

Learn how to grow **Peppers**

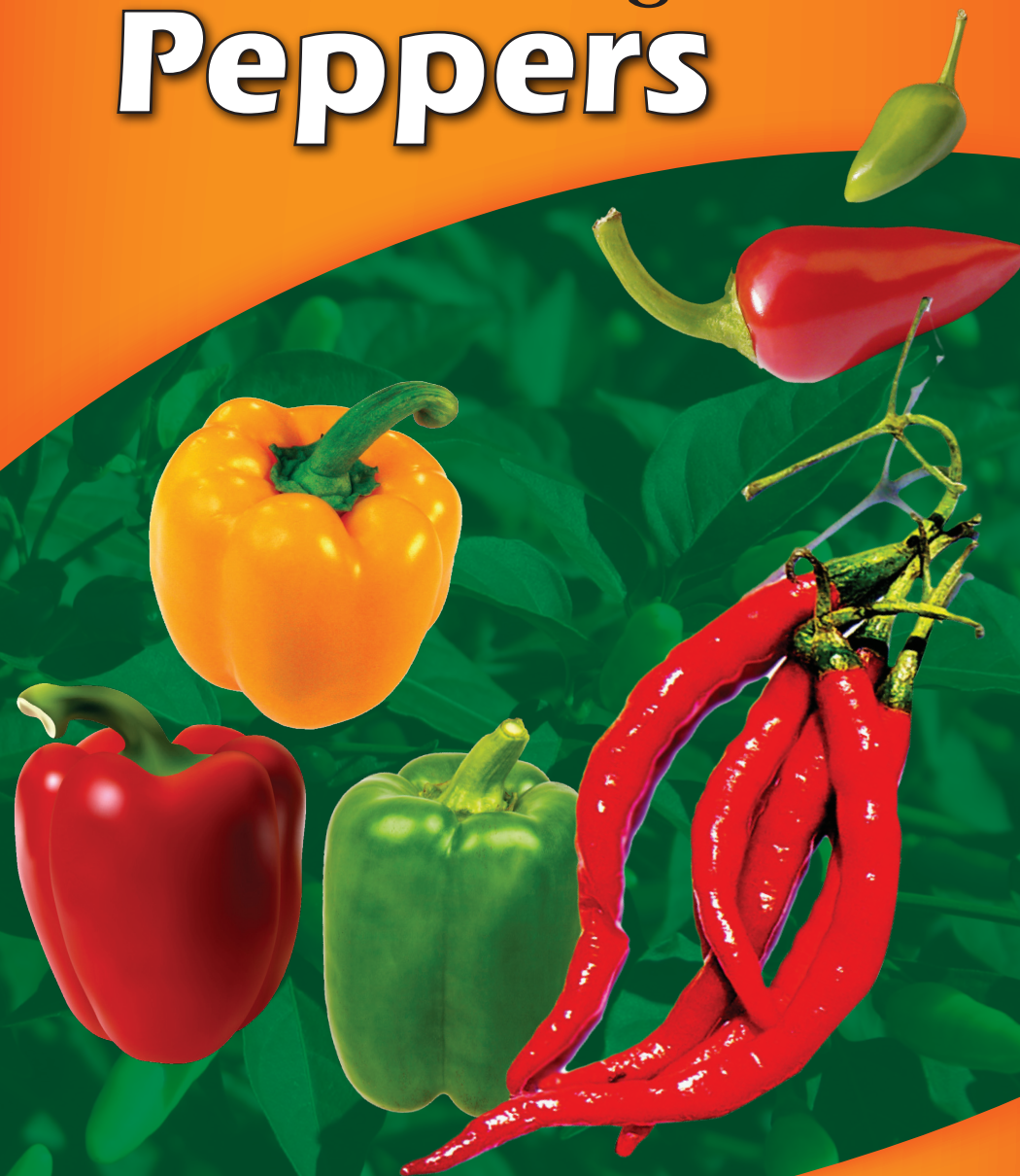
This book provides a step by step guide to production of pepper with much emphasis on out door conditions. It details planning, agronomic aspects and post harvest handling of this vegetable for marketing. The crop protection measures outlined in this book are applicable in both organic and conventional crop production systems. Crop production practices described in this book are simplified and easy to apply in the farm hence it is appropriate for both extension agents and farmers.

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Introduction

Pepper is a vegetable crop. It belongs to the *Solanaceae* family. The *Solanaceae* family includes plants such as tomatoes, Irish potatoes, and egg plants, among others. Pepper is increasingly becoming important as a food, medicinal and industrial crop. Furthermore, the pungent nature of hot pepper renders it effective as a natural pest control product. Large amounts of pepper in developing countries are grown for export to the European Union and other markets. This contributes to foreign exchange earnings to the respective countries and income to farmers, majority of who are small scale growers.

Pepper can be produced in the field and under greenhouse farming using conventional and organic procedures. Conventional production of pepper in the field is easily adoptable by farmers because of its productivity in the short run. However, organic production is of more benefits in the long run because its yields per unit area of land increase gradually while guaranteeing against chemical residues and environmental degradation. On the other hand, greenhouse production of pepper is capital intensive but profitable if good measures are taken to maintain sufficient crop nutrient supply as well as disease and pest free growing conditions.

This book provides a step by step guide to production of pepper with much emphasis on outdoor conditions necessary for its growth. It details planning, application of the various soil and plant sciences to soil management and crop production (agronomic aspects) and post harvest handling of pepper, including marketing. The crop protection measures outlined in this booklet are applicable in both organic and conventional crop production systems. A glossary has been included. It is my hope that through the knowledge gained from reading this booklet, pepper will be produced in a more profitable, efficient and sustainable way.

