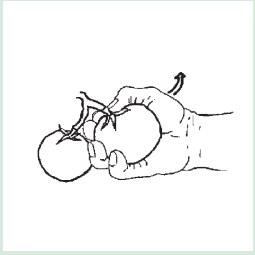
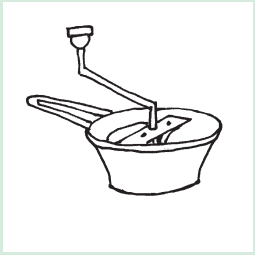
Agrodok-series No. 17

Cultivation of tomato

production, processing and marketing





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Foreword

Tomato is one of the most widely cultivated crops in the world. It is an important source of vitamins and an important cash crop for smallholders and medium-scale commercial farmers.

This Agrodok focuses on good practices for growing a healthy tomato crop and obtaining a reasonably steady yield. It provides practical information on small-scale cultivation, harvesting, storing, processing and marketing of tomatoes. Seed selection and conservation, integrated pest management methods and record keeping are also covered. We hope this information will be helpful to vegetable growers, whether beginners or more experienced farmers, extension workers and agricultural teachers.

In this revised edition, the sections on pepper and paprika growing in previous editions have been omitted to make room for information on all the above-mentioned aspects of tomato cultivation.

Agromisa entered a cooperation agreement with PROTA for the development of this publication. For more information on PROTA see the section at the back of this Agrodok.

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We invite you as a reader to send your comments and suggestions on how to improve or extend the contents of this Agrodok.

The authors
Wageningen, September 2005

Contents

1 Introduction

1.1 A brief description of tomato

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetables worldwide. World tomato production in 2001 was about 105 million tons of fresh fruit from an estimated 3.9 million ha. As it is a relatively short duration crop and gives a high yield, it is economically attractive and the area under cultivation is increasing daily. Tomato belongs to the *Solanaceae* family. This family also includes other well-known species, such as potato, tobacco, peppers and eggplant (aubergine).

Tomato has its origin in the South American Andes. The cultivated tomato was brought to Europe by the Spanish conquistadors in the sixteenth century and later introduced from Europe to southern and eastern Asia, Africa and the Middle East. More recently, wild tomato has been distributed into other parts of South America and Mexico.

Common names for the tomato are: tomate (Spain, France), tomat (Indonesia), faan ke'e (China), tomati (West Africa), tomatl (Nahuatl), jitomate (Mexico), pomodoro (Italy), nyanya (Swahili).

Tomatoes contribute to a healthy, well-balanced diet. They are rich in minerals, vitamins, essential amino acids, sugars and dietary fibres. Tomato contains much vitamin B and C, iron and phosphorus. Tomato fruits are consumed fresh in salads or cooked in sauces, soup and meat or fish dishes. They can be processed into purées, juices and ketchup. Canned and dried tomatoes are economically important processed products.

Yellow tomatoes have higher vitamin A content than red tomatoes, but red tomatoes contain lycopene, an anti-oxidant that may contribute to protection against carcinogenic substances.

Tomato (see Figure 1) is an annual plant, which can reach a height of over two metres. In South America, however, the same plants can be harvested for several years in succession. The first harvest is possible 45-55 days after flowering, or 90-120 days after sowing. The shape of the fruit differs per cultivar. The colour ranges from yellow to red.

Tied up along the stem

Different shapes of the fruit

A: quick cultivar with flat, ribbed fruit
B: late cultivar with large fruit
C: Anglo-Dutch cultivar
D: cultivar with oblong fruit
E: various cultivars of cherry tomato

Figure 1: Tomato

Three different types of tomato plants can be distinguished:
- tall or indeterminate type
- semi-bush or semi-indeterminate type
- bush or determinate type

The tall and bush types are entirely different kinds of crops.

The tall varieties are the best choice for a long harvest period. They keep growing after flowering. This feature is called indeterminate. However, under tropical conditions, diseases and insect attacks will stop growth. The plants generally have more foliage. This will keep the temperature lower within the crop and the fruits grow in the shade of the leaves. Because they are covered, the sun does not damage the fruits and they ripen more slowly. Slower ripening and a high leaf/fruit ratio improve the taste of the fruits and in particular the sweetness. The tall types have to be staked, caged or trellised (see Chapter 4).

Short types usually support themselves and need no staking. Under severe weather conditions such as typhoons, however, staking may be advisable. Determinate types stop growing after flowering. They require less labour, so they are popular for commercial cultivation. They have a relatively concentrated fruit set which lasts only two or three weeks and the fruits ripen much faster than those from indeterminate types.

Advantages of tomato:
- relatively short duration vegetable crop
- short or long production period
- can be grown as an uncovered field crop and in protected cultivation
- fits easily into different cropping systems
- has high economic value
- has high micronutrient content
- fruits can be processed, dried and canned

Botanical description of tomato plant

Root: Vigorous tap root system that grows to a depth of 50 cm or more. The main root produces dense lateral and adventitious roots.

Stem: Growth habit ranges between erect and prostrate. It grows to a height of 2-4 m. The stem is solid, coarse, hairy and glandular.

Leaf: Spirally arranged, 15-50 cm long and 10-30 cm wide. Leaflets are ovate to oblong, covered with glandular hairs. Small pinnates appear between larger leaflets. Inflorescence is clustered and produces 6-12 flowers. Petiole is 3-6 cm.

Flower: Bisexual, regular and 1.5-2 cm in diameter. They grow opposite or between leaves. Calyx tube is short and hairy, sepals are persistent. Usually 6 petals up to 1 cm in length, yellow and reflexed when mature. 6 stamens, anthers are bright yellow in colour surrounding the style with an elongated sterile tip. Ovary is superior and with 2-9 compartments. Mostly self- but partly also cross-pollinated. Bees and bumblebees are the most important pollinators.

Fruit: Fleshy berry, globular to oblate in shape and 2-15 cm in diameter. The immature fruit is green and hairy. Ripe fruits range from yellow, orange to red. It is usually round, smooth or furrowed.

Seeds: Numerous, kidney or pear shaped. They are hairy, light brown 3-5 mm long and 2-4 mm wide. The embryo is coiled up in the endosperm. Approximate weight of 1000 seeds is 2.5 – 3.5 g.

2 Requirements for successful cultivation

2.1 Climate and soil

Temperature and light

Tomato requires a relatively cool, dry climate for high yield and premium quality. However, it is adapted to a wide range of climatic conditions from temperate to hot and humid tropical. The optimum temperature for most varieties lies between 21 and 24 °C. The plants can survive a range of temperatures, but the plant tissues are damaged below 10 °C and above 38 °C.

Tomato plants react to temperature variation during the growth cycle (see Table 1), for seed germination, seedling growth, flower and fruit set and fruit quality. If cool or hot weather spells persist during flowering, pollen production will be low. This will influence fruit formation. Frost will kill the plants. To avoid frost damage, it is best to wait until the winter is definitely over before sowing. It is possible to sow indoors earlier (in pots or trays). Light intensity affects the colour of the leaves, fruit set and fruit colour.

> In tropical lowlands, the minimum temperature at night is also important. Temperatures below 21 °C can cause fruit abortion.

Table 1: Temperature requirements for different stages of tomato

Stages	**Temperature (° C)**		
	Min.	Optimum range	Max.
Seed germination	11	16-29	34
Seedling growth	18	21-24	32
Fruit set	18	20-24	30
Red colour development	10	20-24	30

Water and humidity

A simple rule of thumb can be used to determine whether local water supplies are sufficient for growing tomato. If there are herbaceous plants (plants with many thin leaves) growing in the natural environment, it will be possible to grow tomato. You should be able to count on at least three months of rain. Water stress and long dry periods will cause buds and flowers to drop off, and the fruits to split. However, if rains are too heavy and humidity is too high, the growth of mould will increase and the fruit will rot. Cloudy skies will slow down the ripening of tomatoes. However, adapted cultivars are available. Seed companies have special tomato varieties for hot-humid climates.

Soil

Tomato grows well on most mineral soils that have proper water holding capacity and aeration, and are free of salt. It prefers deep, well-drained, sandy loam soils. The upper layer needs to be permeable. Soil depth of 15 to 20 cm is needed to grow a healthy crop. In heavy clay soils, deep ploughing allows better root penetration.

Tomato is moderately tolerant to a wide range of pH (level of acidity), but grows well in soils with a pH of 5.5 – 6.8 with adequate nutrient supply and availability. Addition of organic matter is, in general, favourable for good growth. Soils with very high organic matter content, like peat soils, are less suitable due to their high water holding capacity and nutrient deficiencies.

2.2 Choice of varieties

Which variety to choose depends on local conditions and the purpose of growing (Chapter 6). Local varieties (land-races) and improved (or commercial) varieties can be distinguished. They are the result of a continuous process of selection of plants. Selection criteria are based on characteristics such as type of fruit, shape of plant, vitality and resistance to pests and diseases, but also on factors related to climate and management. Farmers select varieties that perform best under the local conditions. Only fruits from the best plants must be selected and

kept for seeds for the subsequent season. Farmers may breed their own cultivars, but it is a costly and risky process.

Tomato breeding companies have produced F1-hybrids. These grow from seeds that have been produced by controlled hand pollination of male and female parent lines. These hybrids combine high yield, disease resistance and other plant and fruit characteristics. In Asia, more than 40% of the farmers use hybrids. When using hybrids, new seeds should be purchased each season. This may cost more money, but the resistance against diseases of hybrids means the tomato plants need less spraying with pesticides. The yields are also higher, creating more opportunity to bring tomatoes to the market.

Resistant varieties have an in-built resistance, which is carried in the seed. Resistance to a specific disease means that it is very difficult or impossible for a plant with this resistant characteristic to get that particular disease. Resistance can be a result of various plant characteristics. Leaves can be densely covered with hairs so that certain insects do not like sitting on them. Some colours can be unattractive to certain insects. Such characteristics are visible. Most characteristics that contribute to resistance to fungal and virus resistance cannot be seen. There are no varieties on the market that are resistant to all existing diseases and pests, but you can buy seed from plants that are resistant to one or several diseases.

Many farmers in lowland tropical Africa and the Caribbean grow local varieties of uncertain origin. They have somewhat sour and bitter tasting fruits, small, round or flat, with many segments, and are especially suitable for grinding with condiments for sauces. They give a better yield than most imported cultivars under the heavy environmental stress of the rainy season.

3 Preparation and planting

3.1 Land preparation

Ploughing (or digging) is necessary to prepare the land for a new crop. It improves the structure and water holding capacity. In areas where water is a limiting factor, ploughing enhances water conservation as well. Fallow ploughing the land after harvesting the previous crop improves the soil structure and water-holding capacity. It also helps to reduce soil-borne pests and diseases by exposing the soil to the hot sun. Deep ploughing is necessary to break an impermeable hard subsoil layer (ploughing pan), remove the weeds and bring the land to fine tilth. It also encourages root growth. It is often necessary to harrow two times, breaking the clods and removing crop residues to level the land.

Cultivating tomato on raised beds, ridges or furrows facilitates drainage of water and irrigation. Despite this, more than 60% of the crop is still cultivated using flood irrigation.

3.2 Seedlings

Tomatoes are normally transplanted because much better results are gained when seedlings are raised in a nursery. Two methods of raising seedling in nurseries can be used:

- sowing in seedbed
- sowing in seedling tray (used by many farmers in Southeast Asia)

Smaller quantities of seed are needed, the seedlings can be selected for growth and health before planting in the field, the plantlets can be well protected and the planting distance is more regular than after sowing directly in the field.

Nursery preparation

The seedbed should be 60-120 cm wide and 20-25 cm high. The length depends on the number of seedlings wanted. Remove clods of

earth and stubble. Add well decomposed farmyard manure and fine sand. Bring the seedbed to fine tilth. To raise a sufficient amount of plants for one hectare, 150-200 g seeds should be sown on 250 m^2 of seedbed.

Draw lines, 10-15 cm apart, over the length of the seedbed. Sow the seeds thinly spaced on the lines and press gently. Cover the seeds with fine sand and straw. Water the seedbeds twice a day to ensure sufficient moisture for germination. After germination the straw must be removed.

Growing tomato seedlings indoors

Growing tomato seedlings indoors is an easy, cost effective and healthy method. Sow one seed in a (banana leaf) pot with a diameter of 7.5 cm or in a seedling tray. Cover the seeds lightly with potting compost. Make sure that the compost is moist but not waterlogged. Place the pots in a warm (up to 27°C) dark place (see Chapter 4).

The seedlings will emerge in 7-10 days. After germination the plants need light, but keep them out of direct sunlight to avoid the leaves burning. Thin out the seedlings, leaving the healthiest seedling in the pot. When the roots come through the base of the pot (about 4 weeks after sowing), transfer the plants to a larger pot (12.5 cm). The plants will be ready for transplanting outside 7 weeks after sowing the seeds. Support the plants by staking.

Potted plants can be kept indoors. Five plants will provide healthy fruits for up to three months for a family of 5 members.

3.3 Transplanting

Transplant the seedling to the field 3 to 6 weeks after sowing. A week before transplanting, seedlings should be hardened by reducing the application of water, but 12-14 hours before they are taken out of the seedbed they should be thoroughly watered again to avoid excessive damage to the roots. Seedlings of 15-25 cm tall with 3-5 true leaves are most suitable for transplanting. Transplanting should be done in the afternoon or on a cloudy day to reduce the transplanting shock.

Water the plants immediately once they have been transplanted. When removing the seedlings, keep a large clump of soil attached to the roots to prevent them from being damaged. Spacing between plants and rows depends on the cultivar growth habit, soil type, cropping system and also whether the plants are to be supported by stakes or left on the ground. The common spacing is 50 cm between plants and 75 - 100 cm between rows (see Table 2). If the tomatoes are to be supported by sticks, then the distances between rows can be decreased to 20-40 cm. Make the holes for the plants deep enough so that the lowest leaves are at ground level. Press the soil firmly around the root, and water around the base of the plant to settle the soil.

After transplanting, mulch can be placed on the ground around the plants to protect them from heat during the first five days. Mulch is composed of plant remains (e.g. rice-straw or sorghum-straw) used to cover the soil to control weed growth, prevent erosion and conserve water. Care should be taken not to wet the lowest leaves, as this can stimulate the growth of mould. A more advanced method is to put plastic mulch on the beds and punch holes in the plastic before planting. The transplanted plants should be protected from heat during the first five days, e.g. by covering them with large leaves.

Table 2: Planting distances for the three types of tomato plants

Type of plant	**Distance between rows and plants**
Bush type (determinate)	1.0 x 0.5 m
Semi-bush type (semi-determinate)	0.75 x 0.5 m
Tall type (indeterminate)	0.75 x 0.5 m

4 Crop husbandry

4.1 Manures and fertilisers

To get high yields, tomatoes need to be fertilised. There are two groups of crop nutrients: organic manures and chemical fertilisers.

Organic manures

Farmyard manure, poultry manure and compost are three types of organic manures. They are described in this section.

The most common kinds of farmyard manures are horse, cow and pig manure. Of these three kinds, horse manure has the best balance of nutrients. Cow manure has relatively little phosphate. Pig manure is usually rich in mineral salts but has relatively little potassium. Manure from goat and sheep is also good organic manure.

It is better to use farmyard manure on sandy soils than on clayey soils, because it is quite sticky. Sandy soils will not fall apart as easily if manure is added, and will therefore be able to hold more water.

If only farmyard manure is used, 12.5-25 tons/hectare/year (5-10 tons/acre/year) is a reasonable amount to apply. Smaller applications of manure can also be enough if growing conditions are not so good or if chemical fertiliser is also applied.

