• PRODUCTION GUIDELINE •

# Sweet pepper

(*Capsicum annuum*)

agriculture,
forestry & fisheries

Department:
Agriculture, Forestry and Fisheries
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# CONTENT

## Classification

Scientific name: *Capsicum annuum*
Common names: bell pepper, sweet pepper

## Origin and distribution

Sweet peppers (*Capsicum annuum* L.) originate from central and South America where numerous species were used centuries before Columbus landed on the continent (Manrique, 1993). The cultivation of peppers spread throughout Europe and Asia after the 1500s. Although perennials, they grow as annuals in temperate climates. They are sensitive to low temperatures and are relatively slow to establish. Greenhouse production provides most of the local source of this product.

## Major production areas in South Africa

### *South Africa*

This crop is grown in different parts of South Africa along with a large variety of other vegetable and field crops on individual farms, namely Gauteng (in the highveld and lowveld areas), Northern Cape, Eastern Cape, Western Cape, Limpopo and KwaZulu-Natal.

### *Production requirements*

Most sweet peppers are bell-shaped, therefore the name bell pepper is common. However, sweet peppers come in a range of shapes from round to oblong, to tapered. The skin is smooth and shiny and can be a range of colours. Most peppers are green when immature, and red if allowed to ripen. However, new cultivars offer both mature and immature peppers in red, yellow, orange, purple, or brown.

## Description of the plant

These are tender annuals or perennials from South America. They are green at first and change to red, yellow or purple. They contain many flat, kidney-shaped, white seeds, which are very hot tasting. When the fruit is

ripe it is red or yellow, but it is used as a vegetable in the green stage. Although these plants are technically perennials, they are not worth keeping after fruiting once. It is better to start new plants every year.

Greenhouse production of peppers is based on indeterminate cultivars in which the plants continually develop and grow from new meristems that produce new stems, leaves, flowers and fruit. In comparison, field pepper cultivars are determinate; the plant grows to a certain size, produces fruit and stops growing and eventually dies off.

Indeterminate cultivars require constant pruning to manage their growth. In order to optimise yield, a balance between vegetal (leaves and stems) and generative (flowers and fruit) growth must be established and maintained.

### *Roots*

By the end of the season, the pepper's roots may extend 20 to 30 cm deep and at least as wide, but they remain fairly fine. Pepper's roots are deeper than those of lettuce, broccoli or spinach; however, they remain fairly close to the surface.

### *Stem*

There are many different varieties of peppers ranging from 30 to 90 cm tall.

### *Leaves*

Pepper leaves are oval and taper to a point. They are usually bright to dark green, but can also be mottled. The size of the leaf corresponds somewhat to the size of the fruit; plants that produce very small peppers also tend to have small leaves, while the larger bell pepper cultivars have large, broad leaves.

*Flowers*

They have straight, woody stems and single, star-shaped, white flowers in the axils of the leaves. The flowers are followed by juiceless berries or pods, which vary in shape and size.

*Fruit*

When ripe, the fruit is red, yellow or brown but immature fruit of the large mild types are often picked while still green for use in salads. These species generally bear large fruit.

## Cultivars

Kinds that are frequently grown are varieties of *C. frutescens*, which are the peppers grown in the vegetable garden and include those from which red pepper, cayenne pepper, tabasco and paprika are made.

There are many varieties of garden peppers. They are divided into two groups; the sweet peppers or mild-flavoured varieties, which are used for stuffing, salads and garnishing; and the hot peppers, which are mainly used in sauces and flavouring. The Spanish word "Chili" describes peppers of all kinds, but in English, the name is usually only applied to the pungent varieties used for flavouring. *C. frutescens grossum*, the sweet or bell pepper, is a popular vegetable.

Certain types of peppers are very pretty when grown as potted plants, especially in the fall and early winter. The best are *C. frutescens cerasiforme*, the cherry pepper and *C. frutescens conoides*, the cone pepper. The varieties of these kinds have red, purple or cream-coloured fruit displayed above the rich green foliage.

*Cultivar selection*

Bell pepper cultivars differ in such horticultural traits as fruit size, shape (e.g. blocky *versus* elongated), number of lobes, flavour, and disease resistance. Standard green bell cultivars typically ripen to red; however, specialty bell peppers include cultivars that ripen to a colour other than red. These specialty bells may be yellow, orange, brown, white, and even purple at maturity.

