptoms of elements that can move from places where they are stored to places where they are needed, (refered to as mobile nutrients) are normally noticeable on older tissues/leaves.Nitrogen, phosphorus and potassium are examples of mobile nutrients. Plant immobile element deficiencies are on the other hand noticeable first on younger tissues. It has to be noted that deficiency symptoms of a nutrient may differ from crop to crop.

In Botswana, phosphorus is generally lacking in the soil especially along the eastern side where the main agricultural activity is arable farming. In sandy soils, which covers vast areas of the country, calcium, nitrogen and phosphorus would normally be deficient and not readily available to crops. Therefore, a fertilizer programme providing these nutrients need to be adopted in order to realise increased crop yields. The availability of these elements would also off-set the toxic (too much) effects of iron, aluminium and manganese in soils. The following are some of the essential elements, their functions in plant growth and deficiency symptoms.

Nitrogen

Nitrogen encourages vegetative growth by imparting a healthy green colour to leaves. It is also a catalyst in the efficient utilisation of phosphorus and potassium. Nitrogen deficiency retards plant growth and root development, turns the foliage yellowish or pale green, hastens maturity and lowers yield. Lower leaves show symptoms first. Excess nitrogen causes dark green leaves, succulent growth, delays maturation and reduces the quality of fruits.

Phosphorus

Phosphorus promotes rapid and healthy root growth. It also encourages flowering, fruit and seed formation, and increases disease resistance in plants. It also offsets the harmful effects of excess nitrogen and reduces lodging. Deficiency symptom are stunted growth and a reddish or purplish discolouration of leaves. It is common on acid, clay or chalky soils.

Deep purple tints changing to red in older leaves of rape showing P deficiency

Calcium

Calcium promotes the activity of soil bacteria concerned with nitrogen fixation or the formation of nitrates from organic forms of nitrogen. It encourages root formation. Deficiency symptoms are death of roots at the tips, stunted growth, mottled discolouration of leaves and in tomato, blossom end rot. Its deficiency is common on acidic soils, but is mainly due to unavailability rather than shortage. It can also be caused by excessive application of potassium or nitrogen.

Blossom-end rot in tomato caused by Ca deficiency

Magnesium

This element is an essential constituent of chlorophyll thus playing a leading role in photosynthesis and in the formation of plant tissue. It also promotes the formation of sugar, proteins, fats and vitamins in the plant. It increases resistance to harmful environmental influences, such as drought, diseases and infections as it has a positive influence on the swelling and strength of the cell walls and permeability of cell membranes. Deficiency symptoms are **yellowing of older leaves** and in the case of maize the leaves develop interveinal white or yellow stripes between the veins. It also causes premature defoliation.

Sulphur

Sulphur is essential for the formation of vegetable protein. It is normally absorbed by roots in mineral form (SO_4) and carried in the form of amino acids. Like nitrogen it plays a role in the production of chlorophyl and stimulates plant development. Deficiency symptoms are, young leaves turn yellow, roots and stems become abnormally long and woody, fruits become light green, mis-shapen, thick-skinned and less juicy. Affected plants have small, narrow leaves with veins nevertheless remaining green in contrast to nitrogen deficiency.

Iron

Iron is essential in the formation of chlorophyl and protein. The amount of iron that can be absorbed by the plant generally increases with the soil acidity, hence its deficiency normally occurs on alkaline soils where it is present in the inactive oxide form. The absorption of iron not only depends on the amount available but also on the presence of other heavy metals such as zinc and manganese, which have 'antagonistic' effect. Deficiency symptoms are **chlorosis in young leaves and the veins remaining green.** Iron is not translocated in the plant, therefore cannot be transferred from older parts of the plant to overcome a temporary deficiency.

Leaves of tomato (left) and a rape plant (right) showing signs of iron deficiency

Potassium

Potassium enhances the ability of plants to resist diseases and encourages foramtion of well developed seed and fruit, especially in tomatoes. It is vital in the formation and translocation of starch and sugars particularly in root crops. Potassium deficiency causes **interveinal chlorosis and older leaves are affected first**, growth is also retarded and plants have a low resistance to diseases.

Molybdenum

Molybdenum availability in the soil increases in the alkali range. Its deficiency reduces the activity of the symbiotic and non-symbiotic nitrogen-fixing micro-organism. It also produces whip-tail in brassica crops.

A rape plant showing signs of Manganese deficiency

Manganese

The main role of manganese in plant metabolism appears to be the activation of various enzymes. Manganese deficiency occurs above all on chalky soil with a high humus content. Deficiency symptoms of manganese are **chlorosis in the interveinal tissue of the youngest leaves**. It can be confused with, and occurs with iron deficiency. It is common in poorly drianed soils and also where organic matter level is high.

