

Keep it CLEAN

Reducing costs and losses in the management of pests and diseases in the greenhouse

INTENSIVE INDUSTRIES DEVELOPMENT BRANCH



Know-how for Horticulture™



NSW DEPARTMENT OF
PRIMARY INDUSTRIES

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About the project

This project VG 07118 - Build capacity of greenhouse growers to reduce crop loss through adoption of preventative disease management practices was designed and managed by NSW DPI with industry support through HAL/Ausveg.

The project was set up to provide greenhouse growers with the basic information and skills needed for integrated and preventative pest and disease management and to assist growers in overcoming barriers to adoption when implementing the foundations of integrated pest management (IPM).

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Acknowledgements

The author gratefully acknowledges the valued assistance given by the following people for their input.

Mr Peter Newley, District Horticulturist, NSW Department of Primary Industries

Dr Leanne Forsyth, Plant Pathologist (Vegetables), NSW Department of Primary Industries

Len Tesoriero, Industry Leader Greenhouse & Ornamentals, NSW Department of Primary Industries

Dr Leigh Pilkington, Research Scientist (Entomology), NSW Department of Primary Industries

Virginia Brunton, Education Officer, NSW Department of Primary Industries

Dr Kaye Ferguson, Research Officer, South Australian Research and Development Institute

Mrs Barbara Hall, Plant Pathologist (Diagnostic service), South Australian Research and Development Institute.

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ISBN 978 0 7347 1993 5

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Preventative pest and disease management

This guide has been produced in conjunction with participating greenhouse growers to provide a practical guide to help you to economically and effectively introduce preventative and integrated control strategies to manage pests and diseases in your greenhouses.

Pests are organisms that cause damage or loss, or pose a risk to your crop. Most often people think of pests as insects and mites. Weeds and some animals, such as rats, can also be pests.

Pathogens are organisms that cause disease. A **disease** is any condition in a plant that interferes with its normal functioning, growth and/or development. For simplification, this publication uses the term “disease” to refer to both the pathogen and the disease it causes.

A **weed** is a plant growing where it is not wanted. Weeds provide a home for other pests and diseases which can then get into a crop and in some situations, weeds can compete directly with crops.

Reducing costs and losses

The profitability and productivity of your greenhouse can be significantly improved by minimising the losses caused by pests and diseases. Effective pest and disease management practices, once established, are also very likely to reduce overall chemical and labour costs.

Plant diseases in a typical greenhouse enterprise may be costing you as much as 15% of your potential income. Serious pest damage can regularly take another 10% from your bottom line. If you were growing one hectare of cucumbers (or about 20 tunnel houses), at a market price of \$10 /carton, the loss due to pests and diseases and the cost of trying to control them with pesticides alone would be around \$20,000. Using a combination of preventative practices, you could at least halve this and save hours of your time.

This guide contains a comprehensive list of important practices that will help reduce the problems caused by pests and diseases. It also contains prompt questions that you can use to put in place your own integrated, preventative strategy that works.

Preventative pest and disease management is about planning, cleaning and quarantining. This requires being organised, consistent and using a relevant plan for your farm. A good plan will ensure that you are able to

1. keep growing areas and equipment clean and disinfected and
2. use basic practices to stop pests and diseases getting into your greenhouse. Prevention is cheaper than treatment.

No single practice on its own can completely prevent pests and diseases causing losses to your crop and to your business. There are many different strategies and specific control options or tactics that can be used in and around a greenhouse to manage pest and disease problems.

Each option will tend to

- a. have a different impact,
- b. affect different pests and diseases
- c. have a different cost or benefit.

The key to cost effective pest and disease management is integrating the most suitable strategies from all the available options and establishing a solid prevention program.

Integrated Pest and Disease Management

Integrated pest and disease management (IPM) is a term which most growers have heard about, but is often misunderstood. IPM is the use of multiple tactics to contain pests and diseases to tolerable levels.

This means that more than one tactic, practice or control measure must be used in combination. It also means that the aim is not always to eradicate the problem because sometimes it is more profitable to tolerate a small number of pests or a low level of disease than to spend more money to completely remove the problem.

An important aspect to remember is “integrated”. The combinations of appropriate tactics or practices that are used need to be put together sensibly to fit into your business.

