Collaborating Organisations

Zimbabwe

Plant Protection Research Institute

Agritex (extension services)

Soils and Chemistry Institute

Participatory Ecological Land Use Management Association

University of Zimbabwe

Horticultural Research Centre

Natural Farming Network

African Farmers' Organic Research and Training

Agventure

Agricura

Other countries

Natural Resources Institute, University of Greenwich, UK

Imperial College of Science, Technology and Medicine, UK (including IPARC)

CABI Bioscience, UK

CABI Africa Regional Centre, Kenya

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This handbook provides guidance on vegetable pest management for extension staff and agricultural trainers.

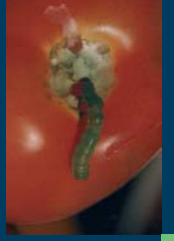
It contains photographs and information to help identify the major pests and diseases of brassicas and tomatoes and gives advice on the safe and effective use of cultural, biological and chemical technologies within integrated pest management systems. Two posters which adapt the key information for use by farmers are also available.

Although developed in Zimbabwe, much of the content of these publications will be useful for expanding small-scale horticultural sectors in many countries in Africa.

CPP

Crop Protection Programme

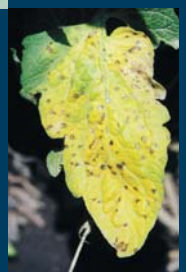
Integrated Vegetable Pest Management: brassicas and tomatoes



Integrated Vegetable Pest Management

Safe and sustainable protection of small-scale brassicas and tomatoes

A handbook for extension staff and trainers in Zimbabwe



INTEGRATED VEGETABLE PEST MANAGEMENT

Safe and sustainable protection of small-scale brassicas and tomatoes

A handbook for extension staff and trainers in Zimbabwe

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The authors are very grateful to the farmers, extension staff and scientists who worked tirelessly on the research programme and who moderated this handbook through workshops in March 2001. Many others too numerous to mention provided valuable critical feedback on the publications. The enthusiastic participation of all collaborators and contributors made the research and production of these outputs possible.

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Introducing this handbook

Vegetables are an increasingly important source of nutrition and income for small-scale growers in Zimbabwe. Although there are numerous constraints on production, the many *pests* and *diseases* that affect vegetable crops are some of the biggest challenges for farmers. *Pesticides* are currently the principal tool used to try and control them. These are often expensive, sometimes ineffective and unless used properly can result in risk to sprayer operators, consumers and the environment.

There have been some successes with *organic farming*, in other words production without synthetic fertilizers or pesticides. However, reliable production of high quality organic vegetables has been confined either to very small-scale labour intensive production systems (especially of crops which suffer fewer pests or diseases) or to relatively large-scale production with complex *biocontrol* regimes.

The crop protection approach promoted in this handbook is somewhere between pesticide-based and organic. The authors feel that this pragmatic middle ground is most appropriate and cost-effective for small-scale vegetable producers.

Wherever possible, advice is given on how to avoid and prevent pest and disease problems. This includes information on choice of appropriate crop varieties, cultural practices such as *crop rotation* and conservation of the *natural enemies* of pests - the organisms which feed on or suppress pests and diseases (also known as *farmers' friends*). Sometimes these measures are insufficient to maintain pests and diseases at an acceptable level, and advice is given on *intervention* with physical, biological and chemical methods to control them. Guidance is also given on the management and application of pesticides so that when their use is unavoidable, they do not cause

unnecessary hazards. When many different methods are used together in this way to protect crops, it is known as *integrated pest management* (IPM).

This handbook on integrated vegetable pest management is designed for extension staff and other agricultural trainers - both governmental and non-governmental - but will also be useful to some progressive small-scale vegetable farmers. Users will find practical guidance on how to minimise damage by the major pests and diseases of vegetable crops in a safe, efficient and sustainable way. The handbook contains clear advice, illustrations, photographs and technical information, together with a glossary of technical terms which are in *italics* the first time they appear. Species names are also in *italics*. It can be used as a 'how to' guide, as a reference book for pest and disease identification and, together with the accompanying posters ('The Winding Road of IPM' and 'Main Pests and Diseases of Brassicas and Tomatoes'), as a training aid to assist effective communication of the messages to others.

A short handbook such as this cannot be comprehensive. This one concentrates on two crop types: brassicas (for example, kale, rape and cabbage) and tomatoes, since these are the two most widely grown vegetable types in Zimbabwe, and describes options for dealing with their most serious and frequently occurring pests and diseases. It should be stressed that some of these techniques have not been rigorously tested and in many cases the best mixtures of options are not yet known. Moreover, there are many other pests and diseases of brassicas and tomatoes which occur less commonly and many other types of vegetable, each with its own specific pests and diseases. The number of combinations of crop, pest, disease, soil type and weather pattern is enormous. A key element of IPM is experimentation in order to produce an effective mixture of techniques and technologies well adapted to each

Foreword

specific situation. The information presented here should be treated as a starting point for users to build their confidence and ability in developing these tailor-made IPM approaches for the full range of vegetable crops, as well as for other types of crop such as cereals, roots and tubers.

This handbook has been prepared using pest, disease, plant and pesticide information which is specific to Zimbabwe. However, much of the information will also be relevant to other countries within and outside the region that have climates and farming systems similar to Zimbabwe's.

A field guide related to this handbook (and accompanying poster) has been produced entitled Farmers' Friends: recognition and conservation of important natural enemies of vegetable pests (Verkerk 2001). This builds on the biocontrol section in this handbook by providing further detail on identifying natural enemies and maximising their beneficial impact in farmers' fields.

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Head, Plant Protection Research Institute (PPRI),
Chairman of the FAO Global IPM Facility Governing Group,
February 2002.

Introduction

1.

Page

Pests and diseases of vegetables

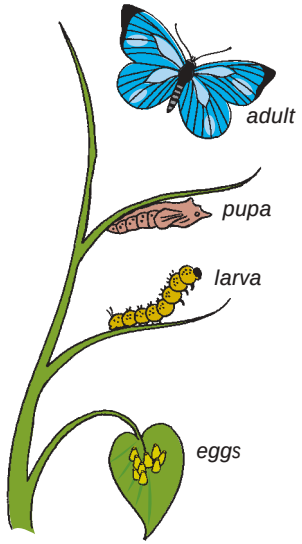
Pests and diseases can severely reduce the yield and quality of farmers' crops. This is especially true for vegetable crops, many of which originated in the cooler climates of Europe, Asia or the Americas, where pest and disease pressure is lower than in hot African climates. Many vegetable types have also been bred to increase yield - a process which often causes a reduction in natural *resistance* to pests and diseases.

Pests of vegetables

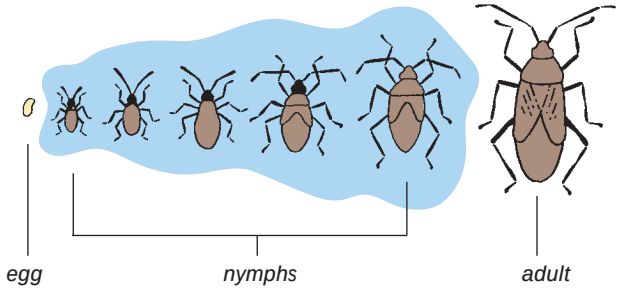
Most crop pests are *arthropods*, which means they have external skeletons and jointed legs. Within this group, there are *insects* which have 6 legs as adults and *mites* which have 8 legs as adults (but 6 legs when younger). Arthropods are usually considered to be pests if they eat any part of the crop plant (chewing pests), or if they suck the crop plant juices (sucking pests). The damage may be caused by *adults* or by the younger stages called *larvae* or in some cases *nymphs*. Other serious pests of vegetables include *nematodes*, tiny worms that live in and feed on plant roots (plant parasites), and larger animals such as rats, monkeys and even hippos.

Life stages of arthropods

Arthropods can look very different at different stages in their *life cycle*. It is useful to understand these different forms so that pests can be identified regardless of the stage they have reached in their life cycle. Arthropods go through a process called *metamorphosis* which means change of form. Some have *complete metamorphosis* where the young stages look completely different from the adults - see the butterfly in Picture 1. Others go through *incomplete metamorphosis* where the young look a little like small versions of the adult, but without fully developed wings - see the bug in Picture 2.



1. Example of complete metamorphosis where the young stages look very different from the adult



2. Example of incomplete metamorphosis where the young stages look similar to the adult

Plant diseases

Plant diseases are caused by various types of *micro-organism* (tiny living organisms) including *fungi*, *bacteria* and *viruses*. When these micro-organisms cause damage, they are called *pathogens* and they are *transmitted* (spread) in a variety of ways.

Most fungi in nature are useful, for example, those that help to break down dead plants and release the plant *nutrients* back into the soil. However, some fungi attack living plants and cause dry dark spots or *moulds*, for example, late blight and downy mildew. Fungal diseases are spread as *spores,* which are like tiny seeds so small that they can be carried by the wind like dust. They can also be accidentally introduced to fields with the planting material (seeds or seedlings) or carried in water. They usually cause more problems in moist, humid conditions, but can often be controlled with *pesticides*.

Like fungi, most bacteria in nature are harmless or useful, but there are some which attack crops. These harmful ones usually cause water-soaked spots on leaves and later on, rotting of leaves and fruit, often accompanied by a bad smell. Examples are bacterial wilt of tomato and black rot of cabbage. Bacterial diseases are usually spread by the bacteria being carried in water and can also be brought into the field on planting material. There are very few bacterial diseases which can be economically controlled with pesticides.

Viruses are not usually useful and can cause crop diseases like tomato mosaic virus which curls and discolours the leaves and reduces crop yield and quality. They can be spread by arthropod pests (*vectors of disease*), but also in infected seeds/seedlings or by physical contact. Virus diseases cannot be cured with pesticides, although controlling insect vectors with pesticide may reduce spread of the viral infection from plant to plant.

Weeds

Although *weeds* of various types infest vegetable crops, most small-scale producers in Zimbabwe remove them mechanically by hand or by hoe. This can be hard work but plot sizes are generally small and this method is considered by most farmers to be more appropriate than the use of *herbicides* (the type of pesticides which kill weeds). This handbook will therefore not deal with identification and management of weeds.

Integrated pest management technologies

Farmers and growers sometimes think that they need to spray crops regularly with pesticides to prevent damage but this is not always true. Although many growers will spray at some time, it is not the only answer, and may cause secondary problems such as pest numbers increasing to even higher levels after a few days. The first

two sections below describe some of the alternative measures that may control pests and diseases or maintain them at acceptable levels. These cultural and biological methods should be considered as the first line of defence. When they are successful they prevent the pest or disease becoming a problem at all. Even when they are not completely effective, they can delay the need for spraying or reduce the number of times that spraying is required.

The third section below covers chemical control using synthetic pesticides (or preparations made from plants, which are known as *botanical* formulations). Their use sometimes become necessary when pests and diseases overwhelm the natural regulating mechanisms in the crop but they should be considered as an option to be used only when other methods are failing.

When several methods of controlling pests and diseases are used together, the methods are said to be integrated, hence the term integrated pest management (IPM). One difficulty with integrating these cultural, biological and chemical methods is that some of them interfere with each other - for example, a pesticide applied to control a pest may also kill beneficial wasps which would otherwise have fed on some of the pests. Every farming system is different and the best pest management solutions are not known for all of them. There is a pressing need for more research into IPM technologies and into ways of combining them in IPM packages that are cheap, safe and effective for small-scale vegetable farmers. On-farm experimentation by farmers developing their own IPM systems is essential, but often needs to be supported by scientists researching specific aspects on field stations.

Cultural Control

Cultural control is based on changing the way the crop is grown, or its habitat, to reduce the likelihood of damage from pests and diseases. It is the oldest form of pest control and most farmers know the value of some of the techniques described below.

Using resistant or tolerant varieties

The choice of *crop variety* (also called *cultivar*) is a crucial decision since it can determine whether pests and diseases become serious problems or not. Some varieties have natural resistance to pest attack either because they produce chemicals toxic or repellant to the pests or because they have physical structures which discourage pests, for example, hairs on the leaves or sticky substances on leaf and stem surfaces. Other varieties produce chemicals which suppress disease pathogens. Tables 1a - 1c (see pages 158 to 161) contain information on different brassica and tomato varieties and their characteristics, including resistance and tolerance to pests and diseases.

Improving the soil

Healthy plants grow strongly and are able to protect themselves better from pests and diseases than weak, stressed or sickly plants. To be healthy, plants need a soft soil in which the roots can grow, plenty of plant food (nutrients), water and sunlight. Poor soils can be improved by adding *organic matter* in the form of manure (from animals) or plant material buried in the soil. Micro-organisms will decompose these manures and *composts* into small pieces which will improve the soil's water-holding capacity and will release lots of nutrients. However, if there are too many nutrients, for example, when too much artificial fertilizer has been applied, the plants may grow too quickly, become *succulent* (soft and juicy) and more susceptible to some pests and diseases.

Avoiding pests and diseases

At certain times of the year the weather favours pests such as spider mites (hot dry conditions) or diseases such as late blight (prolonged cooler, wet conditions). It may be possible to change the planting date to reduce or avoid problems by growing crops when conditions are favourable for the crops and poor for the pests and diseases. For example, farmers who have water for irrigation can grow tomatoes in the dry season, avoiding serious late blight attacks which are worst in the wet season. There

are periods in the year when even such damaging pests as diamondback moth *caterpillars* are less numerous (cooler months), with the result that brassicas will be relatively unaffected. Families with kitchen gardens may be able to avoid the seasons when pest and disease damage is highest but commercial vegetable growers may not be able to do this because they want or need to meet the all-year demand for their produce. In fact, the profits from vegetable production may be greatest during times when pest and disease problems are potentially serious because produce prices will be high. The rewards of successfully protecting the crop are great at these times, but so are the risks of serious crop losses.

Using crop rotation

Pest and disease problems in the soil can build up during the life of a susceptible crop. If the same crop or a similar type is planted in the same field soon afterwards, it will suffer from the accumulated pests and diseases from the previous crop and may not grow well. This can be avoided if the soil is left uncropped for a while, or a different crop is planted which is *tolerant* or *resistant* to the pest or disease. The result is that soil problems will decline and the original crop can be grown successfully again. For example, tomatoes can be affected by root-knot nematodes (RKN). These are microscopic worms that feed on the root system. On light sandy soils RKN numbers can build up to levels which stunt the plant's growth and reduce yield. When an infested plant is pulled up the roots have small lumpy *galls (root knots)* caused by the nematodes. It is only possible to grow a healthy crop in the same soil after the number of nematodes has been reduced. Planting a brassica or onion crop would have a good chance of success since they are relatively unaffected by RKN and would also have the effect of reducing the number of nematodes in the field. However, a crop of pepper would grow poorly and tend to maintain or increase the number of nematodes in the soil because peppers are affected by the same nematodes as tomatoes.

Unfortunately, crop rotation cannot easily be used to control some *persistent soil-borne* diseases which remain in the soil for many years. For example, there is a disease of tomatoes called bacterial wilt that causes sudden wilting and death of the plant. The bacteria causing the disease stay alive in the soil for many years even when tomatoes are not grown, and will quickly infect any new crop of tomatoes or related crops. Rotation is not an effective control option for bacterial wilt, but is an effective cultural control practice against many other pests and diseases.

Destroying source of infection/infestation

Some pests and diseases have *alternate host* plants which they can survive on between vegetable cropping seasons. Some can survive on weeds or crop plants left over from the previous planting. If the problem source is known and it is feasible to destroy it, there will be less carry-over of the pest or disease between seasons. An example is spider mites surviving on weeds related to tomatoes growing around the field edges, and rapidly infesting any new tomato crop in the area. Removing these weeds is a way of delaying or preventing spider mites entering a new tomato crop.

The difficulty arises if the alternate host plant is a crop. An example is the African bollworm which attacks a wide range of crops including maize and tomatoes. Populations of bollworm can survive on maize in the rainy season and can rapidly move to tomatoes and other crops if they are planted at the beginning of the dry season.

When pest and disease outbreaks have occurred, care should be taken with *crop residues* such as stems, rejected fruits or leaves after harvest as they may provide a source of infection or infestation of any newly planted crops. These residues can be *composted* if the process generates enough heat to kill the harmful organisms, or they can be fed to livestock or buried underground. They can also be burned but this is a waste of valuable organic matter which could have been used to improve the soil and

burning should only be used for the most persistent diseases. After handling such crop residues, it should be remembered that the diseases or pests can be transferred to the hands, clothes or shoes - changing clothes and washing is important before entering a healthy crop. Strict hygiene precautions should also be applied to field tools such as hoes and pruning knives.

Preventing diseases with hot water seed treatment

Some diseases of vegetable crops, such as bacterial canker of tomatoes and black rot of brassica crops, can be transmitted in seeds, as well as on infected seedlings and crop residues. Some seed companies treat seed with sodium hypochlorite, which sterilizes the surface of the seed, and they may also dress the seed with pesticide. However, chemicals may not reach pathogens inside the seed.

Research has shown that hot-water treatment can penetrate the seed sufficiently to eradicate some infections inside the seed. Hot water treatment must be done carefully to avoid reducing the germination rate if the water gets too hot. However because other pathogens that attack the seed during germination are killed, germination may actually be increased. If done properly, hot-water treatment is easier, cheaper and more effective than trying to combat disease pathogens in the seed and later in the field with chemicals.

It is important that the water be maintained at a uniform temperature of 50-52° Centigrade throughout the treatment so a thermometer is essential. Brassica seed must be treated for no longer than 20 to 25 minutes and tomatoes for only 10 minutes. To make sure that the seed is not damaged it is a good idea to test the germination of 100 heat-treated and 100 untreated seeds. For treatment, wrap the seed loosely in a cloth with a stone to make sure it stays under the water for the recommended time. Remove the seed and cool in clean water before sowing the seed. If they are to be stored, dry the seeds by spreading them on paper. If the test treatment gives acceptable germination rates, treat as much seed as is needed for planting.

Water management

Even the smallest patch of land can be used to produce useful and nutritious vegetable crops for a household. In the dry season crops can be watered by hand, even using waste water from washing, or by small drip-irrigation units. Larger plots of vegetables can be grown during the rainy season or, if equipment and water supply is available, can be grown during the dry season using irrigation. Irrigation can be via a furrow ditch system or via a piped system.

Some of these irrigation methods can have an influence on the pests and diseases that affect the crop. For example, overhead sprinkler systems reduce the damage caused by *red spider mites*, which prefer dry conditions. However, *overhead irrigation* increases the *transmission* of diseases between plants due to the splashing it causes. Also, if the humidity is high for long periods following irrigation, tomatoes often suffer from blight and mildew diseases. To minimise this, overhead irrigation should be carried out in the heat of the day so that the leaves of the crop are wet only for a short time and are sure to be dry by nightfall.

Seedlings are particularly susceptible to problems caused by poor irrigation. Seedbeds should be thoroughly watered every few days rather than being given small amounts of water each day (except when seeds have just been planted or when it is very hot), otherwise damping off diseases can spread through the bed and cause patches of dead seedlings. Irregular watering can also affect maturing crops. As tomatoes develop, irregular watering can cause blossom end rot, which appears as a dark rotten patch on the base of the tomato fruits. In this case no fungal or bacterial pathogens are involved and the problem is called a *physiological disease*.

Mulching

Covering the surface of the soil with material such as compost or plant residues is called *mulching*. Mulching conserves soil moisture and maintains good soil structure and health. Soil is full of microscopic organisms that help to release nutrients from the mulch, stimulating strong plant growth and improving the crop's resistance to pest and disease attack. There is evidence that mulching reduces certain soil pests such as nematodes, cutworm and thrips. Mulching also prevents surface crusting of the soil, allowing rain or irrigation water to soak in rather than run off and be lost. It also reduces transmission of diseases caused by splashes from rain or irrigation water falling on bare soil and can help suppress weeds between the crop plants. However, care must be taken that the mulching materials do not contain pests or diseases which can pass to the new growing crop.

Mechanical control

Removal of pests by hand, or *hand-picking*, is another way of avoiding or postponing pesticide sprays. Each part of the plant needs to be inspected and any pests found are crushed or removed by hand. Although this takes time and can be hard work, it is practical and effective in small plots, provided the farmers can distinguish between pests and their natural enemies. It may not be possible to find all of the pests, but since the technique does not kill the natural enemies, these can keep any overlooked pests at a low level. Sometimes only a few of the plants in a large field are affected by pests (for example, when only a few cabbage plants are infested with aphids) and pests can be removed or squashed quite easily, or the whole plant can be completely removed.

Pests can also be physically washed off the plants with sprays of water and if soap is added (liquid, powder or bar soap), the water sprays are more effective against sucking pests such as spider mites, aphids and whitefly. Pests can also be kept off the crop by using nets or meshes, but this is often too costly for small-scale producers.

Soil pests such as cutworms can be controlled mechanically by ploughing or hoeing the soil to kill them or bury them to a depth where they cannot reach the surface.

Cultural Control

Mixed cropping

Some farmers prefer to grow a single crop in a field whereas others grow crops in mixtures. Two or more crops in a field is known as *mixed cropping*. Opinions differ as to the value of mixed cropping for pest and disease control, but it can certainly have other benefits. When alternate rows or two different crops are planted, it is usually called *intercropping*.

A *legume* crop such as a variety of bean is a good companion crop for other non-*leguminous* crops, because legumes trap nitrogen from the air and release it into the soil. This stops yellowing of leaves on surrounding plants and produces strong growth. Cotton plants intercropped with cowpeas have been successful. Not only do the cowpeas trap nitrogen but they also attract natural enemies that attack pests such as aphids and caterpillars. Planting a quick maturing crop such as lettuce between other crops with a longer growing period allows better productivity from an area of land, but probably does little to confuse or repel pests. On the other hand, onions and other strong-smelling plants in amongst other vegetables have a beneficial effect against pests since they either repel them or prevent them finding the crop plant.

Trap or catch crops

Some plants are particularly attractive to pests and can be used to trap them. For example, pigeon pea is very attractive to whiteflies and when it becomes severely infested, the plants can be removed and buried or composted along with the pests.

This strategy does not apply to diseases - if a certain plant is susceptible and showing severe *symptoms* (signs of pest and disease attack) it should be removed from the field to prevent the infection spreading to other plants.

There are many other cultural methods in use and farmers can experiment to find the best combination of cultural practices for their particular situation.

Biological Control

Biological control (also known as biocontrol)

This means controlling pests and diseases using living organisms.

Beneficial living organisms which reduce pests and diseases are usually present in any crop unless *broad spectrum* pesticides (which kill a wide range of arthropods) have been used. These so-called *natural enemies* can be *conserved* by taking care with farming practices so that they are not killed or are actually encouraged. If numbers of such biocontrol agents are still not sufficient to keep pests at acceptable levels, it is possible to release additional beneficial organisms of the same type - a process known as *augmentation* or *inundation*. Farmers who collect ladybird beetles in field margins and release them on their crop are practising augmentation. Alternatively if suitable types of beneficial organism are not present in the crop, they can be *introduced*. Where *introduction* involves a local beneficial organism which has simply not yet reached a particular crop, this is known as *inoculation*. If the introduced beneficial organism is from outside the area (typically from the country or area where the troublesome pest originated) and becomes established as the controlling factor for the pest in the new area, it is known as *classical biological control*. Some additional information on the importance of natural enemies in smallholder vegetable pest management is provided below.

Conservation of natural enemies

Areas of land which have not been cultivated or disturbed contain hundreds or thousands of species which tend to form a balance, with each of them depending on some of the others. Although large outbreaks of plant-eating pests do sometimes occur in natural systems, any one particular species is less likely to build up a large population if the organisms which feed on it are also present - in other words, its natural enemies. These are sometimes called farmers' friends because they help the farmer to keep pests (and some diseases) under control. *Predators* are one type of

natural enemy which tend to keep the population of their *prey* in check - they catch and eat other insects and mites, including pest species. *Parasitoids* are another type of natural enemy - they lay eggs in or on other species of insect (called *hosts)* and the larval stage kills the host as it feeds on it and develops.

When crops are grown, it inevitably disturbs the natural balance, especially where the crop is a *monoculture* i.e. all one species of plant. However, the beneficial effect of predators and parasitoids continue to be critically important. If they are correctly managed, they will help prevent some of the pest problems which farmers encounter. An example of how farmers can help to keep the balance in their favour is to try not to harm predatory insects such as ladybirds, spiders and hoverfly larvae which feed on plant-eating pests such as aphids and caterpillars. These predators can be found on most crops together with parasitoid wasps (and occasionally parasitoid flies) which lay their eggs in/on pests. In IPM systems which aim to minimise dependence on pesticides, it is essential that the farmer can distinguish these natural enemies from pests and can use farming techniques which will conserve and encourage natural enemies.