Poultry manure is usually three to four times as strong as farmyard manure. It is a very valuable kind of manure as plants can easily absorb the nutrients from it. A good way to apply poultry manure is by first mixing it with an equal amount of crumbly soil or sand. Sprinkle this mixture between rows, and then rake or hoe it lightly. Poultry manure, unlike farmyard manure can be used on clayey soils because it is not too sticky. It is also suitable for acid soils because it contains a lot of calcium (alkaline).

It is advisable to plough dry manure into the ground as fresh manure is too strong and can damage the sprouting plants.

Compost is easy to make from all kinds of organic materials. Examples of materials that can be used are crop residues, kitchen wastes, garden cuttings and manure. Compost is a rich source of macro- and micronutrients. It supplies nutrients at the right time in required quantities. It is especially useful for improving the soil structure and fertility (see Agrodok No. 8: 'Preparation and use of compost').

It is important to have manure that is well decomposed, and which is not too sticky or too wet. It must not be too dry, as it is difficult to moisten manure again.

Benefits of compost and manure
Improve soil fertility and structure, and decrease the need for phosphorus (P), nitrogen (N) and potassium (K) application. They provide a variety of nutrients for crops and can be prepared in 2½ – 3 months.

Chemical fertiliser

Chemical fertiliser (except for calcium) does not improve the soil structure but enriches the soil by adding nutrients. Chemical fertiliser is relatively expensive, but in some areas, in terms of nutrients provided, it is less expensive than manure. It does not pay to use a lot of chemical fertiliser in small-scale cultivation, or where prices are fluctuating and yields are low (as a result of diseases, unfavourable weather or poor soils). Chemical fertilisers can be divided into two groups: compound fertilisers and simple fertilisers.

Compound chemical fertilisers

This kind of fertiliser is a mixture of nitrogen (N), phosphorus compounds (P_2O_5) and potash (=K_2O). The compound fertiliser 12-24-12 contains 12% N (nitrogen), 24% P (phosphorus) and 12% K (potassium).

Simple chemical fertilisers

This kind of fertiliser contains only one nutrient. It is used when a crop has a specific deficiency (e.g. sodium nitrate, urea or super phosphate). Tomato especially needs phosphorus after transplanting. It is better to apply nitrogen and potash during the growing stage of the crop. Use a slow-release type during the rainy season and a fast-release type during the dry season.

In the tropics the application of chemical fertiliser ranges between 40-120 kg/ha of nitrogen, 30-90kg/ha phosphate and 30-90 kg/ha potash. Never spread chemical fertiliser on young or wet plants because this will cause burns.

How to combine organic and chemical fertilisers

Before planting, the soil is fertilised by applying organic matter. Tomato is usually given a combination of organic and chemical fertilisers. It is not necessary to apply this mixture at one time. For example, you can apply half when preparing the beds or mixed with the soil in the holes for the seedlings. The remainder can be applied when the plants flower or when the fruit is formed. It is best to rake this into the soil between the rows. A second application, to replenish nutrients in the soil, is especially advisable on sandy soils, where nutrients are leached more quickly. Foliar application of nutrients (i.e. to the leaves) is advisable to improve the yield.

4.2 Watering

Tomato is not resistant to drought. Yields decrease considerably after short periods of water deficiency. It is important to water the plants regularly, especially during flowering and fruit formation. The amount of water that is needed depends on the type of soil and on the weather (amount of rain, humidity and temperature). It is especially important to water regularly (e.g. 3 times a week) on sandy soils. Under good circumstances once a week should be enough.

About 20 mm of water per week is needed under cool conditions, about 70 mm during hot and dry periods. Watering plays a major role in attaining uniform maturity and reducing the incidence of blossom-end rot, a physiological disorder associated with irregular water supply and the resulting calcium deficiency in the fruit during its enlargement. There are several irrigation methods:

Surface irrigation

The simplest method is to pour water into channels (furrow irrigation) or onto flat fields that are surrounded by small dykes (flood irrigation). Ensure that the water is evenly distributed.

Sprinkler irrigation

Sprinkling using permanent pipes is widely used in greenhouses. Sprinkler heads are placed underneath the crop and in strips so that the pathways are kept dry.

Drip irrigation

Wetted strips: A black PE-film hosepipe that has small holes about 2 millimetres in diameter can be placed on the ground near the base of the plants. The soil needs to be flat or may slope very slightly towards the end of the tube. The lengths of the hose can be as long as 20 to 30 metres. The water pressure must be about 0.2 atm (2 m).

Watering individual plants: The soil needs to be flat and the water clean because the small droplet openings must not get blocked. Filtering can be done at the place were the water enters.

Many drip irrigation systems work on a low water pressure of 0.1-0.2 atm (1 to 2 metres water column). This can be achieved very cheaply for a small system by attaching a WC-float valve at the beginning of the main pipe. Fertiliser in solution in the correct dosage can be added to the drip irrigation system. As opposed to sprinkling and other types of irrigation, drip irrigation can save 30-70% of your water, especially in a very dry climate.

4.3 Pruning

Pruning is important for tomatoes, especially for thick bush and indeterminate types. It improves the light penetration and air circulation. Pruning the side-shoots is called nipping. Pruning the tops of the stem is called heading.

The need for pruning depends on the type of plant and the size and quality of the fruit. If plants are not pruned, they will grow at random and fruit will be smaller.

Pruning to shape

As far as pruning is concerned, tomatoes come in two forms, bush and upright. Bush varieties are the best for outdoor cultivation because they require no pruning for most of the season. Remove any yellow or decaying foliage as soon as possible to avoid the spread of disease. If plants become too large to support themselves, either trim out a few major branches or add more support canes. The side branches can be tied on to the additional support canes.

Limit the number of tomato-bearing branches to seven or eight by pinching out any surplus ones. When first fruits begin to form, the plant will produce shoots between the main stem and the leaf stems. The lower side-shoots should be removed by pinching them out with the fingers. If they are allowed to grow they will produce masses of foliage but few tomatoes. Any shoots that have been overlooked and allowed to grow should also be removed. Lower leaves that show any sign of yellowing should also be removed to avoid the risk of infection.

When the plant has developed 6-7 branches with tomatoes, stop the plant from growing further by breaking off the growing tip. If more than seven branches of tomatoes begin to develop, pinch extra branches out to encourage the plant to produce good quality tomatoes rather than an abundance of low-quality late-maturing fruits.

Nipping

It is important to pinch out side-shoots. When plants are nipped, the small side-shoots are removed and only one main stem remains (see Figure 2). The fruit clusters grow along this main stem. Nipping enhances quality and size of the fruits.

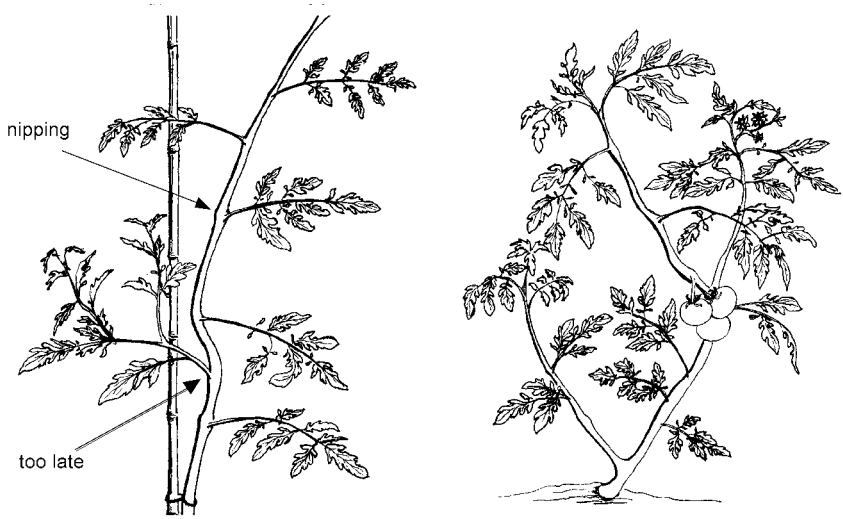

Figure 2: Nipping

Heading

The tip of the main stem of the tall type is pinched off when 3 to 5 leaves are fully grown. The shoots that grow out of the top 2 to 4 buds are left to grow. In this way 2 to 4 side-shoots will grow as main stems, supported by sticks (see Figure 3). When these stems are 1 - 1.25 m long, the tops should also be pinched off. New side-shoots should be removed regularly by nipping them. Usually 3 to 4 fruit clusters grow along each stem.

Trimming leaves

Old, yellow or sick leaves should be removed from tomato plants. This controls the development and spread of diseases. Be careful when pruning the plants. It is very easy to spread disease via your hands or

any tools that are used, so avoid sick plants. Clean tools regularly. It is best to prune in the morning on a sunny day so that the wounds can dry quickly. It is advisable to burn or bury the infected leaves to avoid disease infections.

4.4 Support systems

Staking or trellising tomato plants with bamboo poles, wood stakes, or other sturdy material provides support and keeps the fruit and foliage off the ground. Staking will increase fruit yield and size, reduce fruit rot, and make spraying and harvesting easier.

Indeterminate varieties should be staked to facilitate pruning, pinching, harvesting and other cultivation practices. Determinate varieties should be staked in the wet season to prevent fruit contact with the soil. Many staking arrangements are possible. Plants should be fixed securely to the stake or string supports, beginning about two weeks after transplanting. Rice straw, plastic strips, horticultural fixing tape or other materials can be used for fixing. Fixing should be done to support fruit clusters.

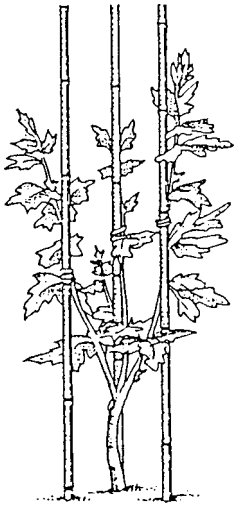

Figure 3: A tomato plant of which the top three side-shoots are supported.

Tying up

Tomato plants (tall type) can be tied to sticks to support the stems while they are growing.

Tie them loosely to the sticks and retie them regularly as they grow. So as not to damage the roots of the plants, support sticks should be put in place before transplanting. The sticks should be at least 1.5 m long, as they will be pushed 40-50 cm into the ground. Sticks that are to be used again should be washed with a disinfectant beforehand, to kill any germs that might still cling to them.

Fencing

It is useful to make fencing (see Figure 4) of sticks and rope or wire to support tomato plants (tall type) for several reasons:

- plant gets better support and this prevents stem from breaking
- there is better ventilation, so less chance of spreading diseases, especially in humid areas or seasons
- preventing contact between fruits and soil means fruits will not rot
- it is possible to plant more plants per hectare
- weeding and harvesting is easier

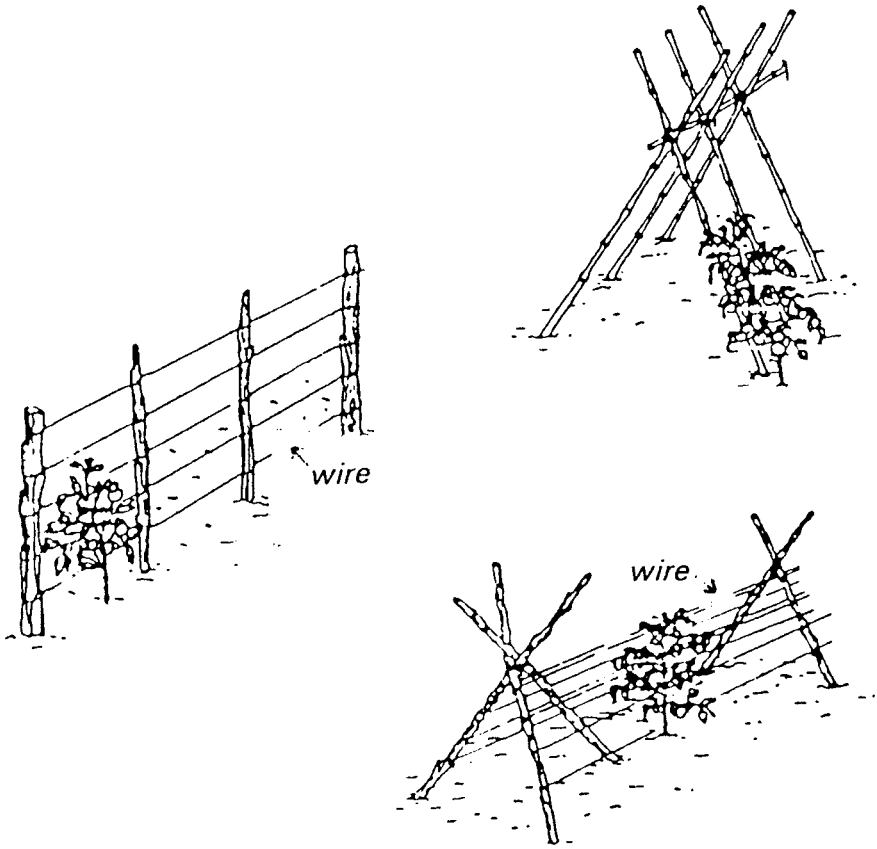

Figure 4: Different types of fencing used

Fencing can also be handy for bush-type tomatoes, to prevent heavy clusters of fruit from touching the ground. Leaves and fruit in contact with the ground rot easily because they are more likely to be damaged by diseases and insects. This can be prevented by placing a fence of two parallel strings on either side of the plant (see Figure 5) or by placing straw or mulch under the plants.

Figure 5: Bush type tomato supported by two parallel strings

4.5 Weed control

Weeds compete with the tomato plants for light, water and nutrients. Sometimes they provide shelter for organisms that cause tomato diseases, such as Tomato Yellow Leaf Curl Virus (TYLCV), and reduce the yield. Effective non-chemical weed management begins with deep ploughing, diverse crop rotations and competitive cover crops.

The following integrated practices are useful for controlling weeds effectively:

- Remove the previous crop residues and use sanitation practices to avoid introducing weed seeds.
- Deep cultivation and exposing soil to sunlight before transplanting help to destroy the weed seeds.
- It is important to keep the field weed free for 4-5 weeks after transplanting. It is during this period that weed competition must be suppressed to avoid reduction in yield.
- Weeds growing between crop rows are the easiest to control. Shallow ploughing (up to a depth of 15-20 cm) or using mulch usually removes them.
- On large acreages, mechanical cultivation is a common method of weed control within and between rows. Shallow cultivation 1-2 inches deep controls weeds and loosens soil that has crusted or become compacted. Loosening the soil helps the absorption of rainwater and supplies oxygen to the soil micro-organisms. In turn, these micro-organisms decompose organic matter and provide nutrients for the tomato crop. Hilling the soil towards the plant row (earthing-up) helps to smother small weeds in the row and tomato plants develop roots further up the stem.
- The first cultivation may be done fairly close to newly established plants and later cultivations should be shallower and away from the stems to avoid plant damage and reduced yield.
- Hand weeding is an effective method to control weeds growing between plants in a row.
- Mulching with plant residues is good for weed suppression, soil moisture retention and slow release of nutrients as they decompose. The plant residues enhance the beneficial insects like predatory beetles. They also increase the population of spiders and earthworms. Commonly used organic mulches are wheat straw, paddy straw, weeds, sorghum and pearl millet straw.

4.6 Crop rotation

Where tomato is planted in monoculture, crop rotation is important. Crop rotation means planting different crops on the field each season and only returning the same crop after at least three growing seasons. This interrupts the life cycle of pathogens and reduces the chance of damage by diseases or pests.

> Do not rotate tomato with potato, tobacco or eggplant (aubergine) because these plants belong to the same family (*Solanaceae*) and have the same types of pests and diseases.

Some examples of crop rotation with tomato are:

- Tomato followed by maize and beans.
- Tomato followed by upland or irrigated rice. It is best to plant tomato two weeks before the second upland rice harvest.

