A Guide to IPM in Tomato Production

in Eastern and Southern Africa

by

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and

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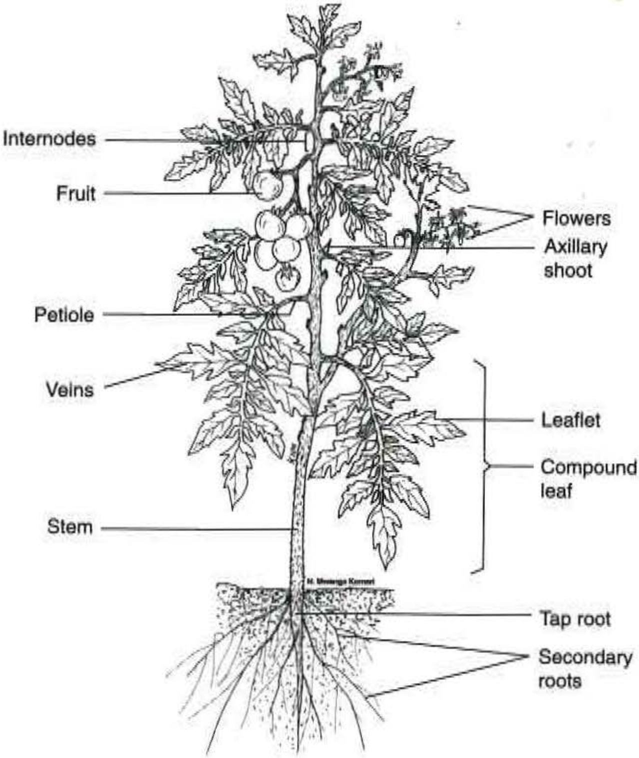

Figure 1. A tomato plant

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Disclaimer

Where specific pesticides have been mentioned in the text, these are generally given as examples and should not be regarded as being exclusive of others. Mention of specific pesticides or trade names in the text does not imply any preference or advantage over similar compounds not mentioned by name. Since some countries have restrictions on the use of certain pesticides, it is advisable to check local regulations before purchase or use.

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The Technical Centre for Agricultural and Rural Cooperation (CTA) was established in 1983 under the Lomé Convention between the ACP (African, Caribbean and Pacific) Group of States and the European Union Member States. Since 2000 it has operated within the framework of the ACP-EC Cotonou Agreement.

CTA's tasks are to develop and provide services that improve access to information for agricultural and rural development, and to strengthen the capacity of ACP countries to produce, acquire, exchange and utilise information in this area. CTA's programmes are organised around four principal themes: developing information management and partnership strategies needed for policy formulation and implementation; promoting contact and exchange of experience; providing ACP partners with information on demand; and strengthening their information and communication capacities.

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Introduction

Tomatoes, or *Lycopersicum esculentum* Mill (Solanaceae), are one of the most widely cultivated vegetable crops in Africa. They are grown for home consumption in the backyard of almost every homestead across sub-Saharan Africa. They are an important source of vitamins and an important cash crop for both smallholders and medium-scale commercial farmers.

Tomato yields in smallholder cropping systems in the region are generally far below the potential of the crop. Average yields as low as 7 tonnes/ha have been reported from Tanzania and 10 t/ha from Uganda, while yields as high as 100 t/ha have been recorded from commercial farmers in Zimbabwe. There are several reasons for the low yields. Among these are low quality seeds, non-availability of inputs, sub-optimum crop husbandry, and a large number of pests and diseases.

The major pests and diseases of tomatoes in the region were prioritised at a Tomato-Planning Workshop held in Harare, Zimbabwe in October 1995. The meeting was organised by the GTZ-IPM Horticulture Project with participants from Kenya, Mozambique, Tanzania, Uganda, Zambia and Zimbabwe. The main pests were identified as arthropod pests (red spider mites and russet mites), insects (fruitworms, whiteflies, leafminers and thrips) and diseases (early and late blights, bacterial wilt, *Fusarium* wilt, bacterial canker and nematodes) (Table 1). Viral diseases were considered very important but they could not be prioritised due to lack of information. Recent surveys have shown that viral diseases are a major constraint to tomato production in the eastern and southern Africa region.

Table 1. Regional prioritisation of tomato diseases and pests in eastern and southern Africa

Priority	Diseases	Arthropod pests
1	Late blight	Red spider mites
2	Early blight	African bollworm
3	Nematodes	Whiteflies *(Bemisia tabaci)*
4	Bacterial wilt	Leafminers
5	*Fusarium* wilt	Thrips *(Thrips tabaci)*
6	Bacterial canker	Russet mites

1 = highest priority.
Source: GTZ-IPM Horticulture Project. Proceedings of Tomato Planning Workshop for Eastern and Southern Africa region. Harare, Zimbabwe 16–20th October 1995.

Current pest control practices in the region rely heavily on application of pesticides. Intensive use of pesticides creates a health hazard to the farm workers engaged in production, and also leads to contamination of the produce and the environment. In addition, injudicious pesticide applications prompt outbreaks of some important pests like red spider mites, whiteflies and leafminers.

Integrated pest management (IPM) programmes for tomatoes have been developed in several countries and elsewhere in Africa. Since the complex of tomato pests and diseases varies from region to region, IPM cannot be transplanted. However, the IPM principles and techniques can be adapted to local conditions.

In this manual descriptions and pictures of major pests and diseases in the region are given to aid in their identification. The occurrence of these pests and diseases during the growing cycle are presented in the flow chart in Figure 2. Also provided in the manual is information on the kinds of damage caused and control options. Examples of IPM programmes elsewhere are mentioned where relevant, and general IPM principles for tomatoes are listed.

Integrated pest management for tomato

Integrated pest management (IPM) is a strategy that focuses on the use of as many methods as possible to minimise problems caused by pests (insects, mites, diseases and weeds). When deciding on a method or technique for management of a particular pest, particular consideration should be given to its possible effects on other organisms, such as other pests, natural enemies and pollinators. When combining several methods, possible interference or synergism among them should be taken into consideration. In particular, pesticides applied for controlling a given pest may affect the natural enemies of this or other pests. Therefore, pesticide use must be minimal and only when it is needed.

An important tool in IPM is scouting. This entails field observation on a regular basis during the crop production cycle for pests, diseases, weeds and crop health (nutrition and water needs). Proper field observations give information about the status of the crop and enable decisions to be made on appropriate intervention(s) to be taken, including fertiliser application, irrigation or pest and disease control. (For more information on scouting see Annex 3.)

IPM programmes for tomato have been developed and are being used in several countries. Although some programmes have been developed for field crops, more work has been dedicated to greenhouse crops, particularly in the USA and Europe. The complex of tomato pests varies from region to region. Some pests are of worldwide distribution, while others are restricted to one continent or smaller areas, and some are of local distribution. IPM cannot be transplanted, but the principles and techniques can be adapted to local conditions. Knowledge of the pest–host plant interrelations is vital for the development of an IPM programme.

It is very important for growers to correctly identify the insect or disease causing the damage, the extent of the damage, and the stage of the crop, before making any control decision. Plates 7–47 show the major pests and diseases of tomato to aid in their identification. Figure 3 presents the major pests and diseases of tomato in the region and their occurrence during the growing cycle of the crop.

Control methods used in IPM for tomato

Biological control

Biological control is implemented through conservation, augmentation and importation of natural enemies such as predators, parasitoids, pathogens and antagonists. (For more information on natural enemies see page 14.)

Although natural enemies cannot always prevent economic damage, they are important for the control of pests. Often the effectiveness of existing natural enemies in regulating pest numbers is affected by adverse farming practices such as the use of broad-spectrum pesticides. One example is the case of leafminers. They are normally controlled by naturally occurring parasitoids. However, the use of insecticides to control other pests has disrupted the natural control of leafminers, and as a result, leafminers have become secondary pests of tomatoes.

Conservation and encouragement of the natural enemy populations are important elements in pest management. One way of preserving existing natural enemies is to avoid or reduce the use of pesticides, particularly broad-spectrum pesticides that kill a wide range of pests. If pesticides must be used, selective pesticides that target only one or a few related pests are preferable. For example, pathogens such as commercial products based on *Bacillus thuringiensis (Bt)* have been successfully used for control of fruitworms, alone or in combination with parasitoids and predators.

The effectiveness of existing natural enemies can be improved by cultural or environmental manipulations or modifications such as augmentation of food sources. This might mean, for instance, providing flowering plants as nectar sources and/or provision of artificial food sources. For example, ants and lacewings (both natural enemies) could be attracted to the crops with sugar baits. Mixtures of yeast, sugar and water increase the numbers and fecundity of lacewings. Application of compost improves the soil condition and the effectiveness of soil microbes that limit the build up of pathogens in the soil.

Natural enemies can be attracted to crops through such methods as encouraging the growth of plants that are attractive to them (by overlapping of different crops on adjacent plots), or by intercropping. These measures would involve changes in the pattern of planting and would require studies of the interaction of the parasitoid with the pest/crop.

In some cases, where locally occurring natural enemies are not able to control pests, releases of imported or locally existing natural enemies is practised. This is known as 'augmentation biocontrol'. For instance, farmers can bring natural enemies from outside the field. This often involves mass rearing of selected natural enemies. High quality natural enemies must be economically produced in large numbers. To achieve satisfactory control, enough parasitoids need to be released at the right time. The releases may need to be repeated.

Natural enemies are extensively used in greenhouse tomato production and increasingly in the field in many countries in Europe, America and Asia. For example, the egg parasitoids *Trichogramma* spp. and larval parasitoids are being used in combination with applications of *B. thuringiensis* for control of the fruitworms *Helicoverpa armigera*. Predatory mites are used for control of red spider mites and tomato russet mites; the parasitic wasp *Encarsia formosa* is used for control of whiteflies, and several parasitoids are used for control of leafminers.

The timing of introductions of identified natural enemies can be determined by monitoring the presence of pests through crop scouting and/or by trapping. For instance, light and pheromone traps are used for trapping the bollworm adults, to detect the start of an infestation, and as a signal to begin scouting for immature stages on the crop. Yellow sticky traps are used for monitoring the greenhouse whitefly for effective release of the parasitoid *Encarsia formosa* Gahan in IPM programmes in Europe, USA, South America and Asia.

Mechanical control

Mass trapping: This method makes use of traps to catch a large proportion of the pest population. Traps used for monitoring (pheromone, coloured sticky traps, etc.) can also be used as a control method when pest densities are low. Yellow sticky traps have been used for control of leafminers, whiteflies and thrips, and have been fairly effective in preventing insects from invading greenhouse tomatoes. Several types of pheromone traps have been developed for monitoring and for mass trapping fruitworms (*Helicoverpa armigera*) on tomatoes.

Use of screening: Screened greenhouses and muslin or polypropylene tents prevent non-persistent virus transmission by insects. However, the increase of sun scorching and fungal diseases has been observed when the tents are used for a long period. They should remain in place until the pest season is over. Due to the costs involved, these methods are probably more likely to be used by large-scale farmers.

Hand picking: Removal of pests by hand is practical in small plots.

Ploughing: This kills pests in the soil such as pupae of caterpillars and thrips, and kills weeds by exposing them to the sun and natural enemies.

Use of plant resistance

Plant breeding for increased genetic resistance to pest damage can be an important component of IPM programmes. The slower development of populations of insects and mites on resistant varieties favours the pest-suppressing effect of other control measures. Moreover, once such a variety is available, no extra labour is required and this method is therefore economical. Breeding for resistance to diseases, nematodes and viruses has been an essential part of commercial breeding programmes. Lately attention has been given to resistance to insect and mite pests.

Cultural methods

Managing the habitat or the way a crop is grown prevents or reduces pest damage. Some cultural methods are described below.

Mixed cropping systems: Mixed cropping of tomato reduces pest infestation, and sometimes trap plants (plants that are attractive but tolerant to the pest), such as cucumber, can be used in the field to attract pests away from tomatoes. Maize and sorghum have been recommended as trap crops to divert the African bollworm from cotton. Female moths are very much attracted to these crops for laying eggs, but the survival of the caterpillars is low. In addition, these plants, particularly sorghum, attract natural enemies such as anthocorid bugs during flowering. However, these measures would imply changes in the pattern of planting, and require further studies in the pest–host plant relationship. Acceptance of the system by the farmers is essential.

Pest and disease avoidance: Pests can be avoided, by regulating the timing of planting. Whenever possible, grow crops when conditions are favourable for the crop but not for pests and diseases. For example, spring tomato in Israel and Jordan escapes TYLCV virus because its vector, the whitefly *(Bemisia tabaci)* does not start migration until late in the season. This approach would be feasible against one particular pest. However, different pests attack tomato during almost every season, and it is not possible to escape all of them.

Providing conditions for growing healthy plants that can withstand pests better: For instance, this would include ensuring adequate conditions for the crop, such as good soils, proper irrigation, proper feeding, proper spacing, and good nursery management to start the crop with healthy, vigorous seedlings.

Sanitation: This means destroying sources of infestation such as crop residues (stems, leaves, fruits, etc.) and weeds. Crop residues can be composted, buried underground or burned.

Staking or trellising of indeterminate varieties: This helps to avoid diseases, since it improves air circulation in the crop and prevents plant parts, including the fruits, touching the soil.

Avoiding dense planting: Always use proper spacing for each variety.

Crop rotation can help to reduce build-up of soil pests and diseases. For instance, accumulation of root-knot nematodes can lead to stunted plants and reduced yield. Rotation with plants which are not susceptible to nematodes, such as onions and maize, will prevent build-up of nematodes and in some cases reduce their numbers. Crops that are easily attacked by nematodes like the ones belonging to the same family as tomatoes (Solanaceae) such as pepper, capsicum and aubergine, should not be used in crop rotation since they will maintain or increase the number of nematodes and other soil-borne diseases.

Solarisation: The soil is covered with clear or transparent polyethylene sheets (mulch) for a period of two to three months depending on the amount of sunshine. Its successful application will depend on enough sunshine, good land preparation and land availability to allow rotation and fallow (up to 6 weeks). It is more suitable for nursery beds and small plots but can also be used in the field. This may require a change on how tomatoes are currently planted. This is how to solarise the soil:

- Prepare the land (plough, harrow, irrigate).
- Apply the mulch. Make sure the mulch is properly tacked in to prevent heat and moisture loss.
- Do not remove the mulch until the process has completed the duration.

These are some of the advantages of the method:

- Reduces soil-borne pests (insects, diseases, nematodes and weeds).
- Increases the range and effectiveness of soil-inhabiting antagonists, which compete or inhibit the micro-organisms causing soil-borne diseases.
- Improves plant health, vigour and yield in general.
- Improves soil condition.
- Reduces soil salinity by preventing upward capillary movement of the soil water and its concentration by evaporation on the surface.

Use of pesticides

Pesticides (insecticides, fungicides, acaricides, nematicides, etc.) should be considered as a last resort, particularly the use of synthetic pesticides.

They should be used only when other measures have not proved successful in maintaining pests at acceptable levels.

When pesticides are needed, preference should be given to selective pesticides (IPM-compatible), which have little or no effect on natural enemies. These include biopesticides (pesticides whose active ingredient is a living organism) such as microbial pesticides (based on micro-organisms such as *Bt*) and botanical pesticides (pesticides derived from plants).

Some botanical pesticides are good alternatives to synthetic pesticides in IPM programmes. For instance, neem-based pesticides are effective for control of a broad spectrum of pests (insects, mites, fungal diseases, nematodes) and are not usually harmful to natural enemies. However, products based on neem oil have more and stronger side effects on non-target organisms than oil-free products. Good control of tomato pests, particularly fruitworms, whiteflies and russet mites has been achieved with neem products alone and in combination with other pesticides. Neem-based pesticides discourage feeding in many homopteran insects. This is particularly important in the case of vectors of virus diseases such as whiteflies. Amending the soil with neem leaves or neem cake is a common method used elsewhere against root-knot nematodes.

The amount of pesticide used can be reduced by:

- Avoiding preventive spraying whenever possible. Decisions on spraying should be based on regular scouting of the crop.

- Avoiding blanket application. Preferred application methods include seed treatment, use of granules, baits or spot treatment.