Like humans, insects also suffer from diseases which can weaken or kill them. Types of fungal, bacterial and viral pathogens which only affect insects and are safe for humans and animals have been identified. Some of these are commercially produced as *biopesticides* and some can be prepared on the farm - see page 25.

Augmentation and inundation with natural enemies

Sometimes there are predators and other natural enemies present which are feeding on the pests, but they are not able to control them effectively, particularly those pests that are capable of breeding very quickly. Farmers can augment the number of natural enemies by bringing them in from outside the field, for example, ladybird beetles or parasitized aphids which contain young parasitoids. Some types of natural enemy can be specially

bred in large numbers, and then released onto the crop in order to attack and control the pest. The natural enemies *inundate* the pest population. Many of the advances in this technique have been against pests of crops which have been economically important for a long time, such as cotton. for example, the egg parasitoid wasp called *Trichogramma* has been bred in laboratories to allow huge numbers to be released when eggs of the African bollworm are present on the crop. The same bollworm can be a serious pest of tomatoes, so it may be possible to use the same biocontrol tactics developed for cotton. Aphid parasitoids could theoretically be produced and released in a similar way, but these technologies are not yet available to small-scale vegetable growers in Zimbabwe.

Using insect pathogens in pest control sprays

Naturally-occurring pathogens that kill insects (fungi, bacteria and viruses) can be obtained from diseased insects and incorporated into sprays applied to control the pest. This is a type of inundation. Pathogen-based sprays are not yet widely available for vegetable pests except for Bt (*Bacillus thuringiensis*) a *bacterium* which kills larvae of moths and butterflies (caterpillars). One example under development is a virus which kills diamondback moth caterpillars - a serious pest of brassicas. The pathogen is called *Plutella xylostella* granulovirus (*Plxy*GV). The pathogen has the important advantage of being highly *specific.* In other words it does not harm other arthropods such as natural enemies so it works together with the natural processes which limit pest numbers. This contrasts with most pesticides which also kill natural enemies. Farmers sometimes use a type of home-made biopesticide - they gather diseased pests, crush and mix them with water, then spray the liquid onto the crop. The fungi, bacteria or viruses which were infecting the collected pests will infect other pests in the crop and kill them.

3. Ladybird adult, showing typical red wing cases with black spots

4. Ladybird larva, showing typical 'crocodile-like' shape and light markings

Important natural enemies or 'farmers' friends'

Ladybird beetles

The adults and larvae of ladybird beetles are important predators of aphids. A single ladybird can eat 200-300 aphids over its lifetime. The adults are typically dome-shaped and orange or red coloured with black markings or spots (Picture 3). The larvae look quite different and are usually longer and thinner (a little like tiny spotted crocodiles), coloured black or dark brown with various types of light markings (Picture 4).

Ladybirds can be encouraged by growing non-crop plants which support aphid species which do not attack crops, for example, thistles and milkweed. They can also be brought in by hand from outside the crop. Spraying with pesticide should be avoided wherever possible in order not to kill the ladybird adults and larvae but if it is necessary, *selective* methods should be used (see page 51).

5. Hover fly adult, showing typical yellow stripes on flattish abdomen

6. Hover fly larva, showing typical tapering head end

Hover flies

Adult hover flies usually have black and yellow stripes on their abdomens (Picture 5) and they can often be seen hovering (staying in one place in the air) to feed on nectar from flowering plants. Although adults help to pollinate plants, it is the larvae which are most useful since they are natural enemies of aphids and small caterpillars. They look a little like pest caterpillars but are more tapered with pointed heads (Picture 6). Some common species appear wet (slimy) on the outside of their bodies and are easy to recognize as they move their pointed heads up and down and from side to side searching for prey.

Hover flies can be encouraged by allowing non-crop plants such as milkweed and thistles to grow around fields - these support non-pest species of aphids that hover fly larvae can feed on. Flowering plants such as the spice crop coriander can be planted so that adult hover flies are attracted to the food source of nectar and pollen. In rape and kale, some of the previous crop can be left to flower (provided the pest and disease levels are low) or a small number of plants from the current crop can be encouraged to bolt and flower by stopping watering. Avoid spraying with pesticide whenever possible but if it is necessary, use selective methods (see page 51).

7. Parasitoid wasp laying eggs in aphids

8. Parasitized aphids - known as 'mummies'. They appear hard and brown.

Parasitoid wasps

These are small wasps, usually black, which lay eggs inside or on other insects such as aphids and caterpillars, or even in the eggs of other insects. Picture 7 shows a parasitoid wasp laying an egg in an aphid. When the egg hatches the larva of the parasitoid feeds on its host and kills it. Picture 8 shows parasitized aphids call *aphid mummies*, which have turned brownish and hard when the wasp larvae *pupated* inside them.

Parasitoid wasps can be attracted and sustained by ensuring that there are flowering plants nearby to provide nectar for them to feed on. They can also be encouraged by providing non-crop plants such as milkweed and thistles which encourage non-pest species of aphid. Avoid spraying pesticide unless absolutely necessary since adult parasitoid wasps walk around a lot on the leaves while searching for hosts so can quickly pick up a harmful quantity of pesticide. If spraying is unavoidable, use selective methods (see page 51).

Predatory mites

These eat plant-feeding mites. They are very small (less than 1mm) and difficult to see by eye but if populations of red spider mites are examined closely, any predatory mites present can be identified by their longer legs and much faster movement.

They can provide effective control of spider mite populations on tomatoes but it can take some time for numbers to build up, especially if the plant variety has very sticky stems and leaves. Most predatory mites cannot survive without live prey to feed on, so hedges and living fences and other non-crop plants can help to provide a refuge and food source for them between crops. Dust tends to kill predatory mites so regular irrigation, which reduces dust, will tend to encourage these natural enemies. Also, *colonies* of plant-feeding mites can be kept on potted plants and when predatory mite numbers build up they can be transferred to the crop. In some countries the mites are commercially available for releasing onto the crop (a type of inoculation).

Ants

Some ants are *generalist* predators, in other words they attack many different types of prey. They can be very effective at removing caterpillars and other pests from crops - they are thought to be one of the most important natural enemies of *Helicoverpa armigera* - the African bollworm. Excessive hoeing or ploughing will destroy ant nests so farming systems which use minimum tillage (very little hoeing or ploughing) are more likely to encourage beneficial ants.

However, some species of ant also protect pests - in particular they stop natural enemies attacking aphids in order to maintain their supply of *honeydew* - the sugary liquid excreted by aphids as they suck the plant sap, and which the ants use as a food source.

Biological Control

There are many other natural enemies, such as spiders, bugs, predatory wasps and mantids which play a vital role in regulating pest numbers. For more details on recognition and conservation of natural enemies, see the field guide entitled 'Farmers' Friends' (Verkerk 2001).

Antagonistic micro-organisms

There are cases where one micro-organism will suppress another. for example, if a harmless species of *fungus* become established on a crop, it may prevent the establishment of some types of harmful fungal pathogens on that crop. It is possible to spray spores of the harmless fungus to prevent the harmful disease fungus, but this technique is not commercially available to small-scale producers in Africa. However, *Trichoderma* is a fungus which is sometimes used as a *seed dressing* to prevent other fungi from damaging the seedling.

Brassicas such as covo are often infected with black rot but may not suffer much damage or yield loss. This is because *antagonistic* bacteria are also living in the plants and can prevent the black rot becoming serious. Unfortunately, there is no easy way for smallholders to make use of these antagonistic bacteria on other types of brassica.

Chemical control

Sometimes, when natural regulation of pests and diseases is not working well enough, farmers apply chemicals to prevent crop damage. These chemicals are called pesticides and they can be derived from plants (*botanical products)*, or they might be man-made chemicals known as *synthetic pesticides*. Many plant products are said to have pesticidal properties, for example, Datura, Tephrosia, Wormwood and Eucalyptus leaves. They are natural products and most of them break down quickly on the leaves or in the soil. However, there is very little information on their effective *dose* rates, their impact on beneficial organisms or their *toxicity* to humans. In fact one or two are known to be

quite hazardous to humans and have no antidote, for example, tobacco extracts. As a result, no firm guidance can be given on their safe and effective use in this handbook.

Synthetic pesticides are generally perceived to be more harmful to humans and the environment (and are more expensive). If used correctly, the risk is very small, but some growers prefer to avoid using them. When crops are produced without the use of most synthetic pesticides, and also without synthetic fertilizers, the process is called *organic farming.*

However, most growers who sell part of their produce use synthetic pesticides from time to time to reduce damage caused by pests and diseases. These pesticides should be regarded as a last resort when natural control and other alternative solutions are not effective. Synthetic pesticides all contain a poisonous component known as the *active ingredient*, but the *concentration* of this active ingredient in the pesticide liquid (how strong the mixture is) and its toxicity (how poisonous it is to pests and to people) vary greatly from product to product - see page 35. All pesticides should be handled with great care - they can all be dangerous to humans and can upset the natural ecological balance in the crop - but when used properly, they can be a safe and effective tool in IPM systems.

Deciding whether to use pesticides

It is important to look carefully at the crop *(scouting)* before deciding whether to spray, rather than applying pesticides at regular intervals - sometimes called *calendar spraying*. It can be difficult to decide the exact number of pests at which spraying should start *(the spray thresholds)*. In most cases, a small number of pests are necessary in order for their natural enemies to become established and survive. These few pests are not likely to cause serious damage, provided the natural enemies are also present to keep their numbers down. However, some pests need to be treated early, for example, certain species of spider

mite before the silk webbing begins to protect the colonies from predators and spray. Some diseases such as late blight are best treated as soon as any signs appear or weather conditions make the disease likely to occur because of the speed they can spread and destroy the crop. Intervening before any signs of infection/infestation appear is called *preventive control*.

Scouting should be carried out each week or more frequently. It means walking through the crop and stopping 10 - 20 times to examine the leaves/flowers/fruit for pests, diseases and natural enemies. The numbers and types of organism and disease should be noted. If there are organisms or disease symptoms which cannot be identified, samples should be taken to show to neighbours or extension staff. If it is not clear if an arthropod is a pest or a beneficial organism, it can be put into a small jar together with leaves from that plant and any pests which were also on that leaf. If it eats or sucks the leaves, it is a pest and if it eats the pests it is a natural enemy. These little containers are known as *insect zoos* and should have gauze over the top instead of an airtight lid to allow the insects to breathe and to allow moisture out.

Even if pests are present, there may be no need to spray. If their number has not increased since the previous scouting it means that natural regulatory processes such as natural enemies or host plant resistance are preventing them multiplying to damaging numbers. In this case, do not use pesticide since it will kill the natural enemies and disturb the natural balance and could make pest and disease problems worse.

Each situation is different and without firm rules for when to spray, the farmer must become familiar with the natural processes going on in his/her crop in order to make good judgements on whether to spray or not. Access to training and specialist advice increases the farmers' knowledge and confidence, which can help him/her to carry out effective

on-farm experimentation. Farmers can try out various methods and approaches in order to develop an IPM strategy adapted for their local conditions.

If the farmer decides that a pest or disease is getting out of control and pesticides are necessary, there are several decisions and actions which must then be taken to ensure that the spraying is effective and economical while minimising the risk to sprayer operator, consumers and the environment. These are summarised below.

Choose a pesticide

Most of the pesticides used by vegetable growers are either *fungicides* applied to control or prevent fungal diseases, or *insecticides* to kill pests. *Herbicides*, which control weeds, are not widely used by small-scale vegetable farmers in central and southern Africa, but if labour for weeding becomes more scarce or expensive, herbicides may become more popular. If a pesticide is needed, the choice of product is important. Extension staff, chemical companies, pesticide retailers and publications such as this handbook should be consulted. Surveys have shown that vegetable farmers do not always choose the best pesticide for the job. Sometimes the wrong type of product is chosen by the farmer and it is not effective against the pest or disease which requires control, or it may be a pesticide which is very toxic to users or natural enemies when equally effective but safer and more selective products exist. *Pre-harvest interval* (*PHI*) should also be considered, in other words, the number of days a farmer should wait after spraying before harvesting the crop. A short PHI is more practical for the farmer and indicates that the product is either not very toxic to humans or has low *persistence* on the crop. See Tables 2c and 2f on pages 163-166 for PHI values of common pesticides in Zimbabwe. Of course, the perfect pesticide may not be available (or affordable) at the time the farmer wants it, but

where possible, an effective product which is safest to humans, to natural enemies and to the environment should be chosen.

Zimbabwe has a simple and useful method of showing how dangerous a pesticide is to people and livestock - its *mammalian toxicity*. Every pesticide has a triangle colour coding on its label based on its toxicity. This is derived from the toxicity of the *active ingredient* (the poisonous part of the pesticide) and the concentration of this active ingredient in the *formulation* (the mixture which is on sale).

The international convention for measuring pesticide toxicity is the *LD50* which means the dose of the pesticide that will kill 50% of a test population (usually rats or rabbits). In other words it is a Lethal Dose for 50% of the population - hence LD50. The LD50 is measured in milligrammes of pesticide per kilogramme of body weight of the test animals. It is assumed that the toxicity to humans will be similar. As the LD50 increases, the toxicity decreases. Some pesticides have a low LD50 (are very poisonous) but are sold in low concentration formulations which are not themselves very toxic. The colour triangle system is based on the toxicity of the formulation, not simply the toxicity of the active ingredient. Pesticides have an oral LD50 - (the toxicity if it is swallowed) and a dermal toxicity (the toxicity if it touches the skin. The oral LD50 is usually lower since pesticide are likely to be most toxic when swallowed, and the triangle colour coding is based on oral LD50 - the worst case scenario.

The colour categories are defined below:

Green triangle products. These are classed as 'Harmful if Swallowed' and are the least toxic category (LD50 is greater than 2000 mg/kg). They can be used in agriculture, in the home, garden and in buildings, and can be displayed directly on a shop shelf and sold to any customer.

Amber triangle products. These are classed as 'Poison' (LD50 between 501 - 2000 mg/kg). They can be used in agriculture, gardens and around buildings (not inside) and can be displayed directly on a shop shelf and sold to any customer.

Red triangle products. These are classed as 'Dangerous Poison' (LD50 between 101 - 500 mg/kg). They can be used in agriculture, gardens and around buildings (not inside), but can only be sold in shops if kept in a special section without direct public access.

Purple triangle products. These are classed as 'Very Dangerous Poison (LD50 less than 100 mg/kg). They can be used in agriculture and industry but not in gardens or homes. They can only be bought by people holding a pesticide application licence and users need to wear more items of protective clothing than for less toxic products.

Specific advice on product choice is given for each pest and disease in Tables 2a-2f on pages 162-166.

Choose pesticide application equipment

There are several different types of pesticide formulation, for example, dusts, granules and baits, and there are many different types of pesticide application equipment, for example, motorised knapsack mistblowers or boom and nozzle tractor systems. However, most crop protection chemicals in small-scale vegetable production are applied as liquid formulations sprayed using lever-operated *knapsack sprayers* (see Picture 9). These consist of a pesticide tank, a lever-operated pump and a *nozzle* mounted on a lance to produce and direct the spray. Compression sprayers are similar but are pumped up to pressurise the tank before starting spraying, then taken off and pumped up periodically during use.

9. Lever-operated knapsack sprayer

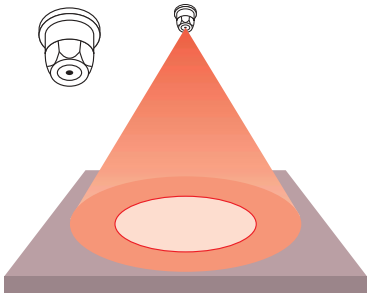
Some farmers have used a brush dipped into a bucket of pesticide to splash the product onto the crop (see Picture 10), but this is inefficient, unsafe and NOT RECOMMENDED. Although using a knapsack sprayer can be strenuous work, it is a good compromise of fairly low cost,

10. Applying pesticide with bucket and brush - inefficient and very dangerous

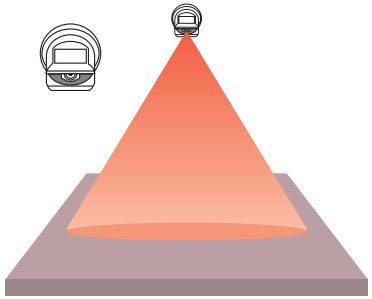
reasonable speed and quality of application. It is advisable for the farmer to buy the best quality sprayer he/she can afford. Cheap sprayers break down frequently, often leak (causing health risks to the operator) and can waste pesticide worth far more than the cost of a good sprayer due to their poor performance. Even the best sprayer will need spares from time to time, for example, nozzles, pump seals and tubing and it is a good idea to ask about the cost and availability of spare parts before buying a sprayer.

Choose a nozzle

Nozzles are a key component of sprayers as they break up the spray liquid into droplets. The best type of nozzle for most vegetable spraying is a *hollow cone nozzle* - see Picture 11. This produces a ring of spray with droplets spreading out quickly and moving in different directions. It gives reasonable spray cover on many plant surfaces and good penetration into leafy crops.



11. Hollow cone nozzle and its spray pattern



12. Flat fan nozzle and its spray pattern

Flat fan nozzles (Picture 12) are better suited to tractor booms and when used on a knapsack sprayer are likely to produce a very uneven deposit with some areas of the crop receiving no spray and other areas receiving too much.

The size of the spray droplets is crucial to good pesticide distribution on the pest and on the plant surfaces. A medium or *fine nozzle* (hollow cone) is best for applying fungicides and

insecticides and will give good coverage of the crop with many small and medium sized droplets. There should be filters in the tank opening, in the lance trigger and at the nozzle itself, which will prevent these smaller nozzles blocking even if the mixing water is a little dirty. A *coarse nozzle* (large) or a worn or damaged nozzle produces unnecessarily large droplets, which will bounce off or run off the leaves. A coarse nozzle or a worn nozzle also has a high flow rate and the farmer will inevitably apply a very large volume of pesticide mixture, which is likely to result in an *overdose* of active ingredient.

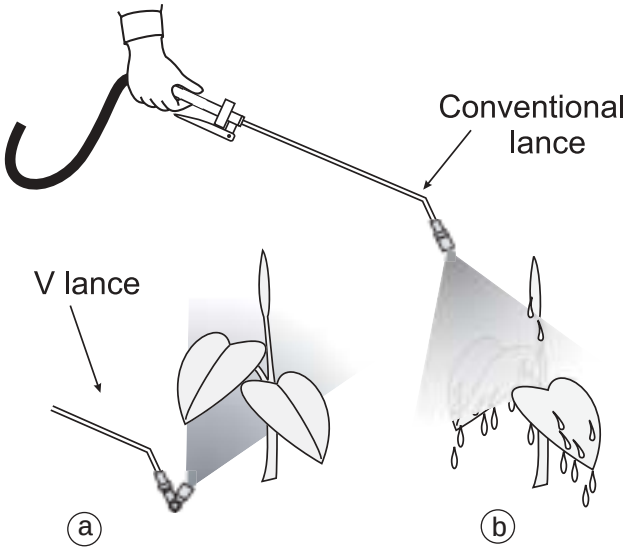
Measuring the flow rate from a nozzle gives an indication of whether it is too coarse, damaged or worn. By spraying at normal pumping rate over a timed period (for example, 1 minute) and collecting the spray in a bucket or other container, the flow rate can be measured. Anything over 800ml (0.8 litres) per minute is likely to be too high, and the nozzle should be replaced. Uneven spray from the nozzle also indicates wear or damage and the nozzle should be replaced. Ask the supplier for a medium or fine hollow cone nozzle for spraying any insecticide or fungicide. Suitable nozzles are metal disc number 12 (with the swirl plate) or disc and core D2-25. (If herbicides are being used, a coarse nozzle should be chosen in order to produce large droplets that are unlikely to drift onto nearby crops and cause damage.)

Some companies produce a device called a *spray management valve*. This prevents the pressure going over a certain limit however hard the operator is pumping, and if pumping is too slow and the pressure drops below the right level, the flow is cut off. This helps to maintain the correct spraying pressure, flow rate and droplet size, and improves application efficiency and safety.

Target the pest

Most farmers hold the nozzle above the crop and spray downwards. This gives good spray coverage on the upper leaf surface but very little on the lower leaf surface where pests such as spider mites, aphids and whitefly spend most of their time, and where many diseases occur. If instead, the nozzle is held near the base of the plant being sprayed and pointed upwards, some of the spray will land on the lower surface of the leaves, and the spray that misses the leaves on the way up will land on the upper surface of the leaves as it falls back down. The *V lance* is a simple adaptation which allows the spray to be directed upwards - see Picture 13. It consists of a swivel joint (black) and a thread adapter (white) which are fitted between the lance and the nozzle.

13. V lance with swivel joint to allow the nozzle to point upwards



14. V lance spraying upwards (a) compared with conventional lance spraying downwards (b)

When adjusted into the V position it is easy to spray upwards into crops such as kale and tomatoes, and also into other crops such as egg plant and beans - see Pictures 14 and 15. Both spray distribution and pest control are improved compared with plants sprayed with a conventional lance.

Such improvements in efficacy open up the possibility of using lower doses of pesticide or fewer sprays. This in turn helps to reduce pest management costs, human and environmental safety risks and helps the spraying to be selective, in other words, effective in controlling pests and diseases, but with minimum damage to natural enemies or other beneficial organisms. Page 51 summarises methods of using pesticides selectively.

It may not be necessary to get spray onto all parts of the plant. If enough is known about the pest or disease that the

spray can be directed only on the affected parts of the crop, the chances of natural enemies surviving will be improved. When a particular layer of the crop is treated this is known as *spray stratification*. If spray is only applied to areas of the crop where the pest or disease can be seen, this is called *spot spraying*. These partial cover sprays can also help the spraying to be more selective.

15. Using a V lance to spray upwards on brassica leaves

Understand dosage instructions

It is important to apply the *correct dose*, that is, the correct amount of the *active ingredient* for a particular area of crop. This correct dose is usually recommended on the pesticide label and should be enough to kill the pest or control the disease, but not so much that pesticide is wasted. Underdosing might not kill the pests effectively and overdosing will be an unnecessary cost and may lead to high *pesticide residues* in the produce or build-up of pest *resistance* to the pesticide where the pests are affected less and less by the pesticide. It will also have an unnecessarily large impact on natural enemies in the crop.

Application of the wrong dose can happen in two ways:

- The farmer puts too little or too much of the concentrated pesticide into the sprayer tank each time he/she refills it.
- The farmer applies too little or too much volume of spray liquid to the crop.

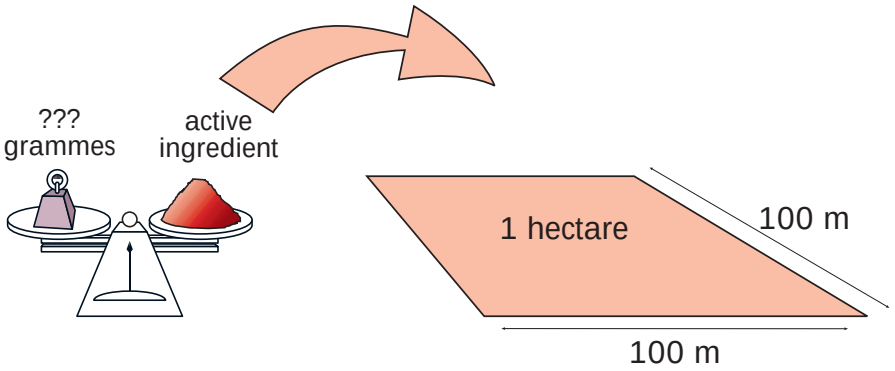
These are the ways that incorrect dosing happens but what are the reasons for it?

- Pesticide labels give application advice in different ways which are sometimes not easily understood by farmers.
- The writing on the label is often small and difficult to read, and may not be in an appropriate language.
- The farmer may have no accurate way of measuring the correct volume of the pesticide formulation to put in the sprayer tank.
- Calculations are sometimes necessary, which some farmers find difficult.
- Nozzles supplied with sprayers are often too big resulting in very high volumes being applied which causes overdosing unless the spray is applied in a very dilute solution.
- Farmers sometimes like to spray until the plant is dripping.

When buying a pesticide, read the label. If the application instructions are not clear, ask the supplier to explain and put it in writing. If it is still not clear, see if there is an alternative product which has better instructions.