> Remember to grow two other consecutive crops before planting tomato again on the same field (i.e. once in every 3 cropping seasons, e.g. cereal-legumes-tomato).

Tomato can be grown in monoculture or in an intercropping system. Intercropping has advantages because this reduces the incidence of diseases and pests. Smallholders will gain the most from the advantages of mixed cropping.

Some examples of intercropping systems:

- Tomato intercropped with sugarcane (see Figure 6). The dwarf cultivars of tomato are planted on a raised bed about 1.2 m wide, with sugarcane grown in the furrows between the beds.
- Tall type tomatoes are grown along stalks covering 0.6 m of the bed (see Figure 7). Next to the bed, about 0.6 m higher, pepper and cauliflower are grown. The furrows are 0.3 m wide and serve as a path.

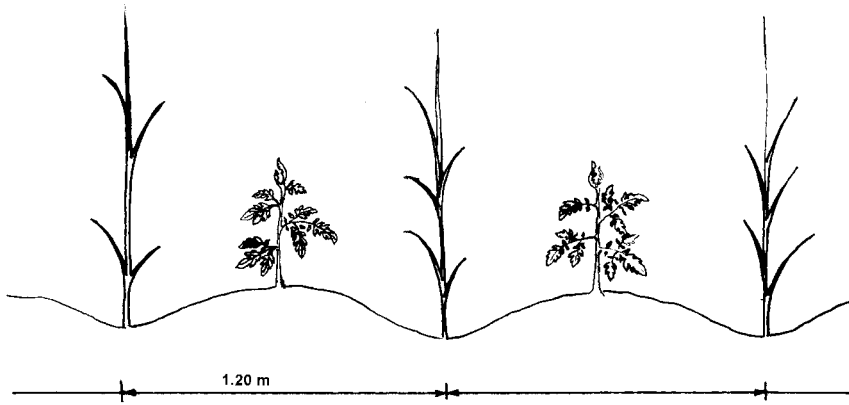

Figure 6: Bush type tomato intercropped with sugarcane.

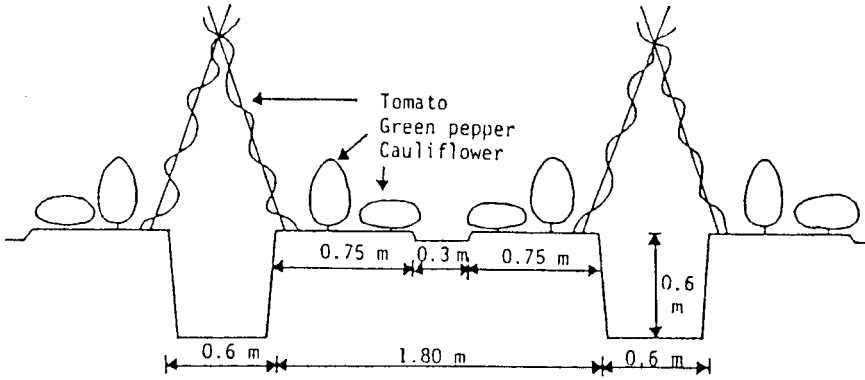

Figure 7: Tall type tomato intercropped with pepper and cauliflower

- Intercropping of tomato with cabbage. Combining these crops will reduce the damage done by the diamond-back moth.
- Alternate climbers, such as runner beans and peas, with tomato. Two weeks before tomato is harvested, the beans and peas can be planted in between the tomatoes. The sticks supporting the tomato can be used for the new crop.

Tomato fits well with different cropping systems of cereals, grains and oil seeds. Cropping systems like rice-tomato, rice-maize, okra-potato-tomato are popular in Asia. Cauliflower-okra-sunflower-cabbage-tomato, maize-tomato-water melon and rice-peas-tomato have been proved economical systems. Leafy green vegetables or radish can be grown successfully as tomato intercrops. In India farmers follow a unique mixed cropping system. Fifteen days before transplanting a tomato crop, marigold (*Tagetes erecta* and other closely related varieties) is sown along the field border and also along the water channels in the field. This mixed cropping system helps to control the fruit borer in tomato. Crop rotation with cereals and other leguminous crops improves the soil health and reduce the pest infestation. Crop rotation with cereals or millets is effective in controlling the nematode population.

4.7 Protected cultivation

People have always protected their crops from unfavourable climatic effects. Shrubs and walls protect against the wind, foliage and slats against harsh sunlight and rain, and glass and plastic against the cold. Traditionally, glass has been used in greenhouses to let the sunlight in, but the discovery of transparent synthetic film was a major breakthrough. It made the building of a greenhouse much cheaper.
(For detailed information see Agrodok No. 23: Protected cultivation).

Greenhouses

Before starting a greenhouse project one must carefully check whether all requirements for its success have been met.

As far as the climate is concerned, besides protection against fluctuating temperatures, protection is also needed against the sun's powerful rays (solar radiation), heavy rain, hail and strong wind. Crops often need to be protected against a combination of weather conditions. The climatic data from the FAO (Food and Agriculture Organisation) database can serve as the basis.

High standards will need to be placed on the type of soil, the soil profile and the location. Thus, if at all possible, choose soil with a good structure in a flat area for your greenhouse project.

In view of the more expensive production equipment and the higher quality of the product, it is important to consider the location of your farm carefully. Greenhouse cultivation needs more attention than outdoor cultivation. Therefore, you need to be within easy reach of your business at all times. Good infrastructure for transporting materials and products is also of importance, as is the availability of electricity. Finally, you need to know how you can sell the products you want to grow.

Climate control

The climate in the greenhouse is regulated by ventilating, heating and cooling and by using screens. The growth and level of production of plants largely depends on the amount of sun that the crop gets per day. Inside a greenhouse the light intensity is lower than outside. Screens can be used to prevent too much sunlight entering the greenhouse. A movable screen can be very useful when the weather changes between sunny and cloudy weather. Screens also reduce evaporation somewhat, so that the crop requires less water.

The most important climatic information concerns the dry and wet periods and the extremes. If there is too much rain you need to make certain to drain the excess water from the greenhouse roof as well as around the greenhouse. The water from the roof can be collected in a basin for irrigation. Sufficient storage capacity will help to better tide over the dry periods.

Tomato grows best at temperatures between 18 and 23°C. Above this temperature ventilation should take place. The wind-chill factor is also significant to the plant. Low atmospheric humidity and much wind are likely to cause damage earlier.

The humidity of the air, (RH, relative humidity), affects the growth and health of the crops in various ways. A high RH encourages fungal

diseases, because condensation can easily occur on the crop in the early morning, creating the ideal conditions for fungal spores to germinate rapidly. The plant itself also becomes less tolerant to sudden dry conditions.

Ventilation can be done by opening a part of the greenhouse cover in the sidewall, the roof or in the front or back entrance.

Water supply and crop husbandry

As no rain may enter a closed greenhouse, it is extremely important that the crops have their own water supply. First of all it is important to know how much water your crop needs and how much water can be supplied by the system you are using.

Plants need water mainly for transpiration, but 5-10% is needed for their growth. Plants transpire to cool themselves and to encourage transport of minerals that the roots have absorbed. The amount of transpiration is determined by sun, temperature, air humidity and wind speed.

The methods by which crops in the open field are supplied with water also apply to crops in the greenhouse. Most of the crop husbandry in greenhouses is the same as for open field crops.

Types and constructions

There are several types of constructions and accompanying covering materials.

The simplest form of cover is to lay sheets of plastic film on the ground or over a simple support system. The sheet on the ground may create a slightly higher temperature in a seedbed and the moisture will be retained. Ensure that the plastic film cannot blow away. A simple support with stakes from wood or bamboo can be used to fix a plastic film or vegetable screening material on top of a seedbed.

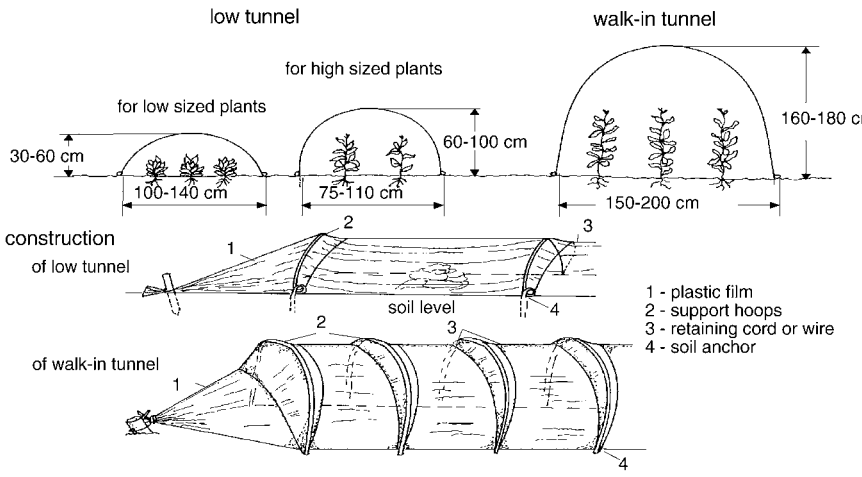

Figure 8: Low tunnels with measurements

Low tunnels can be made of hoops of wood, bamboo, plastic flexible tubes or strong wire (Figure 8). The hoops need to be placed at intervals of about 2 or 3 metres and anchored in the ground. After stretching the plastic film (for instance, polythene or PVC) over the hoops, the sides can be weighted down with a layer of soil. Further anchoring of the tunnel is done by a retaining cord or wire over the plastic film at each support hoop. For ventilation, the plastic film can be lifted up or shifted a little.

The plastic film is removed at harvest time and sometimes even earlier if the weather is favourable. Thus, the tunnel protects the crop in bad weather against low temperatures, hail and also from birds and insects. Low costs and a simple construction method are the most important advantages of low tunnels. The disadvantages are that they only provide a limited temperature gain, opportunities for ventilation are very limited and caring for the plants (husbandry) is difficult.

Low tunnels are usually used for only one crop. In most cases plastic film cover on the ground and low tunnels are the first step towards protected cultivation.

Walk-in-tunnels are high enough for people to walk and work in, and can accommodate a taller crop, but a simple walk-in tunnel has its limitations:

- In a warm climate, the simple means of ventilation limits the cultivation options.
- The use of cheap polythene (PE) film means that the covering will only last for one growing season because it will break down through the solar radiation and friction.
- Wooden hoops may break easily, steel hoops become so hot that the plastic stratches and breaks.
- Simply anchored plastic is vulnerable to storm damage.
- It is difficult to support tall crops properly.

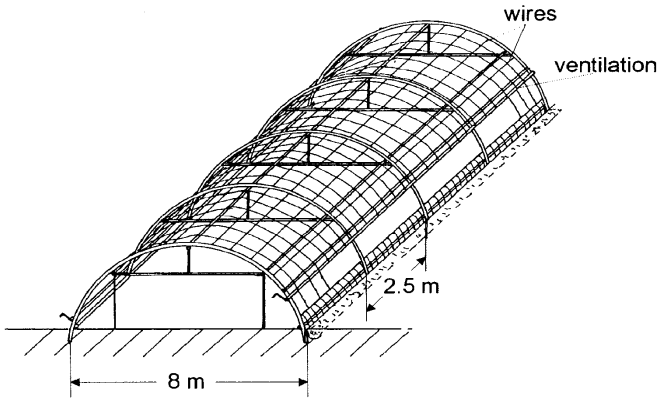

Figure 9: Plastic film tunnel showing cross section and roll-up side ventilation

Tunnels with a solid construction have the advantages of climate regulation, more cultivation options and a longer lifespan. They have enough space for working in them. The structure consists of galvanised tubing, which could be reinforced with wires in the length. To protect the plastic, the frame is covered with foam tape. The simplest form of ventilation can be done by using roll-up the plastic on the side of the tunnel (Figure 9). More advanced methods of ventilation are available and depend only the finance possible.

Shade halls are essential in a dry sunny climate or in the dry season of a monsoon climate to protect the crop against the blazing sun. Special screening material (woven cloth, netting) is available, differing in quality and in the degree to which it shuts out the sunlight. Ventilation occurs via the open netting of the cover on the sides (Figure 10).

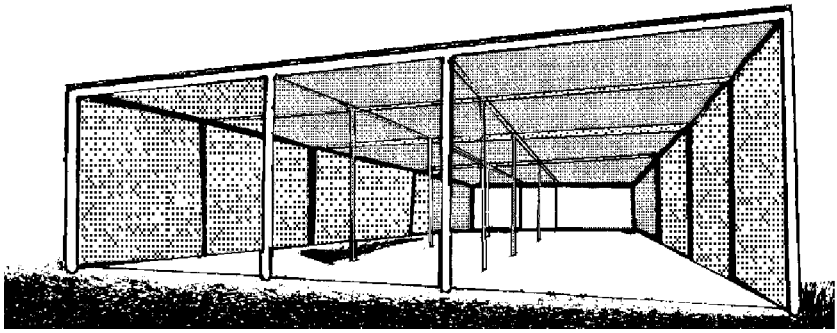

Figure 10: Shade hall (Rovero)

Financial turnover

Whenever growers decide to invest in improvements to their production systems they need to make sure that their income will also grow adequately. Care needs to be taken that the investment also means improvement of the market value of the product. The golden rule is that the greenhouse grower starts on a small scale, gains experience and only then considers expanding the business and investing more.

4.8 Organic farming

Organic farming is a system that excludes the use of synthetic fertilisers, pesticides, herbicides and growth regulators. Organic farmers rely on crop rotations, crop residues, animal manures, legumes, green manures, organic wastes and mineral bearing rocks to feed the soil and supply plant nutrients. Insects, weeds and other pests are managed by mechanical cultivation and cultural and biological controls.

In many developing countries organic farmers can register their farm with the government. A farmer who has organic certification can sell produce on the organic market, which will earn more income than selling conventionally grown products. Organic farm certification procedures are different for each continent and country.

Organic agriculture is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil productivity. It is based on minimum use of external inputs and management practices that restore, maintain and enhance ecological harmony. In most developing countries family members manage organic farming without depending on outside labour. Organic farming provides sustainable food and family income to small and marginal landholders.

The primary goal of organic agriculture is to optimise the health and productivity of soil, plants, animals and people. The principal guidelines for organic production are to use materials and practices that enhance the ecological balance of natural systems and that integrate the parts of the farming system into an ecological process. Organic agriculture practices cannot ensure that products are completely free of residues. Pesticides and chemical residues can reach organic farms through irrigation systems and the wind. Farms that share a common water source are more prone to this problem.

Farmers choose organic methods for a variety of reasons. One of the strengths of organic produce is that it sometimes earns 10-30 per cent more on the market than conventional produce. Organic farming leads to reduced input costs, improved soil health, reduced environmental impact, and a better functioning of agro-ecosystem. The main basis for maintaining sustainable organic agriculture includes integrating livestock, maintaining on-farm tree diversity, using own seeds and compost, applying bio-pesticides and working out suitable cropping systems.

Soil fertility

The foundation of organic farming is a microbially active soil enriched with organic matter and a balanced mineral diet. Humus building practices and additions of rock minerals not only supply plant nutrients, but increase tolerance to insects and diseases, help control weeds, retain soil moisture, and ensure production quality.

The organic fertility system revolves around a combination of practices such as crop rotation, forage legumes, cover crops, and green manures, livestock manures (preferably composted), lime, rock phosphate, and other rock minerals, and lastly, supplemental organic fertilisers. Tomatoes that receive legume and compost treatments, and are grown on soils that have been managed organically for several years, give good yields.

Soil building practices such as green manuring and composting practices encourage abundant soil micro-flora. Maintaining optimum soil fertility improves the disease resistance capacity of the crop. A well-maintained organic farm will give an optimum tomato yield with manure applications of as low as 9-10 tons/hectare/year (4-5 tons/acre/-year).