Compared to green bell peppers, coloured bells are often more difficult and expensive to produce because a longer time to reach maturity is required.

Growers should only select adapted varieties that have the qualities in demand for the intended market. Owing to the prevalence of bacterial leaf spot in Kentucky, only hybrid varieties with leaf spot resistance are recommended for commercial production. While resistance to bacterial leaf spot has helped reduce losses because of this devastating disease, new races of the pathogen have been isolated to which there is currently no resistance.

## Climatic requirements

### *Temperature*

Pepper is a warm-season crop, which performs well under an extended frost-free season, with the potential of producing high yields of outstanding quality. It is very vulnerable to frost and grows poorly at temperatures between 5 and 15 °C (Bosland & Votava, 1999). The optimum temperature range for sweet pepper growth is 20 to 25 °C (Anon., 2000).

The germination of pepper seed is slow if sown too early when soil temperatures are still too low, but seedling emergence accelerates as temperatures increase to between 24 and 30 °C (Bosland & Votava, 1999). The optimum soil temperature for germination is 29 °C (Anon., 2000). Low temperatures also slow down seedling growth, which leads to prolonged seedling exposure to insects, diseases, salt or soil crusting, any of which can severely damage or kill off the seedlings (Bosland & Votava, 1999).

High temperatures adversely affect the productivity of many plant species including green pepper. Sweet pepper requires optimum day/night temperatures of 25/21 °C during flowering.

The exposure of flowers to temperatures as high as 33 °C for longer than 120 hours leads to flower abscission and reduced yields. Pollen exposed to high temperatures (>33 °C) normally becomes non-viable and appears to be deformed, empty and clumped (Erickson & Markhart, 2002). Temperatures lower than 16 °C can lead to fruitless plants (Coertze & Kistner, 1994a).

Higher yields are obtained when daily air temperature ranges between 18 and 32 °C during fruit set (Bosland & Votava, 1999). Persistent high relative humidity and temperatures above 35 °C reduce fruit set. Fruit that is formed during high-temperature conditions is normally deformed. Sweet peppers are also very sensitive to sunscald (Coertze & Kistner, 1994a). Fruit colour development is hastened by temperatures above 21°C (Bosland & Votava, 1999).

## Soil requirements

*Site and soil*

Bell peppers prefer deep, fertile, well-drained soils. Avoid planting in low-lying fields next to streams and rivers because these sites are subject to high humidity and moisture conditions and, therefore, especially prone to bacterial spot epidemics. Producers should also avoid fields where long-residual corn or soya bean herbicides have been used, because herbicide carry-over can cause serious damage to peppers.

Pepper fields should be located as far away from tobacco plantings as possible owing to potential spread of aphid-vectored viruses from tobacco to peppers. It is also advisable not to grow peppers after other solanaceous crops (such as tobacco, tomatoes, potatoes, and brinjals) or vine crops for a period of three years because all of these crops are susceptible to some of the same diseases. Peppers do extremely well following fescue sod.

Use a soil test to determine fertiliser and liming requirements. Peppers grow best at soil pH between 6,0 and 7,0. Adjust the soil pH to near neutral (7,0) for maximum yields.

To reduce the risk of Verticillium wilt and other diseases, avoid using fields in your rotation plans in which eggplant, tomato, pepper, potato and strawberry or caneberry have been planted.

# CULTIVATION PRACTICES

## Propagation

Pepper seed may be sown directly in the field, but most commercial farmers in South Africa prefer to transplant seedlings bought from vegetable seedling growers. With direct sowing, laborious and costly activities must be carried out to ensure a good plant stand.

Emergence of directly sown peppers is hampered by soil crusts caused by raindrops, which results in poor plant stands. Frequent irrigation prior to emergence solves this problem, but it results in an unnecessary increase in water use and production cost (Bosland & Votava, 1999).