Dosage instructions are given on the pesticide label and can be expressed in one of several ways:

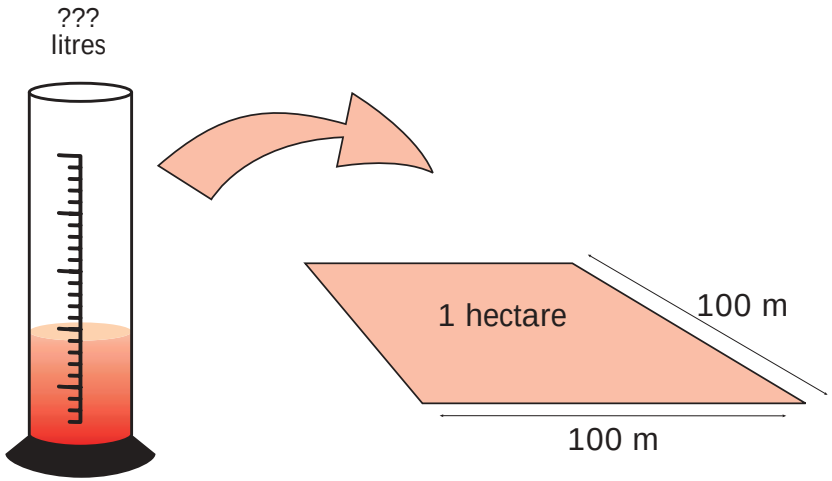
a) Active ingredient dose: the weight of active ingredient per hectare is given (see Picture 16). for example, a label may say ‘use 400 grammes of active ingredient per hectare (400 g a.i./ha)’. This type of dosage instruction is not usually used in Zimbabwe since most farmers and operators find it difficult to convert to a useable recommendation.



16. Active ingredient dose states the weight of active ingredient that should be applied per hectare

b) Concentrate dose: the volume (or weight) of concentrated pesticide which should be applied per hectare is given. for example, ‘use 1 litre of pesticide per hectare (1 l/ha)’. This is somewhat easier to understand but calculations are required to work out how much pesticide and water to mix together.

c) Tank dose: the volume (or weight) of concentrated pesticide to add per 10 litres of water (which is the volume held by some knapsack sprayers). for example, 'use 20ml of pesticide per 10 litres of water (20ml/10 l)'. This *tank dose* is the simplest method of recommending a dose, although basic calculations are still required for tanks of more or less than 10 litres. Calibration procedure below relates to a tank dose, rather than concentrate dose or active ingredient dose.



17. Volume application rate states the volume of liquid to be sprayed per hectare

When a tank dose is given, some labels also state the area which must be covered by each knapsack load, or a guide volume to be applied over a given area, known as the *volume application rate* (VAR - see Picture 17). The tank dose method assumes a certain VAR and the dose of active ingredient per area is only correct at this VAR.

If the manufacturer assumes a person will use 250 litres per hectare and the volume actually sprayed is 1000 litres, the result is four times the recommended dose of active ingredient on the crop. Surveys have shown that this often happens. The result is wastage of pesticide, possible damage to natural enemies and the environment and the risk of high levels of pesticide residue in harvested produce.

In fact, the amount of active ingredient required will vary between different types of crop and between different ages of crop - a kale crop that has just been transplanted will require much less active ingredient per hectare to treat its small leaf area than a fully grown tomato crop. To some extent the tank dose method is self-compensating since farmers are likely to apply larger volumes on larger plants, which will deliver the higher dose needed for its greater leaf area and number of pests.

In practice to make safe and efficient use of pesticide the farmer must not only know how to achieve an accurate tank dose but must also try to ensure that volume application rate is somewhere between 200 and 400 l/ha (or less for very small plants).

Calibrate the sprayer

Step 1. Measure volume application rate (VAR)

Before a farmer can be sure he/she is using the correct dose of pesticide on a particular crop, the VAR must be determined.

- Measure out a square area of the crop which is 5 big paces (steps) long and 5 big paces wide. This will give an area of approximately 25m^2 or 1/400th of a hectare. Mark the corners with sticks.
- Now put the sprayer on a level surface and put water into the tank (no pesticide) up to a level which corresponds with one of the volume markings on the sprayer tank.
- Spray the marked out area of crop with water, as if it is pesticide.

- Put the sprayer back onto the same level surface and, using the volume markings on the sprayer, estimate the volume sprayed onto the crop.
- If the volume used is 1 litre, this corresponds to a VAR of around 400 l/ha. If the volume used is 1/2 litre, this corresponds to a VAR of around 200 l/ha.

Step 2. Adjust volume application rate (VAR)

If the volume used on 25 m^2 is more than 1 litre, this will give a VAR which is too high (more than 400 l/ha) and will be wasteful of pesticide. The farmer should either fit a smaller nozzle to the sprayer, or, if the nozzle is already small enough (giving a flow rate of less than 800ml/min), he/she should modify the spraying technique to apply less spray to each plant, in other words spend less time spraying it. After these equipment and/or technique adjustments, the farmer should measure VAR again to make sure it is less than 400 l/ha.

If spraying equipment is not capable of producing such low VARs - in other words if a smaller nozzle is not available - the farmer must then make adjustments to the tank dose to compensate for this. for example, if the sprayer is putting a VAR of 800 l/ha on a medium-sized crop (at least twice the volume required) then the tank dose can be reduced to half of what the pesticide label recommends without any risk of applying too little active ingredient. In this case, if the tank dose instruction is 20ml of pesticide per 10 litres of water, put 10ml of pesticide in instead.

Step 3. Put in the right tank dose

The label will usually give a volume (or weight) of concentrated pesticide to put in each 10 litres of water. Sometimes, the advice is given for 15 litre sprayer or for 100 litres of water but the amount required for a particular tank volume can be worked out fairly simply. For example, if the label recommendation states that

20ml of pesticide concentrate must be put into every 10 litres of water and the farmer is using a sprayer which contains 15 litres of water, the amount of pesticide to be added can be worked out as follows: 15 litres is one and a half times the volume of 10 litres which the tank dose recommendation is based on. Therefore one and a half times the tank dose recommendation for 10 litres must be added each time the tank is re-filled. One and a half times 20ml-30ml.

Once the volume required per sprayer tank has been worked out, the farmer needs a small measuring cup to make sure the amount added is correct. A measuring cup should be provided by the shop when the pesticide is bought but if it is not, the farmer should borrow one. The cost of a measuring cup is much less than the cost of mistakes in application - either wastage of pesticide, poor spray results or dangerous pesticide residues in vegetable produce. Fertilizer cups can also be used and the number of the cup indicates the volume of liquid it contains. For example, a number 12 cup contains 12ml of liquid. Such cups can also be used as a guide to weights of *wettable powders* - a number 30 cup contains 15 - 20 g of powder.

If there is a large area of crop to treat, a large batch of spray liquid can be mixed in a drum and then knapsack sprayers filled from that. If the drum is 200 litres, this will fill a 10 litre spray tank 20 times, so add 20 times the amount of concentrated pesticide recommended for each 10 litre sprayer tank. Mix only enough for a maximum of 4 hours spraying so that the mixture does not have to be left overnight.

Special application cases

There are times when pesticides are not applied to the growing plant and this sort of calibration does not apply. If the problem is in the soil, for example, cutworm or fungi which are causing damping off in a seedbed, then a soil *drench* may be used. Drenching means applying the high volume pesticide solution

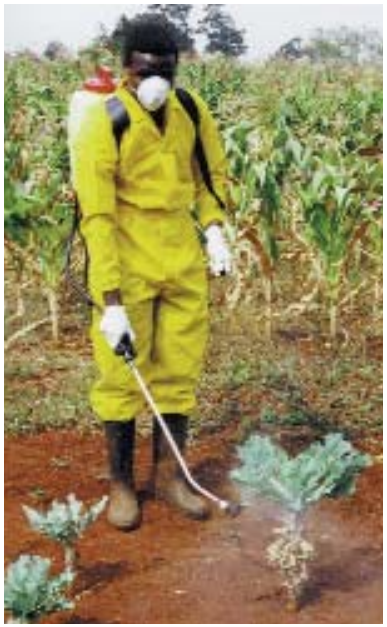
directly to the surface of the soil, either with a sprayer or just poured on, so that it moves down into the soil to control the pest or disease.

Also apart from heat-treatment for control of *seed-borne* diseases, seed can be treated with pesticide before planting. This process is known as *seed dressing*.

Spray safely and effectively

It is important that pesticides are used safely and in a way which is not hazardous to the users, the consumers of the produce, livestock or the environment. The most important points are outlined below:

- Choose a product which is as safe as possible to humans. As a general rule, avoid purple and red label products (see Tables 2c and 2f on pages 163-166 for product toxicity).
- Choose a product appropriate for the pest or disease to be controlled (see Tables 2a - 2f on pages 162-166).
- Read the safety and application instructions on the pesticide label and calibrate carefully (see pages 42-47).
- Wear suitable clothing. If special protective clothing is not available, wear shoes, long trousers and a long-sleeved shirt or jacket then take off and wash the clothes after completing the pesticide application.



18. If special protective clothing such as this is not available, cotton clothing which covers the body should be worn when spraying

19. The concentrated pesticide formulation is dangerous - gloves should be worn when handling it and mixing it with water before spraying.

- Rubber gloves (preferably nitrile rubber) must be worn when handling concentrated pesticide. Take particular care as splashes of the concentrated product can be dangerous - eye protection such as goggles or a visor are useful. Even sunglasses can reduce the risk of pesticide splashing into the eyes. Wash gloves and hands after mixing spray to remove any pesticide concentrate.
- Half fill the sprayer with water before putting the concentrated pesticide in. Then put in the rest of the water, replace the lid and shake the tank. This will ensure that the pesticide is properly mixed with the water.
- Wash off any splashes which fall onto you with soap and water.
- Start spraying at the downwind edge of the crop and move across the wind direction, spraying on the downwind side of your body so that you are not walking through vegetation wetted with spray.
- Do not spray into wind otherwise the spray may be blown back onto you.

- Do not use worn nozzles or nozzles with too large a hole (coarse nozzles). Use medium or fine nozzles which will reduce the amount of pesticide used, conserve natural enemies and produce smaller droplets which will penetrate the crop better and be more effective.
- Do not spray so as to cause liquid to run off the leaves. This wastes pesticide which will fall onto the soil.
- Do not eat, drink or smoke while spraying or before washing properly at the end of spraying.
- Do not let pesticide get into streams and ponds, including when washing the sprayer and pesticide containers after use.
- If you feel unwell, stop spraying and rest in the shade. Get medical help if symptoms get worse - see page 53.
- Make sure pesticides are not transferred to other containers such as drink bottles which children might try to drink from. Also do not use drink bottles to measure pesticide.
- It is best to keep pesticides under lock and key, away from foodstuffs and children.
- When pesticide containers are empty, do not use them for storing food or water - rinse them out three times with water and soap, make holes in them and bury them in the ground well away from houses or water bodies such as wells, rivers or lakes.
- Pesticides break down at different rates on crops. To ensure that vegetables are safe to eat, it is essential to respect the pre-harvest interval for the pesticide used. After this time, the quantity of pesticide on the produce will not be dangerous provided the correct dose was applied. This pre-harvest interval is stated on the pesticide label and for most pesticides is between one and fourteen days (see Tables 2c and 2f on pages 163-166).

Use pesticides selectively

It is also important that pesticides are used selectively otherwise they can disrupt other natural pest and disease control processes which are going on in the crop. The main ways to make pesticide use as selective as possible are outlined below:

- Give natural control a chance. This means scouting properly for pests, diseases and natural enemies and giving time for the natural enemies and host plant resistance to demonstrate whether they can maintain pests and/or diseases at low levels. Only if pests and diseases are increasing to damaging levels and natural enemies do not appear to be increasing too, should pesticides be used.
- Choose selective products. Biocontrol products such as *Bacillus thuringiensis* are highly selective, but there are very few selective synthetic insecticides. Fungicides have a smaller impact than insecticides on natural enemies. Even if a product is broad spectrum, the shorter its persistence, the smaller its impact on natural enemies. Tables 2c and 2f identify some products which are likely to be more selective.
- Apply only when necessary. Even if the decision has been made to spray pesticides, the applications should be made as few times as possible, always on the basis of scouting. This will at least give a chance for natural enemy numbers to recover between sprays and to start to exert a controlling influence on the pests again.
- Reduce volumes applied. Smaller nozzles will apply lower volumes and will produce finer spray which will penetrate the foliage better and be retained better on all parts of the plant. The lower volumes will mean lower doses of active ingredient and the greater efficacy of the smaller drops will reduce the need for as many sprays in future. Both of these

factors will tend to favour natural enemies. Also, the smaller droplets will reduce the level of run off to the soil where the pesticide can affect soil-living natural enemies.

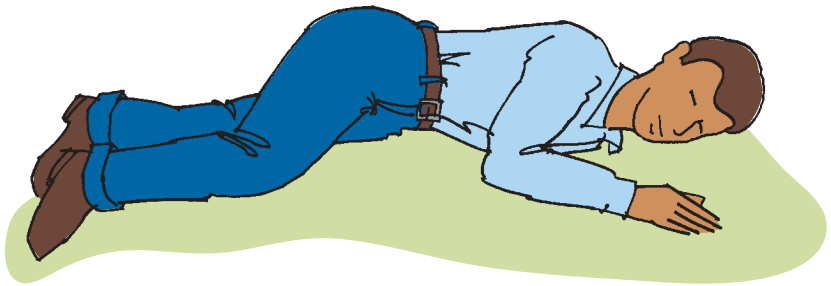
- Calibrate properly. Natural enemies will be badly affected if doses are accidentally higher than those recommended. Doses can in most instances be reduced below recommended levels, provided the application quality is good. Test any reduced doses first on a small scale to be sure that they are still effective.
- Target the pest. The V lance is a device which improves underleaf spray cover, increasing the possibility of good pest and disease control with reduced doses.
- Localise the application. *Spot spraying* and stratified spraying are methods of spraying only part of the plant or field. This allows natural enemies to survive in the unsprayed areas and to re-enter the sprayed area when pesticide residues have diminished.
- Time the application carefully. Spraying should be carried out at a time when pests are likely to receive a dose, but natural enemies are not. Watch the natural enemies of the pest to see when they are most active and where they are at different times of day. It may be possible to identify times when natural enemies are less likely to be contaminated by pesticide, for example, spraying late evening and early morning is less likely to affect parasitoid wasps which tend to be most active during the warmer parts of the day. However, spraying too early in the morning or late at night is likely to affect ladybird and hoverfly larvae which tend to be most active at night.

Action if someone is poisoned with pesticide

Although the mammalian toxicity of pesticides varies, all pesticides are poisons which can affect people if they are not used properly. Symptoms of poisoning can start with a headache or feeling ill. If this happens, stop working and see a health worker (for example, doctor or nurse). If someone else is affected by pesticide, remove any contaminated clothing, wash them, keep them calm and cool and take them to a health worker. Take the pesticide label with you so that informed decisions can be made on the best treatment for the pesticide poisoning.

20. The information on the pesticide label helps the doctor to decide which treatment is best

If the patient feels well enough they should drink water. If they become unconscious, lie them down in the shade on their side with their head back and make sure their airway is clear until the health worker arrives. *Artificial respiration* will be needed if they stop breathing, but take care not to be contaminated if the patient has pesticide around their mouth. Even if pesticide has been swallowed, do not induce vomiting because the pesticide may then be accidentally breathed into the lungs and cause further serious damage.



21. If the patient is unconscious, lie them down in the shade on their side with their head back in the 'recovery position'

IPM in Brassicas

2

IPM in Brassicas

Brassicas include crops such as cabbage, kale, covo, rape, viscose and cauliflower. They are sometimes referred to as *crucifers* because they belong to the Cruciferae family. However, most of the widely grown crucifers are in the genus Brassica and these crops are therefore usually referred to as brassicas.

Brassicas of various types are grown throughout the world and provide a valuable source of nutrition and income. They also add a considerable amount of organic matter to the soil so are useful crops to include in rotations. They originated in Europe and the Mediterranean region as wild cabbage and farming of brassicas began about 5000 years ago. They generally grow best in cool temperatures, although some varieties can withstand hot tropical conditions.

In Zimbabwe, they are usually grown in a seedbed and transplanted to the field when 7 - 10cm tall.

22. A field of cabbages

Various pests and diseases attack brassicas, causing loss of yield, quality and marketability.

The general principles of IPM described in the introduction should be followed, namely:

- Choose a suitable crop variety which grows well in the area and if possible, has resistance to diseases (see Tables 1a and 1b on pages 158-159).
- Use certified disease-free seed or treat it yourself with hot water (see page 19) or fungicide.
- Give plants a good start by ensuring that seedbed soil and seedlings are free of pests, diseases and weeds.
- Use cultural practices which help the plant to grow strongly and reduce pest and disease problems (see page 15).
- Ensure good *crop hygiene* and sanitation, including post-season destruction of debris by burning, composting or deep ploughing, and cleaning of tools between fields. Avoid field activities when vegetation is wet with dew, rain or irrigation water.
- Conserve and encourage natural enemies of pests (see page 23).
- Scout the crop regularly to check pest, disease and natural enemy status (see page 32).
- Only spray when pests and diseases appear to be getting out of control. Use the safest pesticide available (see page 162 onwards) and spray at low volumes, doses and frequencies (see page 31 onwards). Brassicas have waxy leaves and spray droplets tend to roll off. It is useful to add a small amount of washing powder, soap or liquid detergent to the spray tank to help the pesticide spread and stay on these waxy leaves.

CABBAGE SAWFLY
(*Athalia* spp.)

Type: Chewing pest (larvae)
Vegetable hosts: Brassicas
Group: Insect, wasp (Hymenoptera: Tenthredinidae)
Common names: Cabbage sawfly, cabbage leaf sawfly, turnip sawfly

APPEARANCE

Adults are wasps about 1.5cm long with bright yellow abdomens - see Picture 23. They are slow-flying and lay individual eggs in pockets cut into the plant leaf.

Larvae look like oily black or green coloured caterpillars and grow up to about 25mm long - see Picture 24. The head is shiny and the body has a swelling just behind the head like a hump. They fall off the plant at the slightest disturbance. They drop to the ground to pupate in mulch or in the soil. *Pupae* are yellowish.

23. Sawfly adult - typical yellow abdomen is hidden behind the wings

24. Sawfly larva showing typical hump behind the head.

DAMAGE

Larvae feed on leaves and typically eat all except the ribs of the leaf to leave it *skeletonized* - see Picture 25. They are a particular threat to seedbeds where damage can be severe.

CONTROL

- Destruction of remaining brassica plants from previous crops will help to prevent them appearing in new crops.
- Hand picking and squashing the larvae can prevent crop damage in small plots.
- When they appear in seedbeds they will need to be controlled quickly. No specific recommendations are given in the Zimbabwe Crop Chemical Handbook. However, products for control of diamondback moth (see Table 2a on page 162) are likely to give good results with the exception of Bt. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

25. Sawfly damage on kale showing skeletonization of the leaf.

CUTWORM
(*Agrotis* spp.)

Type: Chewing pest (larvae)
Vegetable hosts: Brassicas, tomato, beans, pepper, onion, groundnut and many others
Group: Insect, moth (Lepidoptera: Noctuidae)
Common names: Cutworm, black cutworm, greasy cutworm

APPEARANCE
Cutworms are caterpillars of a specific type of moth (noctuids). The adult moth is grey to brown with a wingspan of about 4cm and lighter coloured hind wings. Whitish yellow eggs are laid at night on leaves of grasses, weeds, and other host plants. These turn darker as hatching approaches. Young larvae may feed on leaves and cause tiny holes, but they drop to the ground after a few days. *Mature* larvae are about 4cm long, but because they hide in the soil during the day, and only emerge at night to feed on the crop, they are not often seen unless the farmer digs them up. The caterpillars are easy to recognize by their smooth skin, greasy grey/black colour and C-shaped posture when disturbed. Larvae pupate in the soil and pupae are shiny reddish-brown with two dark spikes at the tip of the abdomen.

26. Cutworm beside cut seedling

DAMAGE
Cutworms emerge at night, causing serious damage by cutting young plant stems at the base. They may then drag the end of the plant into the soil to feed on it by day. Sometimes, wilting is seen due to plant stems being partly cut. Often, several damaged seedlings are found near each other. Cutworm infestations can appear suddenly (as a result of adult moths flying into the area) and are often associated with fields that are weedy, have high amounts of organic residue or are very wet due to poor drainage or heavy irrigation.

CONTROL
- Fields need to be prepared and weeds eliminated at least two weeks before planting to reduce cutworm numbers.
- Flooding of the field for several days before transplanting seedlings into it can help to kill larvae in the soil.
- Ploughing can help by exposing larvae to predators and can bury others so that they cannot reach the surface.
- Early detection of cutworm infestations means that control can be carried out before serious damage occurs. Cutworms are usually present when seedlings are found cut off at the base of the stem.
- Small infestations can be controlled by digging near the damaged seedlings to find and kill the individual larvae.
- If transplanting is delayed slightly, the bigger seedlings will be more tolerant to damage.
- Hens are also useful because they find and eat cutworms near the surface.
- More widespread outbreaks may require use of a pesticide (see Table 2a, page 162) applied as a *drench*. This means spraying or pouring pesticide around the base of each plant in the evening so that the spray liquid soaks into the soil and kills the cutworms.

DIAMONDBACK MOTH
(*Plutella xylostella*)

Type: Chewing pest (larvae)
Vegetable hosts: Brassicas, aubergine, mustard
Group: Insect, moth (Lepidoptera: Yponomeutidae)
Common names: Diamondback moth, DBM, cabbage moth

APPEARANCE

The adults are small thin moths which fold their wings along their backs (Picture 27). Markings on the wings of the males appear as 3 yellowish diamond-shapes joined together on a brown background, hence the name of this pest (Picture 28). These tiny moths can be seen in the daytime, flying between plants when the crop is disturbed.

27. Diamondback moth adult (male) viewed from the side

The females (which don't have diamond markings) lay small yellow eggs on the leaves and these hatch after 3 - 5 days into green caterpillars (larvae) with no significant marking. The larvae have four *instars* and grow to about 1cm in length (Picture 29). Larvae which are disturbed often curl up or drop from the plant on silk threads. They wriggle rapidly when handled.

When fully grown, the larvae pupate inside a whitish silk cocoon attached to leaves or stems (Picture 30). Adults emerge after several days, mate and the females usually begin laying on the day of emergence.

28. Diamondback moth adult (male) viewed from above, showing diamond-shaped markings.

29. Diamondback moth larva (final instar) and leaf damage, including whitish windowing

30. Diamondback moth larva beginning to pupate in silk cocoon

Diamondback Moth

DAMAGE

This pest can multiply rapidly and the larvae can cause serious damage to brassicas when numbers build up. First instar larvae often mine in the leaf tissue - look for young larvae 1-2mm long emerging from small holes in the underside of the leaf. Older larvae feed on all plant parts and often feed around the growing bud of young plants. They create irregular holes, sometimes leaving the upper surface of the leaf in place - a type of damage known as *windowing*.

31. Diamondback moth larva infected with *Plxy*GV, showing typical whiter and fatter appearance.

CONTROL

- Scouting should begin when the plants are young since the earlier the pest is discovered, the easier it is to control. Larvae that are inside cabbage heart leaves are difficult to find unless outer leaves are pulled back. Growing points should be examined as their feeding can deform the plant.
- Natural enemies can keep the pest at acceptable levels if measures are taken by many farmers in an area to conserve and encourage them (see page 23).
- Heavy rains tend to wash off young larvae so planting during the rainy season can help to avoid problems. Overhead irrigation can have the same effect.

- Hand picking and squashing larvae can prevent crop damage on small plots.
- If it is possible to avoid growing brassicas (or other susceptible crops) for a period of 6 weeks in a particular area, all existing diamondback adults will die from lack of food. The moths generally do not fly very far, and as long as close neighbours have not been growing any host plants, brassicas planted after this break will be safe from the pest for some time.
- Farmers in some countries collect diseased larvae (fat and white or yellowish - see Picture 31 - or with fluffy mould on them), crush them, mix with water and spray them onto the infested crop. The fungal or viral pathogens which were infecting the collected larvae will infect other larvae and kill them in a few days.
- Inter-planting with tomato or chilli is said to repel diamondback moth adults and sprays of neem formulations or dusts of clay can reduce populations.
- Mustard can be a useful *trap crop* since DBM prefers it to brassicas. Once it is infested it can be ploughed in or removed.
- When the numbers of diamondback moths build up and natural control is not sufficiently effective, synthetic pesticides may be required. Unfortunately, this pest quickly becomes resistant to insecticides, so check what is recommended and monitor the effectiveness of spraying. If possible, change the type of pesticide used from time to time to prevent pesticide resistance building up. Table 2a on page 163 gives a list of effective and commonly available pesticides. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

FLEA BEETLES
(*Phyllotreta* spp.)