The overuse and careless use of pesticides has resulted in the development of resistance in pests such as spider mites, fruitworms, leafminers and whiteflies to the major classes of insecticides in many countries. Repeated use of synthetic pyrethroids, particularly when they are used for several consecutive seasons, can result in development of resistance and an increase in pest pressure. Development of resistance to pesticides can be avoided or delayed through rotation of pesticide groups (different chemical types) to minimise selection for resistance. Preventive applications and applications of dosages lower than recommended should be avoided since this may lead to resistance as well.

See also Annex I on Guidelines on Best Use of Pesticides.

Natural enemies as biological control agents

Natural enemies (living organisms that feed on crop pests) are usually present in tomato crops and include predators, parasitoids and pathogens.

Predators

Predators feed on all stages of the host (pest) eggs, larvae, pupae and adults. Each predator requires a number of prey individuals to enable it to reach maturity. The main predators include:

Ladybird beetles: Adult ladybird beetles are small, oval to nearly spherical in shape with short antenna. They are often brightly coloured with black markings, black with bright spots or shiny black (Plate 1). Larvae are soft-bodied, and usually long and thin in shape. Their colour varies from black to dark brown with various types of markings (Plate 1). Some larvae are covered by wax resembling mealybugs. Adults and larvae of most ladybird beetles are important predators of aphids, scales and mites.

Predatory bugs: Adults and nymphs of the predatory anthocorid bug (*Orius* spp.) are important predators of thrips, mites and aphids and of eggs of Lepidoptera (moths and butterflies) (Plate 2).

Hoverflies: Adults are usually brightly coloured with yellowish-brown or black stripes. They feed on nectar of flowering plants and can often be seen floating in the air. The larvae resemble maggots and are usually greenish. They feed on aphids, mites, thrips, small caterpillars and insect eggs (Plate 3).

Lacewings: The wings of the adults are usually greenish (green lacewings) (Plate 4) or brownish (brown lacewings). Eggs are laid at the end of tiny stalks, usually on the foliage. The larvae have long sickle-shaped mandibles (Plate 4). Adults feed on nectar and sugary substances. The larvae feed on soft insects such as aphids, thrips, small caterpillars and insect eggs.

Predatory mites: Predatory mites eat plant-feeding mites and thrips. They are very small and difficult to see with the naked eye. They can be distinguished from spider mites since they are bigger, have longer legs and move faster than spider mites (Plate 5).

Other predators such as spiders, ants and praying mantids, which feed on many different types of insects, are also important in natural control of pests.

Parasitoids

Parasitoids are the immature stages (larvae) of insects that live on (external parasitoids) or in (internal parasitoids) the host (pest). The parasite completes its development from egg to adult on a single host, killing it. Parasitic wasps are important natural enemies of leafminers and whiteflies and attack eggs and larvae (caterpillars) of moths and butterflies. For instance, *Trichogramma* wasps parasitise the eggs of moths and butterflies, including fruitworms (Plate 6).

Pathogens

Pathogens include fungi, bacteria and viruses and are naturally found attacking pests in the field. A few of them, such as the bacterium *Bacillus thuringiensis (Bt)* which kills caterpillars, are commercially available in many countries. In tomatoes, *Bt* is used for control of fruitworms *(Helicoverpa armigera)*. It has the advantage of being specific; that is, it affects only caterpillars, and not the natural enemies. When not commercially available, farmers can produce their own homemade pesticides by collecting the diseased larvae, crushing and mixing them with water. Then the liquid is sprayed onto the crop. The pathogen will infect other pests in the crop and kill them.

Principles and options of IPM for tomato

Nursery stage

- Site the nursery far away from the previous season's crop.
- Prepare the seedbed properly: preferably use forest topsoil or compost; burn plant trash on seedbed surface for 30 min and after cooling, mix soil with equal amount of compost. In semi-arid areas soil solarisation of seedbeds can be done. However, all these options depend on availability of materials and comparative costs.
- Use certified disease-free seed of high yielding and resistant or tolerant varieties to diseases. Cheyenne, Denise, Jackal, Michel, Perlina, Rover, and Sophia, Peto 86, Strain B, and Fiona F1 have been reported to be resistant/tolerant to Tomato Yellow Leaf Curl Virus (TYLCV). In hot lowland areas, opt for heat-tolerant varieties (check with your local seed dealer).
- Where farmers use their own seed, the seed should be treated with a fungicide and an insecticide. In areas where powdery mildew and TYLCV are endemic, dress the seed with triadimenol and imidacloprid.
- Always select the first-formed fruits for seed extraction from disease-free plants.
- Sow seeds thinly and keep the seedbeds free of weeds.
- Irrigate seedbed regularly, but avoid over-watering as it can induce damping-off diseases. Do not water late in the afternoon

because extended wetness of leaf surfaces promotes foliar diseases.

- Cover young seedlings with insect-proof netting in areas where virus diseases are endemic. (This is to restrict infestation by insect vectors of virus diseases.) Where it is not possible to use netting, spray or preferably drench seedlings with appropriate insecticides at recommended doses for control of insect vectors.
- Inspect the nursery regularly for insect pests, diseases and weeds and take appropriate action.

Transplanting

- Avoid transplanting seedlings in a field next to or near an old crop of tomato. Always ensure that a new field is sited up-hill, particularly where surface irrigation is used.
- Use proper plant spacing.
- Plant border rows of coriander, fenugreek, maize, millet, pigeon pea or sorghum. These crops will serve as windbreaks; fenugreek and coriander are non-host plants of whiteflies *(Bemisia tabaci)* and in addition, they are favourable for natural enemies and are also repellent to whiteflies. Pigeon pea can act as a trap crop for whiteflies.
- Avoid transplanting diseased seedlings.
- Harden the seedlings gradually before transplanting (gradually expose the seedlings to sunshine).
- Apply organic manure (compost or farmyard manure) and mix it well with the soil before transplanting.
- Transplant in well-prepared soil preferably late in the afternoon. This is particularly

important in dry areas in order to avoid wilting of seedlings (transplanting stress).

Field stage

- Keep the tomato field weed-free (weeds are potential alternative hosts of many diseases and insect pests).
- Regularly irrigate the field and apply optimal dose of nitrogen fertiliser. An excess of nitrogen generally promotes many diseases, and a combination of excess nitrogen and long watering intervals is highly favourable for blossom-end rot disease of fruits.
- Choose an appropriate irrigation system: In areas where there is a risk of foliar diseases (e.g. late blight), use furrow or drip irrigation; where soil-borne diseases (e.g. bacterial wilt, *Fusarium* wilt, *Verticillium* wilt or root-knot nematodes) are rampant, use over-head or drip irrigation.
- Stake, prune and widely space indeterminate tomato varieties; mulch determinate tomato varieties. (These practices will reduce incidence and severity of late blight and buckeye rot diseases.) In areas prone to bacterial diseases, disinfect pruning knives between plants with any commercial disinfectant.
- Do not work in tomato fields when plants are wet.
- Inspect plants for insects and diseases regularly and keep records of pest infestation through the development of the crop.
- When pesticide intervention is necessary, avoid use of broad-spectrum pesticides, as these would kill beneficials (parasitoids and predators of pests).

- Before using pesticides carefully read product labels (dosage; application frequency; pre-harvest intervals; safety precautions).
- Avoid pesticide use after fruit setting.
- Avoid damaging fruit when harvesting.
- Remove crop residues from the field after harvesting.
- Practise rotation using non-solanaceous crops. Do not plant tomatoes after brinjals, capsicums or chillies.
- Avoid overlapping of tomato crops.

Arthropod pests

Spider mites

(Plates 7–12)

Tetranychus spp. (Acarina: Tetranychidae)

IMPORTANT SPECIES:
Tetranychus evansi Baker & Pritchard, the tobacco spider mite
T. urticae Koch, the two-spotted spider mite
T. cinnabarinus (Boisduval), the carmine spider mite, common red spider mite

OTHER SPECIES INFESTING TOMATOES:
Eutetranychus orientalis (Klein), the oriental red mite
T. lombardinii Baker & Pritchard, the crimson spider mite
T. ludeni Zacher, the dark red mite or red-legged spider mite
T. neocaledonicus André, the vegetable spider mite.

Status and distribution: Spider mites are the most important non-insect arthropod pests of tomatoes. They are more prevalent in areas of low humidity. The most important spider mite species in tomato production in Africa are the **tobacco spider mite,** the **two-spotted spider mite** and **carmine spider mite.**

The **tobacco spider mite** was accidentally introduced to Africa in the 1980s and is specialised on plants of the family Solanaceae (tomato, potato, eggplant, tobacco and wild plants and weeds like black nightshade, bitter apple and wild gooseberry). It is currently the most important dry season pest of tomato in southern Africa and in Kenya, where it was detected in 2001.

The taxonomic status of the *T. urticae/T. cinnabarinus* species group is still unclear and some scientists are of the opinion that they are actually only one species. However, since the biology is identical this is not important for practical considerations. These species are polyphagous and are known to infest well over 300 plant species around the world. They are reported to attack tomatoes in temperate regions, mainly under protected conditions, and in warmer regions in the field, but tomato is not their most preferred host plant.

The other species mentioned above are of minor importance and their biology is similar to the two-spotted spider mite.

Description and biology: Spider mites are tiny; they rarely exceed a size of 0.5 mm. The different species are very difficult to distinguish without the help of a microscope. They are oval in shape with arched back and have eight legs, with the exception of the larval stage, which has six legs (Plate 7).

Spider mites are normally active within a temperature range of 16–37 °C. They flourish at relatively low humidities. In summer (24–26 °C) a new generation will develop every 10–13 days. The lifespan of a spider mite is 13–32 days. It includes five stages: egg, larva (first instar), and two nymphal stages (second and third instars), and adult. A female may lay over 100 eggs during its lifespan on leaves, stems or fruits.

Adult females of the **tobacco spider mite** are orange-red with an indistinct dark blotch on each side of the body and reddish legs (Plate 7). The males are very difficult to see with the naked eye and are smaller than the females. Adult males are straw-to-orange coloured. The eggs are spherical and pale yellow.

The females of the **red spider mites** and **two-spotted spider mites** are yellow-green to brownish-red with two black spots on each side of the body. In very dark specimens these spots are difficult to see. The eggs can only be seen with a magnifying lens. They are translucent whitish to pinkish in colour; sometimes with a distinct red or pale brown spot (Plate 8). Adult males are yellow-green, sometimes with a pinkish tone, and bear small dark spots.

Spider mites spin silk threads that anchor themselves and their eggs to the plant. This silk protects them from some of their enemies and even from pesticide applications. The tobacco spider mites produce much more silk than the other spider mites.

Spider mites are most numerous in hot, dry weather. Their populations normally decline after rain. Wind plays an important role in the dispersal of spider mites. Thus, other crops, wild plants or weeds can serve as a source of infestation. They can also be dispersed on clothing and implements.

Damage: Infested leaves first show a white to yellow speckling and then turn pale or bronzed, as the infestation becomes heavy (Plates 9, 10 and 11). Spider mites prefer the lower surface of the leaves, but in severe infestations will occur on both leaf surfaces as well as on the stems and fruits. As the population increases, the **tobacco spider mite** may completely cover the plant with webbing (Plate 11). Plants with a high infestation of this mite can be covered with an orange cloud of mites (Plate 11). The tobacco spider mite can kill plants very rapidly under hot and dry conditions. It is the most serious dry season pest of tomatoes in the areas where it occurs. Plants are heavily damaged if no control measures are taken.

High spider mite infestations cause defoliation, which leads to production of smaller and lighter fruits with lower percentage of soluble solids and a lower content of ascorbic acid (vitamin C). Spider mite attack may also cause speckling of the fruits (Plate 12).

The **two-spotted spider mite** and **carmine red spider mite** cause yield losses in tomatoes only in exceptional cases. Major reasons for these outbreaks are very hot and dry conditions, destruction of natural enemies through injudicious use of broad-spectrum insecticides, the presence of other highly infested crops in the near vicinity of the tomato field, and insufficient water supply to the tomatoes.

Control options: Before applying any control measures, regular inspections should be done to determine the presence and level of infestation of spider mites. The control of spider mites has been based on the use of acaricides, plant resistance and the use of predatory mites, particularly for tomatoes grown in greenhouses.

Spider mites rapidly develop resistance to pesticides, particularly when they are used for several consecutive seasons. When spraying, rotation of acaricides with different chemical composition is essential to avoid or delay development of resistance. *Preventive applications and applications of dosages lower than recommended should be avoided since this may lead to resistance.*

Some insecticides can enhance spider mite reproduction. In addition, the indiscriminate use of broad-spectrum insecticides eliminates natural enemies. Their use may lead to mite outbreaks. When chemical intervention is necessary, it is important to avoid pesticides that are detrimental to natural enemies. Specific acaricides should be used at the appropriate doses and recommended times of application. Clofentezine (e.g. Apollo®), fenbutatin-oxide (e.g. Torque®), hexythiazox (e.g. Nissorun®), propargite (e.g. Omite®) and tetradifon (e.g. Thedion®) are examples of acaricides that are harmless to most predators. Petroleum oil sprays have been applied to reduce high spider mite infestation and to re-establish the biological equilibrium without seriously affecting the predacious mite populations. Neem-oil formulations have given reasonable control of the **two-spotted spider mite** in the laboratory and the greenhouse.

Spot spraying of localised infestations usually controls initial infestations. A good coverage of the plant, including the lower surface of the leaves, with the spray and small droplet size is essential for successful control of the mites. Only use sprayers that have fully functional nozzles that give small droplets. Pruning and staking of tomatoes facilitate proper plant coverage.

A number of natural enemies (predators) are known to feed on spider mites. These include predatory mites, small staphylinid beetles, ladybird beetles, lacewings, predatory thrips, anthocorid bugs, mirid bugs, and cecidomyid and syrphid flies. Among them, the predacious mites *Phytoseiulus persimilis* (Athias-Henriot) (Plate 8) and *Amblyseius andersoni* (Chant) have been widely used for control of **two-spotted spider mites** in glasshouse crops in Europe and America.

Several species of predatory mites are known from eastern and southern Africa, however, there are as yet no detailed investigations in their role in tomato fields. Field observations show that the naturally occurring predators are in most cases capable of controlling infestations with the **two-spotted spider mite** and the **carmine red spider mite,** provided they are not disturbed by the severe use of broad-spectrum insecticides and the crop is irrigated properly. There are few predators known to feed on the **tobacco spider mite**. This mite is not attacked by *P. persimilis.* To date, only small staphylinid beetles (*Oligota* sp.) are known to feed on this species.

Resistant tomato cultivars are not yet available. In the USA, Kalohi lines, with fairly high mite development and oviposition, showed high tolerance to mite injury. In Brazil, some promising tomato genotypes resistant to *T. evansi* have been identified.

To keep populations of spider mites at a low level, the use of broad-spectrum insecticides, especially pyrethroids, should be avoided as much as possible and plants should be irrigated regularly. To minimise the risk of infestation, keep the field free of weeds, remove and burn or compost crop residues immediately after harvest, and avoid planting next to an infested field.

Tomato russet mite
(Plate 13)

Aculops lycopersici Massee (Acarina: Eriophydae), tomato russet mite or tomato rust mite

Status and distribution: The tomato rust (russet) mite has a world-wide distribution. It attacks solanaceous plants such as tomato, eggplants and potato. Other natural hosts are bitter apple and gooseberry, which serve as source of infestation.

Description and biology: Russet mites may be yellowish, tan or pink. They have a ringed conical body with the head and two pairs of legs at the large end (Plate 13). These mites are very tiny, approximately 0.2 mm long. Therefore they cannot be seen with the naked eye and it is even difficult to locate them with a magnifying lens. They hatch from eggs and pass through two nymphal stages. Their short life cycle (seven days) gives them a high reproduction rate which accounts for the rapid increase of this mite in tomato fields. They prefer warm temperatures and low humidity.

Damage: Russet mites attack all above-ground (aerial) parts of the tomato plant, causing spotting, twisting or folding of the leaves and fine cracks on the fruits. Stems and leaves that are attacked develop a greasy appearance and turn bronzed (Plate 13). The plants can drop their leaves, especially in hot weather, when damaged foliage quickly dries out. Fruits are then exposed to sunburn. Damage to the plant typically begins near the ground and spreads upwards (Plate 13).