Dennis S. Ashilenje
Kitale, Kenya
2013

1.0: Origin, characteristics, species and uses of pepper

1.1: Origin of pepper

Pepper originated from tropical America; Peru and Mexico and spread to Europe where it grows as a shrub. From here it spread to other parts of the world such as African, Caribbean and Pacific countries.

1.2: Characteristics of pepper

- Pepper is an herbaceous annual which matures early under low temperatures. Growth form varies from one species to another.
- Pepper has deep taproots with fibrous lateral roots that spread between 50 and 60 cm wide.
- Its flowers are small with white or purple petals.
- Pepper flowers develop into fruits which are berries with several white coloured seeds.
- Fruits from different species of pepper vary in colour, size, form and flavour, from very hot to mild or sweetly pungent.
- Pepper fruits are commonly green before maturity. After maturity, fruit colour can either be red, orange, yellow or purple.

1.3: Species of pepper

There are two main groups of pepper. These are sweet peppers and hot peppers.

(a) Sweet peppers

In this category we have Cone pepper (*Capsicum annum* Var *conoides*) and Bell pepper (*Capsicum annum* Var *grossum*). Cone pepper has erect and conical fruits that grow to two inches long. Bell pepper has stout bush, while its fruits are large, soft, irregularly compressed, red or yellow and mild in taste.

The most common varieties of sweet peppers are California wonder, Yolo wonder, Emerald giant and Ruby giant.



Carlifornia wonder



Yolo wonder



Emerald giant



Ruby giant

(b) Hot peppers

Under this species we have Chili pepper and Cayenne (*Capsicum annum* Var *longum*), African bird's eye chili (*Capsicum frutescens*) and Cherry pepper (*Capsicum annum* Var *ceraciforme*).

- Fruits of Chili pepper and Cayenne are pendent, slender and tapering. They are also very hot and turn red when mature.
- African bird's eye chilies are perennials that grow as shrubs. Their fruits are small, clustered, erect, conical, pointed, measuring up to 3 cm long and red or purple when mature.
- Fruits of cherry pepper are erect or bending, rounded and measuring about one inch in diameter. They turn yellow or purple at maturity and are very pungent.

The most commonly grown varieties of hot pepper include Fresno, Anaheim, Long red cayenne, Jalapeno and African bird's eye chili.



Fresno



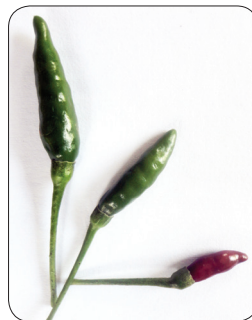
Anaheim



*Long red
cayenne*



Jalapeno



*African bird's
eye chili*

1.4: Uses of pepper

Different types of pepper form a major part of fresh and semi processed export crops from African, Caribbean and Pacific countries to European and other markets.

- Sweet chilies are used fresh in vegetable salads or cooked in stew. Their characteristic of having a mild flavour renders them acceptable to a wide range of consumers.
- Hot chilies are used in fresh form to season foods. They have also been reported to have medicinal properties against illnesses such as flu and asthma. Hot chilies are processed into curry powder, chili source and a variety of bitter flavoured beverages.
- Extracts from hot chilies are used as botanical pesticides against crop pests like arphids in organic farming systems.
- African bird's eye chilies are used to manufacture teargas.

2.0: Climatic requirements for growing pepper

Pepper plants require continuous growth for satisfactory results. They are very sensitive to unfavourable weather though, of course, the farmer has little control over the weather. Peppers will often drop their blossoms when temperatures are high and humidity is low. Cool weather can also keep the plant from flowering. Deep cultivation that cuts the roots causes a water stress on the plant that frequently makes blossoms drop. Even a short dry period can cause the same effects.

2.1: Soils

Soils for growing pepper should be well drained, rich in organic matter with a pH range of 6.0 to 6.5. However, pepper can also tolerate a wider soil pH range of 4.5 (acidic) to 8.0 (slightly alkaline). Light sands, clay sandy and sandy loams are also suitable for growing pepper. These soils have attributes that make the crop to mature early.

2.2: Rainfall

Rainfall above 600 mm and well distributed during vegetative growth and fruiting is favourable for production of chilies. Crop irrigation should be considered in areas experiencing rainfall below 600 mm per year. Irregular rainfall distribution during fruit development exposes sweet pepper to blossom end rot disorder. During the same period water stress will lead to fruit and flower abortion.

2.3: Temperature

Favourable soil temperatures for growing pepper range between 18°C and 25°C. A temperature of up to 29.5°C is the optimum. Temperatures below 18°C affect fruit development in that crops succumb to frost damage. Hot conditions of over 32°C coupled with low humidity cause poor fruit set and both fruits and flowers can abort prematurely.

Temperature also affects fruit quality; best fruit colour is realized at temperatures from 18°C to 24°C. At temperatures below 13°C colour ceases to form. Night temperatures above 22°C lead to poor fruit set.

2.4: Altitude

Pepper can grow optimally up to 2,000 metres above sea level. Cultivation of pepper in lower areas should be avoided during extremely hot periods.

3.0: Planning the production of pepper

It is important to plan the production of pepper so as to realize optimum yields and maximized profits. Before engaging in the growing of pepper, one should consider the following factors:

- target market and market conditions at the time of harvest
- ecological conditions
- block history.

3.1: Target market and market conditions at the time of harvest

Pepper is produced for both local and export markets. Export market requirements are specific especially regarding product quality, traceability and supply. Farmers can be facilitated to meet export market requirements by getting into a contract with an appropriate fresh produce exporter. Such arrangement will ensure that farmers are advised on ways to realize consumer needs such as quality, quantities and when to supply.