Type: Chewing pest (adults)
Vegetable hosts: Brassicas, radish (maize)
Group: Insect, beetle (Coleoptera: Chrysomelidae)
Common names: Flea beetle, cabbage flea beetle, turnip flea beetle

APPEARANCE
Several species of flea beetles attack brassica crops. They are small brown to black beetles about 2mm long that may have yellow stripes on their wing covers. They are easy to recognize since the adult beetles will jump from the crop when disturbed, using their enlarged hind legs. The eggs are laid at the base of the plants or in the soil. The small white larvae with brown heads live in the soil and eat roots. They have three pairs of legs and are about 5mm long when they are ready to pupate in the soil.

32. Flea beetle adult (much enlarged). Some have these yellow markings but many species are completely black.

DAMAGE
Outbreaks only occur occasionally but can be serious. It is the adults that cause the main damage as they feed on young leaves producing lots of tiny holes called a 'shot-hole' effect. Severe infestations may stunt or even kill young plants. Larger plants may be able to tolerate flea beetle attack hence control may not be necessary. On the other hand, young or transplanted seedlings may be killed by severe attack, particularly if it is hot and dry.

CONTROL
- Scout for shot-holes and the small black beetles which jump.
- Frequent watering will help the affected plants survive, but occasionally insecticides may be needed.
- *Cultivation* will help to destroy the larvae and pupae in the soil.
- Mulching will help to break the life cycle of flea beetles.
- No specific pesticide recommendations are given in the Zimbabwe Crop Chemical Handbook. However, products for control of diamondback moth (see Table 2a on page 162) are likely to give good results, with the exception of Bt. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

CABBAGE WEB WORM
(*Hellula undalis*)

Type: Chewing pest (larvae)
Vegetable hosts: Brassicas, radish
Group: Insect, moth (Lepidoptera: Pyralidae)
Common names: Cabbage web worm, cabbage borer, cabbage centre worm

APPEARANCE

Adult moths are sandy brown with lines across them. They look triangular when resting and are just over 1cm across. They lay creamy white eggs either singly or in chains of 2 or 3 - usually near the bud. After hatching, the young larvae begin to feed on the leaves, especially the young tender parts of the bud and usually spin a web around themselves between two leaf surfaces. Larvae are greyish-yellow, and grow through 5 instars up to about 1.5cm long, with five pinkish-brown stripes along their bodies. They then pupate in a silk cocoon. New pupae are soft and very pale yellowish-white, but a few hours later they harden and become shiny light brown with a dark stripe along the top.

33. Cabbage web worm larva showing typical pinkish brown stripes

DAMAGE

Larvae feed on growing points of young plants and burrow into stems and leaves, causing deformed growth and the formation of many growing points. They are often hidden behind a web of silk and masses of *frass* (insect faeces) and these are usually the signs first noticed by farmers.

CONTROL

- Scouting is important in order to detect the pest early since the larvae are difficult to reach once they are protected in their hiding places inside the plants and under webbing and frass.
- See diamondback moth for main cultural, biological and management methods.
- No specific pesticide recommendations are given in the Zimbabwe Crop Chemical Handbook for web worm control. However, products for control of diamondback moth (see Table 2a on page 162) are likely to give good results, with the exception of Bt. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31). Special attention must be paid to targeting the pest since they can be well protected by webbing and frass - spray directly into growing points and other infested areas.

APHIDS
(1. *Brevicoryne brassicae*, 2. *Myzus persicae*, 3. *Lipaphis erysimi*)

Type: Sucking pest (nymphs and adults)

Vegetable hosts: 1. Brassicas, 2. Brassicas, tomatoes, aubergines, beans, 3. Brassicas, tomato and many others

Group: Insect, aphid (Hemiptera: Aphididae)

Common names: 1. Cabbage aphid, 2. Green peach aphid, 3. False cabbage aphid

34. False cabbage aphid adults and nymphs (much enlarged)

APPEARANCE
Aphids are small soft-bodied insects often seen in colonies on crop leaves and stems. Winged adults fly to the crop and quickly produce wingless young or *nymphs* which are initially about 1mm long. These grow and become adults after a few days and the colonies can expand rapidly, usually on the underside of leaves or on growing points. Aphids of several different species can attack brassicas.

35. Dense colony of cabbage aphids with their typical grey/waxy appearance. Two are parasitized and appear brown and shiny.

The pale grey/green aphids which look waxy or dusty (like cigarette ash) are usually *Brevicoryne brassicae* and the shiny green aphids commonly seen are usually either *Myzus persicae* or *Lipaphis erysimi.*

DAMAGE
Aphids damage plants by sucking plant sap, spreading viruses, and excreting a sticky liquid that coats the plant. When they suck sap they cause curling, wrinkling, or cupping of the infested leaves. Plants may be deformed and *stunted* and may produce unmarketable heads and leaves. Some of these symptoms may also be due to the virus diseases which can be spread by aphids (see page 91). Aphids also produce a sweet substance called honeydew as they excrete the extra sugar and liquid which they don't need. When this drips onto leaves below it can cause blackening as fungal mould grows on it.

Aphids

CONTROL

- Plant the crop in a well-prepared, fertile seedbed to promote vigorous growth.
- Do not apply too much nitrogenous fertilizer as this will make the plant very soft, juicy and attractive to aphids.
- Avoid planting near an aphid-infested crop or on land from which an infested crop has been recently removed.
- Rainfall and overhead irrigation tend to discourage aphids.
- Natural enemies can keep the pest at acceptable levels if measures are taken to conserve and encourage them (see page 23). However, it is sometimes difficult for natural enemies to attack aphids since some species of ants 'farm' the aphids and protect them against attack to ensure their supply of the sweet honeydew.
- Growing strong smelling plants such as garlic, onion or parsley near the crop will reduce infestations of aphids.
- Spraying with a soapy solution helps to wash off aphids and disturb their breathing.
- Chemical control of aphid infestations using synthetic pesticides may be necessary when numbers build up and natural control is not sufficiently effective. Table 2a on page 163 gives a list of effective and commonly available pesticides. For sucking pests such as aphids, a *systemic pesticide* is often best - in other words, one which can pass through the leaf surface and be carried in the plant sap which the aphids suck. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

BAGRADA BUG
(*Bagrada hilaris*)
Also shield bugs (*Anestasia* spp. & *Nezara* spp.)

Type: Sucking pest (nymphs and adults)
Vegetable hosts: Brassicas, carrots, potatoes
Group: Insect, bug (Hemiptera: Pentatomidae)
Common names: Bagrada bug, harlequin bug, painted bug

APPEARANCE

36. Bagrada bug showing bright yellow and red markings

Bagrada bugs are a common type of stink bug which are dark coloured and grow to about 6mm long. Adults are black with bright yellow or orange spotted markings. Their shape is similar to the other larger shield bugs which also suck sap. Adult bugs appear most commonly when the temperature is high just before the rains and they can often be seen mating - connected at the abdomen and often facing in opposite directions. When disturbed, they drop from the plant and stay still. Their eggs are laid in the soil in clusters which look like tiny greenish pots in neat regular blocks. These turn darker in colour before the tiny nymphs emerge and spread out on the plant. The nymphs look like small adults but have no wings and turn bright yellow with black spots.

Bagrada Bug

DAMAGE

Bug attack (by both nymphs and adults) is sporadic and coincides with warm weather. Small puncture marks can sometimes be seen where the bugs have pierced the plant tissue and sucked sap. This weakens the plant and it may become stunted. Affected leaves wither and young plants may even be killed if the attack is severe. Other plant-feeding bugs cause similar damage.

CONTROL

- Bugs can be removed by hand and destroyed.
- Watering and irrigation will discourage bugs.
- Old crops or sprouting stumps left in the field will provide refuges for previous infestations so these should be destroyed or dug in deeply. Rotate crops so that susceptible plants are not grown in successive seasons.
- Growing strong-smelling plants such as garlic, onion or parsley near the crop will reduce infestations.
- Spraying plants with a soapy solution helps to wash off young bugs.
- If none of these methods is giving satisfactory control, Table 2a on page 162 gives a list of effective and commonly available pesticides. For sucking pests such as bugs, a systemic pesticide is often best. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

Thrips

THRIPS
(1. *Thrips* spp. & 2. *Frankliniella* spp.)

Type: Sucking pest (nymphs and adults)
Vegetable hosts: Brassicas, tomato, onion, cucurbits, peppers, (cotton) and others
Group: Insect, thrips (Thysanoptera: Thripidae)
Common names: 1. Onion thrips, potato thrips and 2. Western flower thrips

APPEARANCE

Thrips adults are small (about 1.5mm in length) and are black, brown or yellowish/orange with tiny hairs. Eggs are laid in small cuts in the plant surface. The larvae which emerge after a few days look like green *maggots* and are difficult to see on green leaves until they cause damage. The larvae usually drop to the soil to pupate and when adults emerge they crawl or fly back onto host plants.

37. Thrips adult (much enlarged). Colour is often darker.

Thrips

DAMAGE

Both adults and nymphs pierce the leaf surface and suck the sap. This causes blemishes which often look silvery and which weaken the plant. They foul the plant surface with their faeces which also encourages the growth of fungi. Heavy infestations may cause wilting or even death of the plant but this is uncommon on brassicas. As well as reducing vigour and affecting appearance and quality, thrips can spread plant viruses on some crops, for example, tomato spotted wilt virus on tomatoes - see page 146. and their feeding may increase the incidence of fungal and bacterial diseases.

CONTROL

- Natural control by predators is important in control. The main predators are predatory mites, predatory thrips and spiders. These should be conserved by minimising the use of broad spectrum pesticides.
- Thrips numbers can be monitored using yellow sticky traps.
- Intercropping with onion and garlic is said to discourage thrips infestations.
- Mulching can help to control thrips since it can prevent them reaching the soil to pupate.
- Thorough cultivation of the soil before transplanting can help to kill pupae in the soil from previously infested crops.
- Sometimes numbers build up to a level where chemical control is necessary. No specific pesticide recommendations are given in the Zimbabwe Crop Chemical Handbook for thrips control. However, products for control of diamondback moth (see Table 2a on page 162) are likely to give good results, with the exception of Bacillus thuringiensis (Bt). For sucking pests such as thrips, a systemic pesticide is often best. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

Whitefly

WHITEFLY

(1. *Bemisia tabaci* [also known as *Aleurodes tabaci*] & 2. *Trialeurodes vaporariorum*)

Type: Sucking pest (nymphs and adults)

Vegetable hosts: Brassicas, tomato, pepper, cucumbers, beans (tobacco, cotton)

Group: Insect, whitefly (Hemiptera: Aleyroididae)

Common names: 1. Tobacco whitefly, cotton whitefly and 2. Glasshouse whitefly

APPEARANCE

The adults are around 1-2mm long and have bright white or yellowish wings almost completely covering their bodies. They are often found clustered in groups on the underside of leaves. Females can lay over 100 light-coloured eggs which are attached to the undersides of new leaves. They hatch into crawling forms that feed on the underside of leaves, then

38. Whitefly adult (much enlarged)

39. Whitefly adults and nymphs (black ones are parasitized).

moult into scale-like, sucking nymphs which do not move. These nymphs are glassy and yellowish with a flattened scale-like body. After several moults, the nymph becomes a non-feeding, plump, light-coloured pupa, from which the adult whitefly emerges.

DAMAGE

Like aphids, whiteflies damage plants in three ways. Sap-feeding by the adult and nymphal stages causes yellow spots and weakens the plant, produces a coating of sugary honeydew on the leaves which encourages sooty mould, and can transmit plant viruses, for example, tomato yellow leaf curl virus on tomatoes - see page 148.

CONTROL

- Neem tree seed extract (for example, made by soaking and pounding neem seeds in water) controls young nymphs, inhibits growth and development of older nymphs, and reduces egg laying by adults.
- Spraying with soapy water solutions can be effective.
- Growing African marigolds and nasturtiums has been reported to discourage whitefly infestations.

- Parasitoids can play an important role in reducing whitefly numbers so flowering plants should be available to provide them with nectar as a food source and spraying should be kept to a minimum.
- Research is continuing into special oil sprays which do not contain pesticide, but which can help to control whiteflies..
- If numbers build up to high levels, spraying may be necessary. Table 2 gives a list of effective and commonly available pesticides. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31). For sucking pests such as whiteflies, a systemic pesticide is often best. Non-systemic pesticides will not be effective unless applied to the underside of leaves where the whiteflies are found. The addition of soap to the spray solution will help the spray droplets spread on the waxy wings of the whiteflies. The pesticide may not be effective against eggs or nymphs so a second application some days later may be necessary to control the adults which have emerged from them. Whiteflies develop resistance to pesticides very quickly so the type of pesticide should be changed regularly to prevent it.

COTTONY ROT
(*Sclerotinia sclerotiorum; S. minor*)

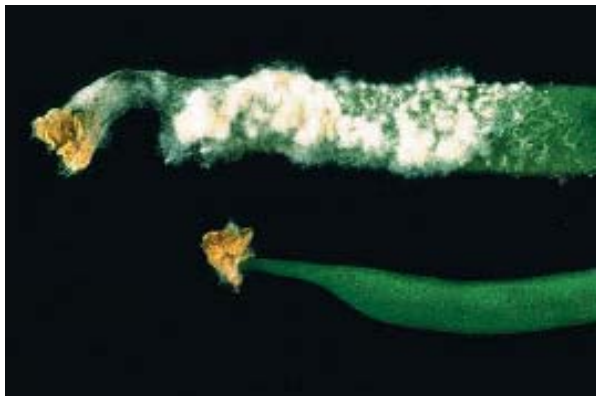
Type: Fungus

Vegetable hosts: Brassicas and many other crops and plants

Group: Leotiales: Sclerotiniaceae

Common names: Cottony soft rot, white rot, sclerotinia blight

APPEARANCE AND DAMAGE
Cottony rot disease is named after the white growth which can be seen on leaves and heads. This follows development of a soft, light brown, watery rot of the leaves. Hard, dark brown to black lumps (*sclerotia*) of the fungus form in the rotting tissues. Patches of disease may circle the stem and enter, causing death of the plant. This is called the white blight phase.



40. Cottony rot showing typical fluffy fungal growth on beans

TRANSMISSION
The fungus can survive for many years in the soil in the hard sclerotia. If conditions are moist and cool, these sclerotia produce spores which can infect nearby plants or be carried away by the wind to infect more distant crops. Overhead irrigation, water-logging, fog, mist and *dew* and provide the ideal conditions for development and spread of the disease.

CONTROL
- Avoid soils which easily flood or become waterlogged.
- Rotate with maize, onions or spinach, but not groundnuts or sunflower (as the disease can also infect these crops).
- If cottony rot is serious, spraying with fungicide may be necessary. No specific product recommendations are given in the Zimbabwe Crop Chemical Handbook - consult extension services or agrochemical industry for advice on product choice. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

DAMPING OFF
(*1. Pythium* spp., 2. *Rhizoctonia solani* & others)

Type: Fungus

Vegetable hosts: Wide range of hosts

Group: 1. Pythiales: Pythiacae,
2. Ceratobasidiales: Ceratobasidiaceae

Common names: Damping off, wire-stem

APPEARANCE AND DAMAGE

These fungi commonly cause damping off and 'wire-stem' of seedlings in the seedbed and bottom rot and head rot in growing cabbage crops or after harvest. Wet soils, crowded seedbeds and high temperatures help the development and spread of these diseases.

Damping off occurs when seedlings fall over and die because the fungus has infected the base of the stem, making it wet and brown - see Picture 41.

Wire-stem is a similar condition which can occur in larger plants as well. The stem discolours and becomes thinner around soil level and looks a little like wire.

41. Damping off with characteristic *girdling* of seedling

Affected plants may survive since the stems can still support them, but they are much less vigorous and yield is reduced.

These fungi may lead to two other conditions. If the leaves wilt and turn brown or black, while remaining on the plant, the name 'bottom rot' is used. If the disease has spread upwards the heads of cabbages can be affected, and this is called 'head rot'. Secondary bacterial infections may cause complete rotting of the head together with an unpleasant smell.

TRANSMISSION

The fungi are common in moist soils and may last for several seasons. Infection of plants can be via the roots or via leaves which are touching the soil or have been splashed by rain or irrigation water. The fungi can also be transmitted on seed.

CONTROL

- Rotation - site seedbeds on land which has not grown brassicas for at least 3 years.
- Seeds should be tested and where necessary, treated for disease by the seed producer. If the farmer knows or suspects the seed is infected, it can be given hot water treatment (see page 19) or treated with a fungicide. Follow the manufacturer's instructions.
- Before planting, seedbed soil can be partly *sterilized* by *solarization* or fire or it can be drenched with a fungicide. Table 2d on page 165 gives a list of effective and commonly available fungicides.
- Spread seed thinly to prevent overcrowding. Allow the seedbed plenty of light and air.
- Seedlings with the disease should be burned.
- During field operations such as weeding, care should be taken to avoid cutting stems and throwing soil into plant heads.

YELLOWS
(*Fusarium oxysporum f. sp. conglutinans*)

Type: Fungus

Vegetable hosts: Brassicas

Group: Hypocreales

Common names: Yellows, cabbage yellows, cabbage fusarium wilt

APPEARANCE AND DAMAGE
The leaves of infected plants turn yellow and the plant gets weak due to blockage or damage of the tubes which carry sap (water and nutrients) around the plant. Affected leaves often bend sideways (see Picture 42) since only one side of the leaves' sap tubes are blocked, but they do not survive long and usually go yellow and drop off. As with black rot (see page 88) the cut stem may show dark areas due to the presence of the disease within the sap tubes.

42. Yellows, showing yellowing and typical sideways bending of the leaf

TRANSMISSION
This disease is soil and seed-borne. The pathogen can survives for several years in the soil even without host plants in the field. It can infect through wounds or roots, and then be transmitted throughout the plant and spread from plant to plant on water splashes or tools, or via infected plants being transplanted. Yellows is more serious in warm weather and on acidic soils (low *pH*).

CONTROL
- Grow resistant varieties (see table 1a on page 158).
- Because of its persistence in the soil yellows is difficult to control, so care should be taken to avoid introducing the disease.
- Remove infected plants and feed to livestock or burn them.
- Liming the soil makes conditions less suited to yellows because it reduces the acidity. Soil from fields affected by yellows should be tested and a liming recommendation obtained if necessary.
- Avoid growing brassica crops year after year on the same field - there should be a break of at least three seasons between brassica crops.

BACTERIAL SOFT ROT
(*Erwinia carotovora var. carotovora*)

Type: Bacterium

Vegetable hosts: Brassicas, carrots and others

Group: Enterobacteriales: Enterobacteriaceae

Common names: Bacterial soft root, bacterial root rot, core rot of carrot

APPEARANCE AND DAMAGE
Bacterial soft rot can affect many types of vegetable, causing them to turn soft and rotten with a bad smell. Although soft rot is usually a problem after harvest, cabbage can be affected in the field. Soft rot can also attack the stems of other brassicas.

43. Bacterial soft rot on cabbage

TRANSMISSION
Because the bacteria which cause soft rot are present everywhere, any damage or weakened tissue can be invaded. Infection with black rot or damping off may provide such opportunities for soft rot, and in warm wet weather the rot can develop and spread rapidly, particularly if the bacterium is spread in the field by water splashes or contact with tools such as hoes or knives. If infected knives are used to harvest cabbages, the stored crop may also rot quickly.

CONTROL
- Plant on ridges or raised beds to prevent waterlogging around the plants.
- Prevention of other diseases will reduce the ability of soft rot to penetrate the crop.
- Avoid harvesting when conditions favour the development of soft rot (warm and moist conditions).
- Wash and disinfect hands and harvesting knives.
- Harvest the healthy cabbage heads first, and make sure the crates are new, washed very thoroughly or disinfected, and that the crop is stored in a cool, airy place.
- Remove and destroy the diseased crops or left over stems in the soil after the crop has been harvested so that diseases will not spread to the next crop planted in that field.
- Avoid growing brassica crops in the same field for a period of at least three seasons.

BACTERIAL BLACK ROT
(*Xanthomonas campestris pv. campestris*)

Type: Bacterium

Vegetable hosts: Brassicas, mustard, radish

Group: Xanthomonadales: Xanthomonadaceae

Common names: Black rot

APPEARANCE AND DAMAGE

44. Black rot symptoms on young leaf

Black rot can affect plants at all growth stages, from seedling to head-formation. It tends to kill the seedling leaves completely after they turn dark in colour. When the plants are larger, the disease causes yellow V-shaped areas at the edge of the leaves, particularly lower leaves near to the soil - see Pictures 44 and 45. These yellow areas become larger and darker, and may cause the leaf to drop from the plant. Affected plants show dark areas if the stem or leaf stalk is cut (always clean the knife well before cutting another plant). The dark parts are evidence of the disease moving through the sap system of the plant, and if all the *vessels* are affected there might be a black ring in the cut stem (see Picture 46). If the heads of cabbage becomes affected the crop may be lost. During wet conditions a secondary bacterial infection may come in and cause complete rotting of the head, accompanied by an unpleasant smell.

45. Black rot symptoms on mature leaves

TRANSMISSION

The bacteria may be carried on the seed (*seed-borne*) or on infected seedlings. It may be present in the soil, in old infected plant debris, or in nearby weeds which are related to brassicas. Once it is in the field, it can be spread from plant to plant by water splashes or people handling diseased plants then healthy plants. The bacterium can get into the plant through the roots, through leaf edges or through damage caused by chewing pests.

CONTROL

- Use of resistant varieties (see table 1a and 1b on pages 160-161) is a powerful tool in black rot disease management.
- Use certified disease-free seed.
- Disease-free seedbeds are crucial. The seedbed land should ideally not have been used for brassicas for several years.
- Seedlings should not be crowded in the nursery.
- Seedlings must not be bunched together and placed in buckets for transplanting as this will spread any diseases to the whole batch.

Bacterial Black Rot

- Mulching will reduce the splashes which can spread infection, particularly if overhead irrigation is used.
- Overhead irrigation should be avoided if possible.
- Weeding and gapping during damp conditions are best avoided.
- Remove and destroy the left over plant tissue in the soil after the crop has been harvested. Feed them to livestock or compost them so that the infection will not spread to the next crop planted in that field.
- Sprays of copper-based products can reduce development of black rot, but may not be economic.

46. Black rot showing black ring in a cut cabbage stem

Mosaic Viruses

MOSAIC VIRUSES (1. Cauliflower Mosaic Virus & 2. Turnip Mosaic Virus)

Type: Virus

Vegetable hosts: 1. Brassicas, 2. Brassicas, spinach (tobacco)

Group: 1. Caulimoviridae: Caulimovirus, 2. Potyviridae: Potyvirus

Common names: 1. Cauliflower mosaic caulimovirus, cauliflower mosaic virus, 2. Cabbage black ringspot virus

47. Cauliflower mosaic virus showing typical stunted leaves

APPEARANCE AND DAMAGE

These two common virus diseases affect brassicas. They can occur as individual diseases, or both together. Mosaic describes the *mottling* symptoms which can also be accompanied by leaf *distortion* and reduced leaf size - see Picture 47. If both diseases are present, severe spotting can develop. These symptoms get worse during storage. The time when the infection enters the crop affects the seriousness of the disease, and the potential yield loss it can bring about. Early infection in the seedbed or soon after transplanting,

48. Turnip mosaic virus showing typical lightening of the veins

Mosaic Viruses

can reduce yield greatly, but it is believed that infection near to the time of harvest is much less serious in lowering yield and quality.

Cauliflower mosaic caulimovirus causes lumpy or warty growths on the veins of the lower leaf surface. In storage affected plants show a black mottle or stipple on leaves inside the head.

Turnip mosaic potyvirus causes mottling and distorted leaves with lightened veins (see Picture 48), accompanied by reduced vigour. Black spots develop on leaves, which fall off early. In stored cabbage, black sunken spots develop on leaves throughout the head. These spots are larger than those caused by cauliflower mosaic virus.

TRANSMISSION

These viruses are both transmitted by the green peach aphid (*Myzus persicae*), and the cabbage aphid (*Brevicoryne brassicae*). They can also be transmitted by mechanical means through plants rubbing together or by human activity, but are not transmitted in seed. Some weeds are known to be alternate hosts of the virus so clean field margins can help to limit the disease.

CONTROL

- Control aphids (see page 70) to prevent transmission.
- Clear weeds and *volunteer crop plants* from land, particularly near seedbeds.
- Take care not to damage plants when working in the crop and wash field tools regularly to prevent transmission from diseased to healthy plants.