The focus of IPM is on reducing costs and losses so it is essential that the effort and resources you use or spend money on, are not wasted or working against each other.

“ IPM is the use of multiple tactics to contain pests and diseases to tolerable levels ”

Every aspect of growing a good crop is part of an integrated pest and disease management program.

Preventative practices make up the majority of management strategies available. This guide focuses on all the practices that can be implemented up to the point of applying a control such as using a biological or chemical treatment.

Preventative practices

Monitoring and checking strategies include regular and systematic checking for pests and diseases in and near the crop. Early detection, correct identification and reliable information will make your management options clearer and more effective.

Cultural management strategies include many valuable tactics including cleaning and disinfecting (sanitation), in-crop quarantine, varietal selection, crop management including nutrition, irrigation, plant growth and balance, pruning and training and environmental settings in the greenhouse.

Cleanliness is the key cultural management strategy.

Other strategies include farm quarantine as well as the design of the greenhouse and the growing system and various engineering controls such as soil cultivation (in soil systems), screening, heating, venting, air circulation, light and drainage.

Biological practices

Biological management strategies include releasing (or at least encouraging) natural predators, parasites, pathogens and other competitors of pests and diseases.

Chemical practices

Chemical management strategies include the use of appropriate chemical pesticides (insecticides, fungicides, miticides), and biorationals (eg soaps, oils, growth regulators and other pesticidal compounds that degrade into non-toxic components) and biopesticides (eg living organisms that are formulated to be used like a conventional pesticides).

How do you start?

Everyone can practice IPM. It is all about using a range of different tactics and practices in combination. The most important and cheapest place to start is with prevention – **KEEP IT CLEAN**

Setting up an effective preventative management program will require:

- Knowing how and where problems occur
- Using as many practices as possible to reduce the risk of pest and disease outbreaks in your crops
- Doing a risk assessment for each pest and disease
- Using this information to plan the best order in which to implement all the preventative strategies you can.

“ use as many tactics and practices as possible ”

Risk assessments and planning gives you the time to prepare and prevent, or at least limit, the damage and cost of pests and diseases. If you do not practice good hygiene and use preventative strategies, it will always be more difficult and costly to get on top of any pest or disease problem and the lifespan of the crop will be shorter.

At a minimum, there are 10 ESSENTIAL MANAGEMENT PRACTICES which need to be used in every farm. Even if you do nothing else, do these. More information about each of these very important practices is given in this manual.

Essential management practices

- Be able to correctly identify pests and diseases (or have them identified for you) and routinely conduct a pest and disease check to ensure early detection and correct identification of problems
- Action points are determined and pest and disease check information is used for all decision making including chemical, biological, whole-crop and hot-spot treatments
- The greenhouse is within a 'clean' zone which is quarantined from the 'outside' zone of the farm
- Check and control points are used to control movement of people, vehicles, plants and materials into the 'clean' zone
- Employees and visitors do not visit another greenhouse before entering your greenhouse
- All seedlings are checked and found free from pests and diseases before they are planted out
- A 5 - 10 metre wide clean buffer area is maintained around every greenhouse
- The greenhouse is always cleaned and disinfected before planting new crop
- The greenhouse and farm surrounds are kept weed free
- Crop debris is removed and stored/disposed of outside the 'clean' zone and away from the greenhouse

Section 1

Reducing the risk of pests and diseases

- Where do pests and diseases come from?
- What preventative actions and practices can you take?

This section looks at where pests and diseases come from and the many ways that you can reduce the risk of them affecting your crop. There are a lot of preventative actions that you can use. Throughout this section, key practices have been described including 10 ESSENTIAL MANAGEMENT PRACTICES which everyone needs to be doing.

*Use this section to work out what might be a problem on your farm, what actions you can take and where on your farm you can implement them. Prompt questions have been included to help you. Each one has a yes/no box. If you answer **no** to any question, this is something that you can do to prevent pests and diseases. For example:*

By removing all weeds in and around the greenhouse, for example, you will significantly reduce the risk of pests and diseases getting into the crop.

Section 2

Implementing effective pest and disease management

- Assessing the risk of pests and diseases
- Recognising key pests and diseases
- Monitoring and checking for pests and diseases
- Measuring the impact of pests and diseases

This section provides some background information about key pests and diseases and identifies some of the CRITICAL MANAGEMENT PRACTICES that can have significant benefits in managing specific pests and diseases.