Growing pepper for local market is prone to variations in market conditions. Producers should therefore identify potential buyers who will give them an assurance of buying their pepper. Food processors usually offer a stable market for pepper, hence need for getting into an agreement with them before production starts in order to meet their demands.

3.2: Ecological conditions

Ecological factors are basically environmental factors that affect the production of pepper directly or indirectly. The three key ecological factors affecting production of pepper are rainfall, soil condition and temperature.

(a) Rainfall

Pepper plants need about 2 000 mm of rain annually for good growth. Areas that experience low or irregular rainfall patterns require crop irrigation to supplement the rainfall. Arrangements should be made to have a stable supply of water for irrigation. In cases where natural water sources like rivers are far away, a water reservoir or tank should be constructed in the farm and water pumped from the source to the reservoir. Water can be harvested from roof catchments and runoffs and stored in reservoirs for use when there is insufficient moisture. Irrigation maintains soil moisture hence good crop quality and yields can be achieved irrespective of season.

(b) Soil conditions

Soils in the area where pepper is to be grown should be analyzed for chemical properties to establish soil pH, levels of organic matter, phosphorus, nitrogen and potassium. Acidic soils (pH less than 5.4) require addition of lime to improve nutrient supply which will promote good crop performance. As a general guide, 1 to 2 tons of quicklime (CaO) should be applied per ha. Appropriate soil amendment measures should be considered to ensure improved soil fertility in soils having low levels of major nutrients. Soils with low organic matter (organic carbon content of less than 4%) require addition of more manures before establishing the crop.

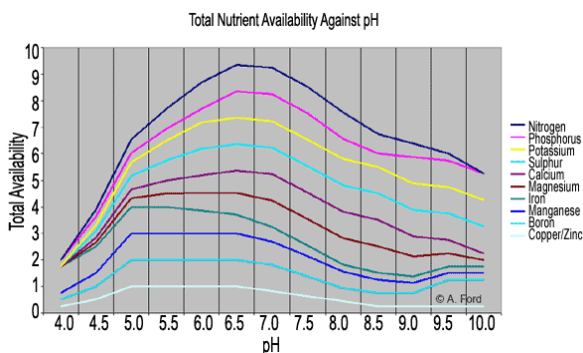


Fig3.1: Total nutrients available

(c) Temperatures

Production of pepper during extremely high temperatures and light intensities will require shading. In such cases structures or cropping systems that cut off excess sunshine and shade the crop need to be planned for. Examples of measures to be taken in controlling temperatures are use of shed nettings, sprinkler irrigation and establishing canopy crops like bananas or fallow shrubs.

3.3: Block history

Previous crop production or agronomic activities in the site chosen for pepper production should be established. Consider such factors as most recent crops, pest and disease incidences, and pollution. Soil suspected to harbour diseases that affect pepper should be tested in a plant health laboratory. Diagnosis of diseases in soils and plant materials can be conducted in the nearest plant clinics or by inspection agencies. Preventive measures should be taken against severe diseases and pests such as bacterial wilt and spider mites.

4.0: Crop establishment in the field

Successful crop establishment involves the germination and emergence of a minimum number of plants which grow and develop with strong seedling vigour. Healthy plants are better able to tolerate pathogens and insects, compete for space and nutrients with emerging weeds and will be more tolerant of applied herbicides.

Pepper growers must consider the following management factors when preparing to establish their crops:

- choose the right paddock to grow pepper, taking into consideration the soil type and rotational history of the soil or block
- sow good quality seed that has a good germination potential and high purity
- select the optimum seeding rate, sowing depth and row spacing for the environment
- plant the crop at the optimum sowing date or season for the variety and length of growing season.

Some of the important points to consider in crop establishment are manure preparation, establishment of seedlings in a nursery, land preparation, transplanting of seedlings and general crop maintenance.

4.1: Manure preparation

Well rotten farm yard or compost manures can be used to improve soil organic matter and structure for effective pepper growth. Soils rich in organic matter store more nutrients which are released slowly with time.



A mature manure pile

A simple manure making process could follow the following steps:

- a) Prepare the area upon which compost manure will be arranged by loosening the soil to a depth of 15 cm.
- b) Arrange materials in a sequence of layers as follows:
 - start with a layer of dry maize stems (or any dry plant materials available; cereals, tree leaves and grasses) cut into 10 cm pieces and laid on the ground to form a layer that is 6 inches thick
 - add a layer of dry grass 2 inches thick
 - put a layer of *Tithonia diversifolia* (wild sun flower) leaves or any green plant materials available locally which are laid to 2 inches thick
 - sprinkle wood ash on green leaves
 - apply animal manure to form a two inch thick layer on *Tithonia diversifolia* leaves (or any green plant material)
 - sprinkle top soil to form a layer half inch thick.
- c) Repeat this sequence until a pile measuring 1.5m by 1.5m base area and 1.5m height is formed.

- d) Each layer should be moistened with clean water.
- e) Turning should be done two weeks after compost arrangement. During turning moisten the manure heap with clean water and make sure that all materials are mixed together. Materials at the centre of the pile should be transferred to the surface while that on the surface should be moved to the centre to form a homogenous composition.
- f) Compost matures one and a half to two months after being set up if the conditions are favourable. Well cured compost will always have a fresh smell similar to that of soil. One pile can generate 600 to 800 kg of cured and dry compost. Cured manure should be stored under shelter if not being used immediately to prevent nutrient loss.
- g) Twelve to sixteen piles of the size described in step c above are required to produce enough manure for an ha of land (5-7 piles per acre).