IPM in Tomatoes

3

IPM in Tomatoes

Tomatoes are members of the Solanacae family, together with other related crops such as eggplant, peppers, Irish potato and tobacco. They are one of the most important vegetables in central and southern Africa. They are relatively easy to grow and are an important source of nutrition and income for smallholders and larger commercial producers.

49. Staked tomato plant

Tomato varieties can be divided into two main types, The first are *bushy varieties* (also called *determinate* cultivars) which can usually grow without support. The second are *vine varieties* (also called *indeterminate* cultivars) which need to be supported - a process known as *staking* or *trellising* - and usually *pruned* to leave only one or two main stems. This staking/trellising helps to avoid diseases since it improves air circulation in the crop and prevents plant parts including fruits touching the soil. In addition, varieties can be *fresh market* (for the table) or *processing* (for canning and making into sauces).

Tomatoes are usually grown in seedbeds then transplanted when they have grown to a height of about 10 to 15cm. As with many crops, it is better to sow seeds thinly and remove competing weeds to produce vigorous plants which are more likely to withstand pests and diseases.

Tomatoes are attacked by a variety of pests that chew or suck their leaves, flowers and fruit. A wide range of diseases also attack the leaves, fruit and roots - particularly in the rainy season when high humidity favours pathogen development and *transmission*.

The general principles of IPM described in the introduction should be followed:

- Choose a suitable crop variety which is likely to grow well in the area and if possible has resistance to diseases (see table 1c and 1d on pages 160-161).
- Use certified disease-free seed or treat it yourself with hot water (see page 19) or fungicide.
- Give plants a good start by ensuring that seedbed soil and seedlings are free of pests, diseases and weeds.
- Use cultural practices which prevent and reduce pest and disease problems (see page 15).
- Ensure good crop hygiene and sanitation including sterilisation of plant stakes, post-season destruction of debris by burning, composting or deep ploughing, and cleaning of tools between fields. Avoid field activities when vegetation is wet with dew, rain or irrigation water.
- Conserve and encourage natural enemies of pests (see page 23).
- Scout the crop regularly to check on pest, disease and natural enemy status (see page 32).
- Only spray if pests or diseases appear to be getting out of control. Use the safest pesticide available (see pages 162-166) and spray at low volumes, doses and frequencies (see page 31 onwards). One or two pests and diseases require more preventive action. For example, late blight can rapidly destroy a tomato crop once it has become established so in areas where it is frequently a problem, fungicides should be applied whenever the weather is wet and cool.

AFRICAN BOLLWORM
(*Helicoverpa armigera*)

Type: Chewing pest (larvae)
Vegetable hosts: Tomato, beans, peas, groundnut (cotton, maize, sorghum)
Group: Insect, moth (Lepidoptera: Noctuidae)
Common names: African bollworm, African cotton bollworm, American bollworm, tomato fruitworm

50. Adult African bollworm moth

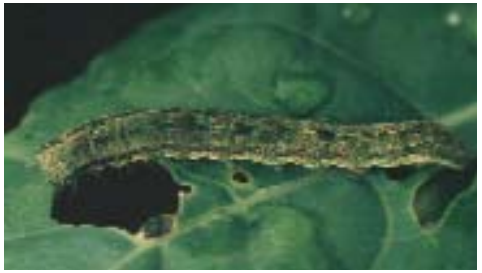
APPEARANCE
Bollworms are large caterpillars often seen living and feeding in tomato fruit, but they also attack many other vegetable and field crops such as cotton and sorghum. Adults are fat brown moths (see Picture 50) which fly at night and lay single round yellowish-white eggs measuring about 0.5mm in diameter, usually on the upper part of the plant. A single female can lay many hundreds of eggs. The young larvae are green to reddish brown caterpillars which grow to around 4cm long. They have dark markings and a light stripe along the length

51. African bollworm larva beginning to burrow in ripe tomato fruit

of each side of their bodies - see Picture 53. The fully grown caterpillars drop to the ground to pupate a few centimetres beneath the soil surface. Pupae are smooth, dark brown with two spines at one end.

DAMAGE
The larvae (caterpillars) feed on leaves, flowers and fruit. The leaf damage can reduce leaf area which slows plant growth and the flower feeding can prevent fruit formation. When they burrow in the fruit (see Pictures 51 and 52) they are difficult to reach and control with insecticide. The damage may cause the fruit to drop or make it more susceptible to secondary fungal and bacterial diseases.

52. African bollworm larva emerging from feeding inside an unripe tomato fruit



53. African bollworm larva showing typical light stripe down the side of the body

CONTROL

- Scouting is important to detect infestations early, preferably for the presence of eggs, since the larvae are well-protected once they move into the flowers and fruits. By this stage the damage caused is severe.
- Crop rotation can only help to prevent build up of populations if it is done over large areas since the adult moths can move quite long distances. This is unlikely to be practical for smallholders.
- Hand picking of eggs and larvae can be an effective method if infestations are not too severe. Hens can help by eating larvae and pupae at certain times of crop development, although they should not be allowed near seedlings or plants with fruit since their scratching and pecking will cause damage.
- Infested fruit should be destroyed, and infested plants should be composted or burnt after harvest.
- Since this pest can infest several other crops, including maize, sorghum and cotton, it is important to ensure that infested crop residues are carefully destroyed to prevent the pest switching backwards and forwards between these different hosts.
- If the infestation is severe, pesticide sprays may be required. The aim should be to target the young caterpillars before they have entered the fruit. Table 2b on page 162 gives a list of effective and commonly available pesticides. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31). Care should be taken not to use the same pesticide time after time since this pest can develop resistance very quickly.

CUTWORM
(*Agrotis* spp.)

Type: Chewing pest (larvae)

Vegetable hosts: Brassicas, tomato, beans, pepper, onion, groundnut and many others

Group: Insect, moth (Lepidoptera: Noctuidae)

Common names: Cutworm, black cutworm, greasy cutworm

APPEARANCE

54. Cutworm beside cut seedling

Cutworms are caterpillars of a specific type of moth (noctuids). The adult moth is grey to brown with a wingspan of about 4cm and lighter coloured hind wings. Whitish yellow eggs are laid at night on leaves of grasses, weeds, and other host plants. These turn darker as hatching approaches. Young larvae may feed on leaves and cause tiny holes, but they drop to the ground after a few days. Mature larvae are about 4cm long, but because they hide in the soil during the day, and only emerge at night to feed on the crop, they are not often seen unless the farmer digs them up. The caterpillars are easy to recognize by their smooth skin, greasy grey/black colour and C-shaped posture when disturbed. Larvae pupate in the soil and pupae are shiny reddish-brown with two dark spikes at the tip of the abdomen.

Cutworm

DAMAGE

Cutworms emerge at night, causing serious damage by cutting the young plant stem at the base. They may then drag the end of the young plant into the soil to feed on it during the day. Sometimes, wilting is seen due to plant stems being partly cut. Often, several damaged seedlings are found close to each other. Cutworm infestations can appear suddenly (as a result of adult moths flying into the area) and are often associated with fields that are weedy, have high amounts of organic residue or are very wet due to poor drainage or heavy irrigation.

CONTROL

- Fields need to be prepared and weeds eliminated at least two weeks before planting to reduce cutworm numbers.
- Flooding of the field for a few days before transplanting seedlings into it can help to kill larvae in the soil.
- Ploughing can help by exposing larvae to predators and can bury others so that they cannot reach the surface.
- In the fields, early detection of cutworm infestations means that control can be carried out before serious damage occurs. Cutworms are usually present when seedlings are found cut off at the base of the stem.
- Small infestations can be controlled by digging near the damaged seedling to find and kill the individual larvae.
- If transplanting is delayed slightly, the bigger seedlings will be more tolerant to damage.
- Hens are also useful because they find and eat cutworms near the surface.
- More widespread outbreaks may require use of a pesticide (see Table 2b on page 162) applied as a *drench*. This means spraying or pouring pesticide around the base of each plant in the evening so that the spray liquid soaks into the soil and kills the cutworms.

Leafminer

LEAFMINER (*Liriomyza* spp.)

Type: Chewing pest (larvae)
Vegetable hosts: Tomato, beans, peas
Group: Insect, fly (Diptera: Agromyzidae)
Common names: Serpentine leafminer, pea leafminer

APPEARANCE

The adults are small black and yellow flies about 2mm long - see Picture 55. Eggs are laid in the host plant leaves and the larvae feed between the upper and lower surface of the leaf making a tunnel or *leaf mine* as they move along (see Picture 56). When the yellow/orange larva is fully grown, it usually cuts a slit in the leaf and drops to the soil where it pupates just below the surface. Occasionally the larvae do not drop to the soil and the dark orange or brown pupae can be seen within the leaf mine.

55. Leafminer adult and stippling caused by its probing on broad bean leaf.

DAMAGE

In heavy infestations, the activities of the adults in feeding and laying eggs in the leaves cause a white spotting or *stippling* as in Picture 55. This can kill seedlings and in older plants, allows fungal diseases to enter the leaves. However, the main damage is caused by larvae mining inside the leaves and reducing the productive leaf area. Some species mine over 2cm per day. If the infestation level is high - usually in August when the weather warms up - the leaves may be killed and drop off, leading to yield loss, fruit sun scald (see page 155) or in serious cases, death of the plant.

56. Leafminer damage on tomato leaf

CONTROL

- Some natural enemies attack the larvae inside their mines - for example, parasitoid wasps or predatory thrips - and these may be enough to prevent economic damage, provided persistent broad spectrum pesticides are not used.
- Sticky traps have been tried. These consist of large sheets of yellow paper coated with a sticky substance. The leafminer adults are attracted to the colour and get caught on the sticky surface. However, it is doubtful whether the traps are a practical option since it is difficult to keep the traps sticky in dusty conditions or when the surface quickly gets covered with large numbers of flies. A more practical option may be yellow basins filled with water (with a little soap added) distributed around the crop. These can attract and kill many adult leafminers.

- There are many alternate vegetable hosts for this pest; care must be taken with rotations and arrangement of fields so as not to allow leafminers to infest new crops from old infested ones.
- If numbers build up, pesticides may need to be used, but product choice and spray timing are important. The pesticide either needs to be *translaminar* (able to pass through the outer layers of the leaves) or systemic (able to pass through the outer leaf layers and move in the plant's *sap*) to reach the larvae in their mines. Also, heavy use of pesticides can make the problem worse by killing the natural enemies of leaf miners. Table 2b on page 162 gives a list of effective and commonly available pesticides. Neem extract - a botanical product - is said to be effective against this pest. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction.
- Pesticide resistance is common and can build up quickly so it is important to rotate pesticides regularly.

SPIDER MITES
(*Tetranychus* spp.)

Type: Chewing pest (nymphs and adults)

Vegetable hosts: Tomato, beans, cucumber, peppers (cotton, tobacco, maize, sorghum)

Group: Mite (Arachnida: Tetranychidae)

Common names: Red spider mite, two spotted spider mite, tobacco spider mite (three different species)

APPEARANCE

Eggs are round, white/pink and tiny (0.1mm) and are usually laid on the under-surface of leaves. They hatch into six-legged larvae (light green) which become eight-legged nymphs after several days (also light green) and become reddish coloured adults which are around 0.25mm long after about a week. These adults have eight legs, and produce a fine silk webbing on leaves which tends to protect them from predators and spray droplets - see Picture 57.

57. Spider mites on tip of tomato leaf

DAMAGE

Initially the infestation may be at one edge of the field or in patches as mites can be dispersed by the wind. In warm dry weather they can multiply and spread very quickly, especially if plants are not receiving sufficient rain or irrigation water. Infestations are usually seen first on the lower surface of leaves, particularly around the main vein. The leaves may become spotted, yellow, brown or silvery as a result of the spider mites' feeding activity (see Picture 58). Yield can be greatly reduced as the plants are weakened or even killed as a result of feeding by large numbers of spider mites. Fruit can also be attacked, causing white speckling and loss of market value - see Picture 59.

58. Spider mite damage on tomato leaf showing typical white spotting

59. Spider mite damage on tomato fruit showing typical white speckling

Spider Mites

CONTROL

- *Field hygiene* is important as an old crop (or weeds) infested with mites can cause infestation of any new crop grown nearby, particularly if it is downwind of the old crop. Staking materials from fields infested with spider mites should be thoroughly cleaned (scrub with water and soap) before using them again - adult mites can hide in the cracks in wooden poles and re-infest new crops. If moving through the crop for weeding, pruning, harvesting or spraying, always leave the infested area until last in order to limit the accidental spread of the mites.
- Natural enemies such as predatory mites control the pests under some conditions. Hedges of perennial pigeon pea are said to encourage these predatory mites. Broad spectrum pesticides, especially pyrethroids should be avoided since they tend to kill the predatory mites, causing spider mite numbers to flare up.
- Spider mites do not like wet conditions so heavy rain or irrigation can reduce their numbers.
- Interplanting with garlic, basil and onion is said to give some protection due to their strong smell.
- The tomato variety Rossol has been found to have some tolerance to spider mite attack.
- If pesticides are required, Table 2b on page 162 gives a list of effective and commonly available pesticides. Apply them using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures for safe and selective application outlined in the introduction (see page 31 onwards). This pest quickly becomes resistant to insecticides, so check what is recommended and monitor the effectiveness of spraying. Change the type of pesticide used regularly to prevent pesticide resistance building up.

Aphids

APHIDS
(1. *Myzus persicae* & 2. *Aphis gossypii*)

Type: Sucking pest (nymphs and adults)
Vegetable hosts: Tomato, brassicas, beans, pepper, cucumber (cotton)
Group: Insect, aphid (Hemiptera: Aphididae)
Common names: 1. Green peach aphid, 2. Cotton aphid

60. Green peach aphid adults and nymphs (much enlarged)

APPEARANCE
Aphids are small soft-bodied insects often seen in groups on crop leaves - see Picture 60. Colour may be shades of green, yellow, pink or black. Winged adults (1-2mm long) fly in to the crop, feed on the sap then quickly give birth to wingless offspring called nymphs which are around 1mm long. These develop into adults and give birth to further nymphs after a few days.

DAMAGE
Aphids damage tomato plants in two ways: they suck plant sap which can reduce plant growth; they also excrete a sticky liquid called honeydew. This honeydew can coat the leaves, causing sooty moulds to develop which also slow plant growth. Although they do transmit some vegetable viruses, they are not believed to be vectors of any of the serious tomato virus diseases in

Aphids

Zimbabwe. Aphids infest upper and lower leaf surfaces and can often be seen on tomato plant stems. Infested plants may show signs of curling, wrinkling, or cupping of leaves.

CONTROL

- Tomato plants can usually withstand a small population of aphids without yield loss. The population may be maintained at acceptable levels by natural enemies such as hoverfly larvae or ladybird beetles (see pages 26-27).
- Plants such as milkweed can be used to encourage non-pest aphids. The aphids which feed on milkweed will not attack the crop, but will attract and support hoverfly larvae and ladybird beetles which can go on to attack the tomato aphids.
- Growing strong smelling plants such as garlic, onion or parsley near the crop are said to reduce aphids problems.
- Avoid planting near an aphid-infested crop or on land from which an infested crop has been recently removed.
- Rainfall and overhead irrigation discourages aphids.
- Spraying with soap and water solution can control aphids. The mixture should be not more than 1 part soap to 20 parts water - if it is too concentrated, it can burn the tomato plant.
- If aphid numbers build up to high levels they can be effectively controlled using pesticides. Table 2b on page 162 gives a list of effective and commonly available pesticides. Since aphids suck the plant juices, a *systemic* insecticide can be used - that is one which passes through the plant cuticle and is carried around in the plant juices. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

Whitefly

WHITEFLY
(1. *Bemisia tabaci* [also known as *Aleurodes tabaci*] & 2. *Trialeuroides vaporariorum*)

Type: Sucking pest (nymphs and adults)

Vegetable hosts: Tomato, cucumber, beans, brassicas (cotton, tobacco)

Group: Insect (Hemiptera: Aleyroididae)

Common names: 1. Tobacco whitefly, cotton whitefly, 2. Greenhouse whitefly

61. Whitefly colony showing different life stages

APPEARANCE

Whiteflies are small insects which feed on the under side of the leaves. Adults, which look like tiny white moths are about 1-2mm long and fly up when the leaf is disturbed whereas the nymphs do not move after they have settled. The light-coloured eggs, which are attached to the lower surface of new leaves, develop into adults in 16 to 38 days, depending

on temperature, humidity and host plant. Females lay 80-100 eggs that hatch into crawling forms that feed on the lower surface of leaves, then moult into scale-like, sucking nymphs. The nymphs are glassy and yellowish with a flattened scale-like body. After several moults, the nymphs becomes non-feeding, plump, light-coloured pupae, from which adult whiteflies emerge.

DAMAGE

Plants with heavy whitefly infestations will not yield well. Whiteflies damage plants in three ways. Sap-feeding by the adult and nymphal stages distorts and yellows the leaves and weakens the plant. Mould will develop on the excreted sugary honeydew deposits which reduces plant growth and fruit quality. Thirdly, whiteflies can carry some virus diseases such as tomato yellow leaf curl virus (see page 148). In terms of direct plant damage, small numbers of whitefly can be tolerated and sprays should only be applied when numbers build up. However, if tomato yellow leaf curl virus is known to be common in the area, even small numbers of whiteflies may need to be controlled.

CONTROL

- Neem tree seed extracts control young nymphs, inhibit growth and development of older nymphs, and reduce egg-laying by adults.
- Spraying with soap and water solution controls whitefly. The mixture should be no more than 1 part soap to 20 parts water - if it is too concentrated, it can burn the tomato plant.
- Research is continuing into special oil sprays which do not contain pesticide, but which can help to control whiteflies..
- Growing African marigolds and nasturtiums has been reported to discourage whitefly.

- If whitefly numbers build up to high levels, spraying may be necessary. Table 2b on page 162 gives a list of effective and commonly available pesticides. A systemic product will work best. Apply the pesticide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31). The addition of soap to the spray solution will help the spray droplets spread on the waxy wings of the whiteflies. The pesticide may not be effective against eggs or nymphs so a second application some days later may be necessary to control the adults which have emerged from them. Whiteflies develop resistance to pesticides very quickly so pesticides should be rotated to prevent it.

62. Whitefly adult

ROOT-KNOT NEMATODE (*Meloidogyne* spp. & others)

Type: Plant parasitic (adults and larvae)

Vegetable hosts: Tomato, cucumber, egg plant, lettuce, beans (rice, coffee, mango)

Group: Nematode (Tylenchida: Meloidogynidae)

Common names: Root-knot nematode, (RKN)

APPEARANCE

Nematodes, sometimes called eelworms, are tiny thread-like worms too small to be seen with the eye. They live in the soil and feed on the root juices, causing small lumps known as root knots or galls. Heavily infested roots are severely distorted and swollen - see Picture 63 - but farmers are often not aware of this symptom since it is out of sight under the soil. Farmers are more likely to notice that affected plants are stunted and yellow and have a tendency to wilt or even die in hot weather. The problem is most serious on light sandy soils and in furrow-irrigated crops. Nematodes are spread by transplanting infested seedlings, in soil washed down slopes, or in soil adhering to farm implements and farm workers. They may also be spread by irrigation water. They can survive for about two years in soil without a suitable host plant.

DAMAGE

Root-knot nematodes damage roots in a way which prevents them absorbing water and nutrients effectively. This reduces the growth and yield of the crop. Nematode infestation may also make it easier for other diseases such as bacterial wilt and fusarium wilt to infect the plant.

63. Tomato roots showing severe root-knot nematode damage (galling)

Tomatoes are particularly susceptible to root-knot nematode (RKN). Infestation can be checked by pulling up a plant and inspecting its roots for root knots. Alternatively, to avoid killing the plant, a hole can be dug carefully next to the plant and the roots washed with water from a sprayer or bucket to check for root knots. After examination, the roots can be covered again with soil.

It should be remembered that RKN are not active below 15 degrees Centigrade so susceptible crops can be grown during cold times of year.

CONTROL

- Rotate tomato crops with other crops so that RKN numbers do not build up. The method developed by AfFOResT (African Farmers' Organic Research and Training - a Zimbabwean non-government organisation that trains farmers in organic production methods) is called the *STRong rotation system*. The letters S, T and R mean *Susceptible* (easily attacked by nematodes), *Tolerant* (not badly attacked by nematodes) and *Resistant* (not attacked by nematodes). Box 1 on page 115 shows the susceptibility

of various commonly grown crops. An example of a STRong rotation would be tomatoes (Susceptible) followed by rape (Tolerant) followed by onions (Resistant), then back to tomatoes again, and so on.

- Do not locate seedbeds where susceptible vegetables have been grown previously.
- Use resistant cultivars with the 'VFN' label. These include Rossol VFN. The N means nematode tolerant - see Tables 1c and 1d on pages 160-161.
- After seedbed preparation, burn wood or other material on its surface to make a hot fire which lasts over an hour so that heat penetrates the soil and kills any nematodes present. Alternatively, solarization may help but it takes longer. If a plastic sheet (preferably clear) is laid on the well-watered seedbed and left for a few weeks, the heat of the sun will destroy most pests and pathogens - including RKN - in the top layers of soil.
- After harvest, uproot entire plants and destroy *crop debris*. Tops can be composted but any infested roots should be burnt since nematodes may survive the relatively low heat of the compost heap.
- Flooding the soil for a few weeks will reduce nematode numbers, as will bare fallow.
- Use mixed cropping or grow some French or African marigolds (*Tagetes patula* and *Tagetes erecta*). These have *nematicidal* properties and will help to suppress root-knot nematode numbers. Sunnhemp (*Crotalaria juncea*) helps suppress nematode numbers too because it prevents the female nematodes becoming mature. It also traps nitrogen and adds a lot of organic matter to the soil.
- Maintain high levels of organic matter in the soil (manure and compost) since this reduces nematode numbers.

- There are chemicals which control nematodes in the soil, but they are dangerous and not recommended for small-scale farmers. They may also not be cost-effective in small-scale production.

Box 1. Crop susceptibilities to root-knot nematodes (from AfFOResT)

Susceptible	Tolerant	Resistant	Nematicidal properties
Beetroot	Brassicas	Garlic	Marigold (*Tagetes* spp.)
Swiss chard	Radish	Leek	Sesame
Lettuce	Tsunga	Onion (most types)	Clean/bare fallow
Cucumber	Turnip	Shallots	Sunnhemp (*Crotalaria juncea*) prevents nematode maturation
Melon	Sweet potato	Maize	
Gourd	Chilli pepper	Millet	
Pumpkin		Sorghum	
Squash		Sweet corn	
Bambara nut		Cassava	
Beans		Rhodes grass	
Cowpea		Several other grasses	
Peas			
Okra			
Egg plant			
Irish potato			
Sweet pepper			
Tomato			
Carrot			
Celery			
Parsley			

DAMPING OFF
(*Pythium* spp. & *Rhizoctonia solani*)

Type: Fungus

Vegetable hosts: Wide range of hosts

Group: 1. Pythiales: Pythiacae, 2. Ceratobasidiales: Ceratobasidiaceae

Common names: Damping off, wire-stem

64. Damping off - showing typical 'girdling' of the seedling

APPEARANCE AND DAMAGE

These fungi (and some others) commonly cause damping off and 'wire-stem' of seedlings in the seedbed. Wet soils, crowded seedbeds and high temperatures help their development and spread.

Damping off can occur when seedlings die before they have pushed through the soil, resulting in patches which appear to have germinated poorly. Alternatively, seedling may emerge but fall over and die some time afterwards because the fungus has infected the base of the stem, making it wet and brown - see Picture 64.

Wire-stem is a similar condition which can occur in larger plants as well. The stem discolours and becomes thinner around soil level and looks a little like wire. Affected plants may survive since the stems can still support them, but they are much less vigorous and yield is reduced.

TRANSMISSION

The fungi are common in moist soils and may survive for several seasons. Infection of plants can be via the roots or via leaves which are touching the soil or have been splashed by rain or irrigation water. The fungi can also be transmitted on seed which has not been treated.