Soils with no history of organic management will probably need additional organic fertilisation. Fertiliser can be incorporated during field preparation and bedding operations, or banded to the side of the row at planting.

Vermicompost is the most suitable organic manure for enriching soil fertility. It provides a wide range of nutrients to the crops in soils that are shifting from inorganic to organic farming.

Crop rotation

Crop rotation is a major component of organic farming, affecting both soil conditions and pest cycles. Rotation with non-*solanaceous* crops for three years will help to avoid pest problems in tomato (see Section 4.6). Long rotations may be impractical for small farmers. Tomato

followed by cereals and millets reduces the incidence of diseases on tomato. Beans, marigold, cowpea and green leafy vegetables are the common crops that are mixed to avoid the incidence of pest and diseases in tomato.

4.9 Sanitation practices

Tomatoes are very prone to damage from pathogens. During cultivation, water sources must be checked to ensure that they do not become contaminated with the water draining out of the tomato beds. Manure used for fertilisation must be applied well before the crop is harvested. Domestic animals must be kept out of tomato fields during growing and harvesting. The same applies to other animals such as small rodents, reptiles and amphibians.

5 Pests and diseases

Prevention of pests and diseases in tomato is extremely important. This chapter discusses the most important pests and diseases and gives advice on their prevention and control.

Practically all pests and diseases can be adequately controlled by applying synthetic chemical pesticides. However, most pesticides are costly and are sometimes very harmful to humans and the environment, so their use should be restricted to emergency cases. In addition, there are a few pests that have developed resistance to certain pesticides. Therefore, Integrated Pest Management (IPM) strategies that combine the use of resistant/tolerant varieties, suitable cultural practices and the rational application of pesticides (with emphasis on biological pesticides) are recommended. Some of these measures are mentioned below.

> IPM is a pest management system that utilises all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury.

Some information will be given on synthetic chemicals and natural pesticides at the end of this chapter. However, we do not give recommendations about specific synthetic pesticides for the control of specific pests and diseases. Growers who intend to use synthetic pesticides, growers may refer to bonafide local pesticide suppliers or the local agricultural extension service. (See also Agrodok No. 29 Pesticides: compounds, use and hazards.)

5.1 Nematodes

Nematodes are very small worms living in the soil that feed on plant roots. Due to their small size (only a few mm long), it is not possible to see them with the naked eye. Some nematodes feed from the outside of plants, others enter the plant. All feed on the plant's sap, which

can reduce the plant's productive capacity. Even greater damage can occur if viruses or fungi enter the plant as a result of the injuries caused by the nematodes, and then proceed to make the plant sick, and eventually die.

If you discover an area in the cultivated field where part of the crop is clearly lagging behind in growth, the plants are lighter in colour, and their leaves are abnormally shaped but do not show signs of a mosaic pattern, then you may well have a nematode infestation. It usually begins in a small, limited part of the cultivated area, and spreads slowly throughout the plantation.

Root-knot nematodes are of major importance in tomato cultivation. They cause galls (infected swellings) on plant roots (see Figure 11). Three common types of root-knot nematodes are: *Meloidogyne incognita*, *M. javanica* and *M. arenaria*. Affected plants remain small, and are liable to soil-borne fungal and bacterial diseases. Nematodes cause yield losses of about 30% in tomato in the tropics.

Nematode infestation and transmission can occur in many ways: via infected plant material, tools, rainwater and irrigation water, strong winds (which carry infested soil particles), and contaminated soil carried on shoes, or animal feet. Nematodes will survive in soil as long as it stays moist.

Chemical pesticides (nematicides) and soil sterilants (including steam-treatment) are effective but costly control methods. It is worth trying the following IPM-measures to suppress or limit a nematode infestation:

- Rotate tomato with other crops such as cereals, cabbage, onion, ground nut, cassava, sesame, etc. Do not rotate with *Solanaceae*, see Chapter 4. It is not advisable to rotate with crops of the *Cucurbitaceae* family (e.g. cucumber or pumpkin) or papaya either, as these can also cause the transmission of diseases.
- Remove weeds and plant remains (rotten leaves and fruit). Interplant with plants that emit substances via their roots which nema-

todes do not like or which kill them, such as sesame or African marigold (*Tagetes erecta* and other related varieties).

- Expose the soil to sun and wind. Plough the soil several times. The nematodes will be ploughed up to the surface of the soil and will be exposed to the sun and high temperatures, which kill them.

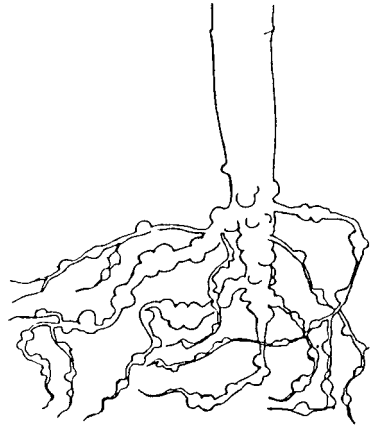

Figure 11: Roots of a tomato plant with galls caused by nematodes.

5.2 Insects

All stinging and sucking insects, such as whitefly, thrips and aphids cause physical damage only when they occur in large numbers. However, they may transmit viruses, which can cause much greater damage. These insects can come from outside your field, and may cause your entire crop to become infected. Also, leaves damaged by insects become more susceptible to fungal and bacterial diseases. Closed glass, plastic sheeting or mosquito netting, or a combination of these, protect crops against insect attacks and virus infestations.

Whitefly (*Bemisia tabaci*)

The adult fly is white in colour and 1-2 mm long. It feeds, just like the larvae, on the leaf sap. When plant leaves are turned over, a whole swarm of whitefly may fly up. They lay eggs on the underside of the leaves. The eggs hatch after about 1 week. After 2 to 4 weeks the larvae form a cocoon and metamorphosis takes about one week (Figure 12).

Whitefly are especially a problem in the dry season. Once the wet season starts they disappear. Some measures to combat whitefly:

- Encourage the presence of natural predators of whitefly, by planting shrubs or other plants between the crop rows (interplanting) or along pathways between borders. Do not spray pesticides.
- Use resistant cultivars (hairy leaves make it difficult for the whitefly to lay its eggs).
- Spray a solution of kerosene and soap to control whitefly (see Section 5.5).

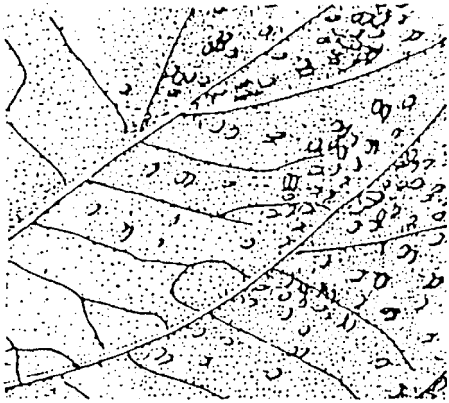

Figure 12: A colony of whitefly on the underside of a leaf

Aphids (*Aphidae*)

Aphids are soft, oblong insects about 2.5 mm in length (Figure 13). There are aphids with and without wings. Direct damage occurs when they attack the crop in large numbers, especially the youngest leaves and stems. In addition to causing direct damage, aphids also transmit several viruses.

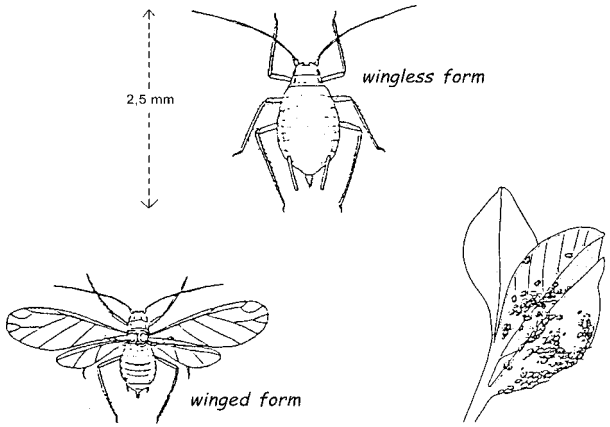

Figure 13: Winged and wingless aphid. Aphids on the underside of a leaf

Measures to control aphids:

- Remove old crop debris before sowing new crop.
- Intercrop with other crops.
- Use nitrogen fertiliser in moderate amounts; apply organic fertilisers.
- Spray a solution of soap, cow urine or extract (*Azadirachta indica*).
- Cover the ground with grey plastic sheeting, which repels the aphids by reflecting sunlight.

Thrips (*Thripidae*)

Thrips are very small insects, only 0.5 to 2 mm long (Figure 14). You have to look carefully to spot them. They usually have wings.

Thrips lay their eggs on the leaf. The larvae appear after about 10 days. The larvae and adult thrips suck the leaf sap, causing silvery spots on the leaf surface.

The adult thrips also leaves its excreta on the leaf; these are small black dots. A few thrips species are vectors of Tomato Spotted Wilt Virus (TSWV). The cocoon metamorphoses in the soil.

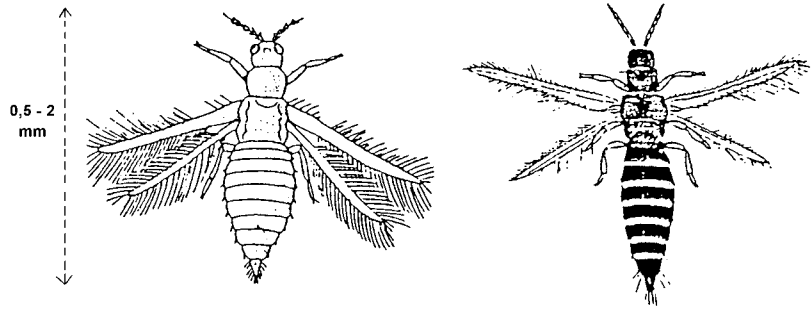

Figure 14: Two different kinds of thrips

Measures to control thrips:

- Cover the ground with plastic sheeting to prevent the thrips from passing into the soil for their cocoon stage.

- Plough well, so that cocoons are brought to the surface where they will dry up and die.
- Remove crop debris.
- Spray plants with a solution of soap or neem extract (*Azadirachta indica*). This will not affect the cocoons in the soil so repeat spraying regularly to kill the aboveground adults.

Butterflies and moths (*Lepidoptera*)

Butterflies and moths are common pests in tomato crops. They lay green or brown eggs on young leaves, flowers and fruit. The hatched larvae (caterpillars, Figure 15) feed on leaves, flowers, fruit and even the roots. While feeding, the caterpillars grow in size, passing through a number of larval stages. Eventually they form cocoons in the soil. A few weeks later these hatch and the adult butterflies fly out and disperse.

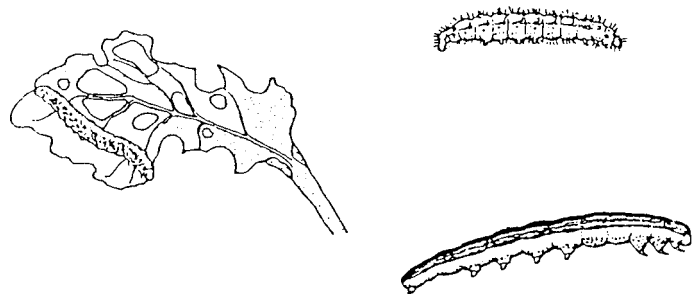

Figure 15: Caterpillars of various butterflies or moths

Measures to control caterpillars:

- Remove weeds regularly.
- Plough one month before sowing or transplanting.
- Remove and destroy the infected fruits.
- Use crop rotation.
- Check regularly for the presence of eggs and then take measures to control the young larvae.
- Use light traps that attract moths at night, preventing them from laying their eggs on the plants.

- Apply wood ash, wood chips or shavings and/or calcium on the seedbeds.
- Intercrop with cabbage.
- Spray *Bacillus thuringiensis*, a biological insecticide, which you can buy from your pesticide supplier.
- Spray with a neem solution (*Azadirachta indica*) or other locally used natural pesticides.

Leafhoppers (*Cicadellidae: Empoasca fabae*)

The most common tomato pest is the potato leafhopper (Figure 16). Leafhoppers are between 2 and 30 mm long, and walk sideways if they are disturbed. They lay green banana-shaped eggs on the underside of the leaf.

The potato leafhopper is only found in North, Central and South America. They feed on plant juice. Where they have sucked, the leaf becomes lighter in colour. If damage is severe, the entire leaf becomes light-coloured.

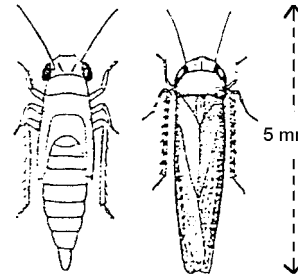

Figure 16: Leafhoppers (nymph and adult)

Measures to control leafhoppers:

- If possible, plant during the rainy season.
- Use resistant cultivars (e.g. hairy leaves make it difficult to lay eggs).
- Mulch well (this prevents leafhoppers from forming cocoons in the soil).
- Spray with a neem solution (*Azadirachta indica*) or other locally used pesticides (e.g. pyrethrum, derris, sabadilla). The best time to spray is in the first month, when the plants are about 10 cm tall, as the female leafhoppers lay their eggs around this time.

Mites (*Tetranychus spp.*)

Mites are spider-like insects (Figure 17). They are smaller than 1 mm, often yellow, red or orange. They lay their eggs on the underside of

the leaf. The larvae and adult insects suck sap from the leaves. Leaves and stems become yellow and dry up. Mites can make an airy web (fluff) of thin threads, similar to that of the spider. They do most damage in the dry season.

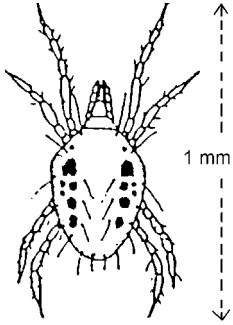

Figure 17: A mite

Measures to control mites:
- If possible, plant in the wet season.
- Stimulate the presence of natural predators by intercropping or growing near roadside, shrubs and other varied vegetation.
- Spray with a soap or a kerosene-soap solution (see Section 5.5).

Helpful insects

Some insects can help to control harmful pests. Some examples of natural predators:
- Ladybird beetle controls whitefly.
- Green lacewings control aphids and whitefly.
- Hover flies (*Syrphidae*) control aphid eggs.
- Trichogramma wasps control codling moth.
- *Bacillus thuringiensis* against Army worm.

5.3 Diseases

Tomato plants are susceptible to several fungi, bacteria and viruses. Fungi and bacteria cause foliar (leaf), fruit, stem or root diseases. A virus infection often leads to dwarfed growth and decreased production. Damage caused by diseases can result considerable yield losses for a farmer.

Bacteria

Bacteria are tiny one-celled organisms. They are visible under a microscope but not with the naked eye. Unlike fungi, whose spores germinate and then can penetrate the plant's intact skin, bacteria almost always infect the plant through weak spots, such as scars, stomata and

lenticels (small openings on the surface of stems and roots) and wounds (e.g. from pruning) or other mechanical injuries. In the soil they can penetrate the plant through root lesions, caused for example by nematodes. Bacteria are everywhere in the air and on objects. Bacteria are carried to the place where they penetrate the plant by humans, on shoes and the legs of insects, by raindrops splashing, or dust in the wind.

Most bacterial diseases are transmitted when humidity and temperatures are high. Once they have penetrated the plant, bacteria usually end up in the vascular system of stems, roots and leaves, often causing the latter to wilt.

To avoid bacterial diseases from spreading in your plantation make sure your tomato plants do not get injured. Many bacterial diseases survive in the soil. Therefore practise crop rotation and do not grow tomatoes for several years on the same soil. The only way to eradicate them quickly is to sterilise the soil using chemicals or steam. We recommend the use of resistant varieties, if seeds are available.