4.2: Establishment of seedlings in the nursery

a) Seed requirements

Pepper can be planted directly or transplanted. Germination is limited by seed dormancy. Raising seedlings in the nursery and transplanting is recommended to ensure maximum seed germination and good quality planting materials. It is advisable to use certified seeds in raising pepper. In cases where farmers use their own seeds, then these should be extracted from mature pods picked from high yielding disease free plants. Seed extraction requires protection of hands of those doing the exercise with gloves to prevent irritation of eyes and nose. The amount of seed required per ha is 200-250 g. Seeds should be soaked in clean water for two hours and dried to improve germination.

b) Raising seedlings

Nursery beds for sowing pepper should be located in an area that has free draining soils and free from soil pathogens. Soils diagnosed with pathogen

and pests should be sterilized by use of pesticides or solarization. The solarization method is preferable in organic farming systems.

Solarization involves covering already prepared propagation media with polythene paper in an open place exposed to sunlight. The media is left for three weeks before being used to raise seeds. However, this method is not effective against all pathogens hence there is need to retest the soils after sterilization.

Steam sterilization can be practiced in enclosed nurseries. However, this involves initial costs of purchasing equipment such as drums and pipes, labour and demand for clean water. Soils should be prepared to a fine tilth in a bed measuring 1.5 by 6 m. Beds should be raised to 15 cm in areas that experience excess rainfall. Some 60 kg of well decomposed manure should be incorporated in the top 10 cm of the soil.

In situations where soil structures are poor, a propagation media can be prepared by mixing top soil, sand and manure in the ratio of 3:2:1. This is then filled in polystyrene containers measuring three inches in diameter which are placed on a propagation bench. Purchased artificial media such as vermiculite can also be used similarly, for high value pepper production where revenues justify initial costs.



Pepper seedlings

Drill pepper seeds in the nurseries at a spacing of 15 cm and 1 cm depth. One seed should be sowed per container. Cover seeded beds with dry mulch or shed netting. Water the beds with fine droplets. Watering should be done once every day. Seeds will germinate five days after sowing. Control measures should be taken against pests and diseases. Seedlings should be hardened off in the fourth and fifth week after seed emergence by reducing shade and watering frequency to three times per week. Seedlings grown in soils that are poor in nitrogen and phosphorus should be sprayed with foliar fertilizers three weeks after seed emergence to boost early root and vegetative growth. Seedling can be transferred into containers when field conditions are not favourable for immediate transplanting.

4.3: Land preparation

Land on which to grow pepper should be ploughed to a depth of 20 to 30 cm preferably during dry season to kill weeds. Soils with hard pan within 150 cm of the soil layer require deep soil cultivation using a chisel plough or double digging. The latter method is recommended where there is sufficient labour and time allowance before planting.

The use of a chisel plough is justified where the farmer can afford fuel costs and land is big enough for mechanized operations. Rippers made appropriate for animal draught can be used where farmers own donkeys or oxen. Raised beds measuring 1 m wide are recommended where soils are heavy and rich in clay, with poor drainage. Making of beds can be done conveniently using a tractor drawn or hand rotary tiller. Second ploughing comes immediately before planting. Double dug beds do not need further tillage before sowing seeds or planting seedlings.

4.4: Transplanting of seedlings

Planting holes are dug 10 cm deep in conventionally made beds. Raised and double dug beds are usually loose enough to insert seedling at recommended spacing. Spacing of chilies depends on variety and mode of land preparation as shown in table 1 below. Manure is applied in each hole at the rate of 10 tons per ha under conventional practice. In organic

production systems manure rates can be as high as 30 tons per ha. Precise manure application rates are shown in table 1 below.

Table 1. Spacing of different types of pepper

Variety	Mode of land preparation	Spacing	Plant population	Manure rate Dry weight
African birds eye chili	Plowing twice	60 x 45 cm	37,037 per ha	270 g/hole
	Double dug bed ^a	45 x 45 cm	42 per bed	60 kg per bed
	Raised bed ^b	90 x 60 x 45 cm	29, 333 per ha	1.5 kg per m ²
Hot peppers	Plowing twice	60 x 40 cm	41, 667 per ha	240 g/hole
	Double dug bed ^a	45 x 45 cm	37, 037 per ha	60 kg per bed
	Raised bed ^b	90x 60 x 40 cm	33, 000 per ha	1.5 kg per m ²
Sweet peppers	Plowing twice	60 x 40 cm	41, 667 per ha	240 g/hole
	Double dug bed ^a	45 x 45 cm	37, 037 per ha	60 kg per bed
	Raised bed ^b	90 x 60 x 40 cm	33, 000 per ha	1.5 kg per m ²

a. Double dug beds measures 1.5 m x 6 m, 575 bed per ha, alternate spacing. Manure is broadcast and incorporated in the top 10 cm of soil.

b. Raised beds measure 1 m by 100 m with 50 cm paths. A ha has 66 such beds. Manure is broadcast and incorporated in the top 10 cm of soil.

Phosphorus should be applied at the rate of 80 kg per ha at planting in the form of Diammonium Phosphate (18 % N, 46 % P₂O₅) or Triple Super Phosphate (46 % P₂O₅). Minjingu Phosphate Rock (21 % P₂O₅) is recommended for supply of phosphorus in organic pepper production. Both fertilizer and manure should be well incorporated in the soil before transplanting.

Transplanting is done at the beginning of rainy season to give seedlings a good start. Seedlings should be transplanted after attaining a height of 7 to 10 cm with about four true leaves. Water nursery beds before lifting seedlings with a ball of soil around their roots. It is advisable to plant seedlings when temperatures are low. Under conditions of very high temperatures and light intensities, one can cover seedlings with shed nettings after transplanting. One can also dry and clean plant materials to prevent transplanting shock. Crops should be irrigated immediately after transplanting.