CONTROL

- Use certified disease-free seed, sown thinly (or thinned later) to avoid crowding of seedlings in the seedbed and do not apply too much irrigation water or nitrate fertilizer. If buying seedlings, look at them in the seedbed to be sure they have been grown well.
- If there is doubt about the seed, for example, with farmer-saved seed, it can be given hot water treatment (see page 19) or seed-treated with a fungicide. Follow the manufacturer's instructions.
- Diseased seedlings should be burned.
- Make the seedbeds on land which is several metres from land which has previously produced crops of tomato or related crops such as potato, pepper or egg plant.
- Seedbed soil can be partly sterilized by solarization, by fire - see page 114 - or by drenching with a fungicide.
- If damping off occurs in the seedbed, spraying may be effective. Table 2e on page 165 gives a list of effective and commonly available fungicides. Apply the fungicide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

EARLY BLIGHT (*Alternaria solani*)

Type: Fungus

Vegetable hosts: Tomato, Irish potato, egg plant, pepper

Group: Hyphomycetes

Common names: Early blight, alternaria blight, dry blight

65. Early blight symptoms on tomato leaf showing typical brown patches with concentric rings

APPEARANCE AND DAMAGE

Affected leaves have brown spots with *concentric* rings (rings inside each other) and yellow *halos* - see Picture 65. Incidence increases in warm moist conditions and may defoliate the crop. In the seedbed, plants may develop dark, wet patches all around the stem (*girdling*) near the soil surface. This is sometimes called collar rot, and will damage or kill the small plants. When plants are larger, patches of disease (*lesions*) can sink into the tissue of the stem forming dark hollows. Blackish sunken spots can also develop around the stalk of the fruit (see Picture 66) causing it to fall.

TRANSMISSION

Early blight can be seed-borne, resulting in damping off (see page 116). Infected plant residues in the soil can carry the early blight pathogen to the following season, particularly if the soil is dry. The spores are formed on the surface of infected tissue and can spread by the wind and splashes of water. A combination of warm weather and rain produces serious outbreaks, particularly if plants are stressed by poor nutrition, nematode attack or a heavy fruit load.

66. Typical early blight damage to the stalk end of tomato fruit

CONTROL

- Use certified disease-free seed.
- If there is doubt about the seed, for example, with farmer-saved seed, it can be given hot water treatment (see page 19) or treated with a fungicide. Follow the manufacturer's instructions.
- Where available, use tolerant varieties, see Table 1c and 1d on pages 160-161.
- Avoid planting tomatoes next to related crops such as potato, pepper and egg plant, and remove solanaceous weeds such as *Nicandra physalodes*, *Physalis angulata* and *Solanum nigrum*.
- When the crop is finished, remove and destroy the plant residues.
- If the problem of blight is serious, spraying may be required. Table 2e on page 165 gives a list of effective and commonly available fungicides. Apply the fungicide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

LATE BLIGHT
(*Phytophthora infestans*)

Type: Fungus

Vegetable hosts: Tomato, Irish potato, pepper

Group: Pythiales: Pythiaceae

Common names: Late blight, potato blight

67. Late blight symptoms on leaves

APPEARANCE AND DAMAGE

Late blight is usually a very minor or non existent problem in the dry season. However, it is one of the most serious diseases in cooler moist conditions (whereas early blight prefers warmer weather) and may completely and rapidly destroy the crop. The disease causes leaves to develop bluish-grey patches, usually at the edge of the leaves - see Picture 67. The leaves turn brown and wither but often stay attached to the plant. Under humid conditions, a white dusty layer which contains spores can be seen on the underside of the leaves. When conditions are good for the development and spread of the disease, the whole crop can be lost in a very short time. Grey green watery spots can develop on the upper half of the fruit, which later spread and turn greasy brown and bumpy - see Picture 68. Stems can also develop long watery brown patches.

68. Late blight damage on fruit showing typical bumpy brown surface

TRANSMISSION

Spores are the mechanism for the rapid and devastating spread of this disease when conditions are cool and moist. Splashes of water can transfer the spores from plant to plant and wind can carry them much greater distances. If Irish Potatoes have been grown in a field, tubers remaining in the soil after harvest can be a source of the disease for crops which follow.

CONTROL

- Currently, there is no resistance to late blight in commercially available tomato varieties in Zimbabwe, although plant-breeders are continuing to work on the problem.
- Cultural techniques can help to reduce the risk of blight outbreaks. Stake plants to keep them off the soil, mulch to reduce splashes, and remove or deeply dig in old crops after harvest. Pruning will increase air movement and allow good spray penetration if pesticides are to be used. Irrigating in the heat of the day should allow the crop to dry before nightfall and reduce transmission and development.
- Rotation away from tomatoes and potatoes for 3 to 4 years also helps to break the disease cycle. However, this will only be effective if it is done in cooperation with neighbouring farmers since the fungal spores can travel quite large distances on the wind.
- In wet weather fungicide sprays should be applied as soon as the disease is seen or as soon as local experience suggests that the weather conditions are favourable for disease development. Table 2e on page 165 gives a list of effective and commonly available fungicides. Apply the fungicide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

POWDERY MILDEW (*Leveillula taurica*)

Type: Fungus

Vegetable hosts: Tomato, pepper, beans, cucumber, egg plant

Group: Erisiphales: Erisiphaceae

Common names: Powdery mildew

APPEARANCE AND DAMAGE

Powdery mildew is so named because it produces a white coating of spores on the leaves which looks like a fine powder - see Picture 69. The leaf surfaces usually develop yellow patches which may merge and cause the leaf to dry out and die. Older plants are more susceptible than young plants.

69. Powdery mildew on a leaf showing typical yellowing and powdery coating of spores

TRANSMISSION

The fungus produces spores that can blow in from other crops or host weeds or be transferred from old infected crop debris in the field. It is not known to be seed-borne. Initial infection needs moisture or high humidity coupled with high temperatures, but spore formation can occur in dry weather.

CONTROL

- Remove and destroy crop debris after harvest. Keep tomato fields weed-free.
- Do not grow tomatoes immediately after other susceptible crops.
- Irrigate regularly to avoid drought stress of ageing plants.
- When mildew is severe, fungicide sprays may be required. Table 2e on page 165 gives a list of effective and commonly available fungicides. Apply the fungicide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

SEPTORIA LEAF SPOT (*Septoria lycopersici*)

Type: Fungus

Vegetable hosts: Tomato, Irish potato, egg plant

Group: Loculoascomycetes

Common names: Leaf spot of tomato, septoria blight

APPEARANCE AND DAMAGE

The disease develops best in moist conditions and is not usually a problem in the dry season. It can occur on plants of any age but often becomes more obvious after fruit has started developing. Small (2-3mm) water-soaked spots are first seen on older leaves - see Picture 70. The spots become circular with grey centres and black margins. Later, small black dots appear at the centre of the spots. These are the fruiting bodies which produce spores. When the disease is severe, spots may appear on the stems and blossoms. Badly affected leaves die and drop off.

70. Septoria leaf spot symptoms on tomato leaf

TRANSMISSION

The fungus can appear in new crops as a result of infected seed or infection from debris of diseased crop plants. Some weeds can harbour the disease and transmit it to new crops. Spread within the field occurs when the fruiting bodies in the leaf spots produce spores which are splashed onto other leaves by rain or spread by physical contact and people moving through the crop.

CONTROL

- Use certified disease-free seed and if possible sow early to avoid conditions which favour the disease.
- Plough crop residues into the soil as deeply as possible. Remove weeds related to tomato, and use rotations of several years with a non-host crop.
- If symptoms are observed early in the wet season, the crop can be sprayed with fungicides. There are no specific product recommendations in the Zimbabwe Crop Chemical Handbook for this disease - consult extension services or agrochemical industry for advice. Apply the fungicide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

ANTHRACNOSE (*Colletotrichum* spp.)

Type: Fungus

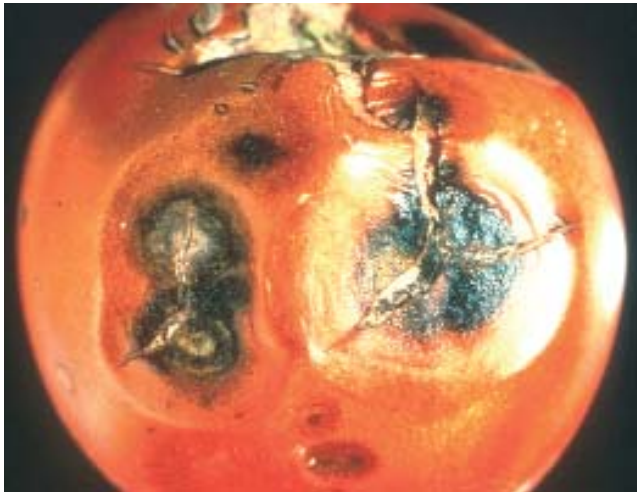
Vegetable hosts: Tomato, Irish potato, peppers

Group: Pyrenomycetes, Phyllachorales

Common names: Anthracnose of tomato; ripe rot

APPEARANCE AND DAMAGE

Small, slightly sunken circular spots develop on the ripe fruit. Even if green fruit are infected, they will not show symptoms until they begin to ripen. As the disease progresses, the spots spread and crack open - see Picture 71. Leaves and stems of infected plants do not show any clear symptoms.



71. Anthracnose damage on tomato fruit showing typical cracked patches

TRANSMISSION

The fungus can be seed-borne or can infect new crops from infected plant debris in the soil. Spores from the soil splash onto lower leaves of the new crop and infect them. Spores produced on these newly infested leaves can be carried by rain splash to the young fruit and spread around the farm by people moving through the crops.

CONTROL

- Use certified disease-free seed.
- Cultural techniques can help to reduce the risk of infection. Stake plants to keep them off the soil and remove lower leaves, Mulch to reduce splashes and remove or dig in old crops after harvest.
- Avoid overhead irrigation as this tends to spread the disease.
- Remove severely infected plants.
- Harvesting fruit before it fully ripens can help, but if conditions favour development of anthracnose, a preventative spray program may be required to give adequate control. There are no specific product recommendations in the Zimbabwe Crop Chemical Handbook for this disease - consult extension services or agrochemical industry for advice. Apply the fungicide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

BUCKEYE ROT
(*Phytophthora nicotianae*)

Type: Fungus

Vegetable hosts: Tomato, egg plant, peppers (tobacco)

Group: Pythiales: Pythiaceae

Common names: Buckeye, fruit rot, stem blight

APPEARANCE AND DAMAGE

Buckeye rot is a fungal disease which causes grey/green/brown rot on green or ripe fruit. The affected areas have characteristic brown rings inside each other and watery margins and can eventually cover half of the fruit - see Picture 72. They are smooth (unlike those caused by late blight) and are firm to the touch, until secondary rots develop. White cottony fungal growths can appear on the fruit in humid conditions and roots and lower stem may have water-soaked patches of rot.

72. Buckeye rot on fruits showing typical smooth brown patches with concentric rings

TRANSMISSION

The fungus can be seedborne or carried over from season to season in the soil and requires water for spore production and fruit infection. The disease generally affects fruit on or near the ground since the fungus can infect by direct contact or when soil is splashed onto the fruit by rain or irrigation water. For this reason, buckeye rot is mainly a problem on unstaked crops. Wet weather and warm temperatures favour infection and disease spread. Poor field drainage makes the problem worse.

CONTROL

- Use certified disease-free seed.
- Rotation of crops, with three or more seasons between tomato crops (or other susceptible crops), will reduce disease pressure.
- Crop residues should be removed or dug deeply into the soil.
- Drain soils or avoid heavy soils which remain wet for long periods. Planting on ridges, staking the plants and mulching the soil will all help to reduce incidence of this disease.
- Avoid overhead irrigation since this helps to spread the disease.
- Where the disease is known to occur it may be necessary to spray at fruit set with a fungicide. There are no specific product recommendations in the Zimbabwe Crop Chemical Handbook for this disease - consult extension services or agrochemical industry for advice. Apply the fungicide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

FUSARIUM WILT
(*Fusarium oxysporum f. sp. lycopersici*)

Type: Fungus
Vegetable hosts: Tomato
Group: Ascomycota: Hypocreales
Common names: Fusarium wilt of tomato

APPEARANCE AND DAMAGE

Fusarium wilt affects the tubes which carry sap (water and nutrients) and blocks the supply to the leaves. The leaves turn yellow and die - usually the lower ones first - see Picture 73. The wilt is typically one-sided - at first only one side of a leaf is affected, then leaves on only one side of a branch, then leaves on only one side of the whole plant. If a stem is cut lengthways, the tubes appear brown/reddish. Light sandy soils and high temperatures both cause *water stress* which make the disease worse.

73. Fusarium wilt symptoms on tomato

TRANSMISSION

Fusarium wilt can be accidentally introduced to the field on infected seeds and seedlings. It can also arrive in soil on farm tools, staking materials and shoes. Once it has been introduced it can survive in plant residues and weed hosts and can re-infect new crops. The fungus also produces special spores which can survive for many years even when no tomatoes are grown. Acidic soils and nitrogenous fertilizer favour the disease, and there is evidence that presence of root knot nematodes (see page 112) encourages fusarium wilt.

CONTROL

- Use certified disease-free seed.
- Grow resistant tomato cultivars. Those showing the VFN label have some resistance (the F stands for Fusarium) and the list of varieties in Tables 1c and 1d on pages 160-161 gives some which are available in Zimbabwe.
- Do not locate seedbeds on land where fusarium wilt is known to have occurred.
- Where soil is acidic, raise soil pH by applying lime or farmyard manure.
- Avoid excessive nitrogen fertilisation and control root-knot nematodes (see page 112).
- Spraying with fungicides will not help to control this disease.

LEAF MOULD
(*Fulvia fulva*)

Type: Fungus

Vegetable hosts: Tomato, peppers

Group: Loculoascomycetes

Common names: Tomato leaf mould

74. Leaf mould showing typical indistinct green/yellow patches

APPEARANCE AND DAMAGE

The upper leaf surface has light green or yellowish patches without clear edges. When humidity is high enough, spores are formed on the lower surface of the leaves and appear as a grey, green or brownish powdery layer - see Picture 74.

TRANSMISSION

The fungus can be introduced to new crops via infected seed. Transmission within the crop can occur when the spores produced on the underside of the leaves are spread by wind, water splash and physical contact. This disease develops quickly in warm, wet weather

CONTROL

- Use certified disease-free seed.
- Cultural control methods can be effective. Prune and stake the plants to reduce canopy humidity. Avoid overhead irrigation if possible since this wets the leaves and helps disease transmission. Remove and destroy crop debris after harvest.
- Avoid excessive shading by providing adequate spacing between plants and rows.
- Fungicide spraying can control this disease. Table 2e on page 165 gives a list of effective and commonly available fungicides. Apply the fungicide using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

VERTICILLIUM WILT (*Verticillium dahliae*)

Type: Fungus

Vegetable hosts: Tomato, egg plant, Irish potato, brassicas, (cotton)

Group: Perithecial ascomycetes

Common names: Verticillium wilt

APPEARANCE AND DAMAGE

Verticillium wilt is a disease which affects the tubes which carry sap (water and nutrients) around the plant. The symptoms are similar to those of fusarium wilt (see page 130) - older affected leaves turn yellow and gradually wither and/or fall off (see Picture 75) - but the damage is not one-sided as with fusarium wilt. Plants with early infections often wilt during the day and then recover at night, but eventually the wilt becomes permanent. When cut lengthways, the base of the plant often shows brown colouration of the tissues.

75. Verticillium wilt symptoms on leaves

The plant may develop a lot of extra roots at the base of the stem. This disease can have a devastating effect on the yield of individual plants, but nearby plants may not be affected.

TRANSMISSION

Verticillium wilt can be both seed-borne and soil-transmitted. Unfortunately it can remain in the soil for many years. When a plant is infected the spores can also be blown on the wind to infect other plants. Slight root damage when transplanting can allow the disease to establish, and root knot nematode damage is said to make infection more likely.

CONTROL

- Use certified disease-free seed and resistant cultivars such as those showing the VFN label. The V refers to Verticillium resistance.
- Avoid alkaline soil (good for the disease) and control root-knot nematodes if present in the field (see page 112).
- Do not locate seedbeds on land with a history of the disease, and destroy crop debris after harvest.
- Rogue out and burn any diseased plants and fruit.
- Temporary flooding will help to reduce the verticillium pathogen in the soil.
- Spraying with fungicides will not help to control this disease.
- Cotton is an important alternate host of this disease so tomato fields should be sited away from current and previous cotton crops.

BACTERIAL CANKER
(*Clavibacter michiganensis subsp. michiganensis*)

Type: Bacterium

Vegetable hosts: Tomato, peppers

Group: Micrococcineae: Microbacteriaceae

Common names: Bacterial canker, bird's eye of tomato fruit

76. Bacterial canker symptoms on leaves, which dry up but stay on the plant.

77. Bacterial canker symptoms on fruit showing typical 'bird's eye' spots.

APPEARANCE AND DAMAGE
The first signs are yellowing, wilting and curling of leaves on a portion of the plant. The leaves eventually become brittle and dry, but do not usually drop from the plant - see Picture 76. In addition, small circular depressed areas called *cankers* may form on the stem. The whole plant may die or only show one-sided disease development causing the plant to lean over. When an affected stem is cut along its length, there is a creamy white, yellow or reddish brown line just inside the woody tissue. If the plant survives until fruit set the bacteria

may pass from the stem through the sap tubes into the fruits, causing them to be small and deformed. Spots also develop on growing fruit. These spots have a raised brown centre with a white halo resembling a bird's eye - see Picture 77. This allows canker to be distinguished from other bacterial diseases such as speck or spot. As the spots age, the centre cracks giving them a ragged appearance.

TRANSMISSION
Bacterial canker can be seed-borne and can survive several seasons in soil. It can also survive in cracks on sticks or poles used for staking or trellising. In the field the disease spreads by being dispersed by water (irrigation or rain) and infects plants through wounds or natural openings, from where it spreads in the plant through the sap tubes. Plants and fruit can be infected by bacteria being splashed and it can also be spread on pruning knives. Warm temperatures, low light intensity and high levels of nitrates in the soil favour the disease.

CONTROL
- Grow resistant or tolerant varieties, if available.
- Use certified disease-free seed. If these are not available, heat-treat the seeds (see page 19).
- Rotate seedbeds and tomato fields with a rotation of at least 5 years between susceptible crops. Make sure purchased seedlings are from clean land.
- Rogue out affected plants and burn them. Other crop residues should be destroyed or dug in deeply after harvest.
- Avoid working in tomato fields when it is wet since this helps to spread the disease.
- Where possible avoid overhead irrigation since this helps the disease to develop and spread.
- Clean pruning knives well between plants.

BACTERIAL SPECK
(*Pseudomonas syringae pv. tomato*)

Type: Bacterium
Vegetable hosts: Tomato
Group: Pseudomonales: Pseudomonaceae
Common names: Bacterial speck

78. Bacterial speck on fruit

79. Bacterial speck on a leaf

APPEARANCE AND DAMAGE
Small black or brown spots appear on leaves, stems, flowers and fruit - see Pictures 78 and 79. The spots on stems are longer and thinner than leaf and fruit spots. Spots on fruit can increase to 1-1.5mm in diameter with distinct edges, but are only on the surface and do not break the skin or develop into soft rot. They are sometimes surrounded by an area that is slow to ripen. When fruits are infected early, the spots may be slightly sunken because the damaged tissue grows slower than unaffected tissue. Mature fruits are resistant to infection as a result of their high acidity.

TRANSMISSION
Bacterial speck can be seed-borne, brought into the field on infected seedlings or infect new crops by surviving in soil and debris from a previous crop of diseased tomato plants. Spread between plants can be by splashing of water or people moving through the crop. Cool moist weather promotes infection and disease spread. Tomato varieties with large fruits are most likely to be affected.

CONTROL
- Use certified disease-free seed. Seed from uncertain sources can be given hot water treatment (see page 19).
- If buying seedlings, make sure they are from a source which does not have the disease.
- Some varieties are less affected, although there is no complete resistance - see Tables 1c and 1d on pages 160-161.
- Site seedbeds on land which has no history of bacterial speck disease and avoid growing tomato crops successively on the same land.
- When plants are wet, do not work in the field since this can spread the disease from plant to plant.
- Use *flood* or *furrow irrigation* where possible. When overhead irrigation is the only form of irrigation available, irrigate in the heat of the day to allow the foliage to dry before nightfall.
- A *bactericide* such as copper oxychloride may reduce disease severity, although when conditions are suitable for development, this may not be effective. Care should be taken since some tomato varieties can be damaged by copper. If such products are being used, apply them using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

BACTERIAL SPOT
(*Xanthomonas campestris pv. vesicatoria*)

Type: Bacterium

Vegetable hosts: Tomato, peppers

Group: Xanthamonadales: Xanthamonadaceae

Common names: Bacterial spot, bacterial scab, stem canker, leaf spot

80. Bacterial spot on fruit, causing bigger spots than bacterial speck.

APPEARANCE AND DAMAGE

Bacterial spot disease is most prevalent on tomato cultivars bred for processing. It attacks leaves, flowers and fruit. On leaves, dark, water-soaked spots appear and turn brown/black. These are usually less than 3mm across, but in humid conditions, they may be larger than this and look like early blight. Heavy infection can result in blossom drop and *defoliation*. Fruits develop small, raised black spots which become brown, slightly sunken spots, occasionally surrounded by a halo - see Picture 80. These spots are on the surface and do not usually lead to soft rot. Ripe fruits are not usually infected.

TRANSMISSION

Like bacterial speck, bacterial spot can be seed-borne, seedling-borne or infect new plantings from debris left in the soil after harvest. Wild hosts such as black nightshade can also harbour and transmit the disease to the crop. The bacterium cannot live for very long in the soil without host plant material to live on. In the crop, splashes can spread the disease from plant to plant, and leaf infection is said to be via the natural openings (stomata) while fruit infection is through wounds caused by insect bites or physical damage. Young leaves and fruit are more susceptible than older tissue. High night time temperatures and rainy periods favour disease spread.

CONTROL

- Use certified disease-free seed. Seed from uncertain sources can be given hot water treatment (see page 19).
- If buying seedlings, make sure they are from a source which does not have the disease.
- Some varieties are less affected, although there is no complete resistance - see Tables 1c and 1d on pages 160-161.
- Site seedbeds on land which has no history of bacterial spot disease and avoid growing tomato crops successively on the same land.
- When plants are wet, do not work in the field since this can spread the disease from plant to plant.
- Use flood or furrow irrigation where possible. When overhead irrigation is the only form of irrigation available, irrigate early in the day to allow the foliage to dry before nightfall.
- A bactericide such as copper oxychloride may reduce disease severity, although when conditions are suitable for development, this may not be effective. Care should be taken since some tomato varieties can be damaged by copper. If such products are being used, apply them using a knapsack sprayer fitted with a fine/medium hollow cone nozzle and follow procedures on safe and selective application outlined in the introduction (from page 31).

BACTERIAL WILT
(*Ralstonia solanacearum*, also known as *Pseudomonas solanacearum*)

Type: Bacterium

Vegetable hosts: Tomato, egg plant, Irish potato, groundnut, peppers (tobacco, cotton)

Group: Burkholderiales: Burkholderiaceae

Common names: Bacterial wilt

81. Bacterial wilt damage on tomato showing typical collapse of the plant

APPEARANCE AND DAMAGE
Bacterial wilt disease causes rapid wilting of the whole plant and the plant usually collapses and dies without any yellowing or spotting of leaves - see Picture 81. Many extra roots may develop at the base of the stem. If the stem of a wilted plant is cut, the centre appears brown and water-soaked, and it may be hollow. Squeezing the cut stem may cause white or yellowish bacterial slime to appear and if the stem is held in a glass of water for a few minutes, the milky bacterial slime starts streaming down from the cut end. Roots turn brown and may become soft and slimy in wet conditions.

TRANSMISSION
The disease can survive in the soil for long periods. It has a very wide host range and infects all members of the tomato family, including egg plant, peppers and Irish potato and some common weeds in Zimbabwe. It infects plants through their roots and when diseased plants are removed, the pieces of infected root which remain can infect new crops. It is often introduced to fields via diseased seedlings which have been raised in infected seedbeds or in drainage and irrigation water. The disease develops best under warm, wet conditions, and in slightly acidic soil. Root-knot nematodes can increase the severity of the disease.

CONTROL
- Rotation is not effective because the pathogen can survive for several years in the soil and can also infect a wide range of crops and weeds.
- Grow varieties which have some tolerance to this disease - see Tables 1c and 1d on pages 160-161.
- Do not grow tomatoes in soil where bacterial wilt has occurred before.
- Remove wilted plants to reduce spread of the disease from plant to plant.
- Control root-knot nematodes (see page 112) since they may help the disease to establish and spread.
- Prolonged flooding of the field can reduce disease levels in the soil.
- Spraying pesticides will not help to control this disease.

TOMATO MOSAIC VIRUS (ToMV)

Type: Virus
Vegetable hosts: Tomato, peppers, chilli, (tobacco)
Group: Tobamovirus
Common names: Tomato mosaic, pepper mosaic, ToMV, TMV

APPEARANCE AND DAMAGE

Affected plants show light and dark green mottling - see Picture 82b - and some distortion of the youngest leaves which may be stunted or elongated, in a condition called 'fernleaf'. This refers to the resemblance of these leaves to leaves of many kinds of ferns. Under high temperature and high light intensity, the mottling can be severe. Under low temperature and low light intensity, stunting and leaf distortion are severe. If fruit is infected when nearly mature, they can develop discolouration (see Picture 82a) and brown streaks inside the flesh.