Some bacterial diseases commonly found in tomatoes are discussed below.

Bacterial wilt (caused by *Ralstonia solanacearum*)

This bacterium is especially common in humid tropical lowlands, where temperatures are relatively high. It causes bacterial wilt, which is a soil-borne disease. The first symptoms in infected plants are wilting of terminal leaves, followed in 2-3 days by a sudden and permanent wilt, but there is no yellowing. Adventitious roots may develop on the main stems. The vascular system in the stem of infected plants appears light brown in transverse or longitudinal section; it becomes a darker brown at a late stage of infection. The pith and the cortex near the soil line also become brown when the plant is completely wilted. A white, milky stream of bacteria will ooze from xylem elements when stem sections of infected plants are suspended in water.

The bacteria survive in the soil and enter roots of young plants through wounds made by transplanting, cultivation, insects or certain nematodes. The bacteria are spread through irrigation water, soil movement, or moving infected plants (e.g. when transplanting).

The following measures will help to control bacterial wilt:
- Use tolerant/resistant varieties.
- Avoid infested fields. Once the soil has been infected, do not grow *Solanaceae* for at least 7 years. Rotate with cereal crops.
- Do not injure roots or leaves, so be careful during transplantation and prune as little as possible.
- Make sure the field is well drained.
- If necessary, sterilise the soil (see Agrodok 9: Vegetable gardening in the tropics).

Bacterial spot (caused by *Xanthomonas axonopodis* pv *vesicatoria*)

This bacterium is distributed worldwide, but it is more severe in the tropics and subtropics. It is spread via seed, insects, raindrops, infected plant debris and *Solanaceae* weeds. Heavy rains and high humidity favour disease development. The bacteria enter the plant through the stomata and wounds. The pathogen affects leaves, fruits and stems. Small spots appear on the leaves and on the fruit of infected plants. These spots are generally brown and circular. Leaves turn yellow and drop off. Elliptical lesions are found on stems and petioles.

The following measures can help in controlling bacterial spot:
- Use pathogen-free seeds or transplants. Give hot water treatment: soak seeds for 25 minutes in water at 50°C.
- Practise crop rotation.
- Weed thoroughly; make sure you remove members of the *Solanaceae* family in particular.
- Clear away crop debris.
- Apply copper or copper+maneb

Bacterial canker (caused by *Clavibacter michiganensis*)

Bacterial canker is an economically important tomato disease that occurs worldwide. The disease is spread via seed or the soil. The bacteria can survive in plant debris. Plants are infected via injured stems or roots. Damage may be severe when root-knot nematodes are present. The leaves of infected plants become yellow, wilt and dry up. Long, brown stripes, which can split open, appear on the stem. Adventitious roots may develop on the stems. Stems may also display cankers under some conditions. Internally, the vascular tissues of the stems display light yellow to brown streaks. Eventually the pith becomes discoloured and 'mealy'. 'Bird's eyes', round slightly raised spots with a red dot surrounded by a white ring, appear on fruits. These do not always occur, but are a helpful diagnostic aid when present.

The following measures help to control bacterial cancer:

- Use pathogen-free seeds or transplants. Soak seeds for 30 minutes in water at 56°C, or 5 hours in a 5% solution of hydrochloric acid to ensure disinfection.
- Do not sow on infected soil. Sterilised soil, potting mix and pots or flats should be used when tomatoes are in a greenhouse.
- Disinfect pruning tools before each use and clean them well after use.
- Remove and burn crop debris.
- Rotate tomatoes with a non-host crop.

Viruses

Tomato is very sensitive to virus diseases. A virus is a very tiny pathogen with a protein structure that is not visible with the naked eye or through an ordinary microscope. It is often spread in the plantation by insect vectors such as whitefly, thrips and aphids. The damage caused by the virus is usually much greater than the mechanical injury caused by the insect vector.

Normally, plant tissue damaged by a viral disease does not die immediately. The most important symptom of viral infections is the light (white or yellow) colour of the leaves, or a mosaic pattern of light and

darker shades of green on the leaves. In many cases, viral disease leads to dwarfed growth, rosette formation or other strange stem and leaf deformations. The symptoms of viral infections are often not found everywhere in a cultivated field, as is usually the case with fungal or bacterial diseases. It is always possible to find a number of plants that show no signs of the disease.

Viruses reported on tomato crops include:
- Tobacco mosaic virus or tomato mosaic virus (TMV or ToMV)
- Cucumber mosaic virus (CMV)
- Tobacco etch virus (TEV)
- Potato virus-Y (PVY)
- Potato leafroll virus (PLRV)
- Tomato spotted wilt virus (TSWV)
- Pepper veinal mottle virus (PVMV)
- Chilli veinal mottle virus (CVMV Or Chivmv)
- Tomato yellow leaf curl virus (TYLCV)
- Tomato Big-Bud mycoplasma (TBB)

Tobacco mosaic virus

TMV causes severe damage to tomato crops. The symptoms include yellow-green spotted leaves, rolled-up leaves, stunted growth and discolouration of fruits. Machinery or workers transmit the virus mechanically to healthy plants. The natural vector of TMV is not known. Seeds transmit the virus.

Control measures include:
- Use pathogen-free seed and destroy infected plants.
- Avoid contact with infected plants and with tobacco: never smoke tobacco near the plants - even cigarette ash can transmit infection. Wash your hands with soap and water before visiting a tomato crop.
- Do not grow other *Solanaceae* near the field.
- Use resistant varieties.

Cucumber mosaic virus

CMV causes stunting in tomato plants. Leaves may show a mild green mottling or more shoestring symptoms in which the leaf blades are greatly reduced. Fruits are small in size and often misshapen. CMV is transmitted by different aphid species. Aphids usually introduce the virus into a tomato crop from weeds or neighbouring crops.

Control of the vector is important to prevent CMV epidemics:

- Grow resistant varieties.
- As CMV has a broad host range, it is important to eliminate weeds and ornamental plants that harbour the virus.
- Remove and destroy infected individual plants as this helps to limit the virus spread within the field.

Potato virus-Y

PVY symptoms vary depending on the virus strain and range from mild mosaic to necrosis. PVY is transmitted by many aphid species. PVY is very difficult to control with insecticides. The use of reflective mulches and yellow sticky insect traps can limit virus spread by aphids. Growing useful weeds in tomato crops is very important for controlling PVY.

Tomato spotted wilt virus

TSWV is an economically important tomato disease in the tropics. Infected plants are stunted and display yellow leaves. Fruits show characteristic green, yellow and red, slightly raised bulls-eye rings. TSWV is transmitted by several thrips species.

It is important to:

- Eliminate thrips and host plants to prevent the disease.
- Locate tomato crops as far away as possible from flower fields.
- Use resistant varieties.

Pepper veinal mottle virus

PVMV causes mosaic spots in tomato. Severe strains may cause leaf and stem necrosis. In the wild PVMV is transmitted non-persistently

by at least five aphid species: *Aphis gossypii, A. crassivora, A. spiraecola, Myzus persicae and Toxoptera citridus*.

To control PVMV:
- Tomato crops should not be planted close to infected crops.
- Weeding and control of aphids in the nursery may also reduce PVMV spread.

Chilli veinal mottle virus
CVMV causes yellow mosaic pattern or chlorotic (pale green) spots on tomato crops. This virus is transmitted in a non-persistent manner by several aphid species.

The main disease control measures are proper cultural practices, including intercropping with maize or using reflective mulches to reduce the vector population.

Tomato yellow leaf curl virus
TYLCV occurs worldwide. Infected plants are erect and stunted. Leaves are yellow and curl upward or downward. An entire yield can be destroyed if plants are infected in the nursery. Whitefly transmits TYLCV.

Common control measures:
- Use tolerant varieties.
- Use reflective plastic mulch.
- Protect seedlings with a net in the nursery.
- Control the insect vector.

Fungi
Fungi are organisms that usually consist of filaments (hyphae). Clusters of hyphae (mycelium) are visible with the naked eye and look like very fine cotton wool. These are usually whitish in colour. Spore clusters and fruiting bodies are often brightly coloured. The green or whitish spore clusters that form on old bread and rotten fruit are a familiar example.

A fungal infection is often caused by fungal spores that land on leaves, germinate there and penetrate the plant tissue through its stomata (small openings in the plant's skin), wounds, or sometimes even directly through the plant's skin. The filaments develop at an increasing rate in the affected plant tissue, from which they extract nutrients and into which they may excrete substances that are toxic to the plant. The affected plant tissue usually dies off. The harmful effects of the fungus are usually limited to the affected area, but there are some types of fungi that invade the plant's vascular tissues (xylem) and thus spread throughout the plant (*Fusarium* and *Verticillium spp.*).

The most obvious symptoms of fungal diseases are leaf spots. These spots are normally round or oval, but they can also be polygonal or spindle-shaped (with pointed ends). In an early stage of infection, 'moist' areas may be noticeable on the leaves, where the leaf will later die off. At a later stage of infection, the leaf spots have a dead brown centre and are surrounded by a light or dark-coloured halo. Concentric rings of different shades of brown or grey form around the centre.

It is easy to control fungal diseases by using resistant varieties. Crop rotation may also help, particularly in the case of soil-borne fungal diseases. It is also important to eliminate crop debris.

Most fungal diseases can be controlled by applying the right chemical fungicides on the foliage (leaves). Where rainfall is heavy and frequent the fungicide (and also insecticide) deposits may be washed off the leaves and lose their effect. To avoid this loss of pesticide it helps to shield the crop plants from raindrops by tying strips of transparent plastic over them. Another reason to keep the leaves as dry as possible is to prevent bacteria and some fungi spores from moving in a film of water, thus easily finding places to enter the leaf and infect the plant, through the lenticels.

The most important fungal infections in tomato are described below.

Early blight (caused by Alternaria solani)
This fungus can be found everywhere, and its effect is most serious in humid and hot climates. It is spread via seed, wind, rain and infected plant remains. Plants that have been damaged are more susceptible to this fungus. Round, brown spots (with concentric rings) appear on the leaves, reaching a diameter of 1.5 cm. Sometimes small lumps can be found on the stem or on leaves, causing leaves to turn yellow and wilt. Flowers and small fruit fall off.

Major control measures:
- Use tolerant varieties.
- Remove and burn damaged plant parts.
- Weed regularly and thoroughly.
- Use pathogen-free seeds.
- Adopt crop rotation.
- Make sure the plants have enough water.
- Do not plant young plants near older plants.
- Apply effective fungicides, if available.

Late blight (caused by Phytophthora infestans)
This fungus can be found in all regions of the world, but is more common in highlands or in cool humid conditions in lowlands. The fungus is usually spread via crop remains. Dark, watery marks with a yellow spot on the inside are visible on the leaves. Sometimes the marks start at the edge of the leaf and spread inward, sometimes the spots spread from the centre of the leaf outward. On the underside of the leaves, the spots are white. The stems and fruit can be affected also. Fruit gets brown spots and the leaves wilt. The signs of late blight become visible early in the growing season.

Measures that can prevent late blight:
- Use tolerant varieties.
- Weed regularly and thoroughly.
- Remove and burn affected plants and plant debris.
- Do not plant young plants near older plants.
- Apply mulch on seedbeds, so that less watering is needed.

- Avoid planting tomato near potato crops.
- Increase aeration by staking and removing affected leaves.

Fusarium wilt (caused by F. oxysporum)
From the bottom up, leaves wilt, turn yellow and curl at the edges. A brown stain can be seen if the stem or roots are cut. The plant may wilt on only one side or on a leaf, while the other half or rest of the plant remains healthy for a long time. Pink fungus fluff is found on dead plant parts.

Measures to help control *Fusarium* wilt.
- Use resistant or tolerant varieties.
- Adopt crop rotation.
- Remove and burn affected plants.
- Minimise the watering schedule. To prevent the soil drying out apply mulch on the seedbed.
- Decrease the acidity of the soil by applying calcium or marl.

Verticillium wilt (caused by V. albo-atrum, V. dahliae)
This disease is most common in cooler climates (e.g. highlands). Signs of infection are similar to those of Fusarium, but they appear more slowly. The plants wilt, and leaves become yellow. Many side roots may form at the base of the plant.

The fungus spreads through crop debris, especially in slightly acidic soils (low pH). This disease also affects other Solanaceous plants.

Measures to control this wilting disease:
- Use resistant/tolerant varieties.
- Weed thoroughly.
- Plough and clear crop remains.
- Use healthy seed.
- Rotate with plants other than *Solanaceae*.
- Apply calcium or marl in the soil.

For the following diseases, apply the general control measures discussed at the beginning of this chapter.

Powdery mildew (caused by *Leveillula taurica*)

This mildew appears as yellow spots on the leaves and powder from spores on the underside of these spots. Unlike other forms of mildew, the hyphae (threads) are completely inside the plant. The plant is infected via the stomata and leaf surface. The disease spreads quickly in dry conditions.

Anthracnose (caused by *Colletotrichum coccodes*)

Signs of infection by this disease are grey-brown spots (dents) on the fruit and, in humid weather, salmon-pink spores. The disease spreads quickly in humid weather, and when it is hot and humid. Transmission is most common via infected plant material (especially the fruit). Therefore, measures relating to crop hygiene are very important.

5.4 Other causes of crop damage

The abnormalities described below are not caused by insects or diseases but mostly by nutritional deficiencies and unfavourable climatic conditions.

Fruit splitting

Little splits appear in the (usually ripe) tomato fruit due to large fluctuations in the moisture content of the soil or due to wide fluctuations of temperature. These reduce the fruit quality. Sensitivity to these fluctuations varies depending on the cultivar. Also, the splits make it easy for pests and diseases to enter the tomato. Two ways to prevent splits are by covering the ground with a layer of mulch and watering lightly but more frequently, or by picking fruit just before it is ripe and letting it ripen indoors in a dry spot (e.g. on straw).

Sunburn (or sunscald)

Brown or grey indentations appear on the fruit. The part of the fruit that is most exposed to the sun rots first. This can be prevented by

providing more shade during fruit ripening by planting trees, or by judicious intercropping. Sunburn is more frequent on un-staked tomatoes.

Blossom-end rot

This disease is caused by calcium deficiency. This is usually a result of too much salt in the soil, which is caused by the use of saline water, or irrigating with too little water during the dry season. The amount of salt in the soil can be lowered by flushing it out with one or more abundant applications of salt-free irrigation water (normally during the rainy season), making sure that there is good drainage.

5.5 Control of pests and diseases

Cultural measures to limit the damage done by pests and diseases are discussed in the preceding chapters. The measures were based on the principles of Integrated Pest Management (IPM). But in cases of emergency, pests and diseases can also be controlled by using synthetic chemical or some natural pesticides, and by biological control.
Keep in mind that pesticides usually have a specific action. That is to say: insecticides kill insects only, and not mites, diseases or nematodes. Fungicides kill only fungi and some bacteria.

Synthetic chemical pesticides

Synthetic chemical pesticides are developed by researchers working for chemical companies, and are sold by these companies. These chemicals can be toxic (sometimes very toxic) to human and animals. They are most effective in controlling the pests and diseases, but they also kill the pest's natural predators, causing a serious resurgence of some pests when not applied at the right time, in the right way and in the right dosage rate per hectare. (See Agrodok No. 29: Pesticides: Compounds, use and hazards). Becausethey leave residues they also can do harm to humans and the environment, and therefore should be applied judiciously and only in cases of emergency. To limit the use of chemical pesticides, we recommend that farmers adhere to the princi-

ples of the Integrated Pest Management (IPM), explained in other booklets.

A simple way to increase effectiveness of fungicides is to add 1 tablespoon of household soap to the knapsack sprayer. This causes a reduction in the surface tension, turning the droplets into a film. In this way, farmers can reduce the number of applications.