Damage can develop very rapidly, and the mites can kill plants in a few days in hot, dry weather. Since the mite cannot be seen, the symptoms are easily confused with fungal or bacterial diseases.

Control options: The small size of the mite makes monitoring difficult. The first sign of infestation is the curling and bronzing of the lower leaves and stems.

Few natural enemies have been recorded. Predatory mites are considered to be the main natural enemies of russet mites. No commercial control by biological agents has so far been developed. The role of these predatory mites for natural control is hampered by the extensive application of pesticides, especially in commercial plantings. The fungus *Hirsutella thompsonii* Fisher had been used in Cuba for the management of these mites.

Insecticides have given little or no lasting control. The most effective acaricides used are flubenzimine, abamectin, dicofol, sulphur and chlorobenzilate. Routine treatments with sulphur (e.g. Thiovit®) or calcium polysulphide (e.g. Orthorix®) usually carried out to control powdery mildew of tomatoes are also effective against the russet mite. However, it should be noted that sulphur is harmful to predatory mites. Control can also be obtained using chorobenzilate (e.g. Acaraben®, Kopmite®). Propargite (e.g. Omite®) is also registered in some African countries for control of this pest.

Neem oil and aqueous neem seed kernel extracts have reportedly given good control in Costa Rica.

Tomato russet mite infestations are higher on tomato plants under water stress. Thus, proper irrigation during early stages of the crop can prevent mite build-up later in the growing season.

No resistant varieties are available. In Kenya, tolerance to leaf damage was observed in two varieties, namely Early Stone Improved and Beauty.

Fruitworms

(Plates 14–17)

Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae), the African bollworm, the tomato fruitworm
Spodoptera littoralis (Boisd.), the cotton leafworm (Lepidoptera: Noctuidae)

Status and distribution: The **African bollworm** is one of the worst agricultural pests in Africa. It attacks a variety of food and cash crops. It is a major pest on cotton, tomato, sunflower, maize, sorghum and legumes. The different host plants overlap in such a way that infestation in one crop is influenced by the population build-up on neighbouring crops. The **cotton leafworm** is widely distributed. It is reported from southern Europe, the Mediterranean Islands, Africa and Islands of the eastern and western coasts, and in the southwestern parts of Asia. It attacks a wide range of plants globally.

Description and biology: The adult of the **African bollworm** is a stout moth, about 6–18 mm long with a wingspan of 16–18 mm. Colour varies from dull yellow or olive grey to brown, with little distinctive marking (Plate 14). Moths are active at night and lay 500–3000 tiny, round, yellowish eggs, which darken before the larvae hatch. Female moths are attracted to tomato plants in the flowering and fruiting stages. Eggs are normally laid near or on flowers or small fruits, usually on the outer section of the plant. Young larvae are generally yellowish-white to reddish-brown in colour. They have a black head and several rows of black tubercles, each with two bristles along their backs that give them a spotted appearance. Soon after hatching the larvae move to green tomatoes, where they bore deeply into the fruit (Plate 14). The fully-grown larvae are about 40 mm long. They vary in colour from almost black, brown or green to pale yellow or pink and they are characterised by lengthwise alternating light and dark coloured stripes, with a typical light stripe along each side of their bodies (Plate 14). The fully-grown larvae drop from the plant and burrow into the soil to pupate. The pupa is light brown in colour. Adults emerge in 1–2 weeks, mate and can begin to lay eggs 48 hours after emergence.

The fully-grown larva of the **cotton leafworm** varies from 30–50 mm in length. It is olive-green, dark grey or brown in colour. The lower surface of the body is green or yellowish-white. The first and the eighth abdominal segments bear two distinct large black triangular dots on either side (Plate 15). The larva pupates in the soil. The moth is about 10–15 mm long. It is brownish-grey in colour with pale yellow lines along and across their veins on the forewings (Plate 15). The eggs are laid in batches, in one or more layers, usually on the underside of the leaves and covered with hair-like scales from the body of the female.

Damage: Caterpillars of the **African bollworm** feed on leaves, flowers and fruit. Caterpillars feeding on flowers and fruits cause the main damage. When flower buds are attacked, flower abortion occurs. Caterpillars prefer green fruit and seldom enter ripe fruit (Plate 16). They usually bore from the stem end, causing extensive fruit damage and promoting decay caused by secondary infections (Plate 17).

The damage caused by the **cotton leafworm** is mainly due to defoliation. However, the caterpillar also has the habit of entering and feeding in the interior of tomato fruits, which are close to or on the soil (Plate 15).

Control options: A very rich variety of natural enemies of the African bollworm and of *Spodoptera* spp. has been recorded. The main natural enemies include parasitic wasps such as *Trichogramma* spp. (egg parasitoids), parasitoids of larvae and predators such as lacewings, ladybird beetles, anthocorid bugs and ants.

Although these natural enemies cannot always prevent economic damage, they play a significant role in controlling pest populations. Therefore, their conservation and encouragement are important for the control of these pests. Using selective pesticides such as the microbial control agent *Bacillus thuringiensis* (e.g. Dipel®, Thuricide®), which are commercially available, can help preserve natural enemies. This commercially produced pathogen has been successfully used, alone or in combination with parasitoids and predators, for management of the **African bollworm**. Measures such as encouraging plant diversity have been suggested to enhance the impact of natural enemies on the African bollworm.

Augmentative releases of *Trichogramma* spp. have often been used as a therapeutic method of management for bollworms on cotton in Europe, Asia and America, considerably reducing the use of chemicals. On tomato, good control has been reported in some countries with releases of egg parasitoids such as *Trichogramma* spp. combined with other natural enemies such as larval parasitoids and lacewings.

Early detection of the eggs or the caterpillars before they bore into the fruits is important. Once the caterpillars have entered the fruit they are well protected and have already caused damage. Early detection can be achieved by scouting the crop regularly. Monitoring the moth populations by using pheromone traps considerably reduces crop inspection time and leads to less and more accurately timed insecticide spraying and releases of natural enemies. Several types of pheromone traps have been developed for monitoring and for mass trapping on tomatoes. Pheromone-based sticky paper traps are recommended due to their effectiveness and ease of operation.

Tilling and ploughing old tomato fields expose pupae which are killed through exposure to the sun and natural enemies.

Hand picking and destruction of eggs is feasible at low infestations. However, it is important to detect small larvae before they enter the fruits.

Using trap crops such as cucumber reportedly reduces the severity of attacks on tomatoes. Maize and sorghum have been recommended as trap crops to divert the African bollworm from cotton. Destruction of weeds which may harbour developing larvae is important for preventing fruitworm infestations.

If the infestation is severe, pesticides may be needed. A considerable number of insecticides are reported to afford good control of fruitworms (e.g. pyrethroids). However, selective pesticides, which preserve natural enemies, are preferred. For example, pesticides based on the pathogen *Bacillus thuringiensis*, or some plant-based pesticides such as neem products can be used, with minimal detrimental effect on natural enemies.

Crop losses due to fruitworms may vary considerably between different tomato varieties. Some varieties such as Red Claude and Urbana in Iran, and Parker, Bonus and VFN-8 in Libya are reportedly resistant.

Whiteflies
(Plate 18)

Bemisia tabaci (Gennadius) (Homoptera: Aleyrodidae), the tobacco whitefly, the sweet potato whitefly
Trialeurodes vaporariorum (Westwood) (Homoptera: Aleyrodidae), the greenhouse whitefly

Status and distribution: Bemisia tabaci is native to the Indian subcontinent but is nowadays widely distributed, and occurs outdoors in all tropical and subtropical countries of the world.

Trialeurodes vaporariorum has been a pest of crops grown in glasshouses and a great deal of research has been done for its control in glasshouses in Europe, USA, Japan and China. There is little information on its importance and control on field-grown tomatoes. In Mexico, *T. vaporariorum* was reported as the most important pest of irrigated tomatoes, particularly during the dry season.

Description and biology: Whitefly adults resemble very small moths. They have a coating of white, powdery wax on the body and wings (Plate 18). The adults will readily fly away when the plant is shaken. The adults of the two species are about 1 mm long; males are somewhat smaller than females. The interior edges of the wings of ***B. tabaci*** meet and the dorsal (top) view of the adult is narrow. In ***T. vaporariorum*** the bases of posterior wings do not meet, hence the dorsal view of the adult is triangular. Eggs are elliptical, about 0.2–0.3 mm long, attached vertically to the leaf surface by a short stalk, which is inserted into the leaf tissue. They are normally laid in an arc or circle comprising 20–40 eggs on the underside of young leaves. The first juvenile stage crawls on the leaf surface for some time before settling and fixes itself on the lower surface 1–2 days after hatching. It then starts sucking and excretes tiny wax filaments from the edges of its body. During the period of larval development, the tomato plant continues to grow and thus the juvenile stages are found on the lower leaves. The 'puparium' (scale-like final juvenile stage) is flat and whitish to yellowish in colour. The dorsal side bears two tubercles, and several pairs (0–7) of short hairs. The two species of whiteflies can be differentiated in the pupal stage. The pupa of ***B. tabaci*** has an irregular oval shape (drop-like) with oblique sides (viewed laterally), while the pupa of ***T. vaporariorum*** is regularly oval, has straight sides (viewed laterally) and is surrounded by wax. The life cycle in warm weather takes 3–4 weeks to complete.

Damage: Whiteflies are serious leaf-sucking pests that remove plant nutrients and weaken the plants. Feeding by whiteflies causes yellowing of infested leaves.

Whitefly larvae excrete a clear, sugary liquid known as 'honeydew'. This honeydew covers the leaves and supports the growth of black sooty mould, which may reduce plant growth and fruit quality.

The main damage caused by whiteflies to tomatoes is indirect as they are the vectors of viruses. At least 10 diseases of tomato in different parts of the world have been attributed to geminiviruses transmitted by ***B. tabaci***. This whitefly is an efficient vector of the Tomato Yellow Leaf Curl Virus (TYLCV).

Small numbers of whiteflies do not cause major direct plant damage and therefore do not justify chemical intervention. However, even small numbers of whiteflies may need to be controlled in areas where TYLCV is common.

Control options: Whiteflies are attacked by a number of natural enemies such as parasitic wasps (*Eretmocerus* spp. and *Encarsia* spp.), phytoseiid mites (*Amblyseius* spp. and *Typhlodromus* spp.) by lacewings and ladybird beetles. Conservation of these and other natural enemies is important.

Yellow sticky traps can be used to monitor the presence of whitefly adults for timing interventions. They have proved also to be useful as a control method for low infestations.

Preventing physical contact of the whiteflies with the plant can prevent the transmission of virus diseases. This can be done by using plastic covers and by cultural measures. Several cover crops (forage peanut, weeds) and inert covers (silver, yellow and white/black plastic mulches) reduce whitefly damage. However, when using plastic covers, care should be taken to avoid sunscald. As long as the plants are young and do not cover the plastic film, the whiteflies will be more attracted by the colour of the plastic mulch (especially yellow). The heat of the plastic kills the whiteflies. The protection can last for 10–20 days after transplanting and about 30 days after direct seeding.

Covering tomato seedling nurseries with nylon nets or use of tunnels for 3–5 weeks protects seedlings from whitefly infestations. These methods have been reported to reduce the transmission of the TYLCV and delay the spread of the virus in Jordan, Egypt and India.

Selection of crops for intercropping can be used to manage whitefly populations. For example, interplanting tomatoes with capsicum or cucumber has reduced whitefly numbers when compared with tomatoes alone or tomatoes planted with aubergine or okra. Planting of border rows with coriander and fenugreek, which are non-hosts for *B. tabaci*, will serve as windbreaks, and are favourable for natural enemies and also repellent to whiteflies.

Time of sowing and transplanting can be an effective cultural approach for disease management. Avoid the season when whiteflies are more likely to occur.

Weeds play an important role in harbouring whiteflies between crop plantings. They also often harbour whitefly-transmitted viruses. Therefore, attention should be paid to removing weeds in advance of planting tomatoes. Tomato fields should also be kept weed-free.

Whiteflies rapidly develop resistance to many insecticides and resurgence of populations is common. When chemical treatment is needed, it is essential to choose a proper product and appropriate application method carefully. It is important to choose insecticides and methods of application that are not damaging to biocontrol agents. Rotation of pesticides is essential to minimise or delay development of resistance. Most insecticides are only effective against adults, so that repeated treatment at 3–5 day intervals is necessary for several weeks before control can be achieved.

Some of the less toxic, selective active ingredients reported to have an effect in controlling whiteflies worldwide include, among others, amitraz (e.g. Mitac®), burpofezin (e.g. Applaud®), imidacloprid (e.g. Confidor® Gaucho®) and pymetrozine (e.g. Endeavour®, Fulfill®). The selective action of pymetrozine makes it especially useful in IPM programmes. The growth regulator buprofezin is used in IPM programmes for control of the **greenhouse whitefly** in Europe.

Some insecticides reduce whitefly populations to a great extent, but are often not effective in reducing the transmission and spread of TYLCV. Combinations of mineral oils and some insecticides give rapid control of whitefly adults and suppress virus transmission.

Spraying with soap and water reportedly controls whiteflies. The amount of soap needed will depend upon the soap type. The use of strong soaps, or soft soap at high concentrations can scorch leaves. Whenever possible use soft soaps made from potash. Users should experiment in small plots to find the right concentration first before large-scale application.

Neem-based insecticides are reported to provide good reduction in egg laying of *B. tabaci*, inhibit growth and development of nymphs, and significantly reduce the risk of TYLCV.

No single control treatment can be used on a long-term basis against whiteflies. Therefore, a number of different control agents should be integrated for an effective level of control.

An integrated control programme based on biological control has been developed for the control of ***T. vaporariorum*** in greenhouses and it has been used in many countries in Europe, USA, South America and Asia. The programme is based on releases of the parasitoid *Encarsia formosa* Gahan in combination with other methods. Control can be satisfactory if large numbers of parasitoids are released in good time.

An integrated control scheme for the control of ***B. tabaci*** aims for control during the first 60 days of the crop, which is the critical period for transmission of the TYLCV. A combination of measures is suggested for the field phase: interference (physical barriers or mulches); repellents such as oils and selective botanicals and synthetic pesticides; and use of trap crops and natural enemies.

Leafminers

(Plates 19 and 20)

Liriomyza spp. (Diptera: Agromyzidae)
Liriomyza trifolii (Burgess), serpentine leafminer
L. sativae (Blanchard), vegetable leafminer
L. bryoniae (Kaltenbach), tomato leafminer
L. huidobrensis Blanchard, the pea leafminer

Status and distribution: *Liriomyza* species are serious pests of vegetables and ornamental plants worldwide. Two species of serpentine leafminer, *L. trifolii* and *L. sativae*, are considered serious pests of tomatoes. Both species are cosmopolitan. *Liriomyza sativae* is a typical American pest, whereas the typical leafminer in Europe is *L. bryoniae*. *Liriomyza trifolii* is common on tomato in America and Europe, and *L. huidobrensis* is occasionally reported on tomato in America, but damage has been recorded mainly on ornamentals.

In Africa, *L. trifolii* has been reported in several countries including Kenya, Mauritius, Reunion Island, Senegal, South Africa and Tanzania. In Kenya, *L. trifolii* was introduced into the country in the late 1970s through chrysanthemum cuttings from Florida (USA). Since then, *Liriomyza* species have been found throughout the country, attacking vegetables and ornamental plants. *Liriomyza huidobrensis* is currently a serious pest of ornamentals and passion fruits. *Liriomyza sativae* was recently recorded in Kenya.

Description and biology: Liriomyza trifolii and ***L. sativae*** are closely related, with similar appearance and overlapping host ranges. Leafminer adult flies are small, about 2 mm long.

They are black and yellow in colour (Plate 19). Both species have a black thorax with a yellow triangular spot between the base of the wings. However, the thorax of ***L. sativae*** is shiny black on the upper surface, while ***L. trifolii*** have the upper part of the thorax covered with bristles, which give them a grey-silver colour. In ***L. sativae*** the lower part of the body and the face between the eyes are yellow, with a large black area behind the eyes. The head of ***L. trifolii*** is mainly yellow with only a small black area at the rear edge of the eyes.