4.5: Crop maintenance

a) Mulching

Dry plant materials are laid on the soil surface in the inter row space to preserve moisture and smother weeds. It also reduces the need for hand weeding hence low chances of transmitting diseases such as bacterial and fusarium wilt through contaminated tools.

b) Weeding

Fields should be kept weed free by doing a shallow weeding in early stages of crop establishment. Areas suspected to have incidences of bacterial and fusarium wilt require that weeding tools be washed and disinfected before weeding a disease free crop.

c) Top dressing

Supply 30 kg per ha of nitrogen as Calcium Ammonium Nitrate (CAN) at the beginning of flowering. Soils that are water logged or alkaline require foliar feed sprays during vegetative growth and flowering to supply macro and micro nutrients. More nitrogen and magnesium is required during vegetative growth. At flowering plants may show increased demand for potassium, boron and phosphorus.

d) Irrigation

Irrigation needs will vary with existing weather conditions. Soil moistures should be tested using moisture meters for accurate irrigation needs determination. Micro sprinklers can be used to irrigate nursery plants.

- During and immediately after transplanting overhead sprinklers are preferred to bring soil moisture to field capacity and creating moist micro climate to promote seedling establishment in the harsh field conditions. After seedling establishment, both drip and overhead sprinkler irrigation methods can be used to water crops.

- Drip irrigation can be done at night when temperatures are low thus ensuring low moisture loss and efficient water uptake by plants. In commercial ventures which limit labour costs, soluble fertilizers and pesticides can be applied in irrigation water.
- Sprinkler irrigation should be used during day time. Use of sprinkler irrigation under low temperatures can create favourable conditions for diseases such as anthracnose and rhizoctonia. Sprinkler irrigation is also recommended towards harvesting of chilies to keep the fruits fresh. Small pieces of land can be irrigated by use of a watering can or hosepipe.

5.0: Crop protection

There are steps that can be taken to protect peppers from diseases and disorders and pests which affect pepper in order to maximize on yields and quality of the final product.

5.1: Diseases affecting pepper

a) Damping off

Damping off is caused by *Rhizoctoni solani* and *Pythium* fungal species. Infected seeds fail to germinate. They become soft and brown before decaying. Seedlings develop slightly darkened water soaked spots and they die before emerging. Roots of young seedlings are water soaked and discoloured while stem bases grow more thin and soft compared to upper parts hence the seedling collapses.

Damping off can be controlled by:

- Sterilization of propagation media
- Use of fungicides (see Appendix 1)

b) Bacterial wilt

Bacterial wilt is caused by *Pseudomonas solanacearum* bacteria. Once it infects a crop it is difficult to control and it leads to total crop losses. This disease is manifested by premature wilting of leaves and succulent top portions of infected plants which become flaccid and drop. Bacterial ooze can be seen from cut stems when immersed in clean water.

Bacterial wilt can be controlled by:

- sterilizing propagation media
- mulching
- sterilizing tools with soap solution before use in uninfected crops
- avoiding using seeds and other plant materials from areas suspected to have the disease
- leaving infected fields fallow for a period of one to two years.

c) **Fusarium wilt**

Fusarium wilt is caused by *Fusarium oxysporum f. pv. lycopersici* fungi. It appears as wilting of young seedlings and mature plants which can be acute when plants are water stressed. The cut cross sections of infected stems have a brown to orange ring around the vascular bundles. Small infected lateral roots decay. This disease is prevalent in poorly drained heavy clay soils. It is spread by infected tools and debris.

Control of fusarium wilt is achieved by:

- sterilizing tools with soap solution before use in uninfected crops
- sterilizing nursery propagation media
- use of healthy seeds and transplants
- treating seeds suspected to have the fungi with hot water at temperatures of 50°C for 25 minutes
- uprooting and destroying infected plants
- amending poorly drained soils with manure
- spraying fungicides (see Appendix 1).

d) **Powdery mildew**

Powdery mildew is caused by a fungus; *Laveillula taurica*. Its symptoms appear as grayish white powdery growth on both the lower and upper leaf surfaces. Young leaves and shoot tips become curled and distorted. Mature leaves have large white patches of fungal growth and colonized tissues eventually die. Powdery mildew can be controlled by spraying fungicides

(Appendix 1). Ensure that crops have well balanced nutrient and water supply.

e) Downy mildew

Downy mildew is caused by *Peronospora tabacina* fungi. Symptoms of this disease manifest as small, pale yellow spots with indefinite borders on the upper surface of leaves. On the lower leaf surfaces directly under the yellow spots are grayish fungal growth. Infected tissues later turn brown and the fungal growth on the underside of the leaves turn brown. Severely infected leaves fall prematurely.

Downy mildew can be controlled by preventive spray of copper based fungicides beginning before flower opening (see Appendix 1). Low temperatures and high humidity are favourable for diseases' development hence more need for spraying fungicides during such conditions.

f) Late blight

Late blight is caused by the fungi *Phytophthora capici*. Symptoms of this disease appear as damping off of seedlings. The stem also develop lesions at soil level which eventually cause seedlings to fall. Dark green spots form on leaves which eventually enlarge and loose their green colour. Severely infected leaves die and fall off. Dark water soaked patches can be seen on fruits which become coated with white fungal growth. Fruit tissues die while the fruit is still attached to the stem. Seeds from infected fruits are shriveled.

Late blight can be controlled by practicing crop rotation. Pepper should not follow any solanaceous crop in a rotation. Both preventive and curative fungicides are effective in controlling the disease when conditions are cool and humid (see Appendix 1).

g) Anthracnose

Anthracnose is caused by the fungus *Gloeosporium piperatum*. It is common in warm to cool humid conditions. It is a seed borne disease.