82a. Tomato mosaic virus symptoms showing typical discoloration of the fruit

TRANSMISSION

The disease can be seed-borne, but can also survive on plant debris in the soil and so re-infect newly planted crops. The virus is easily mechanically transmissible by contact between plants, or through human activities, for example, transplanting seedlings or pruning.

CONTROL

- Choose resistant varieties - see Tables 1c and 1d on pages 160-161.
- Use certified disease-free seed.
- Remove crop debris and roots from the field, and do not overlap tomato crops.
- Remove solanaceous weeds from within and around the field.
- Workers should not smoke or take snuff when working in tomato fields as it is believed that ToMV can be transmitted from the tobacco.
- When working with plants, it is claimed that dipping the hands in milk or skimmed milk prevents spread from plant to plant. Field tools should be washed thoroughly.

82b. Tomato mosaic virus symptoms showing typical stunting and mottling of leaves

TOMATO SPOTTED WILT VIRUS (TSWV)

Type: Virus

Vegetable hosts: Tomato, peppers, lettuce, egg plant, beans, pea, Irish potato (tobacco) and many others

Group: Bunyaviridae: Tospovirus

Common names: Tomato spotted wilt, bronze wilt leaf

APPEARANCE AND DAMAGE

Tomato spotted wilt virus symptoms include overall yellowing, spots on leaves or terminal shoots, and general stunting - see Picture 84. Ripe fruits show paler red or yellow areas on the skin, and concentric rings that may cause tissue to die - see Picture 83. On young leaves the disease causes purplish-brown spots to appear, which can be crescent-shaped. Older infected leaves turn brown and droop. Brown streaks occur on the leaf and plant stems. The whole plant becomes stunted and wilted with drooping leaves.

83. Tomato spotted wilt virus symptoms on fruit showing typical pale red/yellow patches.

TRANSMISSION

TSWV has a very wide host range including ornamentals, weeds and vegetables. It is one of the few plant viruses whose host range includes broadleaf and grassy plants (including onions). The virus is transmitted by thrips (see page 75). The immature insect acquires the virus and the ensuing adults can transmit the virus for life. TSWV persists from year to year in infected hosts from which thrips can spread the disease to nearby crops.

CONTROL

- Grow resistant varieties if available (see Tables 1c and 1d on pages 160-161).
- Rogue out diseased plants and burn or bury them.
- Site seedbeds away from cropped areas and other susceptible plants
- Do not allow volunteer plants to develop from previous crops, nor allow susceptible weeds to grow nearby.
- Control the thrips vector - see page 75.

84. Tomato spotted wilt virus symptoms on leaves

TOMATO YELLOW LEAF CURL VIRUS (TYLCV)

Type: Virus
Vegetable hosts: Tomato
Group: Geminiviridae: Begomovirus
Common names: Leaf curl, yellow leaf curl

APPEARANCE AND DAMAGE

Infection of young plants causes severe stunting of leaves and shoots which results in the plant looking very small and bushy - see Picture 85. The small leaves roll up at the edges and turn yellow between the veins. Fruit set is severely affected with less than one in ten flowers on infected plants producing fruit. There are no signs of infection on any fruit.

85. TYLCV disease symptoms showing stunting and curling of leaves

TRANSMISSION

TYLCV is neither seed-borne nor mechanically transmitted - it is spread by the whitefly *Bemisia tabaci* (see page 109) and can be accidentally introduced on infected seedlings. High temperatures and very dry conditions favour whitefly populations and therefore help the spread of TYLCV. The earlier plants are infected, the more serious the impact on them. Tobacco can also be infected and, although there are no symptoms, it becomes a carrier which can be the source for re-infection of tomato crops. Similarly, weeds such as *Datura stramonium* can also be alternate hosts.

CONTROL

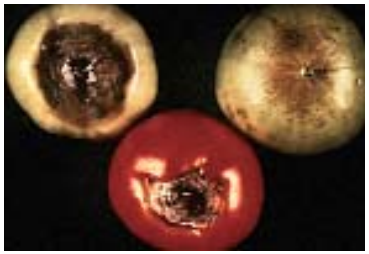
- TYLCV-resistant tomato cultivars are available in countries such as Israel, India and Taiwan, but are not available in Zimbabwe. Locally available varieties with partial resistance (or tolerance) are shown in Tables 1c and 1d on pages 160-161. Cultivars such as Roma and Marglobe are highly susceptible and should not be used in areas where the disease is common.
- Rogue out diseased plants (in the seedbed and the field) and destroy them. Replace them with healthy plants.
- Protect seedbeds with a white nylon net (40 mesh). The later plants are infected, the less the yield loss.
- Use methods to reduce the ability of whiteflies to find the crop, for example, planting in new areas away from previous tomato cultivation, planting maize around the tomato fields, yellow mulches (straw, sawdust or yellow plastic).
- Control the whitefly vector (see page 110). However, whitefly control may be not be sufficiently effective to control the TYLCV in areas where the disease incidence is high - a very small number of whiteflies can transmit the disease between plants.
- Oil sprays are said to be effective against the disease, probably because they reduce the infestation of whiteflies.

Blossom End Rot

BLOSSOM END ROT

Type: Physiological (no pathogen involved)
Vegetable hosts: Tomato

86. Blossom end rot symptoms



APPEARANCE AND DAMAGE

Blossom end rot usually begins as a small water-soaked area at the blossom end of the fruit. This enlarges, becomes sunken and turns black and leathery sometimes turning the core of the fruit brown - see Picture 86. In severe cases, it may completely cover the lower half of the fruit, becoming flat or concave. Secondary pathogens can invade the fruit and destroy it. The problem is caused by calcium deficiency brought about by rapid changes in soil moisture and poor root development. Other factors that reduce calcium uptake such as use of ammonium nitrate and high humidity, can make the problem worse. Rapidly growing plants are more susceptible to the disease.

CONTROL

If blossom end rot is a known problem on the farm, avoid growing varieties which are known to be susceptible such as the processing cultivars Roma, Rossol and HTX. Get the soil tested and if necessary, calcium deficient soils should be limed with dolomitic or high calcium limestone before planting. Soil moisture should be kept constant if possible especially during the flowering and fruiting period. Foliar application of calcium chloride or soil applications of gypsum at transplanting time may help.

Blossom Drop

BLOSSOM DROP

Type: Physiological (no pathogen involved)
Vegetable hosts: Tomato, peppers

APPEARANCE AND DAMAGE

Blossom drop is the withering or abortion of the flower caused by factors such as low or high temperature, high relative humidity, excessive or no wind and lack of pollinating insects due to earlier spraying. Improper nutrition such as deficient micronutrients or excessive nitrogen can also cause the problem. Foliar diseases and pest attack may also lead to blossom drop.

CONTROL

Proper fertilisation and plant nutrition can minimise the problem. Avoiding excessive use of broad-spectrum pesticides will help to conserve *pollinators* such as bees and prevent drop of unpollinated tomato flowers. Overhead watering during very hot conditions may reduce plant temperature and stop blossom drop. Heat tolerant cultivars such as Rossol and Roma can withstand high temperatures and thus have reduced blossom drop. Farmers who have experienced this problem should ask the extension services or the seed merchant for advice on cultivars to grow.

Catface

CATFACE

Type: Physiological (no pathogen involved)
Vegetable hosts: Tomato

APPEARANCE AND DAMAGE

87. Catface symptoms

The fruit is deformed with deep cavities in the blossom end of the fruit - see Picture 87. The fruit is often kidney shaped with elongated blossom scars, but it can also be other shapes. Catface also includes any enlargement or perforation of the blossom scar, even if the fruit shape is normal. The disease is serious on large-fruited fresh market cultivars such as Moneymaker. It is associated with faulty *pollination* and cold weather. Pruning can also increase catface under some conditions and high nitrogen levels in the soil can aggravate the problem.

CONTROL

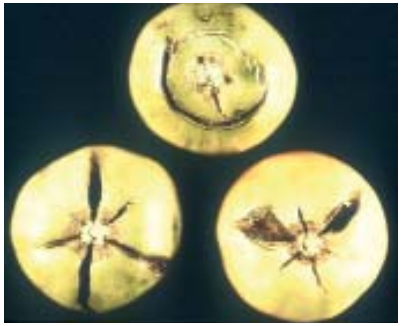
Avoid very cold periods that might have some effect on early fruit. Select cultivars such as Roma and Heinz 1370 that are not susceptible to the problem under cold conditions. Reduce periods between irrigation so that there are no periods of water shortage.

Growth Cracking

GROWTH CRACKING

Type: Physiological (no pathogen involved)
Vegetable hosts: Tomato

APPEARANCE AND DAMAGE



88. Growth cracking symptoms

Two types of cracking occur on tomatoes. In concentric cracking, the fruit develops circular, concentric cracks around the stem end of the fruit (see upper tomato in Picture 88). In radial cracking, the fruit cracks radiate from the blossom end - see lower two tomatoes in Picture 88. Cracks normally occur on fruits as they approach maturity. Susceptibility to cracking 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 disease. Rain and wide fluctuations in temperature also promote cracking. Exposed fruit crack more readily than those protected by foliage.

CONTROL

Use cultivars that are tolerant to cracking such as Rodade, Zest, Zeal, Floradade and most canning cultivars. Manage water and irrigation schedules properly, and do not over-use nitrogen fertilizer as this will make the plant and fruit too succulent (juicy).

Puffiness

PUFFINESS

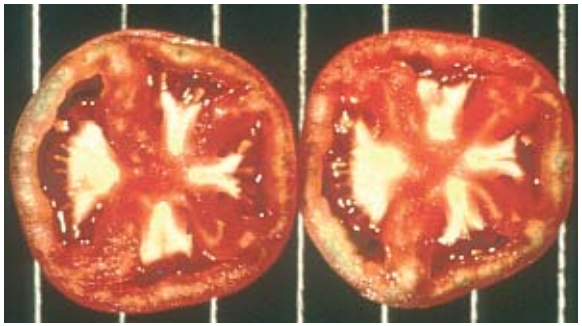
Type: Physiological (no pathogen involved)
Vegetable hosts: Tomato

APPEARANCE AND DAMAGE

As the name implies, fruit suffering from puffiness appear bloated and angular. The fruit feels lighter than it should be and when cut, holes in the flesh are seen - see Picture 89. Puffiness results from incomplete pollination, fertilization, or seed development, often as a result of cool temperatures. Insufficient light or extreme temperatures and high nitrogen and or low potassium can make the condition worse.

CONTROL

Follow a sound nutrition regime to discourage the disease.

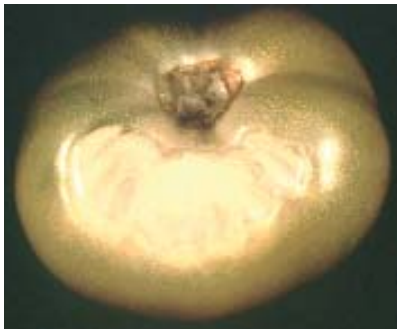


89. Puffiness symptoms showing cavities within the fruit

SUNSCALD

Type: Physiological (no pathogen involved)
Vegetable hosts: Tomato

APPEARANCE AND DAMAGE



90. Sunscald symptoms showing typical whitish patches

This disorder appears as a white or light tan discoloration of the fruit that has been overheated due to exposure to sun - see Picture 90. Damage is usually on the top side of the fruit as this is the area most likely to be exposed to the sun. Sunscald frequently occurs in tomato when the lower leaves drop off due to diseases such as Septoria leaf spot and early blight and some foliar pests. Severe pruning may have the same effect. Fruit sometimes remains yellow rather than turning red. In severe cases the exposed fruit surface becomes white and blistered. The problem is widespread on unstaked tomatoes.

CONTROL

Take care when pruning and harvesting not to over-expose fruits to the sun. Prevent foliar diseases and defoliating pests. Grow cultivars such as Rodade that have good foliage cover.

Notes

Appendices

4

Page

Table 1a Selection of commercially available cabbage varieties and their characteristics*

Name	Type	Size	Maturity (days)	Pest & disease resistance	Remarks
Beverley Hills	round	large	110	Black rot, tip burn	Stores well, winter type
Brunswick		medium	80-90	Black rot (slight)	Greyish green
Capespitz	conical			Black rot	Old cultivar, good quality
Chinese granat	round	medium			Chinese cabbage
Copenhagen mkt.	round	medium	75-85	Black rot	Early, short storage life.
Drumhead	flat	medium	90-95		Needs fertile soil and cool conditions
Glory of Enkhuizen	flat	large		Bacterial diseases	Needs good conditions
Golden acre	round	medium	65		Can bolt in field - needs cool conditions. Susc. to bacterial disease
Grand slam					Cold tolerant winter type
Green coronet	flat	large		Black rot	Long time to mature
Green Star	flat	medium		Black rot	
Hercules F1	flat	large	80-85	General disease resistance	Hardy - all year production
JK1	flat	medium		Anthracnose	Tolerates high temperatures
Marcanta F1	flat	medium -large		Black rot, yellows	Stands hot and cold temperatures
Primero F1 (red)	round	medium		Black rot	
Rotan					Cold tolerant winter type, resistant to bolting
Savoy Julius F1	round	medium			Crumpled leaf type
Star 3301	round	medium		Black rot	
Star 3306	round			Black rot	Winter type. Early variety
Star 3308	round	medium		Good resistance	Very adaptable
Star 3311	flat	medium		Black rot	Heat tolerant

* Information from Prime Seed (Pvt) Ltd, Zimbabwe and Pannar Seed (PTY) Ltd, South Africa

Table 1a continued*

Name	Type	Size	Maturity (days)	Pest & disease resistance	Remarks
Stone head	round	small		Black rot	Prefers cool, can bolt
Sugarloaf	conical	small	75		Early, spring cabbage. Bruises easily
Tenacity F1				Black rot	Stores well
Tropicana	flat	medium	60-80	Black rot, yellows	Heat tolerant

Table 1b Selection of commercially available kale and cauliflower varieties and their characteristics*

Name	Maturity (days)	Remarks
Kale		
Bore Cole	75	Needs cool conditions and regular rainfall. High quality leaf
Collards	50	Needs cool conditions and regular rainfall
Marrow stem	50	Needs cool conditions, good rainfall and fertile soils
Thousand Headed	50	Early maturing, needs moderate/ heavy rainfall and fertile soil
Cauliflower		
Extra Early Six Week	75	Needs cool conditions
Fremont		Can tolerate hot conditions
Christina	120-140	Needs cold conditions for head formation
Tenere	100-120	Dense cream white curd, big heads
Cabrera	100-120	Some tolerance to heat and cold. Does not need cold for head formation
Snow Giant	70	Needs cool conditions and soil with high organic matter content

* Information from Prime Seed (Pvt) Ltd, Zimbabwe and Pannar Seed (PTY) Ltd, South Africa

Table 1c Selection of commercially available fresh market tomato varieties and their characteristics*

Name	Determinate or Indeterminate	Fruit size	Pest & disease resistance	Remarks
Amareto	I	large, flattened	FW, VW, TMV, TYLCV	Long shelf life, uniform fruit
Carmello	I	large	TMV, VW, FW, S	Good under plastic or in open fields
Fanny	I	medium	VW, FW, TMV, N, S	Fruit firm, slightly ribbed
Floradade	D	med-large	VW,FW, S, AC, AB	Prefers drier conditions. Good shelf life
Heinz 1370	D		FW, TMV VW	Travels well
Hytec 36			TMV, BW VW, AC FW, S, N	Firm fruit, resistant to cracking
Julius F1			VW, FW, AC, N, S	Firm fruit
Manapal	I	large	FW (but suscept. to Catface)	Soft fruit
Marglobe	D	medium	low	Old variety. Soft fruit, does not keep well
Mickey	I	v small	TMV VW, FW	Cherry type
Moneymaker	I	medium	low - particularly blights	Needs strong support. Long yield period
Napoli	D	small	FW	Poor traveller, soft
Philadelphia	D	medium	VW, FW, N	Dual purpose (fresh and processing)
Radja	I	medium	TMV, VW, FW, N, S	Long shelf life
Rodade	semi-indet.	medium	variable, see seed packet	Yields better if staked. Firm fruit good for transport and marketing
Rotam IV	D	large	VW, F, N BW, BC	Long fruiting period
Sandiago	D	large	TMV, VW, FW, N, S	Can be grown as bush or staked
Star 9001	semi-det.	large	BW, V, F, N, A, BC	Vigorous growth. Firm
Star 9003	semi-det.	medium	F, N, VW	Dual season
Star 9006	semi-det.	large	TSWV, BW F	Good quality and flavour
Star 9008		large	TSWV	Early maturity. Long shelf life

* Information from Prime Seed (Pvt) Ltd, Zimbabwe and Pannar Seed (PTY) Ltd, South Africa

Table 1c continued*

Star 9054	D	small, plum	V, F, N	Roma-type hybrid
Star 9056	very det.	medium	V, F, N	Good shelf life Processing or fresh mkt.
Summerset F1			N, AB, VW, FW, BW, BC, BS, AB	Firm fruit good for summer
Thomas	I	large	TMV, VW, FW N, S	Long shelf life
Zeal F1	D		VW, FW, BW, N, AB	Summer variety. Firm fruit, long shelf life
Zest F1`	I	medium	VW, FW N, BW, AB	Very firm fruit with good marketing properties and shelf life

Table 1d Selection of commercially available processing tomato varieties and their characteristics*

Name	Determinate or Indeterminate	Fruit size (L,M,S)	Pest & disease resistance	Remarks
Chicago	D	med-large	VW,FW,N	
HTX 14	D		VW, FW, N	Not ideal for fresh market
HTX28			N	
Hypeel 303		round, blocky	VW, FW, N	
Kamatla			VW, FW, N	Extended storage possible
Kamuku		long, blocky	TSWV, VW, FW, N, Thrips	
Roma (Processing)	D	small-med plum type	N, RSM	Tolerates heat stress. Firm fruit good for cooking.
Rossol (Processing)	D	med-large pear shape	N, AB, RSM	Fruit keeps well. Good for travel. Firm
Shiva	D	medium	VW, FW, N	Suitable for processing
UC82B				Unsuitable for fresh market

Key:

AB = altenaria blight
AC = altenaria canker
BC = bacterial canker
BS = bacterial speck
BW = bacterial wilt
FW = fusarium wilt
N = nematodes
RSM = red spider mite
S = stemphylium
TMV = tobacco mosaic virus
TLCV = tomato leaf curl virus
TSWV = tomato spotted wilt virus
VW = verticillium wilt

* Information from Prime Seed (Pvt) Ltd, Zimbabwe and Pannar Seed (PTY) Ltd, South Africa

Table 2a Major brassica pests and pesticide recommendations in Zimbabwe[1]

Cabbage pests	**Pesticide number** - look up name in Table 2c																
Aphid	3	6	8	9	10	12	16	19	24	27	30	31	32	34	35	36	38
Bagrada bug	34	39															
Cabbage moth	3	6	8	13	19	25	39										
Cabbage webworm	No specific recommendations. Try DBM products																
Cabbage sawfly	No specific recommendations. Try DBM products (except Bt)																
Caterpillar	6																
Crickets	25																
Cutworm	21	23	25	28													
DBM	1	4	12	13	19	29	31	33	34	35	38	39					
Flea beetle	No specific recommendations. Try DBM products (except Bt)																
Grasshoppers	25																
Spider mites	9	11	16	19	24	27	30										
Semi looper	25	34															
Thrips	No specific recommendations. Try DBM products (except Bt)																
Whitefly	2	34															
Whitegrub	28																

Table 2b Major tomato pests and pesticide recommendations in Zimbabwe[1]

Tomato pests	**Pesticide number** - look up name in Table 2c																
Aphid	3	5	6	8	9	10	16	19	24	30	31	38					
African bollworm	12	25	31	35	38												
Cutworm	21	22	23	28													
Leafminer	15	26	35														
Spider mites	7	9	11	14	16	17	18	19	24	26	27	30					
Semi looper	12	25	29	31	34	35											
Thrips	11	19															
Whitefly	2	12	20	21													
Whitegrub	28																

▲ ***Choose a green triangle product where possible because this has a lower toxicity to people and livestock***

1. Compiled from the Zimbabwe Crop Chemical Handbook, Volume 1, 2001.

Table 2c Look-up table of pesticides registered in Zimbabwe for pest control on brassicas and tomatoes[1]

Number & triangle colour	**Pesticide active ingredient**	**Brand names of registered formulations**	**Oral LD50 of most toxic formulation**	**Pre-harvest interval (days)**
▲ **1**	Bacillus thuringiensis[L] var kurstaki (Bt)	Biobit	Non-toxic	not stated
▲ **2**	Fatty acids[L]	Naturell	Non-toxic	not stated
▲ **3**	Pyrethrins	Garden Insecticide (ready for use or concentrated)	68667	not stated
▲ **4**	Lufenuron	Match 50 EC	40000	14
▲ **5**	Pymetrozine	Chess 25 WP	23280	3
▲ **6**	Carbaryl/pyrethrins	Pyspray Garden and Vegetable Dusting Powder	20000	1
▲ **7**	Clofentezine	Apollo 50 SC	10400	4
▲ **8**	Carbaryl/copper oxychloride/malathion /dinocap	Guard 'N Care	10000	14
▲ **9**	Sulphur/copper oxychloride/malathion	Pedza Nhamo Agridust Vegidust	7630	14
▲ **10**	Thiamethoxam	Actara 25 WG	6252	3
▲ **11**	Sulphur[L]	Dusting sulphur	6250	not stated
▲ **12**	Deltamethrin	Decis 2.5 FW	5400	1
▲ **13**	Tetrachlorvinphos	Gardona 50 WP	5000	1
▲ **14**	Propargite[L]	Omite 30 WP Omite EC	4746	4
▲ **15**	Cyromazine[L]	Trigard	4516	3
▲ **16**	Diazinon	Diazinon 30 EC	4167	14
▲ **17**	Amitraz[T]	Mitac 20	3250	3
▲ **18**	Dicofol[L]	Kelthane 18.5 EC Dicofol 18.5 EC	3216	7
▲ **19**	Malathion	Malathion 1 and 5 dust Malathion 25 WP Malathion 50 EC	2750	7
▲ **20**	Imidacloprid[S]	Confidor 200 SL	2250	not stated
▲ **21**	Cypermethrin	Ripcord	1250	4
▲ **22**	Lambdacyhalothrin	Karate	1120	not stated

1. Compiled from the Zimbabwe Crop Chemical Handbook, Volume 1, 2001.

Table 2c continued [1]

Number & triangle colour	Pesticide active ingredient	Brand names of registered formulations	Oral LD50 of most toxic formulation	Pre-harvest interval (days)
▲ 23	Fluvalinate[L]	Mavrik 2 E	1044	not stated
▲ 24	Dimethoate[S]	Dimethoate 40 EC Rogor CE	968	14
▲ 25	Carbaryl	Carbaryl 85 WP	588	7
▲ 26	Abamectin[TL]	Dynamec	556	3
▲ 27	Thiometon[S]	Ekatin 25 EC	292	7
▲ 28	Chlorpyrifos	Dursban 4 E	281	4
▲ 29	Trichlorfon[T]	Danex 95 SP Dipterex 95 SP	263	3
▲ 30	Oxydemeton-methyl[S]	Metasystox (R) 25 EC	200	21
▲ 31	Endosulfan	Thiodan 50 WP Thioflo 47.5 SC	140	1
▲ 32	Demeton-S-Methyl[S]	Metasystox (i) 25 EC	120	10
▲ 33	Carbofuran[S]	Curaterr 10 G Furaden 10 G	80	At planting
▲ 34	Dichlorvos	Nogos 50 & 100 EC Vapona 50 EC DDVP 100 EC Dedevap 1000	50	2
▲ 35	Methamidophos[S]	Tamaron 600 SL	26	21
▲ 36	Disulfoton[S]	Disyston 5 Gran Disulfogran 5 G	20	42 - at planting
▲ 37	Fenamiphos[S]	Nemacur 10 Gran	15	Pre-planting
▲ 38	Mevinphos[S]	Phosdrin	13	4
▲ 39	Parathion	Parathion 25 WP Folidol 25 WP Parathion 50 EC	4	21

Key:

O = believed to be obsolete or discontinued
S = systemic products (carried in the plant sap)
L = these products are believed to have low impact on natural enemies - see *Farmers' Friends* (Verkerk, 2001)
T = translaminar products which can pass through the surface of the leaf into the tissue inside