Females make tiny punctures in the upper side of the leaf when feeding and depositing eggs. These punctures are easily seen in a heavy infestation (Plate 19). Eggs hatch into small yellow maggots and feed on the green chlorophyll tissue, leaving a linear and irregular pattern (mines) through the leaf, with occasional thread-like black frass (Plate 20). In some species, mature larvae leave the mines, dropping to the ground to pupate. In other species, larvae pupate within the leaf (in the mines) or on the upper leaf surface (Plate 20). The life cycle varies with host and temperature. The average life cycle is approximately 21 days but can be as short as 15 days. Thus, populations can increase rapidly.

Damage: The larvae are the most destructive stages. Larval feeding may kill a tomato seedling by desiccation (drying out) and defoliation. Defoliation of tomato plants may also expose fruits to sunburn and affect the market value. Disease transmission can result from feeding punctures invaded by bacieria and fungi. Heavy infestation reduces the photosynthetic capacity of the plant and affects the development of flowers and fruits.

Control options: Leafminers are normally controlled by naturally occurring larval parasitoids. However, the use of insecticides to control other pests disrupts the natural control of leafminers.

The parasitoid *Diglyphus isaea* Walker, which has been recorded in Kenya, is being used in IPM programmes for leafminers on tomato crops in glasshouses in America and Europe.

Leafminers can be monitored by foliage examination for the presence of mines and larvae, and by trapping adult flies with yellow sticky traps. Yellow sticky traps used for mass trapping can effectively control the pest at low densities. Visual rating systems to assess the total number of leafmines on tomato have been developed in the USA. For instance, the upper surface of the terminal three leaflets of the 7th compound leaf from the top of any stem may be used as a sample for evaluating density of larvae in field-grown tomatoes.

Pupae in the soil can be destroyed by soil cultivation and solarisation.

Liriomyza leafminers are difficult to control with chemicals due to their feeding habit and to their enormous capacity for developing resistance to insecticides. In addition, the use of chemicals to control leafminers disrupts natural biological control.

Several selective plant protection products, such as neem-based pesticides and insect growth regulators, are used for control of leafminers in IPM programmes. Among the most effective insecticides against leafminers are abamectin (e.g. Vertimec®) and the insect growth regulator cyromazine (e.g. Trigard®). Abamectin and buprofezin (e.g. Applaud®) are reported to be effective in suppressing leafminer populations without harming parasitoids.

Thrips

(Plate 21)

Thrips tabaci Lind., the onion thrips
Frankliniella schultzeii Trybom, the cotton bud thrips
Frankliniella occidentalis Pergande, the western flower thrips
Ceratothripoides brunneus Bagnall (Thysanoptera: Thripidae)

Status and distribution: The onion thrips, ***Thrips tabaci***, occurs all over the world and attacks onions, tomato, tobacco, beans and many other plants. It is found outdoors in warm climates and in greenhouses in colder areas. ***Frankliniella schultzeii*** is endemic to sub-Saharan Africa, but it also occurs in South and Southeast Asia, the Pacific and Australia. ***Frankliniella occidentalis*** originates from the Western USA and has spread throughout the USA and around the world. It has been found in Europe, New Zealand, Australia, parts of Asia, Central and South America and Africa. Both *Frankliniella* species feed on a wide variety of plants.

The thrips species ***Ceratothripoides brunneus*** Bagnall has been recently reported damaging tomatoes in Kenya.

Description and biology: Adult thrips are small (0.5–2.0 mm), slender and usually winged. The wings are long, narrow and fringed with long hairs and, at rest, are tied dorsally (on the back) along the body (Plate 21). The female lays eggs in the leaf tissue. The first two immature stages are called larvae and are similar to adults but wingless. These are followed by two-to-three preadult instars (the prepupa and pupa) which usually have short wing pads, are inactive and do not feed. They usually pupate in the soil or under debris near host plants. Thrips have a short generation time of 2–3 weeks in warm conditions. The adult lifespan is 2 to 3 weeks. Thrips migrate actively between different hosts.

The **onion thrips** are pale-yellowish to brownish in colour and are 1.0–1.2 mm in length. Adult thrips of the genus ***Frankliniella*** are yellow, pale brown or dark brown in colour, and 0.9–1.4 mm in length. Male thrips are smaller than females.

Damage: Thrips usually feed on the lower surface of the leaves, but also attack buds, flowers and fruits. Plant damage results when both larvae and adults puncture the leaves and suck the exuding sap. Attacked leaves frequently have a silvery sheen and they show small dark spots of faecal material (Plate 21). A heavy infestation causes premature wilting, delay in leaf development and distortion of young shoots. Under heavy infestations, when buds and flowers are attacked, abortion usually occurs. Attacked fruits show surface speckling and small necrotic patches affecting the fruit quality (Plate 21). Distortion of fruits may occur. Any environmental stress that weakens the plants makes them more susceptible to thrips attack.

Thrips feed on tomatoes at all stages but their damage is more conspicuous on seedlings. They are therefore an important nursery pest. Heavy infestations can reduce stands of young seedlings in hot weather.

Thrips of the genus *Thrips* (including *T. tabaci)* and *Frankliniella* (including *F. occidentalis* and *F. schultzeii)* are vectors of viruses such as the Tomato Spotted Wilt Virus (TSWV) and the Tomato Chlorotic Spot Virus (TCSV) in greenhouse and field-grown tomatoes. The TSWV is the most economically important virus, limiting tomato production.

Control options: Natural control by predators is important. The main predators include predatory thrips, predatory mites (e.g. *Amblyseius* sp.) and anthocorid bugs (*Orius* spp.). Pathogens such as the fungus *Entomophthora* are also important in natural control of thrips.

Monitor the crop regularly. Pay particular attention to flower buds and flowers. Adult thrips can be monitored by hanging blue, yellow or white sticky boards in the nursery or field.

Mulching with UV-blocking films such as aluminium-surfaced polyethylene, has been shown to significantly decrease thrips levels and virus incidence on tomatoes. Ploughing and harrowing before transplanting, and solarisation can kill pupae in the soil from previously infested crops.

Removal of weeds helps to stop migration of thrips into the tomato crop.

Irrigation by flooding fields has been found to reduce thrips damage. It destroys a large proportion of pupae in the soil.

Thrips are difficult to control with insecticides. Due to their secretive habits (eggs are laid in plant tissue, the larvae and adults shelter in the flowers and larvae pupate in the soil) they are partially protected from pesticides. Some thrips species rapidly develop resistance to pesticides. In particular, the **western flower thrips** has shown to be resistant to the most commonly used pyrethroids in Kenya. Products that give reasonable control of ***Frankliniella*** thrips include fipronil (e.g. Regent®) and spinosad (Tracer®).

The **onion thrips** can be controlled with broad-spectrum pyrethroids. Repeated applications are needed to achieve satisfactory control since the eggs and the pupae in the soil are not controlled. However, their use should be avoided or minimised due to their adverse effect on natural enemies.

Cutworms

(Plate 22)

Agrotis spp. (Lepidoptera: Noctuidae)
Agrotis ipsilon (Hufnagel), the greasy cutworm
Agrotis segetum (Denis and Schiffermuller), the common cutworm

Status and distribution: Cutworms are commonly found throughout the world. ***Agrotis ipsilon*** (Hufnagel), the greasy cutworm, occurs in Africa from the Cape to the Mediterranean coasts. It can attack a wide range of plants, but the common host plants are tobacco, cotton and crucifers. ***Agrotis segetum*** (Denis and Schiffermuller), the common cutworm is a highly polyphagous insect attacking many species of host plants in the temperate, tropical and subtropical regions.

Description and biology: Adults of the greasy and the common cutworms are grey-brown moths, about 22 mm long with a wingspan of 40–45 mm. The forewings have dark-brown markings in the form of rings and lines. Females lay eggs in patches on moist soil, on the stem and lower leaves of tomato plants, or on low growing vegetation. Young larvae are yellowish-green with a blackish head. Young caterpillars initially feed on plant foliage, but later they descend to the soil. The fully-grown larvae are grey-black, smooth-skinned caterpillars, about 4–5 cm long (Plate 22). They normally curl up when disturbed. They are active mainly at night; during the day they hide in soil or in debris at the base of the plants. The pupae are shiny reddish-brown with two small spines at the tip of the abdomen.

Damage: Cutworms are serious pests of tomato seedlings. They cut stems of newly transplanted or emerged plants at the base (Plate 22). Cutworm damage is most critical after thinning or transplanting. The caterpillars occasionally climb into mature plants to feed on leaves and green fruits, but this kind of damage is in general not economically important.

Damage is worst where cutworms are already present in large numbers before planting. Cutworms often reoccur in the same field as a result of crop residues, or dense stands of weeds. During field preparation the food of already existing cutworms is destroyed. If the field is planted soon afterwards, the cutworms may still be alive and feed on tomato plants.

Control options: Fields need to be prepared and vegetation and weeds destroyed 10–14 days before planting tomatoes in the field. Ploughing exposes caterpillars to predators and to dessication by the sun. Flooding of the field for a few days before transplanting can help kill caterpillars in the soil.

Early detection helps to prevent serious damage. Monitoring of cutworm caterpillars should be done at dawn. Newly transplanted or emerging tomato can be monitored for cut plants during the day. Monitoring of cutworm moths can be done with pheromone traps.

Control before thinning is advisable where high numbers of cutworms are present. Control is normally not needed when plants are about 25–30 cm tall.

Bigger seedlings are more tolerant to damage. Delaying transplanting slightly until the stems are too wide for the cutworm to encircle and/or too hard for it to cut may reduce cutworm damage.

Hand picking of caterpillars at night by torch is useful at the beginning of the infestation.

Hens are useful because they eat cutworms near the surface. They are very effective when confined on garden beds prior to planting.

Ashes are reported to deter cutworms. They can be spread thickly in seedbeds, around plants or seedbeds, or mixed with the soil in the planting holes.

A thick dry stick inserted on the side of the seedlings can act as a mechanical barrier reducing loss of plants by cutworms.

When insecticide treatment is necessary, the amount applied can be kept to a minimum by banding the insecticide over the rows rather than broadcasting, by drenching (spraying or pouring pesticides around the base of each plant) in the evening, and by using baits.

Baits can be made out of maize flour and water and an insecticide. Baits containing microbial insecticides such as *Bacillus thuringiensis* or other insecticides (e.g. some pyrethroids) are recommended for control. Baits are more effective when other food is limited. It is thus recommended to check for cutworms before tomato transplanting or before tomato plants emerge when direct sowing is done.

Diseases

Over 40 diseases have been recorded on tomatoes worldwide. The diseases are mostly caused by bacteria, fungi, nematodes, viruses and non-parasitic factors. Non-parasitic diseases are due to unfavourable environmental conditions, such as excessive moisture or drought, extremes of temperature, and lack or excess of mineral elements in the soil. These diseases are not equally important in all countries. Furthermore, their severity in countries of occurrence may vary from season to season depending on prevailing weather conditions.

Many tomato diseases, and particularly viral diseases, cannot be controlled once they are well established in the field. However, it is often possible to limit their occurrence by preventing infection from contaminated seed and soil or from weeds that harbour disease-inciting agents. Hence, clean seed-beds and healthy transplants are very important as the initial steps to growing a good crop in the field. Methods of control vary with the nature and cause of the individual disease, and therefore an accurate disease diagnosis is necessary before control measures can be applied.

Bacterial diseases

Bacterial canker

(Plate 23)

Cause: *Clavibacter michiganensis* subsp. *michiganensis* (Smith) Jensen

Symptoms: Plants can be affected at any stage of development. Often seedlings are infected but symptoms at this stage may not be evident. The first symptom is a wilting and curling of the leaflets, often on one side of the leaf. The affected leaflets turn brown and dry but remain attached to the stem. The whole plant may also show a one-sided disease development causing the plant to characteristically fall down. Where only one stem is infected, the disease eventually progresses to affect the whole plant. The plant may be killed but generally it survives until harvest. Long brown strips appear on stems and shoots. These strips dry and crack open to form cankers from which the disease gets its name. When an affected stem is cut lengthwise, there is a creamy white, yellow, or reddish-brown line just inside the woody tissue. The pith is easily separated from the wood along this line. The vascular bundles within the pith are destroyed and cavities are formed in the soft tissue.

When plants are severely diseased, the bacteria may pass from the stem into the fruits through the vascular tissues. If this occurs when fruits are small, they become stunted and deformed. Seed abortion may also take place. Fruits can be infected on their surface by bacteria splashed by rain. Spots on fruits are circular, up to 3 mm wide, with a slightly raised brown centre surrounded by a pronounced white halo, thus resembling a 'bird's eye'. The halo is flat. As the spots age, the centre cracks, giving a ragged appearance. The spots are superficial (on the surface) (Plate 23).

Source of infection and spread: The bacterium is seed-borne and can survive up to 3 years in soil and in debris of diseased tomato plants. It can also survive in solanaceous weeds such as black nightshade. The bacterium can also be found in cracks on sticks used for staking. Infection occurs through wounds and trichomes, and spreads in the plant through the phloem vessels in the vascular system. Spread of the disease within a crop is by splash from rain or sprinklers and by pruning knives. The disease is favoured by air temperatures of about 24 °C, a low light intensity, and high levels of nitrates in the soil. Fruit infection, which results in 'bird's eye' symptoms, is favoured by sprinkler irrigation.

Disease management: Use resistant tomato varieties (e.g. Bulgaria 12, CMVF 232, Monense, Okitsu Sozai, Rotam IV and Star 9001). Use certified disease-free seed. Rotate seedbeds and tomato fields. Destroy crop residues after harvest. Eradicate solanaceous weeds. Avoid work in tomato fields when it is wet. Avoid sprinkler irrigation. Where feasible, use drip irrigation. Disinfect pruning knives between plants with any commercial disinfectant.

Bacterial speck

(Plate 24)

Cause: *Pseudomonas syringae* pv. tomato (Okabe) Young, Dye & Wilkie

Symptoms: Spots on leaves and stem are small, black and greasy, similar to but generally smaller, than those caused by bacterial spot disease. Spots do not have a halo. When spotting is severe, the entire leaf yellows. On stems, the spots are more elongated. Only young fruits are susceptible. Spots on fruit are small (rarely more than 1 mm wide), black and raised. The spots have a defined margin border (Plate 24).

Source of infection and spread: The bacterium can be seed-borne. It can survive in soil and debris from diseased tomato plants. Spread between plants occurs through strong winds, splashing rains, overhead irrigation and by workers during transplant clipping, transplanting, cultivation and spraying. Cool moist weather promotes infection and disease development. Air temperatures between 17 °C and 25 °C enhance the disease.

Disease management: Use certified disease-free seed. Seedbeds should not be located on soil where bacterial speck occurred in the previous year. Avoid successive tomato culture. Do not work in fields when plants are wet. Practise furrow or drip irrigation where feasible. When overhead irrigation is necessary, irrigate early in the day so that plant surfaces dry before night. Copper hydroxide (e.g. Kocide DF®) is effective in reducing disease severity. Read the product label before using fungicides and observe the pre-harvest intervals quoted.

Bacterial spot

(Plate 25)

Cause: *Xanthomonas campestris* pv. *vesicatoria* Dye

Symptoms: The disease attacks foliage, blossoms and fruit. The disease is common and destructive on seedlings and spreads rapidly in seedbeds. On foliage, irregular greasy, dark green spots, 2–3 mm wide, are observed. The spots eventually dry and the tissue often tears. When severe, defoliation may result. Diseased leaves do not wilt as in bacterial canker. Similarly, if flower parts are infected, serious blossom drop may occur.

The disease is most conspicuous on fruit. On green fruits, the initial spot is very small and water soaked. It eventually enlarges to about 6 mm and becomes slightly raised. A pale green halo may be observed at first but this gradually disappears. As the bacterial spot matures, it becomes brown and scabby without extending deep into the fruit (Plate 25). Ripe fruits are not infected.