Zinc

Zinc activates certain enzymes and plays an important role in formation of protein and chlorophyl. It also encourages ripening of fruit and grain. The amount of zinc absorbed by the plant increases as the pH falls and decreases as the soil phosphorus content increases. Deficiency show in younger plants, starting with interveinal chlorosis leading to stunted growth and mottled leaves.

Zinc deficiency on potato leaves

Table A1. Recommended vegetable cultivars for production in Botswana - Leafy vegetables

Recommended cultivars	CROPS			
	Cabbage	**Swiss chard**	**Lettuce**	**Rape / Kale***
	K. K. Cross (s) Star 3301 Greenstar (s) Tenacity Hercules(s) Big cropper Grandslam Transmark	Fordhook giant Lucullus	Great lakes Queen crown grand rapids Emperor El toro	Giant essex Chou mollier * Thousand-headed*
Seeding rate **- Amount of seed** **- Depth of sowing** **- Field spacing**	0.5 kg/ha 1 cm 50 x 50 cm	3.75 kg/ha 1 cm 20 - 25 x 40 - 45m	0.3 kg/ha 1 cm 30 x 30 cm	3 - 5 kg/ha (D) or 300 - 500 g/ha (T) 1 cm 40 - 60 x 40 cm
Fertilizer **- basal dressing** **- Top dressing**	1000 kg/ha 2:3:2 or 500 kg/ha 3:2:1 2 x 325 kg/ha Ammonium sulphate	5 - 8 kg/m^2 KM or 2 - 4 kg/m^2 CM 700 - 1000 kg/ha 2 : 3 : 2 200 kg/ha Ammonium sulphate	200 kg/ha superphosphate (20.5%) 100 kg/ha LAN or 133 kg/ha Ammonium sulphate	1000 kg/ha 2:3:2 200 kg/ha Ammonium sulphate or 150 LAN every 3 weeks
Planting method	Sown in seedbed and transplant	Direct drill or transplant	Sown in seedbed and transplant	Direct or transplant

NB. KM - Kraal manure
CM - Chicken manure
S - Standard recommended summer cultivars
W - Standard recommeded winter cultivars
D - Direct planting
T - Transplant

Table A2. Recommended vegetable cultivars for production in Botswana - Fruit vegetables

Recommended cultivars	CROPS					
	Tomato	**Green pepper**	**Pumpkin**	**Squash**	**Watermelon**	**Green mealies**
	Moneymaker (O) Heinz 1370 (O) Zeal (H) Zest (H) Expresso (H) Sixpack (O)	California-wonder California-wonder-300 Florida-resistant giant Yolo-wonder Mercury Komati	Flat white Boer 'A' Flat white boer 'ford'	Green hubbard Greenhabbard chicago warted Little gem Butternut- Waltham Rolet	Sugarbaby Black diamond Charleston gray Congo	R 201 R 215 SC 501 KEP (O) SR 52 PNR 6463
Seeding rate - Amount of seed	120 - 160 g/ha	500 g/ha	3 - 4 kg/ha	2 kg/ha	2 - 3 kg/ha	17 - 24 kg/ha
- Depth of sowing	2 cm	2 cm	3 cm	2 - 3 cm	2 - 3 cm	3 - 4 cm
- Field spacing	120 x 40 cm	90 - 60 cm	240 x 90 cm	30 - 90 x 90 - 120 cm	120 - 240 x 45 x 90 cm	75 x 30 cm
Fertilizer - basal dressing	1000 kg/ha 2:3:2 or 125 kg/ha KCL	250 kg/ha S.P (20.5)	30 - 50 t/ha KM and 70 g/m^2 S.P (10.5%)			500 kg/ha 2:3:2
- Top dressing	200 kg/ha A.S	200 kg/ha LAN or 266 kg/ha A.S	12.5 G/M^2 LAN or 16.7 g/m^2 AS			2 x 300 kg/ha AS
Planting method	Transplant	Transplant	Direct	Direct	Direct	Direct

KEP - Kgalagadi Early Pearl
O - Open polinated variety
H - hybrid
KM - Kraak manure
AS - Ammonium sulphate
SP - Superphosphate (10.5%P)
KCL - Potasium chloride

Table A3. Recommended vegetable cultivars for production in Botswana - Bulb, Root and Tuber vegetables