1. Compiled from the Zimbabwe Crop Chemical Handbook, Volume 1, 2001.

Table 2d Major brassica diseases and pesticide recommendations in Zimbabwe [1]

Cabbage disease	Pesticide number - look up name in Table 2f
Damping off	69
Downy mildew	55 58 64 70
Rhizoctonia	68 69
Soil borne fungi	62 69
Cottony rot	No specific recommendations - consult extension services

Table 2e Major tomato diseases and pesticide recommendations in Zimbabwe [1]

Tomato disease	Pesticide number - look up name in Table 2f
Anthracnose	No specific recommendations - consult extension services
Damping off	No specific recommendations on tomato (see cabbage table above)
Bacterial speck	No specific recommendations - consult extension services
Bacterial spot	No specific recommendations - consult extension services
Botrytis	57
Buckeye rot	No specific recommendations - consult extension services
Collar rot	54
Early blight	52 53 54 55 56 60 61 63 64 66 67 70
Late blight	51 53 54 55 56 58 60 61 63 64 70
Leaf mould	53 64
Leaf Spot	51 53 54 63 64 70
Powdery mildew	59 65
Rhizoctonia	62 69
Septoria leaf spot	No specific recommendations - consult extension services
Sclerotium	62
Soil borne fungi	69
Stem canker	57

▲ ***Choose a green triangle product where possible because this has a lower toxicity to people and livestock***

1. Compiled from the Zimbabwe Crop Chemical Handbook, Volume 1, 2001.

Table 2f Look-up table of pesticides registered in Zimbabwe for disease control on brassicas and tomatoes[1]

Number & triangle colour	Pesticide active ingredient	Brand names of registered formulations	Oral LD50 of most toxic formulation	Pre-harvest interval (days)
▲ 51	Captan	Captan 50 WP	18000	7
▲ 52	Procymidone[TL]	Sumisclex 50 WP	13600	7
▲ 53	Metiram[L]	Polyram Combi	12500	3
▲ 54	Sulphur/mancozeb[L]	Flower Power	10400	3
▲ 55	Carbaryl/copper oxychloride/malathion /dinocap	Guard 'N Care	10000	Check label
▲ 56	Chlorothalonil[L]	Bravo 500	10000	3
▲ 57	Dicloran	Allisan 50 WP	8080	1
▲ 58	Metalaxyl/mancozeb[L]	Ridomil MZ 72 WP	7900	7
▲ 59	Sulphur/copper oxychloride/malathion	Agridust, Vegidust	7630	14
▲ 60	Propineb	Antrocol 70 WP	7140	3
▲ 61	Propineb/cymoxanil[T]	Milraz 76 WP	7140	7
▲ 62	Quintozene	Quintozene 75 WP	6660	Soil treatment
▲ 63	Captafol[L]	Captofol 80 WP	6250	2
▲ 64	Mancozeb[L]	Mancozeb flowable Dithane M45	6250	3
▲ 65	Sulphur[L]	Dusting Sulphur, Kumulus DF, Thiovit	6250	Check label
▲ 66	Difenoconazole	Score 250 EC	5812	14
▲ 67	Anilazine[O]	Dyrene 75 WP	3599	5
▲ 68	Thiram/lindane	Agri seed dressing	3466	Seed dressing
▲ 69	Thiram[L]	Thiram 80 WP	3250	Seed dressing
▲ 70	Copper oxychloride[L]	Copper oxychloride 85 WP	824	3

Key:

O = believed to be obsolete or discontinued

S = systemic products (carried in the plant sap)

L = these products are believed to have low impact on natural enemies - see *Farmers' Friends* (Verkerk, 2001)

T = translaminar products which can pass through the surface of the leaf into the tissue inside

1. Compiled from the Zimbabwe Crop Chemical Handbook, Volume 1, 2001.

Glossary of terms

These definitions may not be universal but explain the intended meaning in this handbook

Active ingredient (a.i.): The part or ingredient (often poisonous) of a pesticide which controls the pest.

Adult: Final stage of development of a pest. They often have wings, for example, moths.

Alternate host: Different type of plant which a pest or a disease can survive on, for example, some weeds can support whiteflies.

Antagonistic micro-organism: a micro-organism which can suppress other disease micro-organisms - farmers' friends on a microscopic scale.

Aphid mummies: Aphids, in which a young wasp has developed, killing the aphid. These parasitized aphids look brown and smooth.

Appearance: How the pest looks.

Arthropod: Very small animal with a hard skin (exoskeleton) segmented body, and jointed legs.

Artificial respiration (resuscitation): The emergency first aid technique to establish and maintain breathing and circulation by breathing into someone's mouth when their own breathing has stopped and applying chest compressions.

Augmentation: Increasing the numbers of naturally occurring *beneficial insects* which can help to control pests.

Bactericide: Pesticide which kills bacteria.

Bacterium (plural bacteria): Extremely small single-celled micro-organisms that are found everywhere. Some types are useful while others cause diseases.

Beneficial insects: Insects which are helpful to farmers by killing pests or pollinating plants.

Biological control (or biocontrol): Use of living organisms to control pests and diseases.

Biopesticide: a pesticide whose active ingredient is a living organism, for example, a fungus or a virus which kills pests.

Botanical: A product made from plant extracts.

Brassicas: Common name for crops such as cabbage, rape, kale, covo, viscose and mustard due to them being in the Brassicacae family. This family is also known as the Cruciferae so some people call these crops crucifers.

Broad spectrum: A phrase used to describe pesticides which kill many different types of pests such as caterpillars and aphids. They are likely to kill beneficial insects too.

Bushy varieties: Tomato varieties which do not grow tall and are able to stay upright without the need for staking or trellising. Also known as determinate varieties.

Calendar spraying: Spraying regularly - for example, on a particular day of the week - regardless of pest and disease severity in the crop.

Glossary

Canker: A dead or discoloured area (lesion) on a plant caused by disease.

Caterpillar: The wingless larval stage of a moth or butterfly. This is usually the stage which is a pest due to its feeding on leaves and other plant parts.

Classical biocontrol: Controlling a pest by importing a predator or parasite from the same country or area as the pest originated.

Coarse nozzle: A sprayer nozzle with a large diameter hole. This produces a high flow rate and large droplets (not suitable for spraying insecticides and fungicides on vegetables).

Coarse spray: Spray with large droplets.

Colonies: Groups of pests such as aphids living together on leaves.

Complete metamorphosis: The type of arthropod life cycle where the adult looks very different from the immature stages (nymphs or larvae) for example, butterflies look very different from caterpillars.

Compost: Plant material which has been piled up and left to rot to break down, release nutrients and kill the pests and pathogens which may be present. This compost is then added to the soil to improve soil structure and fertility.

Concentration: The quantity of active ingredient per litre of pesticide - in other words how strong the pesticide solution is.

Concentric rings: Rings inside each other, as in early blight leaf symptoms.

Control: Successfully killing or reducing pests and pathogens to economically acceptable levels.

Crop cultivar: The particular type or variety of crop being grown, with its own characteristics such as yield potential, disease resistance and time to maturity.

Crop debris: Unwanted vegetation (stems, leaves or roots) from previous crops.

Crop hygiene: Taking care not to spread pests and diseases on to new crops. for example, removing debris from previous diseased crops.

Crop residues: See crop debris.

Crop variety: See crop cultivar.

Crucifers: Plants from the Cruciferae family, which is an alternative name for the Brassicaceae family (see Brassicas). The name Cruciferae derives from the cross-shaped arrangement of leaves.

Cultivation: The process of growing crops. It can also mean hoeing or ploughing the soil.

Cultural control: Controlling pests and diseases by changing the way the crop is grown, or its habitat. Examples are crop rotation, field hygiene.

Defoliation: Causing leaves to drop off.

Determinate: A word used to describe the varieties of tomato which are short and bushy and do not usually need staking/trellising or pruning.

Dew: Water droplets often found on leaves early in the morning which have condensed from moisture in the air due to cold temperatures.

Disease: Plant sickness caused by a pathogen or physical and chemical factors such as low temperatures or shortage of particular nutrients.

Distortion: Abnormal change of plant shape or appearance often caused by pests or diseases.

Dose: Quantity of pesticide active ingredient applied to a given area of crop - often expressed as grams of active ingredient per hectare, but may be in millilitres per hectare.

Drench : Use of high volumes of dilute pesticide solution applied directly to the soil with sprayer or bucket to control pests and diseases in the soil.

Drip irrigation: Type of irrigation where water is supplied directly to plants through small holes in pipes laid on or in the soil next to crop rows.

Dust: A powdery pesticide formulation which is scattered dry onto the crop and pest.

Egg: Stage of life cycle which is produced by female adults after mating with males.

Emulsifiable concentrate (EC): A liquid pesticide formulation which is mixed with water before spraying.

Farmers' friends (natural enemies): Organisms which feed on and kill pests. Examples are ladybird beetles which feed on aphids and parasitoid wasps which lay their eggs in moth larvae. See also *Natural Enemy*.

Field hygiene: Taking care not to spread pests and diseases on to new crops. for example, removing crop debris from previous diseased crops.

Fine nozzle: A sprayer nozzle with a small hole. These have a low flow rate and produce small droplets suitable for applying insecticicdes and fungicides.

Fine spray: Spray with small droplets.

Flat fan nozzle: The type of sprayer nozzle which projects spray liquid in a flat pattern. More appropriate for tractors than for knapsack sprayers since coverage of bushy plants is not so good.

Flood irrigation: Type of irrigation where water is regularly allowed to flood a relatively flat field.

Formulation: The mixture of ingredients, including the active ingredient, which makes up a commercial pesticide.

Frass: Insect droppings, faeces or excreta - often a sign of presence of a hidden pest for example, cabbage webworm.

Fresh market: Refers to tomato types which are suitable for eating fresh – usually thin-skinned and quite juicy.

Fungicide: A pesticide designed to control fungal diseases such as tomato late blight or powdery mildew.

Fungus (plural fungi): Organisms which are similar to plants but have no chlorophyll for trapping sunlight. Many are useful in nature, but some cause diseases such as early blight and damping off.

Furrow irrigation: Type of irrigation where water is channelled down furrows which run beside the crop rows.

Galls: Swellings on plants caused by pests or diseases. In the case of root knot nematodes these galls (or root knots) appear on the roots.

Generalist: type of natural enemy that can feed on a wide range of different pests.

Girdling: Plant damage by pest or disease which extends right round the stem, causing it to shrink and constrict the stem at that point.

Green triangle pesticides: Pesticides which have a green triangle on their label meaning that they are in the lowest toxicity category in Zimbabwe 'Harmful if swallowed'.

Halo: Circular pattern of discoloration (often yellow) around damage by pest or disease on leaves, stems or fruit.

Hand-picking: Method of controlling pests by picking them off or crushing them.

Herbicide: Pesticide which kills weeds.

Hollow cone nozzle: The type of sprayer nozzle which produces a cone-shaped circle of spray (recommended for knapsack sprayers used in small-scale vegetable production).

Honeydew: Sticky sugary substance excreted by pests which suck plant sap such as whitefly and aphids. This can coat lower leaves or fruits on the plant and encourage the growth of sooty moulds.

Host: Organisms on which a pest, disease or natural enemy feeds.

Host plant resistance: ability of a plant to resist attack or infection by particular pests or diseases.

Immature: Stage of arthropod life cycle before they become adults for example, nymphs, larvae and pupae.

Incomplete metamorphosis: Type of arthropod life cycle where the immature stages look a little like the adults, for example stink bugs.

Indeterminate: Type of tomato variety which usually needs pruning and cannot support itself so needs staking or trellising.

Inoculation: Introduction of natural enemies to a crop so that they can control pests.

Insect: Arthropods which have six segmented legs, a head, thorax, and abdomen, and typically one or two pairs of wings in their adult stage.

Insect zoo: Clear glass or plastic container to hold and observe arthropods and plant material from the crop. Those eating the plant material are pests and those eating the pests are natural enemies.

Insecticide: Type of pesticide designed to kill insects.

Instar: The stages between moults of larvae and nymphs. These usually pass through several instars, getting progressively bigger as they shed their skin at the end of each stage.

Integrated pest management (IPM): An ecologically based pest control strategy that relies heavily on resistant crops, hygiene and natural predators and parasitoids, and tries to disrupt these factors as little as possible by only using appropriate chemical pesticides when necessary.

Intercropping: Planting more than one type of crop plant together in order to confuse pests or increase productivity.

Intervention: Doing something to control a pest or disease, for example, moving natural enemies in from other areas or applying a spray.

Introduction: Bringing in new types of natural enemy from another region.

Inundation: Releasing large numbers of natural enemies, usually reared specially, to find and kill the pests.

Knapsack sprayer: Type of sprayer carried on the operator's back. These are usually lever-operated or pressurised by pumping beforehand, but may be powered by an engine as in motorised knapsack mistblowers.

Larva (plural larvae): One of the stages in life cycles which exhibit complete metamorphosis. Examples are caterpillars (larvae of butterflies and moths) and maggots (larvae of flies). Larvae usually look very different from the adults and do not have wings.

LD50: The amount or dose of a pesticide which will kill 50 % of a test population of mammals (usually rats or rabbits) The letters stand for lethal dose.

Legume (leguminous plant): Plants which have seeds in pods (for example, peas) and have root nodules with helpful bacteria capable of trapping nitrogen from the air, so that plants can use it.

Lesion: Damaged area of a plant, often hollowed slightly, resulting from pest or disease attack or by physical injury.

Life cycle: A description of the changes which take place through the life a living organism from adult through to adult again.

Maggot: The larval stage of a fly.

Mammalian toxicity: a measure of how poisonous a pesticide is to mammals, in other words animals such as humans, cattle and rats.

Mature: Stage of arthropod life cycle when they become adults.

Maximum residue limit (MRL): The limit or amount in parts per million, which is set by regulatory authorities as the amount of pesticide allowable in agricultural produce. These MRLs vary from one pesticide to another, from country to country and from crop to crop.

Mechanical control: Method of pest control which relies on force to kill or expose the pest or disease, for example, disc ploughing a field to kill the cutworms.

Metamorphosis: The change of form that arthropods go through between immature stages (larvae or nymphs) and adult stage.

Micro-organism: Tiny living plant or animal too small to see without a microscope, for example, bacteria or viruses. [Also spelt microorganism]

Mine (as in leaf mine): Long thin hollowed out tube between the two surfaces of a plant leaf caused by pest larvae (usually of flies) as they eat within the leaf.

Mite (or spider mites): Tiny arthropod sucking pests with eight legs as adults, but sometimes only six when younger.

Mixed cropping: The practice of planting more than one type of crop in a field (the opposite of monocropping). This may take the form of intercropping (see definition above) or could be patches of different crops near each other.

Monoculture (monocropping): The practice of growing large areas of only one crop.

Mottling: Patchy discoloration of leaves or fruit.

Mould: Powdery or fluffy fungal growth which can be white, black, green or brown. Black mould can grow on honeydew from sucking insects and can block sunlight from the leaves.

Mulching: Covering the surface of the soil with material such as crop residues, compost or plastic sheeting to reduce water loss, reduce splashing and break some pest life cycles.

Natural enemy (Farmers' Friend): Organisms which feed on and kill crop pests. Examples are ladybird beetles which feed on aphids, and wasps which lay their eggs in moth larvae. See also *Farmers' Friend*.

Nematicidal: Able to kill nematodes, for example, African Marigolds have nematicidal properties.

Nematodes: Microscopic worms without segments sometimes called eelworms which may feed on plant roots. Other types feed on insects and may turn out to be useful biocontrol agents.

Nozzle: Device with a small hole fitted at the end of a spray lance to break up the liquid into spray droplets.

Nutrients: Chemicals in the soil which plants use for growth. Either made available naturally from breakdown of organic matter or added by farmers as artificial fertilizer.

Nymph: One of the stages in life cycles which exhibit incomplete metamorphosis. Nymphs usually look very similar to the adults but do not have wings.

Organic farming: Farming without using most synthetic pesticides or fertilizers.

Organic matter: Material in the soil deriving from plants or animals. Organic matter gives soil good structure, helps it hold water, and breaks down to release nutrients.

Overdose: Application of more than the recommended dose of pesticide is applied.

Overhead irrigation: Type of irrigation where water is sprayed from sprinklers like rain over the crop.

Parasitoid: Arthropod which lays its eggs in or on other arthropods (either their eggs, larvae or nymphs) and which usually kills its host. A common example is a parasitoid wasp which lays its eggs in aphids.

Pathogen: Infectious micro-organism which can cause disease, for example, fungi which cause late blight.

Persistence: The capacity of a pesticide to remain active for a time after spraying.

Persistent: Means long-lasting. It can refer to a pesticide which remains active for a long time after spraying, or a disease which can survive a long time in the soil after an infected crop has been growing in the field.

Pest: Living organism which feeds on or otherwise damages crop plants. Usually used to describe animal pests such as insects, mites and rats, but sometimes also used to include diseases.

Pesticide: Product designed to kill pests (including diseases). Pesticides may be synthetic (man-made), biological (containing a living organism) or botanical (made from plant extracts).

Pesticide residue: Pesticide remaining in agricultural produce after harvest. Overdosing or not respecting the pre-harvest interval can cause excessive residues which may harm the consumer.

pH: The pH scale is a measure of how acidic the soil is. Below ph 7 is increasingly acidic (possibly requiring lime) and above 7 is increasingly alkaline (possibly requiring use of special fertilizers).

Physiological disease/disorder: Plant damage caused by factors other than pathogens or pests. for example, sunscald of tomatoes caused by strong sun on the fruit.

Pollination: Transfer of pollen from the male sexual parts of a plant to the female sexual parts in order to achieve fertilization which is required to set some fruits and crops. The pollen may be carried by the wind, for example, wind-pollination of maize, or by an insect, for example, pollination of tomatoes by bees.

Pollinator: Type of insect which carries pollen from male parts of a plant to the female parts, for example, bees.

Predator: Animal which catches and eats other animals, such as a lion. An example in pest management is hover fly larvae which catch and eat aphids.

Pre-harvest interval (PHI): Period of time after spraying before the crop becomes safe to harvest and eat. This can vary from a day to several weeks. Read the pesticide label carefully to find out how long the PHI is and see Tables 2c and 2f on pages 163-166.

Preventive control: taking action to prevent pests and diseases before they appear or become serious.

Processing: Refers to tomato types which are suitable for cooking or canning – usually with thicker skins and less juicy.

Prune: Cutting off parts of a plant to control size or improve its growth or shape. For example, pruning tomatoes improves air circulation which discourages disease, and also makes fruit bigger and more marketable.

Pupa (plural is pupae): One of the stages in the life cycle of arthropods which undergo complete metamorphosis, for example, moths and flies whose younger stages are very different from adults. Pupae usually have a hard skin and do not move or feed.

Pupate: The process of forming a pupa (see above).

Recommended dose rate: This is manufacturer's advice on the amount of pesticide to use to achieve good control of a pest or disease.

Red spider mite (RSM): A type of mite which feeds on leaves.

Repellent: Describes something which is able to make organisms stay away (be repelled) - for example, the smell of onion plants repels some pests.

Resistant (resistance): Able to withstand something. for example, a plant may be resistant to a disease or pest, meaning it cannot be affected by it, or an insect may be resistant to a pesticide, and not be killed by it.

Root knot nematode (RKN): A type of nematode which feeds on and damages roots of some plants, often forming lumps or knots which are visible if the plant is pulled up.

Roguing or roguing out: This is removing/destroying plants which are affected by pests or diseases in order to prevent infestation/infection spreading to other plants in the field.

Root knots: Lumps or knots on plant roots as a result of infestation by root knot nematodes (see above).

Rotation: The practice of changing the crop type in a field at each new planting to prevent the build up of pests and diseases. After 3 or more years, the first crop type can often be planted again, so the rotation starts again.

Sap: Plant juices containing water and nutrients.

Sclerotia: Hard lump formed by fungal diseases in some plants.

Scouting: Examining crop plants in a systematic way to assess pest, disease and natural enemy situation in order to decide whether any crop protection intervention is necessary.

Seed-borne: A disease carried in or on the seed, for example, fusarium wilt.

Seed dressing: A treatment which coats the seed with pesticide to prevent early season attack by diseases (and some pests).

Selective: A word relating to pesticides which only kill organisms in a narrow range. For example, diflubenzuron only affects pests which have a cuticle because it disrupts formation of the cuticle - it cannot affect fish, birds or people. Selective pesticides are also sometimes known as specific pesticides.

Shot hole: Damage caused by flea beetles and other pests whose feeding produces small holes which look as though they have been caused by the pellets from a shotgun.

Skeletonized: used to describe leaves which have had most of their softer tissue eaten by a pest, leaving only the thicker veins intact.

Soil-borne: Pests and diseases which can survive and infect crops from soil in the field, for example, bacterial speck on tomato.

Solanaceae: The plant family containing tomatoes and other crops such as egg plant, Irish potato and peppers.

Solarization: Covering the soil with plastic (preferably clear) so that hot sunshine will heat the soil and kill pests and diseases in it.

Spore: The microscopically small seed of a fungal disease which can be carried by wind or water splashes.

Spot spraying: Spraying only the area of crop which is affected by pests or diseases, rather than spraying the whole field.

Spray management valve: Device fitted to spray lance which regulates spraying pressure so that flow rate and droplet size remain constant.

Spray stratification: Spraying only one level of the crop, for example, spraying the bottom of the crop to reduce transmission of rain-splashed fungal diseases.

Spray threshold: the level of severity of pest or disease attack - for example, number of aphids per plant leaf - which prompts a decision to spray pesticides.

Staking: Using a pole (or stake) to support plants so that they can grow upwards without falling on to the soil.

Sterilize: To treat with heat or a chemical so that diseases and pests are killed.

Stippling: Damage showing as small white dots on leaves as a result of leaf sucking pests or leaf miner adults laying eggs or probing to find good egg-laying sites.

STRong rotation system: A crop rotation system for mostly aimed at control of root knot nematodes. Crops are planted in the sequence: Susceptible, Tolerant, Resistant (STR), then Susceptible again and so on, see page 113.

Stunted: Plants which are small and poorly developed.

Succulent: Very soft sappy or juicy plants which are quick growing. Over-use of nitrogen-containing fertilizer can produce succulent growth which may be especially liable to aphid damage.

Sunscald: Physiological condition of tomato fruits caused by exposure to hot sunshine (often caused by harsh pruning).

Susceptible: Capacity to be affected by something. For example, a plant which is susceptible to a disease can be infected by it, and an insect which is susceptible to a pesticide can be killed by it.

Symptom: A visible sign of damage by pest or disease.

Systemic pesticide: A pesticide which can pass through the plant cuticle and be carried around in the plant sap. Very useful for controlling sucking pests.

Tolerant: Capacity to withstand particular diseases without major damage or yield loss.

Toxicity: a measure of how poisonous a pesticide is either to mammals (see *mammalian toxicity*) or to pests or natural enemies.

Translaminar: Capacity of a pesticide to pass through the plant cuticle, but unlike systemic pesticides, not to be carried around in the plant sap. Very useful for controlling pests inside the leaf such as leaf miners.

Transmission: The way in which a disease is spread to other plants.

Trap crop: Crop which is planted to attract a pest and is then destroyed together with the pest.

Glossary

Trellising: Supporting tomato plants with wire strung between posts. The plants are tied in to the wire.

Underdose: Application of less than the recommended dose of pesticide is applied.

Vector: Organisms which spread a disease, for example, thrips transmitting tomato spotted wilt virus.

Vessel: Tube in stems and leaves which carries plant water and nutrients (sap).

Vine varieties: Tomato varieties which are indeterminate and required staking/trellising and pruning.

Virus (plural viruses): Some of the smallest of living organisms. Cause diseases which discolour and deform the plant and may reduce vigour and yield.

V lance: Spraying device fitted at the end of a spray lance which can swivel to direct the spray upwards and improve underleaf cover. Good for control of pests found underneath leaves and for preventing diseases which are splash-borne to underleaf surfaces.

Volume application rate (VAR): The volume of diluted spray applied per crop area, usually expressed as litres/hectare. Farmers often unknowingly apply a VAR which is far too high, resulting in heavy overdosing and unnecessary run off on to the soil.

Volunteer crop plants: Plants growing from seed, tubers or debris left over from the previous crop in the field.

Water stress: Damaging plant condition resulting from insufficient water supply which may cause wilt disease symptoms to show.

Weed: Wild plant which competes with the crop for water, nutrients and/or light.

Wettable powder (WP): Powder pesticide formulation which is mixed with water before spraying.

Windowing: Caused by pests eating only the upper or lower surface of the leaf, leaving the other surface intact, looking like a translucent window.

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