Direct (*in situ*) sowing of peppers requires seed of about 2 kg/ha$^{-1}$ (Anon., 2000). Seedlings are produced by sowing seed in seed trays under greenhouse or shade-cloth conditions. Pepper seedlings are ready to be transplanted after 6 to 8 weeks when the seedlings are 150 to 200 mm tall. Stands established using seedlings are more even and uniform and can achieve earlier maturity than direct-seeded plants. The use of seedlings also reduces thinning cost and can tolerate or avoid early unfavourable plant growth conditions (Bosland & Votava, 1999). The quantity of seed required to produce enough seedlings for one hectare is 400 to 800 g (Anon., 2000).

Many hectares of plant beds in the open field are used to grow pepper ***(author???)*** plants for selling to farmers. However, pepper plants are somewhat more difficult to grow. They have to be transported over long distances and delivered to the field in good condition for transplanting. Pepper plants are harmed more than tomato plants by unfavourable conditions in the plant bed, in transit, or upon delivery. Transported plants therefore, are used for a smaller percentage of the total number of hectares under peppers than under tomatoes.

## Soil preparation

More important than fallowing in particular rotation over many years is the precaution to avoid growing peppers on the same soil more often than once in 3 or 4 years. As tomatoes and peppers are subject to some of the same diseases, neither should follow the other in successive seasons in the same soil. Soil used for plant beds should have had no peppers grown in it for 4 or 5 years, preferably never before.

## Planting

*Planting period*

Greenhouse peppers are sown in October through February for harvest of red fruit approximately five months later, March through July.

### *Days to maturity*

The exact time to maturity varies depending on the exact variety of bell pepper. Most sweet peppers mature in 60 to 90 days after planting; hot peppers can take up to 150 days. Keep in mind, however, that the number of days to maturity stated on the seed packet refers to the days after transplanting until the plant produces a full-sized fruit.

### *Spacing*

Although much of the greater part of the total area of all kinds of peppers is grown from transplants, seed is also sown directly in place in the open field, principally in some of the warmest parts of the country. Ten to 12 seeds can be planted 45 cm apart on rows that are 75 cm apart and later thinned when 8 to 10 cm tall to 2 plants per stand. The costs of production by sowing in place are nearly the same as by transplanting, because of the costs for much more seed, thinning and additional cultivation to control weeds. Sowing in place is not generally recommended, even in places where the season is long enough to permit its use.

The seedbed for raising seedlings is made 120 to 150 cm wide and as long as necessary. The soil is pulverised by forking and breaking up the clods and removing stones and straw.

### *Seeding rate*

One hectare requires 100 to 200 g of seeds.

## Fertilisation

Recommendations for supplemental organic matter, fertiliser, lime and manure should be based on a soil test and a nutrient management plan. Nutrient management plans balance the crop requirements and nutrient availability, with the aim to optimise crop yield and minimise ground-water contamination, while improving soil productivity.

### *Field fertilisation*

A soil test is the most accurate guide to fertiliser requirements. The following recommendations are general guidelines for loamy soils or when organic matter exceeds 2,5%.

The fertiliser programme for sweet pepper production depends on the type of soil, the nutrient status and the pH of the soil. It is therefore important to analyse the soil before planting to determine any nutrient deficiency or imbalances (Coertze & Kistner, 1994a). The withdrawal quantities for sweet pepper are 1,5 to 3.5 kg N, 0,2 to 0,4 kg P and 2 to 4 kg K of fruit harvested (FSSA, 2007).

Nitrogen is important for sweet pepper plant growth and reproduction. The element is mobile in the soil and leaches out easily. Split applications of nitrogen are therefore necessary to minimise leaching (FSSA, 2007). On sandy soils, topdressing with lower and more frequent split applications is necessary to reduce the risk of leaching. Excess application of nitrogen promotes too much vegetal growth which leads to large plants with few early fruit. Under high rainfall and humidity conditions, too much nitrogen delays maturity, resulting in succulent late-maturing fruit (Bosland & Votava, 1999).

Phosphorus plays a role in photosynthesis, growth, respiration and reproduction. It is in particular associated with cell division, root growth, flowering and ripening. Potassium is associated with resistance to drought and cold, and fruit quality. It promotes the formation of proteins, carbohydrates and oils (FSSA, 2007). Phosphorus is applied before planting while potassium fertilisers are usually applied at planting time (Ngeze, 1998). Sweet pepper is sensitive to calcium deficiency, which normally results in blossom-end rot (Pernezny *et al.*, 2003). The crop is also sensitive to deficiency of micronutrients such as zinc, manganese, iron, boron and molybdenum (Portree, 1996).