Anthrachnose causes death of seedlings before emergence. On plant stems, sunken lesions develop which are covered with pink spores. Symptoms of anthracnose on leaf veins and petioles manifest as long, dark, brick red to purple lesions that later darken.

Anthrachnose can be controlled using the following measures:

- using plant disease free seeds
- applying crop rotation where disease hosts such as pepper, beans, cotton and tomatoes should be avoided
- ensuring field hygiene; remove and burn infected plant materials
- avoiding overhead irrigation when temperatures are low
- spraying fungicides (see Appendix 1)

h) Bacterial leaf spots

Bacterial leaf spots are caused by *Xanthomonas vesicatoria* fungi. Symptoms of this disease are wet round dark spots which can be seen on leaves, stems, and fruits. Dots become brown, moist and scabby on fruits.

Bacterial leaf spots disease can be controlled by:

- practising crop rotation
- ensuring field hygiene and seed treatments
- using fungicides to prevent infections (see Appendix 1).

i) Rhizoctonia

Rhizoctonia is caused by *Rhizoctonia solani* fungi. It causes rotting of roots and stems of seedlings. Leaves and fruits near the ground develop spots. At advanced stage, sunken water soaked areas appear on fruits after which infected tissues collapse. White mycelial growth can be seen on the damaged tissues which eventually turn brown. This disease is prevalent during wet and cool conditions. If not controlled it can cause post harvest losses.

Rhizoctonia can be controlled through the following means:

- observing field hygiene; remove plant residues of infected plant hosts
- using clean seeds
- sterilizing seeds suspected to have the disease with hot water (50°C for 25 minutes)
- avoiding areas with poorly drained soils
- spraying fungicides (see Appendix 1)

j) Viral diseases

Pepper is attacked by different strains of virus; tobacco mosaic virus, cucumber mosaic virus. This disease appears as yellow mottling and curling of leaf edges. Infected crops become stunted. Viruses are transmitted from infected plant materials such as cucumbers, black nightshade, Irish potatoes and pepper. They are transmitted mechanically through injuries on plant tissues caused by contaminated tools, smokers and arphids.

Viral diseases can be control by:

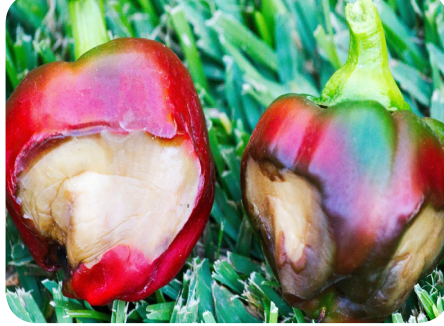
- using resistant seed varieties
- practicing hygienic crop cultural practices such as cleaning tools and hands of smokers
- practising crop rotation
- spraying copper based fungicides especially after a hail storm
- controlling insect vectors; arphids (see Appendix 1)

5.2: Disorders affecting pepper

a) Blossom end rot

Blossom end rot is a physiological disorder in pepper, caused by poor supply of calcium to developing fruits. It is triggered by low or irregular water

supply to crops, excess vegetative growth; usually encouraged by nitrogen fertilizers and low uptake of calcium by plants. It causes disintegration of tissues at the distal end of fruits. Affected areas eventually turn brown and can be attacked by fungus which causes fruit rot.



Blossom end rot

Blossom end rot can be controlled by:

- ensuring regular and sufficient watering
- liming acidic soils to improve uptake of calcium
- avoiding excessive use of nitrogen especially at reproductive stage
- pruning excess foliage.

b) Sunscald

The symptoms of sunscald on the pepper fruit are very similar to those for blossom end rot. Soft, tan coloured sunken lesions develop fruit that are exposed to direct sunlight. It is important to adjust pruning practices to ensure that all fruit are shaded from direct sunlight.

c) Fruit cracks

This condition is characterized by the appearance of very fine, superficial cracks on the surface of the pepper fruit which gives a rough texture

to the fruit. The development of these cracks is associated with sudden changes in the growth rate of the individual fruit. The appearance of fruit cracks can follow periods of high relative humidity (over 85%), changes from hot sunny weather to cool cloudy weather or vice versa. Maintaining a consistent, optimized growing environment is the best way to prevent the development of fruit cracks.

d) Fruit splitting

The development of large cracks in the fruit is a direct response to high root pressure. Factors that contribute to the development of high root pressure directly impact fruit splitting. Adjust the timing of the last watering in the day so as not to water too late. Eliminate any night watering cycles.

e) Fruit spots

The appearance of small white dots below the surface of the pepper fruit is associated with excess calcium levels in the fruit, and the subsequent formation of calcium oxalate crystals. Conditions that promote high root pressure will also favour the development of fruit spots.

5.3: Pests affecting pepper

Pests are animals or plants that cause damage to agricultural produce by feeding on the crops. There are various pests that damage pepper crops. These include arphids, worms such as American bollworms and cutworms.

a) Arphids

Pepper is attacked by green peach arphids (*Myzus persicae*) and potato arphids (*Macrosiphum euphorbiae*). Arphids suck sap from infested plants and transmit viral diseases. They also produce honey dew which distorts leaf and fruit surfaces.



Aphid

Aphids can be controlled by spraying insecticides (see appendix 1). In organic farms hot chili extracts can effectively control aphids.

b) American bollworms

The colour of American bollworms (*Heliothis armigera*) caterpillars ranges from dark brown to green and yellow. They feed on the inside of fruits in which they deposit their excreta.



American bollworm

American bollworms can be prevented by practicing crop rotation. Preventive chemical spray should start at flowering. Curative insecticides are recommended when 1 % of the pods have been attacked. See appendix 1 for insect control options.

c) Cutworms

The larvae of cutworms (*Agrotis segetum*) attack plants both in the nursery and field. They cut stem bases of young seedlings. They hide under the soil and usually near the damaged plant when not feeding.