	CROP			
	Onion	Sweetpotato	Carrot	Beetroot
Recommended cultivars	Granex 33 Pyramid Texas grano Bon accord Texas grano 502PRR Brownsville	Eland Ribbok Blesbok Mafutha IITA TIS-3290 Kenya (SPN/O)	Chantenay red core Cape market Nantes Oxheart	Detroit dark red Crimson globe
Seeding rate				
-Amount of seed	100g/m^2 (s) or 8kg/ha (d)	~25000 cuttings/ha	4.5kg/ha	1.2-1.5kg/ha
-Sowing depth	1-2cm	20cm	0.5-1cm	1cm
-Field spacing	30-45 x 6-10cm	75 x 40cm	30-45 x 4-6cm	25-40 x 8-12cm
Fertilizer				
-Basal dressing	1000kg/ha 2:3:2	500kg/ha 2:3:2	700kg/ha 2:3:2	800kg/ha 2:3:2
-Topdressing	300kg/ha Ammonium sulphate	150kg/ha Ammonium sulphate	90kg/ha LAN	2 x 185kg/haLAN
Planting method	Transplant Direct drill Sets	Cuttings (vegetative propagation)	Direct drill	Direct drill

Table A4. Seed chart for sowing vegetables

Vegetable	Amount of seed per hectare	Sowing depth	Spacing between row	Spacing within row	Sowing method
Cabbage	300gm	1cm	50cm	50cm	seedbed
Swiss chard	14kg	1cm	30-45cm	20 cm	Direct planting and thinor transplant
Tomato	370g	1cm	60-1.5m	30-50cm	Seedbed/see-d tray
Green-pepper	300gm	5cm	60-90cm	30-40cm	Seedbed
Rape	3-5kg	1cm	60cm	40cm	Direct planting and thin or transplant
Chou moellier	3-5kg	1cm	40cm	40cm	seedbed
Lettuce	1-75kg	1cm	30cm	30cm	seedbed/tray
Pumpkin	3-4.5kg	2cm	2.4m	90cm	field
Squash	2-3kg	2cm	2.4m	90cm	"
Butternut	2-3kg	2cm	1.8m	90cm	"
Gem Squash	2-3kg	2cm	1.2m	45cm	"
Water melon	2-3kg	2cm	2.4m	90cm	"
Sweetpotato	25000 cuttings	10-20cm	1.0m	40cm	"
Onions	3-4kg	1cm	30-45cm	5-10cm	seedbedand setts
Beetroot	9.5kg	2cm	30-45cm	10cm	Direct planting and thin
Carrots	4.5kg	1cm	30-45cm	5 cm	Direct planting and thin
Potato	30kg(28-112g seed)	10cm	75-100cm	30-45cm	field
Bean (Dwarf)	100-120kg	4-5cm	45-60cm	10cm	"
Bean Runner	80-120kg	4-5cm	40cm	10cm	"
Maize	17-24kg	5-10cm	75cm	30cm	"

Table A5. Recommended sowing dates for vegetables in Botswana

REGION / VEGETABLE	Ngamiland & Tuli block	Chobe	Ghanzi, N-Kgalaga-di, Kweneng & Kgatleng	Central & North East	Gaborone & Southern Region	Kgalaga-di South
Beans (French dwarf)	March-July (April-Jun-e)	Feb, Mar, Jul, Aug (Mar-Jul)	Feb-Mid Mar Aug	Feb-Mid Mar (Aug)	Aug-Feb Sept-Jan	
Beetroot	Mar-Aug (Apr-May)	Mar-Aug (Mar-Apr)	Mar-Aug (Mar-Apr)	Feb-Sept (Mar-Apr)	July-Mar Feb-Aug	Feb-Mar, Aug
Cabbage	Feb-June (Mar-May)	Jan-July (feb-Mar)	Jan-July (Feb-Mar)	All year round (Jan-Mar)	July-Mar Jan-Feb	Jan-Mar (Feb)
Rape & Choumoellier	Feb-May (Mar-Apr)	Jan-June (Feb-Apr)	Jan-June (Feb-Mar)	All year round (Jan-Mar)	July-Feb (Mar)	Jan-Feb
Carrot	Mar-July (Apr-May)	Mar-Aug (Mid-Mar - May)	Feb-Aug (Mar-May)	Feb-Aug Mar-May	Jan-Mar June-Sept (Feb-Aug)	Jan-Mar Feb
Lettuce	Mar-June (Apr-May)	Mar-June (Mid Mar-Apr)	Mar-June (Mar-Apr)	Mar-July Mar-May	Feb-Aug	Feb
Onion	Mar-May (Mid Mar-Apr)	Mar-Apr (Mid Mar-Mid Apr)	Mar-Apr (Mar)	Mar-Apr (Mar)	Feb-Mar (Mid Feb-Mid Mar)	Early Mar
Potato	Mar-May (Apr)	-	Feb, Mid July-Mid Aug	Feb-Mid July-Mid Aug	Mid Jan-Mid Aug	-
Pumpkin and Squash	Feb-Aug (Mar-July)	Aug-Jan (Aug-Sept)	Aug-Jan (Aug-Sept)	Aug-Jan (Aug-Sep-t)	Sept-Dec (Sept-Oct)	Sept-Dec Sept-Oct
Spinach (Swisschard)	Feb-July (Mar-Apr)	Feb-July (Mar)	Jan-Sept Feb, Mar, July	Jan-Sept Feb, Mar, July	Jan-Feb July-Sept	Feb, Aug
Sweetpotato	Oct-Jan	Oct-Mid Jan	Nov-Dec	Nov-Dec	November	Nov-Mid Dec
Tomato	All year round (Feb, Mar, July)	Aug-Mid Jan	Aug-Dec	Aug-Dec	Mid Aug-Mid Dec	Mid Aug-Mid Dec (Nov-Mid Dec) Mid Sept-Dec
Watermelon	June-Jan (July-Aug)	Aug-Jan	Sept-Jan	Sept-Jan	Mid Sept-Dec	Mid Sept-Dec
Greenmealies	Aug-Jan	Aug-Jan	Sept-Jan	Sept-Jan	Mid Sept-Dec	