## Irrigation

Many growers of fresh-market peppers, plant under black plastic mulch with trickle irrigation laid under the plastic. This provides uniform moisture and fertilisation during the growing season.

Dry conditions result in premature small-sized fruit set, which leads to reduced yields (Bosland & Votava, 1999). Sweet pepper has a total water requirement of about 600 mm and a weekly water requirement of 25 mm during the first five weeks and 35 mm thereafter (Anon., 2000).

Excessive rainfall or water supply can negatively affect flower and fruit formation and eventually lead to fruit rot (Coertze & Kistner, 1994a). Unrestricted water supply to the crop can be as harmful as not enough water. Root rot diseases can be caused by waterlogged conditions that last for more than 12 hours; therefore drainage of the field is very important. If plant growth is slowed by water stress during flowering, blossoms and immature fruit are likely to drop off (Bosland & Votava, 1999).

Irrigation is essential in arid and semiarid regions to provide enough water for pepper production (Bosland & Votava, 1999). Furrow irrigation is well known as a major factor favouring conditions leading to the development of diseases like bacterial wilt (Pernezny *et al.*, 2003).

Drip irrigation is one method of water application that optimises water supply for pepper production and conserves water in arid regions. Drip irrigation with cultural practices like mulching generally leads to additional yield increase. Drip irrigation allows for frequent application of low levels of soluble nutrients to the root zone (fertigation). The control over the root environment with drip irrigation is a major advantage over other irrigation systems (Bosland & Votava, 1999). Sprinkler irrigation requires very good quality water. However, the type of irrigation is likely to make bacterial diseases more of a problem through splashing (Grattidge, 1993).

## Weed control

Good weed control in peppers begins similarly to any other crop, before the crop is planted. Control established perennials before planning to plant peppers in the field. Use cultural, mechanical and chemical weed control techniques in a coordinated manner to reduce the risk of interference with the crop. Plastic and organic mulches control weeds effectively. Higher density plant spacing will also smother weeds. Shallow cultivation will help to avoid root damage especially around young plants.

Annual and perennial weeds such as ragweed, lambsquarters, redroot pigweed, galinsoga, nightshade species, yellow nutsedge, annual and perennial grasses, mustards and others, are a problem throughout the growing season. Weeds growing up through the planting holes of plastic mulch can be a particular problem.

## Pest control

### Aphids (primarily *Myzus persicae*)

Aphids can make pepper fruit unmarketable because of the honeydew that is secreted by the aphid and/or associated sooty mould fungi. Infested plants can be stunted, with deformed foliage.

Green peach aphids are variable in colour and have a wide host range. Aphids overwinter as eggs on crop residue or host plants. Winged forms,

less frequently found than wingless forms, enable the insect to move into a field from other areas. Females can reproduce without mating with males. Aphids are generally most abundant from mid-summer through October. Their severity is greatly influenced by weather patterns.

Cultural control practices: Greenhouse infestations of transplants can be minimised by practising good greenhouse sanitation. Controlling weed hosts around the edges of fields may help to control aphid infestations.

Post-harvest control practices: Crop debris should be destroyed as soon as possible after harvest.

### European corn borer (*Ostrinia nubilalis*)

Larvae tunnel into and feed on fruit, causing direct damage, premature ripening and entry points for fruit-rot pathogens. Many infested fruit appear unaffected on the outside but have sustained much damage internally.

Cultural control practices: Locating pepper fields as far away as possible from maize may help to lower infestations. Eliminating weeds around field edges may make pepper fields less attractive to ovipositing females.

Post-harvest control practices: Destruction of pepper residue and ploughing in the fall can destroy a large percentage of overwintering larvae.

### *Mites*

Mite feeding damage is expressed as downward curling of leaves, giving an inverted spoon shape and suppression of lamina development of young leaves, causing these to become narrow. Affected leaves develop a bronze appearance, especially on the lower side, and they become thickened and brittle. Heavy infestation kills off the apical meristems. Fruit develop a russeted, corky surface and may be distorted (Black *et al.*, 1991). Weeds, e.g. nightshade that serve as hosts for the mites, should be controlled to reduce infestation. Several insecticides and miticides provide effective control of broad mites (Pernezny *et al*., 2003).