Cutworm

Cutworms can be controlled by drenching the soil or propagation media with appropriate insecticides (See appendix 1).

Other pests that attack pepper are red spider mites (severe under greenhouse conditions), thrips, leaf miners, flea beetles, white flies and nematodes.

6.0: Harvesting, post harvest handling and marketing of pepper

Farmers need to plan well for the harvesting of pepper, all that goes into it after harvest, including the marketing of the pepper and its products.

6.1: Harvesting

Pepper pods mature two and a half to three months after transplanting. However, the harvesting stage varies with expected market.

- A yield range of 1000 to 3000 kg per ha of dried African bird's eye pods is possible under good management.
- Chilies are harvested for fresh market after attaining a green orange to red colour at maturity. Green pods are usually harvested for making vegetable salads. Chilies for processing should have full red colour. Pods of some varieties of hot chilies turn yellow at maturity which is the right time for them to be harvested.
- Sweet pepper is harvested at maturity when green, yellow or orange in colour depending on variety.
- Fresh pod yields of 15 tons per ha can be realized in optimum conditions.

6.2: Post harvest handling

Picking of pods after maturity continues for two to three months in sweet peppers and four to six months in hot chilies. Harvested pods

should be placed in clean containers; where possible washed with sodium hypochlorite (Jik®) or any other soap solution to prevent post harvest infections.

Fresh pepper is covered from direct sunlight while being transported on tracks or pickups to local markets. Pepper pods should be taken to the market on the same day they were harvested preferably late in the afternoon.

Fresh pods for export and processing require refrigerated tracks in which temperatures can be maintained at 8°C. On arrival at the pack house, the crop should undergo pre cooling at a temperature of 8°C to remove field heat. Chilies can remain fresh for three to five weeks when stored at a temperature of 7°C to 10°C and 95% relative humidity. Chilies for making fresh pre packs need to be washed in clean water with 15% chlorine to remove contaminants. Thereafter, they are sorted to remove damaged and diseased pods. Fresh hot chilies should be handled using gloves to avoid irritation of eyes and nose during processing.

Post harvest loss through dehydration can be limited by storing pods under shade usually near the harvested field. Pepper meant for dry products is dried in direct sunlight or in solar driers that are covered with transparent polythene or glass and which have ventilations. In direct sunlight, pods should be placed on racks raised one meter high and lined with clean shed clothes. Drying pods should be turned frequently to speed up the dehydration process.

Chilies should be dried to a maximum moisture content of 13% which discourages growth of aflatoxins. After drying pods can be packed in sacks and stored in a dry and well ventilated place.

Marketing of pepper

A farmer needs to conduct a market research for his produce long before he embarks on the actual planting of the crop. There is need to research

on the national and international competitiveness of the pepper harvest, selecting those markets that are major consumers of pepper carefully.

Given the globalization of markets, international competitiveness requires industries to be competitive in both the domestic and relevant foreign markets. At the same time, regional producers have as one of the main targets the export markets for the fresh peppers as well as value-added pepper-based products.

Glossary

Active ingredient, that component part of an insecticide, herbicide or fungicide formula that has toxic properties.

Aflatoxin, fungus that grows on plant materials kept in poorly ventilated conditions which can poison consumers.

Alternate spacing, growing crops in a manner that plants in succeeding rows are mid the distance of two plants in adjacent row.

Berries, fruits with fleshy or pulpy pericarp.

Botanical pesticides, extracts from plants used to control pests.

Certified seeds, seeds that have undergone breeding, production and cleaning to maintain purity and ensure that they are free from seed borne diseases and pests.

Chisel plow, a machine with penetrating points drawn to a depth of 12 inches to loosen subsoil.

Conventional system, farming that involves use of external farm inputs which consist of inorganic products such as pesticides and synthetic fertilizers to mainly maximize production per unit area.

Curling, abnormal bending of the leaf blade downward along the main vein.

Damping off, a fungal disease characterized by rotting of seedlings usually beginning from the stem base.

Distal end, the side towards the fruit tip.

Double dug bed, a seedbed measuring 9 m² in which soil has been dug to a depth of 60 cm to break the hardpan.

Drenching, application of liquid pesticides in the soil to control soil borne pests and diseases.

Erect, upright growth.

Fallow, leaving the farm unplanted for a period of time to improve soil quality.

Fibrous, profusely branched roots with many lateral rootlets.

Field hygiene, practice that eliminates contaminated materials and conditions that can encourage pest or disease build up in a field.

Frost damage, degradation of plant tissues as a result of freezing temperatures.

Greenhouse, glass or plastic covered structures whose environment can be modified for growing plants.

Hardening off, exposing young seedlings to harsh field conditions by reducing watering frequency and quantity, shading and nitrogenous fertilizers.

Herbaceous annual plants, plants whose tissues are largely composed of water and they lack pronounced woody structure that grow and finish their life cycle in one year.

Homogenous, uniform.

Mild, not strong or bitter in taste.

Mottling, a spot or blotch of colour different from the mass colour of surface.

Organic, produced using inputs of plant or animal origin available on the farm to sustain crop production and preserve the environment.

Outdoor, open environment in which crops are grown, compared to greenhouse.

Pathogens – micro organisms that cause diseases in plants.

Perennial, a plant that lives for more than two years.

Pods, mature fruits of chilies.

Pre-cooling, lowering temperatures of fresh produce after harvesting using forced air to eliminate field heating hence prolong its shelf life .

Pre-harvest interval, time allowed between spraying pesticides and harvesting so as to get produce that is free from active chemical residues.

Productivity, production per unit of a resource used.