Source of infection and spread: The bacterium is seed-borne and survives in soil-borne plant debris or in weeds such as black nightshade. Apparently, the bacterium cannot survive for long in soil. The disease is spread by splashing rain or sprinkler irrigation. Infection of leaves normally occurs through stomata. Fruit infection is through wounds caused by insects or wind-blown sand. Young leaves and fruit are more susceptible than older tissue. High night time temperatures of 24 °C to 28 °C and rainy periods favour disease development.

Disease management: Use certified disease-free seed. Do not locate seedbeds on soil where bacterial spot occurred in the previous year. Eradicate solanaceous weeds such as black nightshade. Remove and destroy crop residues after harvest. Use drip or furrow irrigation. Avoid working in fields when plants are wet. Rotate fields with legumes. If past experience indicates possible occurrence of the disease, spray seedlings or field tomatoes with copper hydroxide (e.g. Kocide DF®). Observe pre-harvest intervals as shown on the labels.

Bacterial wilt

(Plates 26 and 27)

Cause: *Ralstonia solanacearum* (Smith)

Symptoms: The disease causes rapid wilting and death of the entire plant without any yellowing or spotting of leaves. All branches wilt at about the same time (Plate 26). When the stem of a wilted plant is cut across, the pith has a darkened water-soaked appearance, and there is a greyish, slimy ooze on pressing the stem. In later stages of the disease, decay of the pith may cause extensive hollowing of the stem. Bacterial wilt causes no spotting of fruits. Affected roots decay, becoming dark brown to black in colour. If the soil is moist, diseased roots become soft and slimy. To distinguish this wilt from others, take a thin slice or sliver of the brown stem tissue and place it on the inside of a glass of water at the water level. If bacterial wilt is present, a milky stream flows from the lower cut surface of the sliver in about 5 minutes (Plate 27).

Source of infection and spread: The bacterium is soil-borne and can survive in soil for long periods. It has a very wide host range and infects all members of Solanaceae. Weed hosts include black nightshade, lantana and Jimson weed. It infects plants through roots. As the roots of wilted plants decay, the bacteria are released back into the soil. Infestation by root-knot nematodes aggravates the disease. The bacterium is especially destructive in moist soils at temperatures above 24 °C. It is sensitive or not favoured by high pH (alkaline soils), low soil temperature, low soil moisture and low fertility levels. Spread occurs from running water, movement of infested soil and also diseased seedlings.

Disease management: Use resistant varieties such as Hytec 36, Rotam IV, Star 9001, Summerset F1 and Zest F1. Do not locate seedbeds where bacterial wilt has occurred. To prevent infection from drainage water, do not plant seedbeds or field crops close to land where the disease was present in the previous year. If only a few wilted plants are found, immediately remove them from the field to prevent further spread of the disease. In semi-arid and arid areas, solarise the seed-beds. Liming of the soil could be helpful. Eradicate weeds. Maintain high soil-nitrogen levels. Rotation with paddy rice or controlled flooding for several months can keep the disease in check.

Fungal diseases

Damping-off diseases
(seed-bed diseases)
(Plate 28)

Cause: *Pythium* spp.; *Rhizoctonia solani* (Kühn)

Symptoms: The injury from damping-off fungi is of two types: *pre-emergence damping-off* consists of a decay of the germinating seed or killing of the seedling before it can push through the soil. This injury is a common cause of poor stands, which are often attributed to inferior quality of the seed or seed not treated with fungicides. The other type is *post-emergence damping-off* which occurs after the seedlings have emerged from the soil but while still small and tender. The roots may be killed, and affected plants show water soaking and shrivelling of the stems at the ground level; they soon fall over and die.

Damping-off usually occurs in small patches at various places in the seedbeds. These disease spots often increase in size from day to day until the seedlings harden. Seedlings are extremely susceptible for about two weeks after emergence. As the stem hardens and increases in size, the injury no longer occurs. Some seedlings are not killed at once, but the roots are severely damaged and the stem is girdled at the ground level. Such plants remain stunted and often do not survive transplanting.

Disease management: Use certified disease-free seed. Seed should be treated with a fungicide and an insecticide to protect it from soil-borne pests. The seedbed should not be sited on a field previously planted with brinjals (eggplant), pepper, potatoes, tomatoes or other related crops. Do not site the seedbed next or near to tomato production fields. The seedbed should preferably be up-wind to tomato fields. Solarisation of seedbeds should be done where feasible. Thin the seedlings in seedbeds to permit good air circulation. Avoid excessive watering and fertilisation, particularly with nitrate. If post-emergence damping-off symptoms occur, spray the seedlings or drench the soil with copper oxychloride (e.g. Cuprocaffaro® and Perecopper®), or etridiazole (e.g. Terrazole®).

Anthracnose fruit rot

(Plate 29)

Cause: *Colletotricum* spp.

Symptoms: Fruits may be infected when green and small, but they show no evident spotting until they begin to ripen. Infected ripe fruits exhibit small, slightly sunken, water-soaked circular spots (Plate 29). These spots enlarge to up to 3 mm in diameter. The centres become dark because of the formation of small black fruiting bodies of the fungi. In moist weather, masses of spores are produced having a characteristic salmon (pinkish) colour. The rot may penetrate into the fruit and render it worthless.

Source of infection and spread: The fungi survive on crop residues. In moist weather the spores produced on the surface of the infected fruit are splashed to other fruits by rain or spread by farm staff working in the fields. Overhead irrigation also spreads the disease. Although fruit at all stages of development is susceptible to the disease, susceptibility to infection increases as the fruit ripens. Thus, symptoms are evident only on near-ripe and ripe fruit. Fruits on plants partially defoliated by leaf spot diseases are particularly subject to infection.

Disease management: Use certified disease-free seed. Eradicate weeds. Grow plants unrelated to tomato for at least 3 years between tomato crops. Remove crop refuse after harvest. Avoid overhead irrigation. Drip irrigation is recommended. Harvest fruit as soon as possible after it matures. Where anthracnose is a serious problem, apply registered fungicides at fruit-set. Chlorothalonil (e.g. Bravo®, Daconil®) and dithiocarbamates (e.g. Dithane M45®, Mancozeb®, Maneb®) provide satisfactory control. Read the product label before fungicide use and observe pre-harvest intervals.

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Buckeye rot

(Plate 30)

Cause: *Phytophthora nicotianae* var. *parasitica* Dast; *P. capsici* Leonian; *P. dreschsleri* Tucker

Symptoms: A greyish-green to chocolate-brown firm rot with an indefinite, water-soaked margin and often with broad zonate markings develops on fruit (Plate 30). These markings give the disease the name 'buckeye rot'. The surface of the rot is generally smooth and the skin is intact. Although the rot progresses well into the flesh, affected fruit remains firm.

Source of infection and spread: These fungi are soil-inhabiting and require water for spore production and fruit infection. The disease is generally confined to fruit on or near the ground and consequently it is mainly a problem in unstaked crops. The fungi enter into the uninjured surface of the fruit, and infection occurs either where the fruit touches the soil or where soil is splashed on the fruit by rain or irrigation water. Wet weather and temperatures around 26–28 C favour infection and disease development. The disease is most common in low-lying or poorly drained areas of the field.

Disease management: Use certified disease-free seed. Do not locate seedbeds in fields recently planted to tomatoes. Avoid poorly drained soils. Mulch seedbeds and tomato fields. Stake tomato plants. Plant on ridges. Drip irrigation is advisable. Avoid overhead irrigation. Practise a 3-year rotation with crops unrelated to tomato. Where the disease is commonly found, spray with registered fungicides at fruit set. Suggested fungicides include chlorothalonil (e.g. Bravo®, Daconil®), copper-based compounds, mancozeb (e.g. Milthane Super 80 WP®, Oshothane 80 WP®), mancozeb +metalaxyl (e.g. Ridomil MZ®) or propineb+cymoxanil (e.g. Milraz®). Read the product label before use of fungicides and observe pre-harvest intervals.

Early blight
(Plate 31)

Cause: *Alternaria solani* (Ell. & Martin) Sor.

Symptoms: The disease affects all aerial parts of the plant including the fruit. Collar rot may develop on seedlings; it is characterised by girdling of the stem at the base of the plant. Affected seedlings are stunted and may wilt and die. When older seedlings are infected, stem lesions usually are restricted to one side of a stem and become elongated and sunken.

Leaf spots are circular, up to 12 mm in diameter, brown and often show a ridged concentric (circular) pattern which distinguishes this disease from other leaf spots on tomato (Plate 31). Leaf spotting first appears early in the season on the oldest leaves and progresses upward on the plant. However, the greatest injury usually occurs as the fruit begins to mature. If high temperatures and humidity occur at this time, much of the foliage frequently is killed before the end of the season. This weakens the plant and exposes the fruit to sunscald.

Spots on the stem resemble those on leaves but tend to be more elongated and the circular or ring-like pattern is more pronounced. Dark, leathery, sunken spots may develop on the fruit at the points of attachment to the stems. These spots may also show concentric markings like those on foliage (Plate 31). The dark, dry decay extends to some depth into the flesh of the fruit. Infected fruit frequently drops. In production fields, the disease first appears on early varieties and in early plantings, and it becomes more widespread when plants are loaded with fruit.

Source of infection and spread: The fungus is seed-borne, and therefore can.cause pre- and post-emergence damping-off. The fungus survives from one season to the next on debris from diseased tomato plants. Thus, the disease is particularly well adapted to semi-arid areas. The spores are formed on leaf, stem and fruit spots. The disease is also spread from plant to plant when spores of the fungus are dispersed by wind and rain. The disease is favoured by periods of warm rainy weather with temperatures between 21 °C and 24 °C.

Disease management: Use resistant varieties, e.g. Summerset F1, Zest F1. Use certified disease-free seed. Plant into well prepared seedbeds. Seed no earlier than necessary for the planned transplanting date and avoid delays in transplanting. Use disease-free transplants. Do not plant consecutive tomato crops on the same land. Tomato should be rotated with crops other than brinjals, pepper and potatoes. Avoid planting adjacent to earlier planted or old crops of brinjals (eggplants), pepper, potatoes or tomatoes as they could be a source of disease. Avoid windbreaks and shady areas as they extend the dew period (leaf wetness period), thus creating favourable conditions for disease development. Keep tomato fields free of weeds. Compost any crop residues and use as manure. If that cannot be done, crop residues should be removed from the field or destroyed immediately after harvest or ploughed deeply into the soil before planting. If the disease is serious and cultural measures do not provide adequate control, fungicide sprays may be used. Many broad-spectrum fungicides including chlorothalonil (e.g. Bravo®, Daconil®), mancozeb (e.g. Milthane Super®, Oshothane®), propineb (e.g. Antracol®) and propineb + cymoxanil (e.g. Milraz®) provide good control. Ensure that only registered products are used. Read the product label before use and observe the pre-harvest intervals indicated.

Late blight

(Plates 32 and 33)

Cause: *Phytophthora infestans* (Mont.) de Bary

Symptoms: Irregular, greenish-black, water-soaked patches appear on the leaves. The spots soon turn brown and many of the infected leaves wither, yet frequently remain attached to the stem. Under moist conditions white fungal growth may be seen on the underside of leaf spots. In damp weather the disease spreads so rapidly that almost all the foliage is affected, and the plants look as though scorched (Plate 32). The fungus also produces water-soaked, brown streaks on the stem. Infection of fruit occurs at any stage of growth. It is most common on the upper half of the fruit, but it may occur elsewhere on the surface. The first symptom is a greyish-green, water-soaked spot. The spot becomes greasy brown and has a firm, corrugated (rough) surface that occasionally shows narrow zonate markings (circular) (Plate 33). The disease also affects potatoes and brinjals (eggplant) but it does not seem to occur on pepper.

Source of infection and spread: The fungus does not persist for long on crop debris in the soil. The white, downy fungal growth produced on diseased areas in moist weather contains large numbers of spores, which are spread by wind for considerable distances. These spores serve as a source of infection. Cool, wet weather (heavy dews, cloudy conditions, drizzly periods, temperature of 18–24 °C) favours infection and disease development. Infected tomato transplants can also introduce the disease in far-away areas. Where potatoes are grown, infected tubers used as seed can serve as a source of infection.

Disease management: In potato growing areas, destroy potato cull piles, remove from the field volunteer potato plants (these are plants derived from tubers left in the soil the previous season), and plant tomatoes as far as possible from potato crops. Do not plant tomatoes after potatoes. Indeterminate tomato should preferably be planted at wider spacing, staked and pruned; this will improve air circulation, reduce humidity within the crop, and thus reduce disease intensity. Mulching, where feasible, is recommended. Fungicide sprays should be applied as soon as the disease is seen, or as soon as experience suggests that the weather conditions are favourable for disease development. The dosage and frequency of application of fungicides can be reduced if good cultural practices are used (staking/pruning/mulching/low density planting). Chlorothalonil (e.g. Bravo®, Daconil®), mancozeb, metalaxyl + mancozeb (e.g. Ridomil MZ®), and propineb+cymoxanil (e.g. Milraz®) provide adequate control. Ensure that only registered products are used. Observe pre-harvest intervals indicated on the labels.

Fusarium wilt

(Plate 34)

Cause: *Fusarium oxysporum* f. sp. *lycopersici* Snyder & Hansen

Symptoms: The lower leaves of the plant usually turn yellow and die. One or more branches may show definite symptoms. Leaflets on one side of a petiole (see Figure 1) may be affected, while those on another side remain without symptoms. Diseased leaves readily break away from the stem. Sometimes the affected leaves may dry up before wilting is detected. When affected stems just above ground level and petioles are cut diagonally, a brown discoloration of the water-conducting tissues inside the stem will be seen (Plate 34).

Source of infection and spread: The fungus is both seed- and soil-borne. It may become established in many types of soil, but it is likely to cause the most damage on light, sandy soils. It is most active at temperatures between 25 °C and 32 °C. Since the fungus produces resting spores (chlamydospores), it can survive and remain in the soil indefinitely, even when no tomatoes are grown. It can also survive in fibrous roots of weeds such as *Amaranthus*, *Digitaria* and *Malva*. It can be spread by movement of infested soil or infected transplants. Acidic soils (pH 5.0 to 5.6) and ammonium nitrogen (as in ammonium nitrate and urea fertilisers) promote disease development. Infestation by root-knot nematodes makes the disease worse.

Disease management: Use resistant tomato varieties, e.g. Diego, Duke, Floridade, Fanny, Napoli, Radja. Use certified disease-free seed. Do not locate seedbeds on old soil or land where wilt is known to have occurred. Where soil is acidic, increase the pH to 7.0 by liming. Avoid excessive fertilisation and cultivation. Control root-knot nematodes (see page 87) if present in the field. Graft tomato plants on resistant root stocks where available.

***Sclerotium* wilt**

(Plate 35)

Cause: *Sclerotium rolfsii* Sacc.

Symptoms: The initial symptom is a general drooping of the leaves. Wilting progresses with time and finally the plant dies without much yellowing of the foliage. The stems show a brown decay of the outer tissues at the ground level. The decayed tissues are covered with a white fungal mat in which are embedded many small, light-brown bodies about the size of a cabbage or mustard seed (Plate 35). The bodies are known as 'sclerotia' and are characteristic of the disease. The fungus also infects the fruit where they touch the soil. It causes yellow, slightly sunken areas that break open as the spots enlarge. Fruit decay is rapid and the fruit soon collapses and is covered by the fungal growth.

Source of infection and spread: The host range for the fungus is very wide and it includes crops such as beans, brinjals (eggplant), cabbage, lettuce, okra, peppers, potatoes, squash, sweet potatoes, watermelons and some ornamentals. It requires abundant moisture and high temperatures (30 C) for growth and is most prevalent on acidic, light, poorly drained soils. The fungus is spread in running water, with infested soil, with infected seedlings, and as sclerotia mixed with seed. The sclerotia can survive in the soil for a long time.

Disease management: Do not locate seedbeds on land where the disease has occurred within 3 years. In smallholdings, where all the plants can be readily observed for the presence of the disease, removal and burning of any infected plants could keep the disease in check. Three- to 4-year rotations with maize and sorghum could reduce the amount of disease. Better still is to rotate tomato with paddy rice. Other helpful practices include eradicating weeds, avoiding contaminated manure, avoiding dense planting, and choosing fields with soil that is not acidic, but is high in humus, and well drained. In areas where water is plentiful, flood tomato fields with water for several months each year.