### *Thrips*

Thrips feeding damage includes distortion and upward curling of leaves, developing a boat-shaped appearance. The leaves become crinkled and the lamina may be reduced, resulting in narrow new leaves. The lower surface of the leaves develops a silvery sheen that later turns bronze, especially near the veins. Damaged fruit is distorted with a network of russeted streaks (Black *et al*., 1991). The control measures include the use of resistant cultivars and mulching with plastic (Pernezny *et al*., 2003).

## Disease control

### Bacterial leaf spot (*Xanthomonas campestris* pv. *vesicatoria*)

Bacterial leaf spot (BLS) is the most economically significant disease of peppers. The causal bacterium infects both pepper foliage and fruit. Leaf spots first appear on the undersides of leaves as small, irregular, water-soaked areas. The spots grow larger, become purplish-grey with black centre, and may have a narrow, yellow halo. Affected leaves become ragged, turn yellow and drop off. Spots on fruit are like blisters, becoming rough and cankerous and often extending into the seed cavity, predisposing the fruit to secondary pathogens. Loss of foliage also predisposes the fruit to sunscald.

Cultural control practices: An increasing number of resistant varieties with good horticultural characteristics are becoming available to producers. Two year rotation away from tomato and pepper crops is recommended. Seed should be certified and disease free. A seed treatment using bleach may help provide control. Good field sanitation should be practised to minimise the spread of the disease. Planting disease-free transplants is a key step in managing this disease in the field. Most growers have switched from overhead irrigation to drip irrigation in part to minimise the spread of BLS.

Post-harvest control practices: Crop debris should be destroyed as soon as possible to remove this source of disease for other plants and to initiate decomposition.

### Phytophthora blight (*Phytophthora capsici*)

All parts of the pepper plant can be infected with the causal fungus. Infected seedlings can develop damping-off. The symptoms on older plants include root rot, stem canker, leaf blight and fruit rot. A white mould growth often appears inside and on the surface of infected fruit.

Cultural control practices: Low-lying or poorly drained areas should be avoided. Overhead irrigation should be curtailed in favour of drip irrigation.

A rotation away from all solanaceous crops for three years is recommended. Planting on raised beds to improve drainage can help to control the disease. Only disease-free seed should be used. A few resistant varieties are available.

### Powdery mildew caused by *Leveillula taurica* (Coertze *et al.*, 1994)

The symptoms are chlorotic spots on the upper leaf surface. Numerous lesions may coalesce, causing chlorosis of the leaves. Lower leaf surface lesions develop a necrotic flecking and generally, but not always, are covered with a white to grey powdery growth. It progresses from older to younger leaves, and leaf shedding is a prominent symptom. The disease is promoted by warm weather (dry and humid). Fungicides are used to manage the disease during periods of heavy disease pressure (Black *et al.*, 1991).

### Damping-off caused by *Rhizoctonia solani* and certain *Pythium* species

This mainly affects young seedlings (Coertze *et al.*, 1994).

Symptoms include failure of seedlings to emerge, small seedlings suddenly collapse or are stunted. The development of the disease is enhanced by undecomposed organic matter in the soil and high soil moisture. Seed should be treated with a suitable registered fungicide, nursery beds should be placed on well-drained sites and covered beds should be adequately ventilated to prevent high humidity (Black *et al.*, 1991).

### Bacterial wilt is caused by *Pseudomonas solanacearum*

The initial symptom in older plants is slight wilting of the lower leaves, but upper leaves wilt first in young seedlings. Initial wilting is followed by a sudden, permanent wilt of the entire plant with only slight or no leaf yellowing. It is promoted by relatively high rainfall coupled with warm weather.

Crop rotation with non-solanaceous crops helps in managing the disease (Black *et al.*, 1991).