Natural pesticides

Natural pesticides are products, such as pyrethrum, derris (rotenone). They are called 'natural' as they are found in nature. These insecticides have been used since ancient times. Their application has a quick effect. Chemistry researchers have developed better formulations and have thus improved their effectiveness. They can be as toxic to the natural enemies of crop pests as synthetic chemical pesticides.

Other natural pesticides have a slow action, such as neem extract (*Azadirachta indica*), which represses rather than controlling pests. Its formulation and effect have now been improved too by chemical companies. But farmers themselves can prepare a rough formulation, as the neem tree is common in tropical areas.

Besides these pesticides there are other ways to suppress the development of pest populations such as spraying the crop with cow urine, cow dung, garlic and other products. (See Natural Crop Protection in the Tropics, Further Reading list) These products are not really pesticides. They are not as effective and fast acting as synthetic chemicals can be. Also some of them are laborious to prepare. But these methods for suppressing pests do little harm to natural predators and are safer for the environment and for consumers. Because of the negative side effects of synthetic chemical pesticides it is recommended to use these pest-suppressing methods wherever possible. More details on natural crop protection can be found in booklets on Integrated Pest Management.

Biological control

Controlling an insect pest by using its natural enemies is called biological control. Natural enemies can be birds, spiders, other insects and even fungi or bacteria. Insect pests can be controlled almost completely in a biological way when the crop is grown in greenhouses. In the warmer regions the same effect can be achieved by enclosing the cropped area with mosquito netting. This prevents the natural enemies from flying away, and pest insects re-entering the plant. Information on the insects and micro-organisms that control the various crop pests can be found on the internet sites of the providers, e.g. http://www.koppert.nl and http://www.biobest.be.

Natural enemies can also play an important role in protecting crops grown in the open. You should enhance and protect the natural enemies that are already present in and around your plantation. You must NOT use pesticides, because these kill the natural enemies as well, and this may lead to a much more serious resurgence of the pest. More details can be found in books on Integrated Pest Management (IPM).
Some ways to control or suppress the development of insect populations (from 'Natural Crop Protection' by Gaby Stoll):

Kerosene-soap solution

This solution helps to get rid of aphids, mites, thrips and leafhoppers.
Application: Dissolve 500 g soap in 4 litres of boiling water. Then add 8 litres of kerosene to make an emulsion. This can be done by beating the mixture well, or by spraying the solution into the kerosene (use a powerful pump, e.g. a plant spray). You should end up with a creamy mixture, and no oily layer on top. Once it has cooled down it will congeal into a smooth, thick paste. Dilute the emulsion 10 to 15 times before using it.

Soap solution

This is a good remedy against aphids and thrips.
Application: Dissolve 30cc liquid soap in 5 litres of water by shaking it. Before spraying it on the crop, test the solution on a single plant. If

the concentration of the solution is too high, burns (spots) will appear on the plant. The solution should then be diluted more.

Cow urine

This has proven to be effective in controlling aphids, mites, thrips and other insects, and also against mosaic-virus and fungi.

Application: Store urine in the sun for two weeks. The urine should be diluted 6 times before spraying it. Test it first on the leaves and fruit of the plants, and dilute more if necessary. A second spraying after 1 or 2 weeks will have more effect. This treatment can be used as a preventive measure.

Cow manure

Cow manure can be used in the same way as cow urine as a pesticide and fungicide for pests and diseases in tomato.

Application: Put 3 cowpats in a bucket of water. Store the mixture for two weeks, stirring every day. If the smell becomes too strong, cover with a cloth. This solution should be diluted 3 to 5 times before spraying it. Other animal manure can be used in the same way, but test it on a single plant first!

Neem - Azadirachta indica (Melicaceae)

Neem is a fast-growing tree, widespread in South-east Asia, Africa and Central America. The tree grows in various climates and soil types. It bears fruit (Figure 18) after 4 or 5 years (average of 30 to 50 kg/tree). The seeds contain 35% to 45% oil. Neem is effective against all the pests mentioned in this book, and against nematodes.

Preparation: A watery extract from the neem seed is used as a spray. As the product is broken down by sunlight, it is best to prepare it in the evening. Collect the fallen fruit, remove the pulp and wash the seeds. Dry the seed well and store in a well-ventilated space (e.g. baskets or bags). The seeds you need should then be peeled and ground. The ground seeds (about 5 kg) are wrapped in a piece of cloth and soaked in 10 litres of water overnight. The next day, drain the water off with a sieve and dilute it 10-20 times with water (making a total quantity of 100 to 200 litres). You will need about 500 litres to spray 1

ha (i.e. 13-25 kg ground seed). As a preventive measure, use a weaker dilution. It might be necessary to spray a second time.

The pressed neem fruit cake (not only the seeds) can be used to control nematodes in tomato. Plough 1 to 2 tons/ha of the cake into the soil.

Figure 18: Leaf with fruit from the neem tree

6 Harvest and seed production

Harvesting on time and proper post-harvest treatment of the fruit is very important. The high water content of tomatoes makes them vulnerable to post-harvest losses. Over-mature fruit gets easily damaged or starts rotting. The first measure to help limit the extent of post-harvest damage is harvesting at the right moment. It will be necessary to harvest several times as the fruit of tomato plants do not all ripen at the same time. The first tomato harvest is possible 3 to 4 months after sowing. Harvesting will continue for about one month depending on climate, diseases, pests, and the cultivar planted. During one season tomatoes must be harvested 4 to 15 times.

Quality tomatoes are firm and are uniform in colour. If the tomatoes are to be used for the production of, for example, ketchup, chutney, purée or juice, the fruit must be picked when it is red and completely ripe. If the tomatoes are to be sold as vegetables on the market, they can be harvested while still green. Green tomatoes can be ripened after picking, until they are red. A few red, ripe tomatoes will speed up the ripening process. One disadvantage of early picking is that the nutritional value of the tomatoes is lower. One advantage is that green tomatoes are less likely to get damaged or to rot.

To uphold the quality and ensure a good harvest some simple and easy guidelines can be followed when harvesting:

- Workers need to know which tomatoes are to be harvested and what end use they will have.
- Harvesting needs to be carried out in dry weather and cool temperatures, hence in the early morning.
- Tomatoes must be picked with clean hands and twisted gently off a plant and not be squeezed or damaged by fingernails (Figure 19).
- Tomatoes must be gently placed in the container and not thrown in or dropped.
- Containers must be clean nylon net bags, plastic buckets, or wood or plastic crates.

- Picking containers should never be too full.
- The small picking containers used by labour need to be emptied into larger containers in the field. Larger containers need to be wide, shallow and stackable to avoid excessive weight.
- Larger containers must be kept clean and away from direct sunlight. In this operation the tomatoes have to be placed gently in the larger containers and never too many tomatoes should be piled on top of one another.

Figure 19: Proper way to pick tomatoes.

6.1 Harvest labour planning

Tomato harvesting is labour intensive and it is important to estimate the time required, the cost involved and how much labour may be required.

A farmer estimates that his crop will require 6 harvests and each harvest will take a full day's work. He needs to hire four workers at $1.00 per day. This will cost him $24.00 for the total harvest (6 harvests multiplied by 4 labourers at $1.00 per labourer per day. In figures 6 x 4 = $24).

It is important to understand that the farmer's time has to be calculated as well. Beside labour costs, other costs like the cost of containers, food for workers etc, must be calculated. A farmer should list all the possible sources of costs.

Costs can be divided into fixed costs and variable costs. In simple terms, fixed costs are those that do not change with an increase or decrease in harvesting requirements (e.g. tools). Variable costs are those that increase or decrease according to harvesting requirements (e.g. labour). A simple harvest budget is shown in Table 3.

Table 3: A simple harvest budget

Item	Unit	Cost	Calculation	Total cost
Harvests	6			
Variable costs				
Labour	2	$ 1,-	6 x $ 2,-	$ 12,-
Food	6	$ 0,10	6 x $ 0,10	$ 0,60
Fixed costs				
Small containers	4	$ 0,05	4 x $ 0,05	$ 0,20
Large containers	2	$ 0,10	2 x $ 0,10	$ 0,20
Total costs				$ 13,-

6.2 When to harvest

Harvesting will continue for about one month, depending on climate, diseases and the cultivar planted. Tomatoes can be classified in four stages of maturity:

- Stage 1: Seed are white in colour (immature) and can be cut when the tomato is sliced. There is no juice inside the tomato.
- Stage 2: Seeds have a tan colour (mature) and some juice present.
- Stage 3: Seeds are pushed aside when cut. The colour inside is still green.
- Stage 4: Juice becomes red in colour.

Tomatoes that are harvested at the first stage of maturity will ripen into poor-quality tomatoes. Tomatoes harvested at third and fourth stages of maturity will ripen into good-quality tomatoes.

It is also good to look carefully at how ripe the tomatoes are. How ripe a tomato is when it is harvested affects the fruit composition and tomato quality. Tomatoes accumulate acids, sugars and ascorbic acid when they ripen on the plant. Field-ripened tomatoes have a better flavour and overall quality than tomatoes that ripen after picking. Hence it is important to understand ripeness stages. A simple colour index for red tomatoes can be given to the tomato pickers so that they are familiar with this.

- Green ripeness stage: Fruit surface is completely green. The shade of green may vary from light to dark.
- Breaker ripeness stage: Break in colour from green to tan yellow, pink or red on not more than 10 % of the tomato skin.
- Turning ripeness stage: 10% to 30% of the tomato skin is not green. It can be tan yellow, pink or red.
- Pink ripeness stage: 30% to 60% of the tomato skin is not green. It can be pink or red.
- Light red ripeness stage: 60% to 90% of skin colour is not green. It can be pinkish red or red.
- Red ripeness stage: 90% of the tomato skin is not green. It shows a red colour.

6.3 Seed selection and cultivation

If tomatoes are grown for seed production some special practices are needed, from sowing to harvesting. Pests and diseases must be controlled, and nutrient and water management should be optimal to achieve good fruits and seed yield. When collecting seeds it is important to pick fruit only from healthy plants that also have other desirable characteristics, such as:

- good taste and easy to prepare
- resistant to diseases or pests
- produce a lot of fruits that are easy to store.

> The selection process requires a lot of patience. However, if you continue to select the best plants every year, you will notice that fruit production increases in quality and quantity.

6.4 Hybrid seed production

F1-Hybrid

Hybrids are plants that are a result of artificial cross-pollination. The first crop from hybrid seeds will produce well, but it is not advisable to use second-generation seed for planting. The chance that you will

get plants with inferior characteristics is high. New seed must be bought and used for each crop.

Hybrid tomato varieties have many advantages compared to open-pollinated varieties. Hybrids usually produce higher yields. They generally mature earlier and more uniformly. Many hybrids have better fruit quality and disease resistance. With all of these advantages, many farmers prefer to sow hybrid seeds in spite of the higher seed costs.

The demand for hybrid tomato seeds can open a new market for growers interested in seed production. This is good news, but hybrid tomato seed production is not easy. First, it requires much labour, especially during the time when crossing is done. Second, it requires the mastery of special skills and a close attention to detail. Hybrid seeds can also be bought from commercial seed companies. We recommend doing this, rather than trying to produce them yourself.

6.5 Seed quality

The quality of seed is crucial. If you have healthy seed, then your crop will be stronger than one grown from bad seed. It is better to have little seed of good quality than a lot of seed of bad quality. It is possible to recognise good quality seed. Unfortunately good quality is only confirmed once the seeds have germinated. However, it is easy to spot bad quality seed before germination takes place. Bad quality seed smells dusty, looks damaged, wrinkled or empty. You might see mould or insects, and the seeds will not all be the same size. You will usually just have to trust the quality of seed. There are ways to determine seed quality but they require precision work and time. One way to do this is to make 4 groups of 50 seeds each. Sow the seeds in 4 trays or in 4 marked plots. For the seeds to be considered good, at least a third of them should produce healthy plants.

7 Post harvest handling

Tomatoes are delicate fruits and need to be sent to the market quickly. If they are not handled carefully they decay easily, which affects their taste, flavour and nutritional value.

7.1 Handling

Containers

Tomatoes are picked in picking containers (nylon net bags or plastic buckets). These picking containers need to be emptied into larger containers placed in picking areas. The large containers must be transported frequently to the sorting areas on the farm. Therefore they must not weigh more than 25 kg. The containers need to hold only tomatoes that are mature, ripe and free from damage. When the field containers are full, they should be transported to a sorting area located on the farm.

Sorting area

In sorting areas, the fruits are washed and sorted by size, colour and variety. Sorting areas need to be out of direct sunlight, preferably cool and clean. People working in the sorting areas, must have clean hands and clothes. It is important that each worker is trained regarding his or her task.

Sorting

In some small-scale handling and sorting operations, machines are used for washing, sorting and grading of tomatoes. Such machines cost a lot of money and are a fixed cost to handling operations.

Efficient washing and sorting can be done with ‘sorting canals’. These are long water containers in the reception areas that look like livestock drinking troughs. They have several advantages. Tomatoes can be off-loaded more quickly from field containers, for tomatoes can be gently poured into the water. The water prevents the tomatoes from hitting a

hard surface, so fewer will be damaged. Water cleans the dirt off the tomatoes. It is also possible, to add a permissible amount of chlorine solution to the water, to disinfect the tomatoes. It may also be possible to heat the water to several degrees above the temperature of the tomato pulp. This will prevent the tomatoes from absorbing water and will also counteract pathogens. It is important to use clean and good quality water in sorting canals. The water must also be changed regularly.

Once the tomatoes are taken out of the sorting canal they must be dried and carefully placed in a container, ready for dispatch to their final destination.

Grading simply consists of arranging the tomatoes into a number of uniform categories according to the economically important physical and quality characteristics. The process involves identification, classification and separation.

Grading has advantages:

- Uniformity is one of the first attributes that buyers look for. Appearance comes before aroma and taste.
- Tomatoes of different qualities can be sold to different customers.
- Setting standards will create customer confidence in the product and more importantly in the producer.

In some cases farmers may be able to pool their financial resources so that they are able to buy a washing and sorting machine.

Packaging

Badly packed tomatoes will not only ruin the tomato crop for sale, but will also mean lower prices. How tomatoes are packed depends on the end use to which they will be put. For example, some buyers may want fresh table tomatoes to be packed in small containers; other buyers may require dried tomatoes or tomatoes for processing. Even if tomatoes are just being sold at the farm gate, they will require some form of packaging, which can be a simple traditional basket.

Packaging is convenient for handling, transporting and storing tomatoes. It protects against pathogens, natural predators, loss of moisture, temperatures, crushing, deformation of tomatoes and bruising. It also has an aesthetic function.

Fresh tomatoes are often packed without stems. Mature green mature tomatoes can be stacked on top of one another in a package, since they are firm, but remember that not too many must be packed all at once, or the tomatoes at the bottom of the package will be deformed or bruised due to excessive weight on top of them. In all cases it is a good idea to use padding material at the bottom of packages and in between layers of tomatoes. Packaging material is expensive, in terms of total costs, and must not be wasted.

Some of the most common packaging materials:
- large green leaves
- clay pots
- baskets
- wooden crates
- cardboard crates
- cardboard boxes
- glass bottles or jars
- plastic bottles
- tin cans

It may be possible to form formal or informal associations with other farmers to organise packaging operations.

7.2 Storage

Storing tomatoes in tropical and subtropical climates can be difficult without cold storage. Sometimes fast marketing is the only solution.

Tomatoes that are to be sold fresh for table consumption must not be stored for long. Tomatoes that have been processed, for example into

tomatoes purée or juice, or dried or pickled can be stored from several months to a few years.