Verticillium wilt

Cause: *Verticillium albo-atrum* Reinke & Berhold

Symptoms: Older leaves yellow and gradually wither and drop, and eventually the crown (top) of the plant is defoliated. All branches are affected and have a tendency to be less erect than those of healthy plants. In late stages of the disease, only the leaves near the tips of the branches remain. Symptoms are more noticeable when the plants are heavy with fruit or when a dry period occurs. Because of severe defoliation, much of the crop is often lost due to sunscald. When the stem is cut lengthwise, the base shows a brownish colour in the woody tissues much like that caused by *Fusarium* wilt (see page 70 and Plate 34).

Source of infection and spread: The fungus has a wide host range. It often affects vegetables such as broad bean, brinjal, cucumber, muskmelon, okra, pepper, potato and watermelon. It is seed-borne and soil-borne. It can survive in the soil for a long time in a dormant form (mycelium, micro-sclerotia) or as a soil inhabitant. The disease is worse after root injury caused by transplanting or cultivation, and if nematode feeding occurs. The fungus can be spread by wind and water and with infested soil and seed. Growth of the fungus is favoured by cool temperatures (21–25 °C). This is in contrast to *Fusarium* wilt, which prefers warm temperatures.

Disease management: Use resistant tomato varieties, e.g. Rutgers, Radja, Thomas, Carmelo, Heinz 1370. Use certified disease-free seed. Do not locate seedbeds on land where wilt was previously observed. Remove and destroy crop debris immediately after harvest. Rotate with cereals, grasses and maize. Fields should be kept free of weeds. Control plant parasitic nematodes, if present in the field (see page 87).

Leaf mould

(Plate 36)

Cause: *Fulvia fulva* (Cooke) Ciferri (*Cladosporium fulvum* Cooke)

Symptoms: Pale-green or yellowish areas with undefined margins appear on the upper leaf surface. Under humid conditions the lower surfaces of the spots become covered by an olive-green to greyish-purple velvety growth of the fungus (Plate 36).

Source of infection and spread: The velvety mould produced on the underside of the affected leaves contains large numbers of spores, which are spread by air currents, watering and contact with plants. The disease can also be seed-transmitted. Temperatures around 26 °C and wet weather favour disease development.

Disease management: Use resistant varieties where available. Use certified disease-free seed. Remove and destroy crop debris after harvest. Prune and stake to reduce humidity. Avoid excessive shading by providing adequate plant and row spacing. Avoid wetting leaves when watering. A large number of fungicides provide adequate control; these include chlorothalonil (e.g. Daconil®, Bravo®), mancozeb (e.g. Dithane M45®) and propineb (e.g. Antracol®). Read the product label and observe pre-harvest intervals when chemical intervention is necessary. Ensure the products are registered for use on tomato.

Powdery mildew
(Plate 37)

Cause: *Leveillula taurica* (Lev) Arnaud (*Oidiopsis taurica* Tepper)

Symptoms: Light chlorotic to bright yellow spots appear on older leaves. These spots later run together and become necrotic. Whole leaf blades may collapse and dry up. On the upper leaf surface of green leaves a fine talcum-like powder is observed (Plate 37). This is fungal growth. Soon it becomes evident on both upper and lower leaf surfaces.

Source of infection and spread: The fungus survives in crop debris. Spores are wind-blown. The fungus reproduces under remarkably dry conditions, but for infection to occur, it requires humidity in the range of 52 to 75% and temperatures around 26–27 °C.

Disease management: Remove and destroy crop debris after harvest. Keep tomato fields free of weeds. Do not grow brinjals or tomatoes in succession. Chemical intervention should be applied only when necessary. Ensure the products are registered for use on tomato. Sulphur-based fungicides, bupirimate (e.g. Nimrod®), triadimefon (e.g. Bayleton®) and triforine (e.g. Saprol®) afford adequate control. It should be noted that sulphur is harmful to predatory mites which are useful natural enemies of some arthropod pests. Prior to chemical application, read the product label and observe pre-harvest intervals.

Septoria leaf spot
(Plate 38)

Cause: *Septoria lycopersici* Spegazzini

Symptoms: The disease may occur on plants of any age, but it usually becomes most evident after the plants have begun to set fruit. Small (2–3 mm) water soaked spots are first seen on older leaves. These spots become circular with grey centres and black margins (Plate 38). Later, tiny black dots are seen at the centres of the spots; these are fruiting bodies (pycnidia) of the fungus. The spots are smaller, without concentric rings, and more numerous than those of early blight. Affected leaves die and drop. Because of defoliation, fruits are exposed to sunscald. Fruits are not spotted. When the disease is severe, spotting of stem and blossom may occur.

Source of infection and spread: The fungus can infect brinjals, potatoes, tree tomatoes and weeds such as black nightshade. It can survive in or on seed and debris of diseased plants. Spores are produced by the pycnidia (see above). During wet weather they are released onto the leaf and are splashed onto other leaves by rain or spread by brushing against the moist foliage. The fungus is most active at 20–27 C. During hot, dry seasons the disease causes little damage.

Disease management: Use certified disease-free seed. Plough deep to bury crop refuse. Clean-cultivate and remove solanaceous weeds. Rotations of up to 3 years with cereals or legumes may help in control. Plant early to escape disease. If symptoms are observed early in the wet season, the crop could be sprayed. Chlorothalonil (e.g. Bravo®, Daconil®) or mancozeb (e.g. Dithane M45®) give satisfactory control. Ensure the products are registered for use on tomato. Read the product label before using a fungicide and observe pre-harvest intervals.

Viral diseases

Common mosaic

(Plates 39 and 40)

Cause: Tomato Mosaic Virus (ToMV)

Symptoms: Affected plants exhibit a mottling with raised dark green areas and some distortion (odd-shaping) of the youngest leaves (Plate 39). Under conditions of high temperature and high light intensity, the mottling is frequently severe, but stunting is slight. Under conditions of low temperature and low light intensity, the mottling is not noticeable, but stunting and leaf distortion are severe. Internal browning of the fruit sometimes occurs and this symptom is most common when fruits become infected at the mature green or pink stage (Plate 40).

Source of infection and spread: The virus has many strains. It is very persistent, has a very broad host range, and is transmitted with ease by mechanical means. Virus-infected seed and plant debris in the soil are generally considered the most important sources of ToMV.

Disease management: Use resistant varieties (e.g. Tengeru 97, Carmello, Radja and Thomas). These practices may help to reduce the disease: do not overlap tomato crops; do not use freshly harvested seed; remove crop refuse and roots from fields; and eradicate weeds.

Cucumber mosaic

(Plate 41)

Cause: Cucumber Mosaic Virus (CMV)

Symptoms: Infected plants are stunted, have short internodes, and appear bushy and compact. Leaves show mottling, mosaic, and may be extremely distorted and malformed. Often the leaflets consist of only a central rib and have a shoestring appearance (Plate 41).

Source of infection and spread: Several strains of CMV exist. It is not persistent in soil and refuse, but can be mechanically transmitted, and usually is spread by aphids. However, infection by aphids is not common as tomato is not a preferred host of the aphids that usually feed on cucurbits (pumpkins, cucumbers). Infection can take place at any time during the growth period, even when plants have reached maturity and are bearing fruit. Since aphids are responsible for spread, infected plants may be widely separated within the field.

Disease management: Avoid overlapping crops of tomato. Remove all weeds. Do not plant tomato near fields of cucurbits. Plant aphid trap crops such as beans around tomato fields and spot spray with fast-acting aphicides registered for use on tomato. Barrier crops such as sunflower are generally planted around the main crop, e.g. tomato and beans. These can check aphid movement. They are planted a month or two earlier than the main crop. Where the disease is endemic (commonly found) and serious, use reflective mulches such as rice straw, sawdust or aluminium-coated sheets. Pull out any diseased plants.

Veinal mottle disease

Cause: Chili Veinal Mottle Virus (CVMV)

Symptoms: Leaves of affected plants become yellowish along the veins and later between the veins. The affected leaves often are stunted, narrow, and severely distorted. Such leaves frequently drop prematurely. Flower drop is also evident on diseased plants. Fruit may be distorted. Fruit size and number may be reduced on partially defoliated and chronically infected plants.

Source of infection and spread: The major sources of the virus are infected weeds and cultivated plants. Hosts include mainly solanaceous plants, but also a few plants in other families. The virus is transmitted by aphids and also mechanically. Aphids can pick up the virus in five seconds from an infected source and remain infective for about one hour, after which they lose the ability to transmit the virus.

Disease management: Avoid overlapping crops of tomato. Isolation from diseased fields of solanaceous crops can help. Eradicate weeds. Pull out diseased plants. Use straw, sawdust or aluminum-sheet mulch. Plant an aphid trap crop like beans around tomato fields and spot spray with a fast-acting aphicide registered for use on tomato. Planting a barrier crop such as sunflower between trap crop and tomato may reduce or prevent aphid movement.

Spotted wilt disease

(Plate 42)

Cause: Tomato Spotted Wilt Virus (TSWV)

Symptoms: Purplish-brown spots appear on young leaves. The spots are often crescent-shaped and up to 3 mm long. Older infected leaves turn brown, die and droop. Similar streaks occur on the petioles and stems. The entire plant becomes dwarfed, and with its drooping leaves it resembles a plant affected by a wilt. Symptoms on fruits consist of concentric (circular) zones of shades of yellow or brown alternating with green and later with pink or red (Plate 42). The fruit symptoms are the most characteristic of the disease.

Source of infection and spread: TSWV has an exceedingly wide host range including many ornamental plants, weeds and vegetable crops. The virus is transmitted by thrips *(Thrips tabaci, Frankliniella schultzei, F. occidentalis* and *F. fusca)*. Adult thrips are unable to pick up the virus from infected plants. The virus must be acquireo by the larvae and the adults from these larvae can then transmit the virus. These thrips vectors often retain the virus for life. TSWV persists from year to year in infected host plants, thus providing plenty of inoculum for the thrips each crop season.

Disease management: Use resistant/tolerant varieties, e.g. Star 9006, Star 9008. Keep tomato fields isolated from ornamentals, and remove weeds. Remove diseased plants from fields. Control thrips at early growth stage. Chemical intervention should only be applied when necessary. Make sure the products are registered for use on tomato. Fipronil (Fipronil®), methiocarb (e.g. Mesurol®) and spinosad (Tracer®) provide reasonable control of larval forms. Read the product label and observe pre-harvest intervals.

Yellow leaf curl disease
(Plate 43)

Cause: Tomato Yellow Leaf Curl Virus (TYLCV)

Symptoms: Tomato plants infected early in the season are normally stunted and excessively branched (Plate 43). Such plants have terminal and axillary shoots erect while leaflets are reduced in size and abnormal in shape. Affected leaves are chlorotic and curled upward. Flower drop is common, and therefore infected plants have a reduced number of flowers and fruit. If infection takes place at a later stage of growth, fruits already present develop normally. Generally, table tomatoes are severely affected by the disease, especially when infection occurs before the flowering stage.

Source of infection and spread: TYLCV is not seed-borne and is not transmitted mechanically. TYLCV can infect only solanceous plants. The disease is spread by whiteflies *(Bemisia tabaci)* (see page 35). Whiteflies have a wide host range. New plant growth attracts whiteflies which feed on the lower leaf surface. It takes about 15–30 minutes for the whitefly to become infected by the virus. The incubation period is 21–24 hours, and the transmission period at least 15 min. The disease is favoured by high temperatures, and low or no rainfall.

Disease management: Use resistant/tolerant varieties, e.g. Amareto, Peto 86, Fiona F1, Perlina, Denise, Cheyenne (E 448), Rover. Protect seedbeds with a white nylon net (40 mesh). Mulch the seedbeds and drench with imidacloprid (e.g. Gaucho®, Confidor®). Eradicate weeds. Pull out diseased seedlings. Plant barrier crops like maize around tomato fields. These crops should be sown a month or two before transplanting of tomato. Mulch tomato fields with sawdust, straw or yellow polyethylene sheets. Avoid continuous growing of tomato. Drench or spray with imidacloprid (Gaucho®, Confidor®) at the early growth stage. Do not spray with insecticide more than once in a season. Read the product label and observe pre-harvest intervals.

Plant-parasitic nematodes

Root-knot nematodes

(*Meloidogyne* spp.)

(Plate 44)

Symptoms: Affected plants become stunted and yellow and have a tendency to wilt in hot weather. Very heavily infested plants are killed. If infested plants are pulled from the soil, the roots are severely distorted, swollen and bear knots or galls (Plate 44). The galls range in size from smaller than a pinhead to 25 mm or more in diameter.

Source of infection and spread: Root-knot nematodes are soil inhabitants. They affect a wide range of crops, particularly vegetables. They are spread by transplanting infested seedlings, or from soil washed down slopes or sticking to farm implements and farm workers. They may also be spread by irrigation water. The disease is most serious on light, sandy soils and in furrow irrigated areas. Attack of a plant by nematodes may greatly increase the severity of bacterial, *Fusarium* and *Verticillium* wilt diseases.

Disease management: Use resistant varieties (e.g. Caracas, Piersol, Zest F1, Star 9001, Star 9003). Do not locate seedbeds where vegetables have been grown previously. After preparation of the seedbed, burn the topsoil using dry leaves or other waste plant material. Solarise seedbeds if possible. Mix neem cake with soil in seedbeds. Uproot entire plants from the field after harvest and destroy crop refuse. Fields should be ploughed deep and then followed by a dry fallow.

Rotate tomato with small-grained cereals (e.g. millet, sorghum) or *Crotalaria* (sunhemp). Use trap crops such as marigold (*Tagetes* sp.) and Indian mustard. Mixed cropping with marigold can also minimise root-knot nematode damage.

Non-parasitic diseases

Blossom-end rot

(Plate 45)

Cause: Calcium deficiency

Symptoms: The disease always occurs at the blossom-end of the fruit. It starts as a water-soaked spot that enlarges to become dark brown and sunken (Plate 45). The surface of the spot becomes dark and leathery, but there is no soft rot unless it gets invaded by soft rotting bacteria or fungi.

Disease management: Calcium-deficient soils should be limed before planting. Nitrogenous fertilisers should be applied sparingly at planting. Soil moisture should be regulated at a relatively constant level where possible. Avoid water stress during early stages of fruit development by watering regularly. Soil acidity should be maintained around pH 6.5. Foliar spraying with calcium chloride can reduce damage by blossom-end rot.

Fruit cracking

(Plate 46)

Cause: Water fluctuation/high temperatures

Symptoms: Whenever tomatoes are grown, the surface sometimes cracks at the stem end of the fruit. The cracks may be concentric (circular) or radial (Plate 46). They vary in depth, but are often deep into the flesh. Cracks in the fruit, which usually appear as the fruit starts to ripen, reduce value and also provide entry points of infection for organisms causing rots.

Control options: Susceptibility to cracking in tomatoes relates to the strength and stretching ability of the fruit skin. Rapidly growing fruit tend to be more susceptible and changes in growth rate promote the disorder. Rain and wide fluctuations in temperature also promote cracking. Exposed fruit crack more readily than those protected by foliage. Varieties of tomato differ in their susceptibility to cracking. The varieties Roma, Chico and Parker are markedly resistant to cracking. To reduce the incidence of this physiological problem, particularly with susceptible varieties, it is important to manage irrigation schedules properly, and not to over-use nitrogen fertiliser. Harvesting before the pink stage of ripeness and selection of crack-resistant cultivars probably offer the best protection against cracking.

Sunscald
(Plate 47)

Cause: Exposure to the sun

Symptoms: Sunscald is most common on immature, green fruit. At first a yellow or white patch appears on the side of the fruit exposed to the sun. This spot may remain yellow as the fruit ripens, but frequently the tissues are more severely damaged and a blister-like area develops (Plate 47). Later this shrinks and forms a large, flattened, greyish-white spot with a dry paper-like surface. The problem occurs most frequently during hot, dry weather and on unstaked tomatoes. This injury is common on plants that have suffered defoliation as a result of leaf-spot diseases such as early blight or defoliating insect pests.