Bacterial soft rot is caused by *Erwinia carotovora* subsp. *carotovora* (Coertze *et al*., 1994)

Soft rot begins in the peduncle and calyx tissues of harvested fruit, but infection can occur through wounds on the fruit. Internal tissue near the site of infection softens and the expanding lesion reduces the fruit interior to a watery mass. Fruit infected on the plant collapse and hang on the plant like a water-filled bag and when the content leaks out, a dry shell of the fruit is left behind. The disease is severe during rainy periods because the bacteria are splashed from the soil onto the fruit. The decay can be reduced by harvesting dry fruit, reducing damage during handling and controlling insects that cause damage to the fruit (Black *et al*., 1991).

Tobacco mosaic virus (TMV) is a member of the genus Tobacovirus (Pernezny *et al*., 2003)

Symptoms include mosaic, stunting, systemic chlorosis and, at times, systemic necrosis and leaf drop. It can be eliminated from the seed coats by soaking the seed in a 10% solution of trisodium phosphate for two hours (Black *et al*., 1991). The virus can spread widely when peppers are field-grown from transplants or are handled frequently (Pernezny *et al*., 2003).

## Other crop management considerations

### *Mulching*

Plastic mulch has been used on peppers since the early 1960s. Some of the advantages of mulches are earlier yield, increased water retention, inhibition of weeds, reduced fertiliser leaching, decreased soil compaction, fruit protection from soil deposits (from splash) and soil microorganisms and facilitation of fumigation. Plastic mulches are often used in combination with drip irrigation when establishing seedlings. Plastic mulches have been shown to raise soil temperatures and increase fruit quality (Bosland & Votava, 1999). Organic mulches, which include lawn clippings, chopped sorghum and sugar-cane leaves are also used to improve and increase vegetable production (Messiaen, 1992).

### *Physiological disorders*

#### Blossom-end rot

Blossom-end rot (BER) is a common disorder of greenhouse peppers, with the symptoms occurring on the pepper fruit. The disorder is associated with a number of environmental stress triggers as well as a calcium deficiency (Howard *et al.* 1994). Any condition which causes water stress or a reduction in transpiration, and resultant movement of nutrients through the plants can bring on the symptoms. Lack of water, fluctuating water conditions, from dry to wet to dry, etc., damage to the root system and high EC in the root zone can cause BER (Howard *et al*. 1994, Portree, 1996). An actual calcium deficiency to the plant is rarely the primary cause of the disorder as BER can develop when adequate levels of calcium are being fed to the plants. The environmental factors that can trigger the disorder interfere with the movement of calcium within the plant, causing less calcium to reach the fruit. Some cultivars are more prone to this disorder than others (Portree, 1996).

Symptoms of BER begin as soft spots on the fruit, which develop into sunken, brownish to tan lesions with a very distinct border between affected and healthy tissue. The spots usually occur on the bottom third of the fruit and are not strictly confined to the bottom, or blossom end of the fruit. Affected fruit is unmarketable.

Control is obtained by avoiding conditions of moisture stress or conditions of reduced transpiration in the crop; ensure that the plants receive adequate water and that vapour pressure deficit (VPD) targets are met. Weekly foliar applications of calcium nitrate can have a significant impact on reducing the occurrence of BER (Schon, 1993).

#### Sunscald

The symptoms of sunscald on the pepper fruit are very similar to those for blossom-end rot. Soft, tan coloured sunken lesions develop on fruit that is exposed to direct sunlight. It is important to adjust pruning practices to ensure that all fruit is shaded from direct sunlight. Applying shading to the greenhouse during the summer months will also help reduce the incidence of sunscald. Temperatures of exposed fruit can often be 10 °C higher than shaded fruit, reaching over 35 °C during the midday, even when air temperatures in the greenhouse are maintained below 27 °C. Fruit temperatures over 35 °C should be avoided (Portree, 1996).

#### Fruit cracks

This condition is characterised by the appearance of very fine, superficial cracks on the surface of the pepper fruit, which gives a rough texture to the fruit (Portree, 1996). 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* (Portree, 1996).

Maintaining a consistent, optimised growing environment is the best way to prevent the development of fruit cracks.

#### 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 on fruit splitting (Portree, 1996). Ensure that optimal VPD targets are met at all times. Adjust the timing of the last watering in the day so as not to water too late. Eliminate any night-watering cycles.

#### 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 (Portree, 1996). Conditions that promote high root pressure will also favour the development of fruit spots.