Storage facilities will vary according to marketing demands. Fresh table tomatoes will need to be stored somewhere where they can ripen or be stored for a short amount of time. At other times cold storage rooms are required. Processed tomatoes can be stored in typical storage rooms. Tomatoes often need to be stored at different points while they are in transit to a final destination. For example the tomatoes are picked when ripe and stored for a few days in a cool room, after which they transported to distant markets. During the journey the tomatoes will ripen to the market stage. Tomatoes that go for export are often transported in large containers that have cold storage facilities and ethylene treatment units.

Fresh tomatoes can be stored after they have been harvested and sorted or they can first be packaged before storing. Cooling before and during storage is important.

Tomatoes are sensitive to chilling. Tomatoes that suffer chilling injury fail to ripen, and do develop full colour and flavour. Their colour development is irregular, and they are likely to suffer premature softening, browning of seeds and increased decay. Tomatoes will deteriorate if they are kept at temperatures below 10°C for longer than 2 weeks or if kept at 5°C for longer than 6 to 8 days.

Clearly it is difficult to keep tomatoes at cool temperatures without the aid of cold storage facilities, especially in the tropics and subtropics. Hence storage methods have to be adapted to methods used locally. For example, one method of storing nearly ripe tomatoes is to place them in green leaves that have been washed. The leaves must be changed every 2 or 3 days until the product is sold. These operations need to be conducted in a cool location that is ventilated. Other forms of storage are tomato drying and purée production.

It is important to estimate what the costs of storage are likely to be, both for fresh tomatoes and well as for processed tomatoes. Costs will vary depending on the situation. For example if a farmer has her own storage facilities, she will have to calculate the costs for maintenance of the building, cleaning, loss of produce, etc. If a farmer does not have her own facilities she will have to calculate the costs of renting storage space and loss of produce.

To work out storage costs, first list all costs and then do the calculations. For example a simple cost calculation for storage space could be:

15 days storage required
100 crates of 15 kg each to be stored
Price per day per 15 kg crate stored: $0.02
Price of tomato loss (based on market price per kg) based on quality loss, rodents, theft: $0.15 per kg

So in numbers:
Storage time required costs = 15 x $0.02 = $0.30 per 100 crates = 100 x $0.30 = $30
Produce loss based on one crate of 15 kg = 15 x $0.15 = $2.25
Total storage costs for 15 days = $30 + $2.25 = $ 32.25

7.3 Processing

Processing allows fresh table tomatoes to be kept for longer. Processing can be done for farm household consumption and for commercial purposes. For farm household consumption it provides a more varied diet and also means tomatoes can be eaten out of season. For commercial purposes it is a way of generating extra income and means more products to offer to buyers.

Do not forget that the nutritional value of tomatoes, especially for water-soluble vitamins, is highest when they are consumed fresh. When sold fresh, good quality table tomatoes in top condition will usually yield the highest possible profit, especially early in the season. At the peak of the season however, supply may exceed demand, which

will cause prices to drop. If you do not have much storage capacity, the surplus tomatoes will rot, unless they are is preserved. Well-preserved tomato products can be kept for up to a year or more, depending on processing techniques and storage conditions.

New processing operations should not be commenced for commercial purposes just because some of the left over crop has not been sold. Processing is an operation that costs money and if you are new to processing, it is not advisable to invest money in these operations if you only have a small quantity of tomatoes to process. In this situation it is advisable to either sell the tomatoes at a lower market price or to carry out minimal processing operations for home consumption. If a processing activity is already in place then it is advisable to process tomatoes that have not been sold, keeping a careful eye on market prices to check whether the operation is economically feasible.

Alternatively, it may be possible for farmers to join together to organise processing operations. Joining forces creates an opportunity to share processing costs, and to process, pack and store greater quantities of produce. This may put farmers in a better position when it comes to bargaining with rural merchants, wholesalers and retailers.

Processing has a number of advantages:

- Enables out-of-season consumption.
- Improves farm-household nutrition.
- Improves storage capacities for tomatoes.
- Longer storage periods than for fresh tomatoes.
- Easier storage: bottles, jars, etc. can be stored more conveniently then fresh tomatoes.
- Lower post-harvest losses of tomato crop.
- Improves marketing of tomatoes by making them more convenient for buyers to use.
- Provides an opportunity for labelling, which will attract consumers.
- May provide a new taste for consumers.
- Allows the farmer to diversify his/her income.

Processing also has some disadvantages:

- Competition from very large commercial processors. They can sell processed tomatoes at prices that small scale processors cannot match.
- Costs of setting up processing facilities can be high.
- Costs of actual processing (labour, time, machines, etc.) can be high for a seasonal operation.
- Energy sources required for processing may be scarce and may cost a lot.

Like all post-harvest operations, processing requires good management.

Tomatoes destined for processing must be of good quality, uniform in size and appearance, and have a good aroma and taste. One of the biggest mistakes made is that low quality tomatoes are used for processing. It is important to remember that low-quality fresh tomatoes will result in low-quality processed tomatoes.

Field tomatoes must be weighed on arrival for processing. Weigh again once the product has been processed. Then it is possible to calculate product loss during processing, as well as the costs of processing. These figures are useful for determining the price of the product.

It is important to be aware of the by-products generated by tomato processing: tomato skins and seeds. These by-products have value when treated correctly and should not be or thrown away. For example seeds from drying tomatoes can be used as seed used for next year's crop; tomato skins can be used in farm animal feed.

People who are going to do the processing operations must be trained to carry out their jobs. It may be possible for one person to do all the processing operations. On the other hand it may be that one person does the reception, washing and classification tasks, while another does the peeling, bottling, sterilisation and labelling jobs.

Machinery and utensils used for processing may be as simple as a pestle and mortar, or a hand-driven tomato pulp extractor, bottles, jars, knives etc. Machinery and utensils used should be made of stainless steel, enamel, aluminium or plastic. Do not use equipment made of iron as rust will spoil the product. All equipment must be kept in good working order, and most importantly, kept clean.

Hygiene

Processing tasks must be clearly set out and it is very important that they are carried out in hygienic conditions. All people must have clean hands, and all equipment must always be clean, e.g. cutting surfaces. You must also ensure that there are no flies etc. in the processing space. Water used for washing must not be contaminated and materials used must be easy to clean.

If processing tasks are not carried out properly they will result in low quality processed products. Bottles and jars of processed tomatoes must be sterilised. Make sure there is enough fuel available to be able to boil water for sterilising. For example, a jar weighing 500 g must be boiled for 30 minutes, a jar weighing 750 g requires 40 minutes, and a jar weighing 1 kg needs 50 minutes to be sterilised. This requires a lot of energy.

Traditionally, the most important preservation methods used are drying and concentration (to juice, purée or paste). Both processes are described briefly here. A more elaborate description of these and other preservation techniques can be found in Agrodok No. 3: Preservation of fruit and vegetables. For both processes the tomatoes should be ripe, free of mould (cut out infected parts) and free of stems, leaves and dirt (wash).

Drying

In hot dry regions, sun drying is a cheap and relatively easy way of preserving. Firm, not too large plum or paste type tomato varieties (e.g. Roma type) are best suited for this purpose. Large, juicy varieties

are not suitable. The tomatoes may be blanched before drying (dipped in boiling water for 1-2 minutes) but this is not absolutely necessary.

Open air drying

Wash the tomatoes, cut them in halves or quarters and place in the sun on clean flat surfaces with the cut side facing up. Trays with plastic mesh stretched over them are well suited for this purpose. Place them on stands well above the ground. Cover the tomatoes with fine muslin cloth or mosquito netting to reduce contamination by insects, dirt and dust. Depending on air humidity and presence of wind, drying takes 2-5 days. The end product is dark, red, leathery pieces with a water content of 15-20 percent. Further drying (to a water content of 5 percent) yields a hard and brittle product that can be pounded into small flakes or a powder. These products are convenient to store and easy to use in soups and sauces.

Sun drying

If the weather is not hot and dry, artificial drying can be considered. An example of a simple solar drier is given in Figure 20.

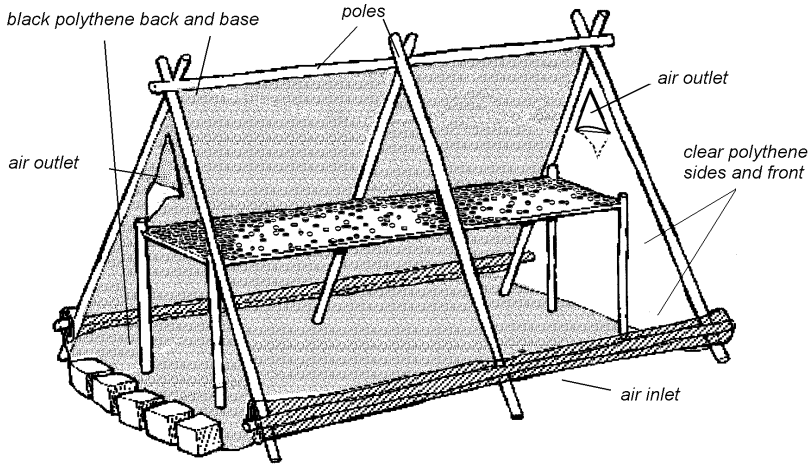

Figure 20: Solar tent drier

See Agrodok No. 3 for more examples of both solar and fuel driers. Take care that the temperature inside the drier does not exceed 65°C, as this will affect the taste of the tomatoes. Solar driers are cheaper than fuel driers, but the cost of the drier and fuel should be carefully calculated to see if it is economic to use this method of preservation.

Heat treatment and concentration

Preserving tomatoes and (concentrated) tomato products by means of bottling or canning generally yields products of fair nutritional value which can be kept for up to a year. The basic technique described here can be used for very small-scale operations. It requires:

- investments in equipment
- heat resistant containers (bottles or jars)
- a lot of fuel
- abundant clean water

The process involves placing the products in containers (e.g. bottles or jars) and heating them to a temperature that destroys micro-organisms that could be a health hazard or cause the food to spoil. The containers are sealed hermetically, which prevents re-contamination from outside. Before filling them, clean and disinfect the bottles and jars in boiling water or scalding steam. Heating times and temperatures depend on several factors. For tomato products the most important are:

- The number and kind of micro-organisms present. Hygiene is most important. All tools should be spotlessly clean. Hands should always be well washed.
- The shape and size of the containers. It takes longer to heat the contents of a large jar than those of a small bottle.
- The acidity of the product. Some dangerous bacteria form spores that can survive temperatures higher than 100°C, the boiling point of water. When the product is not acid enough, these spores can germinate and cause disease. A pH of lower than 4.5 is acid enough. Tomatoes have a pH value of between 3.9 and 4.6. Check acidity with a pH-meter (expensive) or litmus paper. If necessary add acid, such as lemon juice or citric acid.

Preparation of tomato pulp

Tomato pulp serves as a base for a range of preserves such as bottled juice, sauces, purée and paste. The first step therefore is to prepare tomato pulp. Use only fully ripe tomatoes. Most tomato varieties can be processed this way, but for concentrated products the smaller types with a higher content of solids are preferred.

a. Pan of hot water

b. Tomatoes in colander submerged completely

c. Rinsing and cooling

Figure 21: Blanching (household level)

To prepare pulp, sort, clean and wash the tomatoes. Next, they should be blanched: dip them in boiling water for 2 minutes (Figure 21). This will kill most (invisible) micro-organisms remaining on the skin and will make the next step of pulping and sieving easier.

Pulping can be done with pestle and mortar, a hand pulper (Figure 22) or pulping machines. Skins and seeds (which can serve as fodder for animals) are removed by straining through a coarse sieve first with holes of 4 mm and then a finer sieve with holes of 1 mm. Most hand pulpers and pulping machines combine pulping and sieving. The pulp is now ready for further processing, which should take place without delay. For most products the pulp should be heated right away to destroy micro-organisms and enzymes. This can be done in a stainless steel or aluminium pan over a fire, stir-

Figure 22: Hand pulper

ring continuously. Fresh tomato pulp can also be kept in a freezer, if frozen immediately after preparation.

Products from tomato pulp

Tomato juice

Tomato juice is prepared from the entire pulp. Salt and lemon juice can be added to taste. The addition of lemon juice or citric acid (4-5 g per litre) is recommended to make the product more acid. Bring the pulp to the boil quickly, pour it into bottles or jars and close these with lids or caps.

Leave some space under the lid: 0.5 cm for a jar and about 2 cm for a bottle. Preserve (pasteurise) bottles and/or jars by placing them in a bath of boiling water and heat them for at least 10 minutes (Figure 23). During storage a certain amount of separation of pulp and liquid may occur, but a clear separation into a pale liquid and a solid pulp layer is a sign of under-pasteurisation. Though it is not likely to be harmful, it looks less attractive.

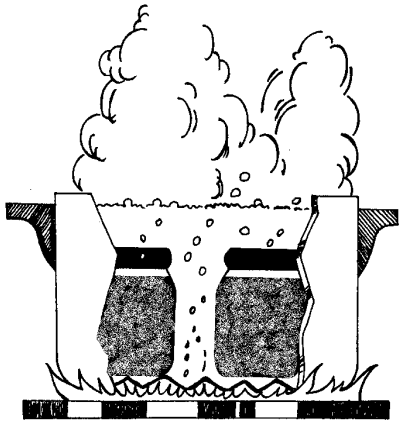

Figure 23: Pasteurising jars in a pan

Tomato purée and tomato paste

Purée and the more concentrated paste can be made from tomato pulp by carefully boiling it (stirring constantly to prevent burning) until enough water has evaporated. Fresh tomato pulp contains about 5-6 percent solids, depending on the tomato variety used. Boiling it down to half its volume will therefore yield a purée with 10-12 percent solids. Further evaporation will yield a product with a solids content of up to 35-40 percent. This tomato paste has a very dark red colour and a strong taste of cooked tomato. Salt can be added to taste.

Using a steam-jacketed boiling pan with steam from a boiler will improve the colour and speed up the process. However, this is expensive and should only be considered for larger scale operations. After it has been concentrated, pour the product into jars and pasteurise in a hot water bath (water temperature near boiling) for 30 minutes (Figure 23). The bright red colour of imported tomato pastes and purées can only be achieved by using vacuum evaporators at industrial scale. This is outside the scope of this book.

Another method for producing tomato paste is to hang the fresh, unheated, pulp in a sterilised cotton sack from a spring scale (Figure 24). The watery juice (the serum) will leak out and can be collected for further processing. After one hour, when the pulp has lost about half its weight, up to 2.5 % salt is added to the remaining pulp. This facilitates further draining and after another hour the weight will have fallen to one third of the original weight. The remaining paste can then be potted and pasteurised. The heating time in a hot water bath (water temperature near boiling) is about one hour.

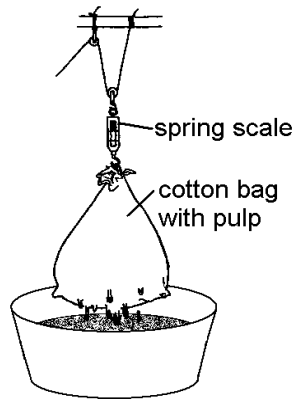

Figure 24: Straining sack

This tomato paste has a more natural flavour. The unsalted serum could serve directly as food for animals or be made into a soft drink. Add sugar and lemon juice to taste, bottle and pasteurise. The salted serum can also be used as a base for soups or sauces. After each use, the cotton sacks must be washed well and sterilised by submerging them for five minutes in boiling water.

8 Marketing

Marketing is an important activity in any business and should be approached systematically. If well planned, it will yield profit. If it is not properly done it may lead to heavy losses. That is why you need to adopt the best marketing methods that will yield profit in your business.

At the market, products are sold in bulk (wholesale) or in small quantities (retail). The prices are determined by the supply of and the demand for the products. Negotiations may be needed to finalise a sale. This process of buying and selling is called marketing. It includes all aspects of moving products from producers to the final consumer.