Control option: Prevent foliar diseases and defoliating pests. Stake tomato plants. Where fruits are exposed, screen from the sun with a light covering of straw over fruit clusters. Take care when pruning and harvesting not to over-expose fruits to the sun.

Annex 1

Guidelines on best use of pesticides

Pesticides are among the pest control tools most frequently used. They have been the foundation of pest control in the last few decades. However, the sole reliance on pesticides and their indiscriminate use have led to problems such as environmental contamination, toxic residues, side effects on non-target organisms, increase of pest resistance to pesticides, secondary pest outbreaks, and pest resurgence. Nowadays, chemical pesticides are regarded as important tools in pest management programmes only when used in combination with other control options. Only in the case when no alternatives are available should a pesticide be used. As with other control options, application of pesticides should be done based on pest monitoring and scouting. Prophylactic (preventive) applications are often in the long term not advantageous, and might lead to development of resistance.

The proper use of pesticides requires the following:

- Proper identification of the target pest, knowledge of its biology, feeding habits and population dynamics. This allows selection of the best or most appropriate pesticide and proper timing of application.
- Information on damage caused by the pest and on value of the crop.
- Compatibility with other control options, for instance, the effect of the pesticide on non-target organisms, particularly natural enemies.

- Use of recommended dosage rates and application frequency.
- Use of appropriate application techniques
- Observation of safety precautions (human, livestock and environment).

Pesticides can be classified according to the type of pest they control as follows:

- Insecticides: chemicals that kill insects
- Acaricides (mitecides): chemicals that kill mites
- Fungicides: chemicals that kill or inhibit the growth of fungi
- Bactericides: chemicals that kill or inhibit the growth of bacteria
- Nematicides: chemicals that kill or inhibit the growth of nematodes
- Herbicides: chemicals that kill weeds.

Chemical pesticides have been classified according to their toxicity by the World Health Organisation (WHO) as follows:

- Class Ia: extremely hazardous
- Class Ib: highly hazardous
- Class II: moderately hazardous
- Class III: slightly hazardous
- Table 5: product unlikely to present acute hazard in normal use.

Pesticides in Class Ia and b and Class II should not be used in vegetables because of their high toxicity.

Keys to responsible use of pesticides

- Use pesticides only when it is necessary. Seek appropriate advice, if unsure.
- Choose the pesticide according to the target pest (use insecticides for control of insects, fungicides for control of fungal diseases, acaricides for mite control, etc.)
- Avoid pesticides in WHO Toxicity Class Ia, Ib and II. Select environmentally compatible pesticides (those that are not harmful to beneficial insects, bees, birds, aquatic life and wildlife). Seek advice, if unsure.
- Use products that are registered for use for particular crops by your local regulatory agency. Seek advice, if unsure.
- Do not buy pesticides from unauthorised dealers.
- Read the product label carefully.
- Never exceed the rates, timing and number of applications recommended by manufacturers.
- Ensure spray equipment is clean, accurately calibrated and in good working order.
- Do not apply pesticides when honeybees are visiting plants or when there is a high activity of beneficial insects. The best spraying time is very early in the morning or late in the afternoon.
- Avoid drift during application.
- Wear protective clothing when applying pesticides.
- Do not eat, drink or smoke while spraying or handling pesticides. Ensure hands are washed after application.
- Strictly observe pre-harvest intervals quoted on the product labels.

- Do not clean spray equipment or dump excess spray material in or near water sources.
- Never use empty pesticide containers for carrying or storage of milk, water, food or feed or for any other purposes. Always perforate and crush empty containers and bury them deep, far from water sources.
- Store pesticides in their original tightly closed containers under lock and key. Ensure pesticides are kept in a cool and dry place, out of the reach of children and animals, and away from food and feed.

Annex 2

Vegetable nursery management guidelines

Seedbed preparation

There are three ways to raise seedlings:

- on seedbeds
- in seed trays
- in seed pots

Seedbeds: Seedlings can be raised in an open seedbed. Selection of a good site is important. The site should be near a water source, well protected from wind and in a disease-free area (an area which was not previously under vegetables). It is advisable to sterilise the soil to kill weed seeds and soil-borne pathogens. This can be done by placing on the seedbed plenty of dry maize or sorghum stubble or straw and burning the trash for 30 minutes. After cooling, mix the soil with compost.

In theory, a seedbed can be of any size depending on the number of seedlings required. Usually seedbeds are 1.2 m wide and 8 m long and slightly raised. A path of 15 to 18 cm is left open for walking in between the beds.

A loose soil is required for good seed germination and for healthy and strong seedlings. A sandy loam soil well supplied with humus is ideal. Application of farmyard manure and double super phosphate at the rate of 3 kg and 3 g per square metre, respectively, is recommended. These are well mixed with the soil.

In many cases seeds are sown in rows. Spacing within and between rows depends on the vegetable species. For example, tomato spacing is 5 x 5 cm and planting depth is about 1.5–2 cm in the soil. The rows are made prior to sowing. Very small seed like celery may be broadcasted. The seed is sown thinly and is covered with light soil and firmed lightly. The depth of covering is determined largely by the size of the seed and the texture of the soil. Very small seed should be covered lightly with fine soil. In heavy soils, seeds should not be sown deeply.

A seedbed should be shaded to protect it from bright sunshine, heavy rains and excessive drying. If the top centimetre of the soil feels dry, it is necessary to moisten the seedbed. It is best to water the beds once a day, preferably in the morning. The seedlings and the top layer of soil should be dry before night. Do not excessively water at one time because it can cause moulding (especially in shaded areas).

Seed trays: An easier way to nurse healthy seedlings is in seed trays. Seed trays are easy to transport and to water. In addition, it is also possible to use a better soil mixture for the seed trays than for the seedbeds. Compost or an equal mixture of compost and soil could be used. However, do not use soil that was previously under vegetables. Such a soil could be infested by root-knot nematodes and soil-borne pathogens. It is advisable to disinfest the soil before it is used. One way to do this is by steaming the soil. Place the soil on a flat sheet of aluminium (or corrugated iron). Wet the soil and heat it by placing the sheet over a fire. Heat

30 minutes until almost dry. Let it cool and then mix it with compost. Sow seeds in rows.

Seed pots: Seed pots can be made from cardboard, compacted peat, banana leaves or plastic. If plastic pots are used, seedlings need to be taken out of the pot when transplanting. This is not necessary if pots of degradable (organic) material are used. The advantage of using organic pots is that the roots are less damaged during transplanting and less likely to dry up. Compost or a mixture of compost and soil could be used.

Seedbed care

Mulch the seedlings in the seedbed. The seedbed should be carefully watered with a fine spray from a watering can or a garden hose. The seedbed should be kept moist throughout but not wet—avoid over-watering. Water the seedlings in the morning and thin out seedlings to avoid congestion. The seedlings pulled out can be planted in other beds. Weak or diseased seedlings should be pulled out and discarded. Shade the seedbed to avoid sun scorching, drying of the soil and also against heavy precipitation. Shade should later be removed when hardening the seedlings. Damping-off diseases constitute the biggest problem in the nursery. Information on damping-off diseases and their management is given in detail under the section 'Damping-off diseases' on page 59.

Choice of vegetable species and varieties

Appropriate species of vegetables and varieties suitable to the growing areas have to be chosen.

This decision is governed by climatic conditions (particularly the prevailing day and night temperatures and rainfall patterns), the complex of pests and diseases likely to be present and market demands. Therefore, there may be a need to grow different vegetables from season to season. For example, do not grow tomatoes during the wet season due to the high prevalence of diseases and a possible glut in the market, as most farmers plant tomatoes during the long rains. If possible, plant varieties which are tolerant or resistant to the major pests or diseases prevalent in the area.

Always purchase high quality seed true to type from reputable stockists and demand certified disease-free seed. This is particularly important in vegetable production, otherwise all efforts would be fruitless, not to mention the monetary loss from a poor or diseased crop.

Transplanting

Field preparation: Plough and harrow the field well. Use level or sunken beds in dry seasons or in dry areas and in sandy soils. In humid areas or during the rainy season and in loamy or clay soils, it is better to plant on raised beds to prevent water-logging. The height of the bed can vary from 20 to 50 cm depending on rainfall, soil type and slope of the land. The distance between the beds varies from 30 to 50 cm. A bed can be 1–1.5 m wide. Distances between rows and plants are largely determined by the type of crop.

Transplanting: Before removing the seedlings, the seedbed should be thoroughly watered. This helps to keep more soil around the roots and reduce root damage. Use a hand-fork to remove seedlings from the beds. A phosphate fertiliser such as double super phosphate should be applied in the planting holes at the recommended rate and thoroughly mixed with soil. Select vigorous disease-free seedlings true to variety for transplanting. When transplanting, set the seedlings a little deeper than in the nursery bed to ensure that the upper roots are not exposed. It is advisable to transplant in the late afternoon or under humid weather conditions. In the dry season, water the transplants till they are well established.

The size and quality of the seedlings set in the field will determine the yield and quality of the crop. Seedlings should be transplanted when about 15–20 cm in height and about 6–10 weeks old. Older or leggy seedlings are difficult to transplant and the mortality rate is higher. Regularly weed the field and monitor for pests and diseases.

Annex 3

Crop scouting, inspection and monitoring

Crop scouting

Crop scouting, also referred to as monitoring or inspection, is the constant vigilance of a crop for arthropod pests, diseases, nutritional disorders and general plant health. It involves gathering and recording of information about a crop on a regular basis. Regular crop inspection is essential to detect a problem at its earliest stage in the crop and take action before serious damage occurs. It helps to reduce many preventative tactics that may be unnecessary.

Crop monitoring methods include plant sampling, use of insect traps and indicator plants. To scout a crop the farmer walks through the crop area to get an overview of the major problems and/or crop condition. This also helps the farmer to develop a record sheet for the day. The farmer will then inspect the crop, picking plants at random on pre-determined stations (sampling sites). Different sampling spots should be checked each time the crop is inspected. The plant samples should be selected in such a way that the whole field is covered. The number of sampling sites on each stretch will depend on the size of the field. The number of plants to be inspected on each station will depend on the size of the plants, the crop and spacing. Even while carrying out a random sampling, the farmer should be alert for unusual problems or conditions in the rest of the field.

Examination involves a thorough inspection of the whole plant from soil and roots to the top of the newest shoot, with a careful check of both the upper and underside of all the leaves and fruits and flowers.

Problem recognition

For proper management, it is important for the farmer to know what a healthy crop looks like, to be familiar with normal crop growth changes, and to recognise the major pests of the crop in their various stages of development and the typical damage caused by a specific pest. It is important for a farmer to be able to differentiate a pest damage symptom from a nutritional problem, a chemical burn, weather damage and physiological disorders.

Record keeping

Proper record keeping is equally important. A written logbook or record sheet should be kept of the problem type, locality, abundance and any other disorder observed. A record of all remedial measures taken should also be kept. Such records may also be of long-term benefit, as many pests and diseases tend to appear about the same time each year. In the short-term, the records would be handy to decide on a management strategy.

Decision-making

Once the field has been inspected, a farmer has to make a decision on what to do to optimise production. For a farmer to make a valid informed decision, it is proper to consider the following:

- prevailing weather conditions
- growth stage

- yield potential
- pest stage
- pest damage relationship
- previous field records
- results of options already implemented
- presence of beneficial arthropods (e.g. bees, ladybird beetles, predatory mites, etc.)
- potential management options available.

Glossary

Arthropod: an animal, usually very small, with a hard skin, segmented body and jointed legs. Includes the insects, spiders, mites, ticks, millipedes and others.

Broad-spectrum pesticides: pesticides that kill many different types of pests.

Canker: a dead area on a plant caused by a disease.

Classical biocontrol: control of imported pests by importing natural enemies (predators or parasitoids) from the same country or region where the pest originated.

Collar rot: stem end (at soil level).

Concentric: circular or round.

Crucifers: plants in the family Cruciferae (another name for the family Brassicaceae) such as cabbage, cauliflower, kale and others.

Cucurbits: vegetables/fruits in the family of cucumbers, sweet melons, watermelons, pumpkins, squash and others.

Damping off: rotting of seeds in the soil or dying of seedlings.

Defoliation: removal or shedding of leaves.

Determinate varieties: varieties that do not grow tall and are able to stand without staking or trellising. Also known as bushy varieties.

Elongated: long.

Entomophagous: organisms that feed on or attack insects

Forewings: front wings of insects.

Frass: droppings or wastes left by feeding insects.

Geminiviruses: disease-causing agents that can be seen only with electronic microscope.

Girdled: constriction around the stem caused by pest damage.

Indeterminate varieties: tall growing varieties that usually need pruning and cannot support themselves, but which need staking and trellising.

Internodes: part of a stem between shoots.

Maggots: young stages of flies. They look like short worms with no legs.

Mosaic: a colour pattern on leaves consisting of yellow and green shades.

Mottling: discolouration of a leaf or fruit.

Mycelium: fungal growth inside or outside of a plant tissue.

Necrotic: containing dead tissue.

Nymph: one of the stages of the life cycle of mites or some insects. They usually look very similar to adults, but in the case of insects, do not have wings.

Persistent: when a virus is not easily destroyed and stays active for a long time.

Petiole: leaf stalk.

pH: a measure of acidity/alkalinity in the soil. The pH of 7.0 is neutral, lower than 7.0 is acidic and higher than 7.0 is alkaline.

Pheromones: chemicals produced by insects that attract individuals of the same species.

Phloem: tubes/vessels that transport water in the plant.

Pith: tissue filling the centre of plant stems.

Polyphagous: organisms feeding upon a range of plants (hosts).

Pupa (plural pupae): the stage of development between larva and adult in the life cycle of some insects (for example moths, flies). Pupae usually have a hard skin and do not move or feed.

Pupate: to develop into a pupa.

Sclerotia: resting bodies of the fungus produced when conditions are not favourable for disease development.

Solanaceae: plant family containing tomatoes and other crops such as eggplants, potatoes and peppers.

Solarise: to cover the soil with clear or transparent polyethylene sheets, with the aim of heating the soil with the hot sunshine to kill pests and disease organisms.

Staking: supporting plants with a stake or pole.

Stomata: openings on the lower leaf surface.

Stunted: restricted growth.

Translucent: allowing light to pass through but not transparent.

Trellising: supporting plants by tying them to wire, or a strip of wood or plastic strung between posts.

Trichomes: hairs on the leaf surface.

Tubercles: raised growths bearing hairs in insect bodies.

Vascular bundles: tubes/vessels in the stem that carry water and nutrients.

Vectors: arthropods which carry and transmit disease agents (e.g. viruses).

Zonate markings: ring or circular patterns.

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Figure 2. A guide to implementation of IPM in tomato production

Before you get started

Check the following:

- **Soil fertility:** take samples for analysis of macro- and micro-nutrients.
- Availability and quality of **water for irrigation:** take samples for analysis of salt content.
- **Disease history of the farm:** do not grow tomato if the farm has a history of serious soil-borne problems such as bacterial wilt, *Fusarium* wilt, *Sclerotium* wilt or *Verticillium* wilt. (For identification, refer to relevant sections of this manual.)
- **Suitable varieties:** to cater for existing or expected pest and disease problems and also for the agro-ecological zone.
- **Market** trends for the produce.

Standard recommendations for all production areas

Do's & don'ts

Nursery management

- Situate the nursery far away from previous season tomato crops.
- Prepare seed-bed properly: preferably use compost.
- Use certified disease-free seed treated for seedling pests and diseases.
- Treat your own seed with a fungicide and an insecticide.
- Mulch the seedbed.
- Avoid over-watering the seedbed: do not water late in the afternoon.
- Drench or spray with an appropriate product when virus vectors are observed.
- Constantly check your nursery and remove weak and unhealthy looking plants.

Transplanting and field operations

- Avoid transplanting seedlings in a field next or near an old crop of tomato.
- Transplant only robust, healthy seedlings.
- Keep tomato fields free of weeds.
- Avoid over-fertilising with nitrogen.
- Choose an appropriate irrigation system in relation to existing or expected pest and disease problems.
- Stake and prune indeterminate varieties; mulch determinate varieties.
- Avoid working in tomato fields when wet.
- Inspect plants for pests and diseases regularly and keep records of the same throughout the crop cycle.
- Ensure proper identification of pests and diseases; when in doubt consult extension officers or nearest research institution prior to taking intervention measures.