Propagation media, substance in which seeds or plant propagules are grown to multiply e.g. soil.

Propagation bench, a raised surface with spaces to allow for drainage and aeration on which young potted plants are supported while growing in a greenhouse or shed house.

Pungent, strong and irritating smell.

Rack, raised surface with wire mesh or shed clothing which allows free air circulation through plant materials that are being dried.

Raised bed, a seed bed prepared by cultivating the soil to a depth of 20 cm which is raised to 15 cm from the general ground surface.

Shrub, perennial woody plant usually less than 10 ft tall which has several branches starting at near ground.

Solarization, a method of sterilizing soils that involves covering a 15 cm layer of the media with transparent polythene paper for three weeks hence pathogens are eliminated by effect of heating from the sun.

Species, more or less continuous and interbreeding group of plants which have in common one or more genetic characters by which they may be differentiated from other species.

Stout, strong and thick.

Tapering, a form that has gradually reducing diameter.

Traceability, information used to track a product in the market from the procedure used in field production, harvesting and post harvest handling.

Transplanting shock, death of seedlings as a result of exposure to adverse field conditions such as low soil moisture and high light intensities after transplanting.

Vermiculite, minerals classified as micas treated to high temperatures and used as a sterile medium for rooting plant cuttings and propagating seedlings.

Water logged, soil moisture content in which all pores are filled with water.

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Appendix 1. Pesticide recommendations for control of pests and diseases in pepper

Pests	Chemical active Ingredient	Maximum dose	PHI	Production system	Special recommendations
American bollworm	Bacillus thuringensis (Bt)	0.75 kg/ ha	1 day	C/O	Biological pesticide
	Bifenthrin	1.6 l /ha	3 days	C	Alternate with non pyrethroids
	Deltamethrin	0.5 l/ha	3 days	C	Alternate with non pyrethroids
	Lamda cyhalothrin	1 l /ha	4 days	C	Alternate with non pyrethroids
Aphids	Bifenthrin	1.6 l /ha	3 days	C	Alternate with non pyrethroids
	Deltamethrin	0.3- 0.5 l/ha	1 day	C	Alternate with non pyrethroids
	Lamda cyhalothrin	1 l /ha	4 days	C	Alternate with non pyrethroids
	Imidachloprid	0.5 l/ha	3 days	C	
Cutworms	Azadiractin	1 l ha	1 day	C/O	Natural product
	Pyrethrum (1%) and garlic extract (37.7 %)	1 l ha	1 day	C/O	Natural product
	Bifenthrin	1.6 l/ha	3 days	C	Drench soils at planting
	Beta cyfluthrin	0.6 l/ha	3 days	C	Drench soils at planting
Spider mites	Alpha cypermethrin	0.25 l/ ha	3 days	C	Drench soils at planting
	Pyrethrum (1%) and garlic extracts (37.7 %)	1 l ha	1 day	C/O	
	Abamectin	0.25 l/ha	3 days	C	Maximum of 3 applications (alternate with pyrethroids)

	Bifenthrin	1.6 l /ha	3 days	C		Alternate with non pyrethroids
Thrips	Azadiractin	1 l/ha	1day	C/O		
	Petroleum oil	5 l/ha	1 day	C		
	Pyrethrum (1%) and garlic extracts (37.7 %)	1 l ha	1 day	C/O		
	Soap solution (Teepol®)	7 l/ha	0 days	C/O		
Diseases						
Powdery mildew	Sulphur	3 kg/ha	1 day	C		Avoid flowering stage
	Quaternary ammonium	1 l ha	0 days	C/O		
	Garlic extract (40 %)	1 l/ha	1 day	C/O		
	Tebuconazole	0.5 l/ha	7 days	C		
	Azoxystrobin	0.75 l/ha	7 days	C		
	Copper hydroxide	2.5 kg/ha	5 days	C		
	Bitertanol	1.5 l/ha				
	Neem products					
Downey mildew	Propamocarb Hydrochloride	0.75 l	10 days	C		Pre-plant
	Quaternary ammonium	1 l ha	0 days	C/O		
	Propineb	2.5 kg/ha				
	Matalaxyl					
Late blight	Matalaxyl			C		Preventive- apply from seedling stage
	Mancozeb	2.5 kg/ha	14 days	C		Preventive-start applying at flowering

	Benalaxyl+Mancozeb	2 kg/ha	3 days	C	Curative- maximum of 3 applications (alternate with preventive)
	Propineb+Cymoxanil	2 kg/ha	7 days	C	Preventive
	Chlorothalonil	2 l/ha	14 days	C	Preventive
Anthracnose	Chlorothalonil	2 l/ha	14 days	C	Preventive
	Mancozeb	2.5 kg/ha	14 days	C	Preventive-start applying at flowering
	Carbendazim	0.75 l/ha	14 days	C	Curative
Bacterial leaf spot	Copper hydroxide	3 kg/ha	5 days	C	Preventive, combine with Mancozeb
	Mancozeb	2.5 kg/ha	14 days	C	Preventive
Fusarium wilt	Carbendazim	0.75 l/ha	14 days	C	Curative, apply at seedling, flowering and fruiting stages
	Imazalil+Pencycuron	8 g/kg of seed	Not applicable	C	Preventive seed treatment
	Fungi and bacteria enzymes (Rootguard®)	1 kg/ha	0 days	C/O	
	Iprodione	3 l/ha	7 days	C	
Rhizoctonia	Imazalil+Pencycuron	8 g/kg of seed	Not applicable	C	Preventive seed treatment
	Iprodione	3 l/ha	7 days	C	
Damping off	Propamocarb Hydrochloride	0.75 l	10 days	C	Pre-plant

C-Conventional, C/O- Both conventional and organic PHI- Pre-harvest interval