Table A6. Common pests and diseases of vegetable crops and their recommended control measures

CROP	PEST OR DISEASE	CONTROL
Tomato	1. Red spider mite 2. American bollworm 3. Nematodes (root-knot) 4. Early blight 5. Bacterial spot 6. Bacterial canker 7. Fusarium wilt 8. Looper 9. Curly top virus	Dicofol, Sulphur dust Cypermethrin, Endosulfan Nemacur Copper oxychloride* Certified seeds, Crop rotation Certified seeds, Crop rotation Resistant varieties Cypermethrin, Deltamethrin Remove and destroy affected plants
Onion	1. Thrips 2. Aphids 3. Fusarium rot (basal rot) 4. Purple blotch	Malathion*, Endosulfan, Deltamethrin Trichlorofon Rotation, Improve drainage Mancozeb*
Cruciferae (Brassica) -Cabbage -Cauliflower -Brocolli	1. Bagrada bug 2. Diamond back moth 3. Cutworm 4. Aphids 5. American bollworm 6. Stem borer 7. Black rot 8. Downy mildew	Gamma-BHC*, carbofuran, parathion, phorate. Cypermethrin, methomyl, parathion., carbofuran Carbaryl bait, Chlorpyrifos Dichlovors, Dimethoate, endosulfan, parathion. Dimethoate, Cypermethrin, Methomyl Alphamethrin, Mevinphos, Deltamethrin Cypermethrin, Mevinphos, Alphamethrin Use resistant varieties, mancozeb
Sweetpotato	1. Sweetpotato weevil 2. Sweetpotato moth (catapillars) 3. Nematodes (root-knot) 4. Cutworm 5. Ladybird	Cultural control- fill up soil cracks Trichlorfon Resistant varieties Chlorpyrifos Malathion, Gamma- BHC
Irish potato	1. Aphids 2. Black scurf/black leg 3. Early and late blights 4. Leaf Roll virus 5. Common scab 6. Soft rot 7. Fusarium dry rot	Demeton-s-methyl, Dimethoate Benodanil Propineb, Mancozeb, Chlorthalonil Use certified seeds, remove and destroy affected plants Resistant varieties, cultural control Avoid damage to tubers Resistant varieties, careful handling
Cucurbits - Watermelons - Pumpkins - Squashes	1. Downy and powdery mildews 2. Cutworm 3. Aphids 4. thrips	Mancozeb Trichlorfon bait* Dimethoate Malathion, Fenthion
swisschard and beetroot	1. Nematodes 2. Leaf spot (cercospora) 3. Catapillars (various)	Nemacur, crop rotation Captan dust Alphamethrin, Mevinphos, Deltamethrin
Carrots	1. Nematodes (root-knot) 2. Aphids	Nemacur, crop rotation Dementon-s-methyl
Green beans	1. Aphids 2. Red spider mite 3. C.M.R. Beetle 4. American bollworm 5. Bacterial blight 6. Leaf rust 7. Bean stemfly	Dimethoate, Demeton-s-methyl Dicofol Malathion Cypermethrin, Endosulfan Copper oxychloride* mancozeb Gamma-BHC, Endosulfan
Greenmealies	1. Stalk borer 2. American bollworm 3. Aphids 4. Maize streak virus	Trichlorfon, Endosulfan, Deltamethrin* Deltamethrin, Cypermethrin, Endosulfan Demeton-s-methyl Avoid late planting