#### Misshapen fruit

The development of misshapen fruit is generally associated with suboptimal growing conditions at flowering and pollination, which result in poor flower development or poor pollination. Ensuring that all environmental targets are met and maintained to reduce or eliminate the development of misshapen fruit.

#### Internal growths in the fruit

The development of growths within the pepper usually appear early in the cropping cycle, generally at the first fruit set (Portree, 1996). This results from abnormal tissue development in the honey gland of the fruit (Portree, 1996).

### *Thinning*

Thinning is done when the plants are 8 to 10 cm tall (to 2 plants per stand).

## Harvesting

Yields of 6 to 10 t/ha of bell peppers may be obtained for processing. Fresh market yields may range from 500 to 1 000 12 kg cartons per hectare.

When using appropriate plasticulture techniques, yields of 1 428 12 kg cartons per hectare have been reported. Pimiento and dried chilli pepper yields range from 1 to 2 t/ha. Pepper yields are greatly influenced by the number of harvests and season. As peppers mature, their walls thicken. Pick peppers when the fruit is firm and well coloured.

In some areas, bell peppers are generally hand harvested as green mature fruit. For the fresh market, or when the fruit is to be stored, peppers should be cut cleanly from the plant, using a hand clipper or sharp knife, leaving about a 2 cm section of the pedicel (stem) attached to the fruit. A clean cut is important as such cut surfaces heal more quickly. This reduces incidence of decay in storage and during transport to the market. Care should also be exercised to ensure that the stems do not cause puncture wounds in harvested fruit.

Maturity is determined when the fruit is smooth and firm to the touch (it is a function of wall thickness). Bell peppers for the fresh market must also be 8 cm in diameter and not less than 9 cm long. They can also be harvested red, which are considerably sweeter and more flavourful. Mature yellow, orange and purple bell peppers, together with red bell peppers represent a generally higher-value product in fresh market channels.

Cherry peppers are machine harvested, most successfully. Cherry types are harvested as both green and red fruit and the banana types are generally harvested as yellow, mature peppers. Jalapeño and some cherry peppers have been machine harvested successfully in other areas. Machine harvesting may be successful with other types, especially where the peppers are intended for processing.

### *Harvesting methods*

Peppers are generally broken off from the plants with the stems left attached to the fruit. For sweet peppers strong cloth picking bags, which are suspended from the shoulders of the pickers, are preferable to baskets or boxes. This frees both hands for rapid and careful removal of the fruit from the plants. Hard picking containers may become rough and sandy, and as a result cause damage to the peppers. Pepper fruit is later carried to a central point where it is graded and packed into standard baskets or put into containers for delivery to the market or processing plant. The red-ripe peppers are sometimes sun dried and stored in bags.

Care should be taken when breaking the peppers from the plants, as the branches are often brittle. Hand clippers or pruners can be used to cut peppers from the plant to avoid excessive stem breakage. The number of peppers per plant varies with the variety. Bell pepper plants may produce six to eight or more fruit per plant.

### *Harvest recommendations*

Bell peppers are harvested when they are immature and green, but when they have reached full size and maximum wall thickness. Each field is harvested multiple times by hand. Some are picked after they have ripened to red or other colours. Peppers destined for wholesale shipment are usually washed, sorted and graded on a packing line.

# POST-HARVEST HANDLING

## Preparation for market

### *Sorting and grading*

Green bell peppers are hand harvested for the fresh market when they are at the mature green stage. Coloured or specialty bell peppers are allowed to ripen fully on the plant. Coloured peppers generally weigh more than green fruit.

The fruit must be handled carefully to prevent skin breakage and puncturing that could lead to decay. Cooling peppers, as soon as possible, after harvest, will extend their shelf life. Once the fruit is cooled, it can be stored for two to three weeks under the proper conditions.

## Packaging

Nearly all bell peppers are harvested by hand, usually into bulk bins or trailers for transit to a packing facility. A limited number of growers pack peppers in the field from mobile packing platforms. The fruit is graded by size and condition. The standard unit of sale is a carton holding approximately 12 to 14 kg of fruit. Some growers of specialty bell peppers pack the fruit into smaller cartons. Chilli peppers and yellow types are packaged in 7 into 11 kg lugs or 4 to 9 kg cartons. Peppers are usually packed according to the preference of the particular market/buyer.