Fruiting period and harvest

- Consider pre-harvest intervals when applying pesticides after fruit set.
- Avoid damaging fruit when harvesting.
- Place harvested crop in a cool shaded area.
- Remove crop debris from fields after harvest.
- Avoid overlapping of tomato crops.
- Practise rotation with crops unrelated to tomato: examples include brassicas, cereals, fodder grass, legumes, lettuce, onions and cucurbits.

Where do you grow tomatoes?

Tomato production systems are basically different in semi-arid areas under irrigation and in the cool highland areas with supplementary irrigation during the dry seasons. The complex of pests and diseases and their intensity in these two areas varies due to differences in cropping systems and weather conditions. It is important to take into account these differences when planning pest and disease management measures.

Pests and Diseases

What are the major pests and diseases of tomato?

Semi-arid areas

Diseases

- Root rot nematodes (p. 87)
- Yellow leaf curl disease (p. 85)
- *Fusarium* wilt (p. 70)
- Bacterial wilt (p. 57)
- Early blight (p. 65)

Pests

- Whiteflies (p. 35)
- Fruitworms (p. 30)
- Mites (p. 21, 27)
- Thrips (p. 43)

Cool highland areas

Diseases

- Late blight (p. 68)
- Root-knot nematodes (p. 87)
- Bacterial canker (p. 52)
- *Verticillium* wilt (p. 74)
- Tomato Mosaic Virus (p. 80)

Pests

- Fruitworms (p. 30)

What other pests and diseases attack tomatoes?

Diseases
- Damping-off (p. 59)
- *Sclerotium* wilt (p. 72)
- Powdery mildew (p. 77)
- Blossom-end rot (p. 89)

Pests
- Cutworms (p. 47)
- Leafminers (p. 40)

Diseases
- Damping-off (p. 59)
- Leaf spot (p. 78)
- Bacterial spot (p. 55)
- Blossom-end rot (p. 88)

Pests
- Cutworms (p. 47)
- Whiteflies (p. 35)
- Leafminers (p. 40)
- Thrips (p. 43)

Always remember that proper identification is the first and most important step in controlling pest and disease problems. A misdiagnosis leads to mismanagement and to increased losses and costs. If in doubt after consulting this manual, check with a qualified crop protection professional.

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Specific management of major pests and diseases

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Tolerant/resistant varieties

Varieties that are tolerant or resistant are available for root-knot nematodes (examples: Caracas, Carmello, Diego, Piersol and Vegas); *Fusarium* wilt (examples: Carmen, Diego, Duke, Floradade and Peto 95-43); *Verticillium* wilt (example: Rutgers); Tomato Yellow Leaf Curl Virus (examples: Fiona F1, Peto 86, Strain B and Tengeru 97); bacterial canker [examples: Bulgaria 12, Bulgaria (P.I.324708), CMVF 232, Monense, MR4 and Okitsu Sozai]; fruitworms (examples: Bonus, Parker, Red Claude and Urbana); and early blight (example: PI-127833). Note that a lot of new tomato varieties are being launched into local markets. Therefore, always consult local seed companies on variety requirements prior to purchase.

Choice of irrigation system

Check the pest and disease history of the farm before deciding on the irrigation system to be used. Where soil-borne problems are common, avoid furrow irrigation and opt for either drip or overhead irrigation. Use overhead irrigation when red spider mites or thrips infestation is severe. Where foliar diseases such as early and late blights are common, use surface (preferably drip) irrigation. Drip irrigation is the choice system where both soil-borne and foliar diseases are prevalent. Nowadays, reasonably cheap drip systems are available in the market using buckets or drums. Consult the nearest agricultural research centre for information.

Protection of seedlings in seedbeds against root-knot nematodes, damping-off diseases and viruses

Burn plant trash on seedbed surface for 30 minutes, and after cooling, mix soil with equal amount of compost. Solarise the seedbed in semi-arid areas. These two practices are for control of root-knot nematodes and damping-off diseases. In semi-arid areas the latter practice could also minimise infection by bacterial wilt. (This is in addition to treatment of seed with a fungicide and an insecticide.) Where Tomato Yellow Leaf Curl and Tomato Spotted Wilt Viruses are a problem, cover young seedlings with insect-proof netting to restrict infestation by insect vectors such as whiteflies and thrips. If use of insect-proof netting is not possible, spray seedlings with an appropriate insecticide. Where root-knot nematodes are present at transplanting stage, place nematicide granules at planting holes in fields. In virus-prone areas, plant border rows of coriander or fenugreek which attract natural enemies and also repel whiteflies.

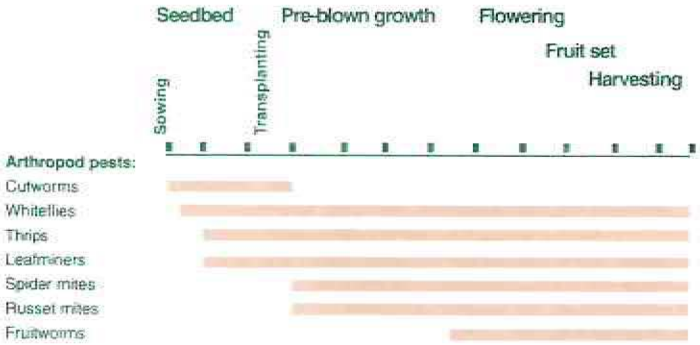
Field management of the major diseases and pests

If early and late plantings are made, grow them in separate isolated fields to reduce movement of foliar diseases and pests into late plantings. It is always advisable to stake and prune the plants. Wherever possible, mulch the soil surface to restrict soil splash during rains or irrigation, thereby reducing chances of late blight spread. Add lime to the soil where *Fusarium* wilt is a problem. Incorporate organic amendments where root-knot nematodes and bacterial wilt are a problem. Monitor fields weekly for pests and diseases. Use of sticky paper traps for pest monitoring is recommended. If a farm has a history of bacterial spot and bacterial canker, use copper-based products from transplanting to four weeks after transplanting.

Care should also be taken when pruning: disinfect pruning knives with a detergent after every plant. Thereafter bactericides should only be used when initial disease symptoms are observed. This principle is also applicable in the case of early and late blights. Choice of fungicides is very important and therefore consult extension officers or the nearest agricultural research station. If mite infestation is severe, spray with appropriate acaricides. Target the sprays at the top of the plants. In areas known for severe whitefly infestation, use neem-based insecticides. From fruit set to harvest, pay attention to fruitworms. If control of fruitworm caterpillars is required, use *Bt* products.

Always review what went wrong, but more importantly, what went right? Did the control measures work? Take a close look at the crop and compare pest and disease activity before and after treatment. What needs to be improved? Keep records of what you do and what you observe.

Figure 3: Tomato growth cycle and the occurrence of major pests and diseases



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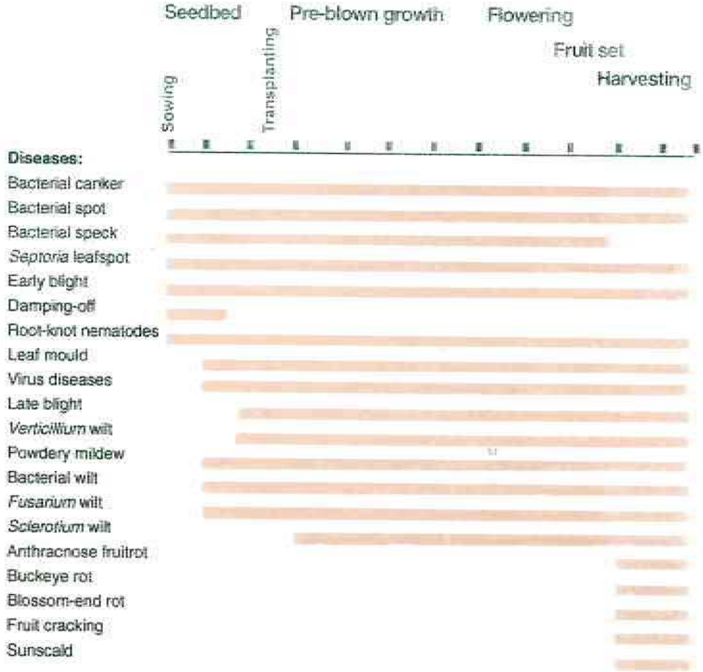
Seedbed
Pre-blown growth
Flowering
Fruit set
Harvesting
Sowing
Transplanting
Diseases:
Bacterial canker
Bacterial spot
Bacterial speck
Septoria leafspot
Early blight
Damping-off
Root-knot nematodes
Leaf mould
Virus diseases
Late blight
Verticillium wilt
Powdery mildew
Bacterial wilt
Fusarium wilt
Sclerotium wilt
Anthracnose fruitrot
Buckeye rot
Blossom-end rot
Fruit cracking
Sunscald

Natural enemies of tomato pests

Plate 1: Larva (main picture) and adult (inset) of a ladybird beetle

Plate 2: Nymph (main picture) and adult (inset) of the predatory bug *Orius* sp.

Plate 3: Larva (main picture) and adult (inset) of a syrphid fly

Plate 4: Larva (main picture) and adult (inset) of a lacewing

Plate 5: Predatory mite (bright red coloured) feeding on spider mites (dark red coloured)

Plate 6: Egg parasitoid *Trichogramma* sp.

Arthropod pests

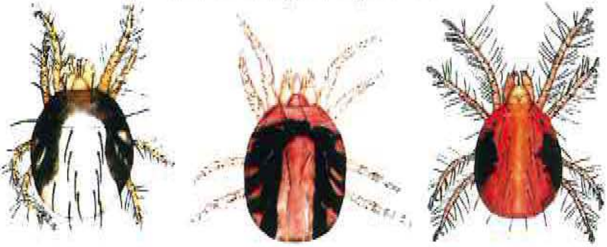

Plate 7: Female of *Tetranychus urticae* (left), *T. cinnabarinus* (centre) and *T. evansi* (right). Body size: 0.5 mm long

Plate 8: Two-spotted spider mites, eggs and females (green with dark spots); note the predatory mite *Phytoseiulus persimilis* (big and red-coloured) near central leaf vein

Plate 9: Leaf damage caused by spider mites

Plate 10: Tomato plant damaged by spider mites

Plate 11: Tomato plant with a high infestation of *T. evansi*

Plate 12: Spider mite damage on tomato fruit

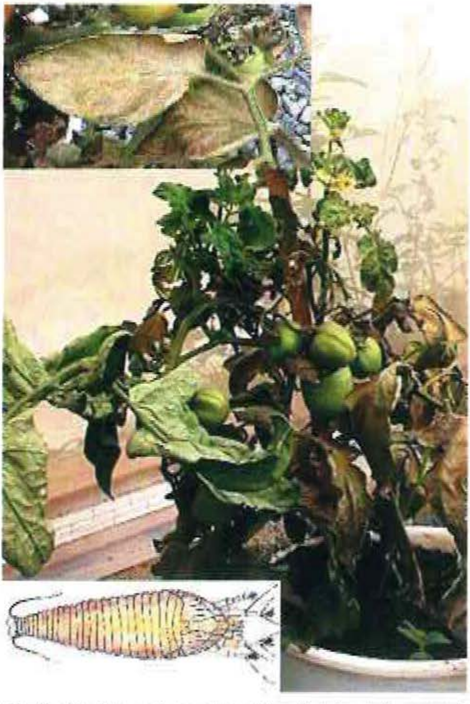

Plate 13: Damage caused by the tomato russet mite *Aculops lycopersici* (body size: 0.2 mm long). Close-up of a damaged leaflet (upper left inset)

Plate 14: Tomato fruitworm *Helicoverpa armigera* larva; adult moth (inset)

Plate 15: Adult moth of *Spodoptera* sp. (inset) and damage caused by the larva on a tomato fruit

Plate 16: Tomato fruits damaged by fruitworms

Plate 17: Fruit damaged by fruitworms, showing secondary infection

Plate 18: Whiteflies on tomato

Plate 19: Leafminers on tomato: note feeding punctures made by the adults and two leafminer flies on leaf. INSET: Close-up of a leafminer fly

Plate 20: Damage caused by leafminer larvae mining on leaf: note larva ready for pupation (yellow) and pupa (brown) on leaf

Plate 21: Heavy damage by thrips on tomato leaflet (top), and tomato fruits (bottom). Inset: A thrips adult (body size = 1–2 mm)

Plate 22: Larva of greasy cutworm

Bacterial diseases

Plate 23: Bacterial canker: 'Birds-eye' spotting. Note a white halo around the spots. Centre of the spot breaks open

Plate 24: Bacterial speck. The specks are superficial and pits may be formed due to differential growth of fruit tissue

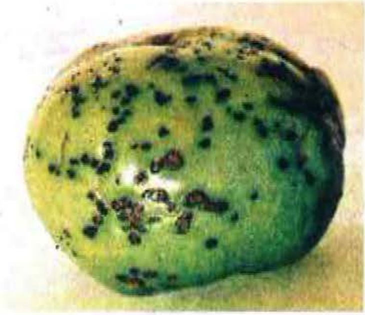

Plate 25: Bacterial spot. Older spots are blackish and slightly raised; centre spots eventually disintegrate and sink

Plate 26: Bacterial wilt caused by *Ralstonia solanacearum*: note wilting without necrosis of the foliage compared to *Fusarium/Verticillium* wilt

Plate 27: Water test for detection of bacterial wilt (*Ralstonia solanacearum*): note bacterial strands oozing from infected tissue

Fungal diseases

Plate 28: Seedbed affected by damping-off

Plate 29: Anthracnose on tomato fruit

Plate 30: Buckeye rot showing water-soaked margin and circular markings

Plate 31: Left: Early blight *(Alternaria solani)* on leaves and fruits: note concentric rings in the spots (inset). Right: Lesions on the fruit

Plate 32: Late blight (*Phytophthora infestans*): note scorched appearance of leaves and stems

Plate 33: Late blight (*Phytophthora infestans*): note corrugated surface of affected fruits

Plate 34: *Fusarium* wilt: note browning of conducting tissues

Plate 35: *Sclerotium* wilt: note brownish round bodies (sclerotia)

Plate 36: Leaf mould: note olive green to greyish purple growth of the fungus on lower leaf surface

Plate 37: Powdery mildew: note talcum-like powder on upper leaf surface

Plate 38: *Septoria* leaf spot: note spots with grey centres and dark margins (inset)

Viral diseases

Plate 39: Leaf from plant affected by Tomato Mosaic Virus (left) and leaf from healthy plant (right). Inset: close-up of leaflet showing symptoms

Plate 40: Strain of Tomato Mosaic Virus (ToMV): note internal browning

Plate 41: Cucumber Mosaic Virus symptoms

Plate 42: Tomato Spotted Wilt Virus symptoms

Plate 43: Tomato Yellow Leaf Curl Virus symptoms

Parasitic diseases

Plate 44: Root-knot nematodes: diseased (left) and healthy plant (right)

Non-parasitic diseases


Plate 45: Blossom-end rot (note concentric pattern of the symptoms)


Plate 46: Fruit cracking (concentric left) and radial (right) cracking

Plate 47: Fruit affected by sunscald

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Pest and disease damage in tomatoes: by fruitworms (a), blossom-end rot (b), bacterial spot (c).

Front cover: Two pests, two diseases; From left: cutworm larva, late blight fruits, tomato fruitworm larva and *Alternaria* fruit rot.

As one of the most widely cultivated vegetables in Africa, tomatoes are grown by smallholders for home consumption and as a cash crop on medium-sized commercial farms.

Yields are generally low, however, due in part to a large number of pests and diseases. These were prioritised at a meeting of horticulturalists from eastern and southern Africa, and are described in this manual, together with the symptoms and damage they cause.

Recommended methods of control are presented, with emphasis on integrated pest management (IPM) wherever possible. The IPM approach, an environmentally safe and affordable alternative to the use of synthetic chemical pesticides, will help commercial growers meet the increasingly rigid minimum residue level standards set by importing countries such as the European Union.

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