Table A8. Water requirements for summer season crops

Crop	Predetermined irrigation based on the pan evaporation replenishment (mm) RD_m x PASM (mm/m x RA %)	Irrigation crop response		Highest crop interval in days response summer E_p (10mm/day)	Expected Yield (t/ha)
		%	mm		
Green pepper	23.8	100	28.56	3	89.63-91.87
Hot pepper	23.8	100	23.8	2	49.58-51.28
Okra	23.8	100	23.8	2	20.54-21.10
Eggplant	23.8	100	23.8	2	91.47-94.10

Table A7. Water requirements for winter season crops

Crop	Predetermined irrigation based on the pan evap. Replenishment (mm) RDm x PASM mm/m x RA %	Best Ep crop response		Irrigation interval in days winter Ep (5mm/day)	Highest yield response (t/ha)
		%	mm		
Brocolli	17.8	80	14.24	3	20.1
Carrot	19.8	80	15.8	3	35.0
Rape	23.1	80	18.48	3-4	67.0
Cabbage	17.8	80	14.24	3	97-98
Onion	15.8	80	12.64	2.3	46.5

NB.

Figures on tables A7 and A8 are based on results of experiments conducted in Ngamiland, and as such are likely to be different for other areas where environmental and soil conditions are different from this area.

Guide to fertilizer application

Fertilizer calculations

It should be noted that the fertilizer rates given in this manual are intended as a guide only, the exact figures will depend on the fertility status of the soil dealt with. Fertilizer rates in this manual are mostly given in element weight basis and therefore have to be converted to actual fertilizer rates as follows:

Amount of fertilizer to apply = elemental rate x 100 / elemental percent in fertilizer

Suppose the recommendation (elemental rate) is 32 kg/ha of nitrogen and you want to apply it in the form of LAN (28% N).

Amount of LAN to apply (kg/ha) = 32 x 100 / 28
= 114 kg/ha

Guide to fertilizer measure

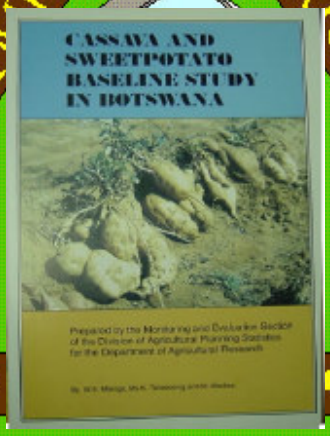
Where weighing scales are not available, a soft drink can with the top removed may be used to estimate the amount of fertilizer to be applied. Such a can (340 ml) holds the following amounts of fertilizers:

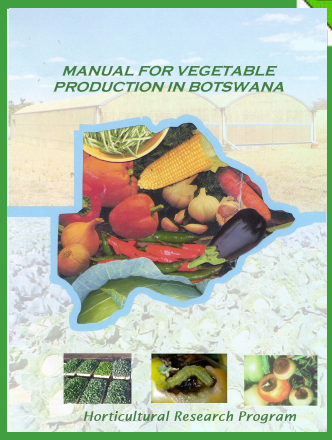
Ammonium sulphate = 380g
Limestone ammonium nitrate (LAN) = 305g
2:3:2 (22%) = 370g
Single Superphosphate = 390g
Ammonium sulphate should be used instead of LAN for alkaline soils and vice-versa

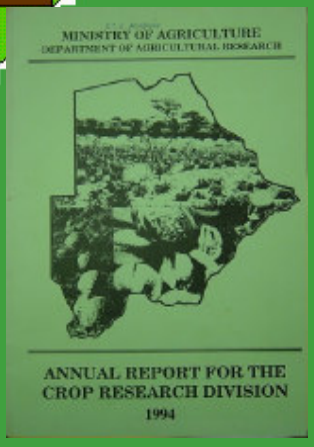
Content of nutrient elements in different commonly used fertilizers

Ammonium sulphate = 21% Nitrogen
Urea = 46 % Nitrogen
Ammonium phosphate = 11% Nitrogen
LAN = 28% Nitrogen
Potasium chloride = 50 % Potasium
Single superphosphate = 10.5 % Phosphorus
Double Superphosphate = 21% Phosphorus

For supplementary reading on related topics check the following documents published by the Department of Agricultural Research







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