8.1 What is a market?

Selling tomatoes involves transactions in which tomatoes are exchanged for money. This requires understanding of how, where and when transactions take place. Typically transactions take place in markets.

The market

A market is the place where products are exchanged. It is a location, for example a village market, a retailer's shop or a roadside stall. At these markets, sellers offer their produce for sale and consumers are able to choose and buy produce. In other words, it is the place where 'suppliers' (small-scale businesses, such as farmers, retailers, etc.) meet 'demanders' (customers who are buying for themselves and their families, and business customers who are buy for processing or reselling).

A farmer has to offer a certain quantity of products to be able to make enough money to survive. What the farmer has to earn is profit. Profit is the difference between what the farmer has paid to produce the tomatoes and the price the farmer receives for his or her tomatoes.

Profit
Farmers need to obtain a price for tomatoes that is higher than the costs involved in producing and marketing tomatoes.

Supply and Demand

Prices of products are determined by suppliers and demanders. Suppliers are all the people who can and want to sell tomatoes. Demanders are all the people who want to buy tomatoes. If for example demand is high and supply is low, the price of the product in demand will rise. For example if there is a lot of demand for tomatoes, but there are few suppliers of tomatoes (few sellers), the price of tomatoes will increase.

Demand is influenced by:

- Tastes: consumers all have different tastes.
- Season: consumer demand changes according to the season.
- Location: consumers living in different places have different demands for products.
- Income: consumers' demand for produce depends very much on how much they earn.
- Population: an increase or decrease in population will affect consumer demand.
- Age: affects quantity demanded and price.
- Price: the higher the price, the lower demand will be. The lower the price, the higher demand will be.

Supply is influenced by:

- price
- season
- weather
- costs of production
- change in production techniques
- prices of other products
- quantity available
- import

The price is simply an agreed price between suppliers and demanders where both are willing to exchange.

Market research

Before deciding to grow tomatoes to sell fresh or processed, it is important to find out whether there is a market for your product. This is called market research.

A typical marketing research process is as follows:
Step 1: Recognise that you need information
Step 2: Define clearly the objectives of your research
Step 3: Find out what methods can be used to gather the information
Step 4: Understand the best methods for gathering information
Step 5: Gather the information
Step 6: Understand the information
Step 7: Gain knowledge and learn from it
Step 8: Make decisions based on new knowledge

8.2 Financing

Any business activity needs money. This is necessary to be able to pay for items such as farm tools, fertilisers, seeds, etc. However farmers sometimes have difficulty finding the money they need to pay for all the expenses. This is because farmers have to pay for raw materials at the start, and then wait quite some time to able to sell the tomato crop. Money made from sales of the previous tomato harvest season can be of great help. It is important to save part of the money earned, so it can used to buy the inputs required for the next production cycle. Money can also be borrowed and from many sources. However, like all other products money also has its costs. The cost of borrowing is called the interest rate. This is the cost that the farmer has to pay for using money to finance production and marketing. It is important to work out how much money has to be paid back and when. It is also important to consider how the payback period will affect the money in your pocket. This is called the liquidity of the business.

Make a list of all your expenses and a list of all your sources of income for each period of time. Compare the two to see if you have enough money to carry out all farming operations you plan to do.

There are various ways to obtain money. You may be able to borrow from family members, such as close or distant relatives. Advantage: the money is easily accessible and interest rates can be low.

Money can also be borrowed from money lenders. They are often the only source of money in an area and can charge quite high interest rates, but they are easily accessible.

Banks are also available for loans, but usually banks are not interested in very small loans and demand proof of property as a guarantee. On the other hand, banks charge low interest rates, well below those of money lenders.

Rural traders, processors, wholesalers or retailers can be good sources of money. They may be willing to lend money because it ensures their own supplies and it can create a good working relationship with the farmer.

Another good source of money for borrowing may be non-governmental organisations (NGOs) that offer assistance to small farmers. These are called micro-finance institutions (MFIs). Some of them help small-scale producers to organise themselves into formal or informal associations. In many developing countries this has proved to be the best method of getting money to finance production and marketing.

Associations

Sometimes farmers unite together, to form cooperatives or informal associations, for example marketing groups or production groups. Pooling resources together can have big advantages for small farmers. The size of the association may for example encourage banks to lend larger sums of money than they would otherwise be willing to lend to

individuals. Associations can also obtain advantages when buying raw materials. More raw materials can be bought at one time, for example farm tools, hence prices may be lower. Also associations may have better negotiation power with rural traders, processors, wholesalers and retailers. Importantly, associations can often help with market research.

How to sell

Farmers must decide how to sell their produce, in other words which marketing channel to use. Farmers may sell their products directly to final consumers at the farm, at the local village market, or at the roadside. It may also be possible to sell produce to a rural trader, processor, wholesaler, retailer, street hawker, exporter and also institutions such as schools, hospitals, hotels etc. It is important to consider here which method will provide the most advantages for the farmer. In other words, which method will guarantee the best possible prices for your tomato products? For example, part of the fresh produce may be sold to a processor, part to a wholesaler and part directly at the local village market. Many combinations of selling methods are possible.

Where to sell

Farmers have to decide where to sell their produce. For example, if a small-scale farmer wants to sell to a processor, it is important to find a processor in a good location. This could mean a processor that is nearby, but it might mean a processor further away, but who offers better prices. Selling at the local village market might be good, but you might get higher prices if you sell at a market in a bigger town. However, although prices may be higher at urban markets, costs may also be higher. You have to compare prices at different markets and also the transport costs to reach the location. For example selling at a village market may cost little in terms of transport and setting up a stall. If a town or city is further away from the farm, the cost of transport will be higher and you may have to pay a fee for setting up a stall.

When to sell

When to sell involves two important factors for a farmer. The first factor is earning the most money by choosing the right time to sell, usually when prices are higher. The second factor is reducing risk; the prices of fresh table tomatoes and processing tomatoes usually follow a regular pattern.

The nature of fresh tomatoes and the fact that they are not easy to store for long means that farmers are usually obliged to sell at harvest time, and receive low prices. It is worthwhile looking around for the best possible price from buyers. These could include exporters or processors. This may involve a lot of negotiation, and it is good to carry out negotiations well before the produce is ready to harvest.

In some cases farmers can sell their crop before they have even planted it. This is often done for fresh tomatoes destined for processing by large processing companies. These companies need an assured supply in terms of quantity and quality, and may be willing to buy the produce beforehand. They often base the price they offer on past price patterns, and it is usually a little bit below market prices. This may seem unfair to the farmer, but it is good method of reducing price risk at harvest time and ensuring your income. Clearly the farmer must deliver the required quantity and quality. Risk is reduced, but not fully eliminated for the farmer.

When to sell processed tomato products will depend on demand for them. Some processed products can be sold throughout the year to many final consumers, or they can be sold in bulk to an institution, such as a school or hospital. If you can store your processed tomatoes you will have more time to decide when and where to sell your products, based on buyer demand.

Costing

Farmers need to list all their marketing costs. These include:

- labour: for harvesting, handling, washing.
- processing: equipment.
- packaging: wooden crates, glass bottles.
- storage: storage shed, renting storage space.
- family consumption: the quantity of tomatoes used for family needs
- transport: bicycle, animal-drawn cart, motorised vehicle.
- produce losses: damage, theft.
- capital costs: interest rates on borrowed money, storage of processed tomatoes.
- fees, taxes, unofficial payments: fee for urban markets, porters to unload produce, government taxes, road payments while in transit.
- unexpected costs: costs of accessing an urban market may have increased etc.

It is always good to allow for some unexpected costs when calculating production and marketing costs. These include:

- labour: for ploughing, planting, scouting for pests, applying fertiliser, etc.
- capital costs: equipment such as farm tools, buckets, depreciation, etc.
- organic fertilisers, fungicides and pesticides: nitrogen, phosphorus, potassium, etc.
- land: renting land, etc.
- water: irrigation, etc
- unexpected costs: more insecticide applications due to high level of infestation.

Record-keeping

For keeping records it is vital that farmers keep track of all their costs and sales. They must keep written records of these. This will help the farmer understand his daily, weekly and monthly costs and sales. Keeping track of costs and sales is called accounting.

Records help farmers to assess how their farm is performing. Record-keeping takes a lot of time and requires discipline, but gives the farmer insight into the following matters:

- what has been bought from other people, such as farm suppliers
- produce that has been sold
- payments made to labour
- the total value of the farm as a business
- help in understanding where losses are being made
- payments made to the farmer as an employee of his/her own business

Good record-keeping will give the farmer a clear picture of how much money is coming into and going out of the business in specific time periods. Importantly, record-keeping not only look shows money flows, as we saw above with cash flow, but it enables the farmer to evaluate all aspects of the farm business in money terms.

In record-keeping, what is owned by the farmer (the farmer's possessions) are called assets, e.g. farm tools. What the farmer owes (things that are not the farmer's possessions) are called liabilities, e.g. money borrowed. Accounts are kept to keep track of the assets and liabilities a farm business may have. An account has two sides, like a weighing the scale. One side shows the assets and the other side shows the liabilities.

Table 4: Cash account for the farm

Assets		**Liabilities**	
Cash	$ 90,-	Loan from friend	$ 18,-
Tools	$ 20,-	Loan from bank	$ 132,-
Shed	$ 40,-		
total	$ 150,-		$ 150,-

In accounts for record-keeping, assets and liabilities must balance. Note in Table 4 that the total in each column, assets and liabilities, equals the same amount, $150. The reason is simple: when a farmer makes a cash payment, both cash amount in assets and liabilities will be reduced at the same time. For example, in Table 4, if the farmer pays back the loan he obtained from a friend, $18, he reduces his cash assets by $18, but he also reduces his liabilities by $18. This double action keeps the account in balance. If the account does not balance the farmer will know that a mistake has been made. This is a good control system for the farm business.

Farming tomatoes requires not only good production but also good marketing functions.

About PROTA

The Plant Resources of Tropical Africa (PROTA) programme was initiated in 2000 and developed into an international partnership of 11 institutions in 11 countries during the Preparatory Phase 2000–2003. Since February 2003, PROTA has been operating as an international foundation domiciled in Wageningen, the Netherlands.

PROTA is a major 'information brokerage and knowledge repatriation' programme. The objectives are to bring the 'world literature' on the useful plants of Tropical Africa, now accessible only to the resourceful happy few, into the (African) public domain, and contribute to greater awareness and sustained use of the plants, with due respect for traditional knowledge and intellectual property rights. PROTA will describe the estimated 7,000 useful plants during the Implementation Phase 2003-2012. The information carriers will be freely accessible Web databases (www.prota.org), a low-price Handbook and CD-Rom series featuring 16 Commodity Groups, and Special Products for each commodity group for rural development, education, research and policy actors (all in English and French).

PROTA 1: Cereals and pulses
PROTA 2: Vegetables (2004)
PROTA 3: Dyes and tannins (2005)
PROTA 4: Ornamentals
PROTA 5: Forages
PROTA 6: Fruits
PROTA 7: Timbers
PROTA 8: Carbohydrates
PROTA 9: Auxiliary plants
PROTA 10: Fuel plants
PROTA 11: Medicinal plants
PROTA 12: Spices and condiments
PROTA 13: Essential oils and exudates
PROTA 14: Vegetable oils
PROTA 15: Stimulants
PROTA 16: Fibres

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World list of seed sources, published by the FAO:
http://www.fao.org/scripts/wlss/query/wlsscros.idc?function=form
Copies may be purchased from CTA's bookseller SMI (Distribution Services) Ltd, P.O.Box 119, Stevenage, Hertfordshire SG1 4TP, UK
Tel: (44) 1438 748 111, Fax: (44) 1438 748 844
E-mail: CTA@earthprint.co.uk, Website: http://www.earthprint.com
When you apply for seed, do provide the following information:
1 main use of the product (dried, fresh, for direct use or sale)
2 months in which sowing and planting takes place
3 annual rainfall in mm
4 the dry months
5 minimum and maximum temperatures
6 information about the soil, such as pH and fertility
7 altitude of fields which will be planted
8 seed import regulations

Useful addresses

Asian vegetable Research & Development Centre
POB 42, Shanhua, Tainan 74199, Taiwan
Phone: +886 6 583 7801, Fax: +886 6 583 0009
Email: avrdcbox@avrdc.org, Website: www.avrdc.org

ATTRA , Appropriate Technology Transfer for Rural Areas
(organic tomato production) POB 3657, Fayetteville, AR 72702, USA
Phone: +800 346 9140, Website: www.attra.org

East West Seed Company
Km 54 Cagayan Valley Road, Sampoloc, San Rafael, 3008 Bulacan, Philippines
Email: infoph@eastwestseed.com, Website: www.eastwestseed.com

ECHO, Inc. (*samples of seeds for free)*
17391 Durrance Road, North Fort Meyers, Florida 33917, USA
Phone: +239 543 3246, Fax: +239 543 5317
Email: echo@echonet.org

ICAO - International Cooperative Agricultural Organisation
(www.agricoop.org)

IFOAM – International Federation of Organic Agricultural Movements (www.ifoam.org) for information about organic farming and certification.

OISAT – On-line information service for non-chemical pest management in the Tropics (www.oisat.org) hosted by PAN- Germany.
Phone: +49 40399 19100

PANNAR SEED, *specialised in seeds for Africa*
Pannar Seed P/L, P.O. Box 19, Greytown 3250, South Africa
Tel: +27 33 4131131, Fax: +27 33 4131261
Website: www.pannarseed.com, E-mail: info@pannarseed.co.za

Glossary

Ascorbic acid	White crystalline vitamin, $C_6H_8O_6$, found in citrus fruits, tomatoes, potatoes, and leafy green vegetables and used to prevent scurvy; also called vitamin C.
Biological control	Control of pests by disrupting their ecological status, e.g. through the use of organisms that are natural predators, parasites, or pathogens; also called biocontrol.
Carcinogenic	A descriptive term for things capable of causing cancer.
Dietary fibre	Bulky part of food that cannot be broken down by enzymes in the small intestine of the digestive system.
Enzyme	Any of numerous proteins or conjugated proteins that are produced by living organisms and act as biochemical catalysts.
Essential amino acid	An alpha-amino acid that is required for protein synthesis but cannot be synthesised by humans and must be obtained in the diet.
Growth regulator	A chemical substance used to destroy or inhibit the growth of plants, especially weeds.
Herbicide	A chemical substance used to destroy or inhibit the growth of plants, especially weeds.
Infrastructure	The basic facilities, services and installations that a community or society needs to function, such as transportation and communications systems, water and power lines, and public institutions including schools, post offices, and prisons.
Lycopene	A red carotenoid pigment, $C_{40}H_{56}$, found chiefly in blood, the reproductive organs, tomatoes, and palm oils.

Mineral	An inorganic element, such as calcium, iron, potassium, sodium, or zinc, that is essential to the nutrition of humans, animals, and plants.
Monoculture	The cultivation of a single crop on a farm or in a region or country.
Pathogen	An agent that causes disease, especially a living micro-organism such as a bacterium or fungus.
Pesticide	A chemical used to kill pests, especially insects.
Polythene (PE)	A polymerised ethylene resin, used especially for containers, kitchenware, plastic bags and tubing, or in the form of films and sheets for packaging.
Relative humidity	The ratio of the amount of water vapour in the air at a specific temperature to the maximum amount that the air could hold at that temperature, expressed as a percentage.
Retailing	The functions and activities involved in the selling of commodities directly to consumers.
Variety	A taxonomic subdivision of a species consisting of naturally occurring or selectively bred populations or individuals that differ from the remainder of the species in certain minor characteristics.
Vermicompost	(or worm compost) Is produced by feeding kitchen scraps and shredded newspaper to worms.
Vitamin	Any of various fat-soluble or water-soluble organic substances essential in minute amounts for normal growth and activity of the body and obtained naturally from plant and animal foods.