## Storage

Store sweet peppers at 7 to 12 °C and 90 to 95% relative humidity. Sweet or bell peppers are subject to cold damage at temperatures below 7 °C, and temperatures above 12 °C encourage ripening and spread of bacterial soft rot. Bell peppers should not be stored longer than 2 to 3 weeks even under the most favourable conditions. At 0 to 2 °C peppers usually develop pitting in a few days. Peppers held below 7 °C long enough to cause severe cold damage also develop numerous lesions of Alternaria rot, which causes mould and decay of the calyx at 4 °C and below and predisposes peppers to Botrytis rot.

Rapid precooling of harvested sweet peppers is essential in reducing marketing losses, and this can be done by forced-air cooling, hydrocooling or vacuum cooling. Properly vented cartons are recommended to facilitate forced-air cooling. If hydrocooling is used, care should be taken to prevent the development of rot. Sweet peppers prepackaged in moisture-retentive films, such as perforated polyethylene, have a storage life (at 7 to 10 °C) up to a week longer than non-packaged peppers. The use of film crate liners can help in reducing moisture loss from the fruit.

It is commercial practice to wax fresh-market peppers. Only a thin coating should be applied. Waxing provides some surface lubrication, which not only reduces abrasions in transit but also reduces shrinkage; the result is longer storage and shelf life. Senescence of sweet peppers is hastened by ethylene. Therefore, it is not a good practice to store peppers with apples, pears, tomatoes, or other ethylene-producing fruit types in the same room.Low-oxygen (3 to 5%) atmospheres retard ripening and respiration during transit and storage. High concentrations of carbon dioxide delay the loss of green colour. However, high carbon dioxide also causes calyx discolouration.

## PRODUCTION SCHEDULE

| **Activities** | **January** | **February** | **March** | **April** | **May** | **June** | **July** | **August** | **September** | **October** | **November** | **December** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil sampling | | | | | | | | X | X | X | X | X |
| Soil preparation | X | | | | | | | | X | X | X | X |
| Planting | X | X | | | | | | | | X | X | X |

| Activities | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fertilisation | X | X | | | | | | | | X | X | X |
| Irrigation | X | X | | | | | | | | X | X | X |
| Pest control | X | X | | | | | | | | X | X | X |
| Disease control | X | X | | | | | | | | X | X | X |
| Weed control | X | X | | | | | | | | X | X | X |
| Leaf sampling | X | X | | | | | | | | X | X | X |
| Harvesting | X | X | X | X | | | | | | | | X |
| Marketing | X | X | X | X | X | | | | | | X | X |

## UTILISATION AND NUTRITIONAL VALUE

### Culinary/Cooking

In general, fresh bell peppers are treated like any other vegetables in the kitchen. Their firm, crunchy consistency and delicate, sweet flavour make them one of the most sought after vegetable items in cooking.

- Fresh, raw bell peppers are being used as vegetables in cuisines. They can be eaten as salads or cooked in stir-fries.
- In many parts of South Africa, they are mixed with other vegetables like potato, carrots, green beans, etc., along with tomato, garlic, onion, mustard seeds, cumin, and other spices in various mouth-watering stir-fries.
- They can also be grilled and served with sauce, cheese and olive oil or with dips.
- Sweet peppers are one of the popular ingredients in pizza and pasta.

### Nutritional value

Bell pepper contains an impressive list of plant nutrients that are known to have disease preventing and health promoting properties. Unlike other chilli peppers, it is very low in calories and fats: 100 g provide only 31 calories.

Sweet (bell) pepper contains minimal of health benefits and an alkaloid compound capsaicin. Early laboratory studies on experimental mammals suggest that capsaicin has anti-bacterial, anti-carcinogenic, analgesic and anti-diabetic properties. When used judiciously, it is also found to reduce triglycerides and LDL cholesterol levels in obese individuals.

Compared to green peppers, red peppers have more vitamins and nutrients and contain the antioxidant lycopene. The level of carotene, like lycopene, is nine times higher in red peppers. Red peppers have twice the vitamin C content of green peppers. Also, one large red bell pepper contains 209 mg of vitamin C, which is three times the 70 mg of an average orange.

## REFERENCES

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