Effective management is linked to a risk assessment in order to work out which practices to implement first. A simple method of monitoring for and measuring the impact of pests and diseases is also provided.

Use this section to find out which pests and diseases get into your crop and how important they are. You can then use this information to plan which preventative actions you will adopt first.

Section 1

Reducing the risk of
pests and diseases

Reducing the risk of pests and diseases

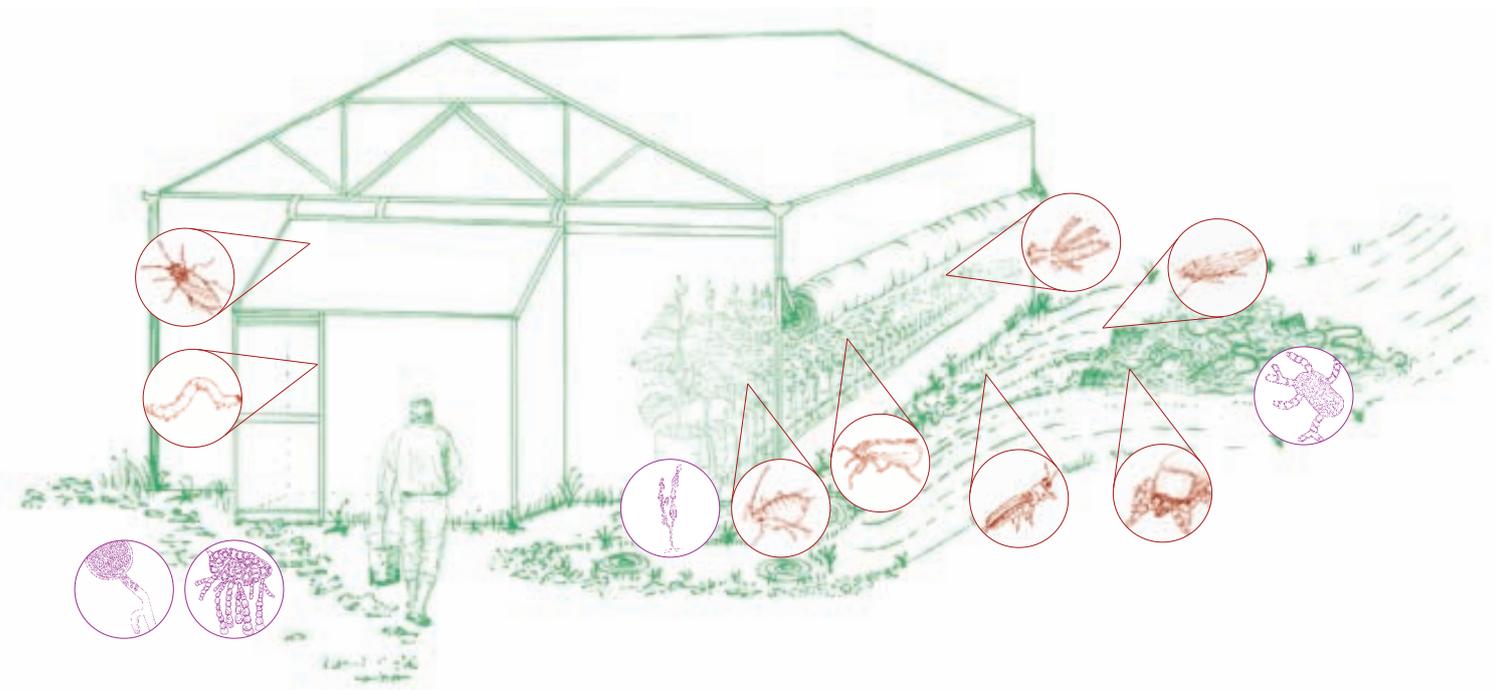
Where do pests and diseases come from?

Pests and diseases of your crop can come from lots of different places and they can get into your crop and spread from plant to plant by a number of different ways.

They can come from sources already in your greenhouse, somewhere else on your farm or from off-farm. Knowing which pests or diseases are around and how they could get into your crop enables you to stop them early. Even though it is not always possible or practical to completely prevent a pest or disease getting in, reducing the amount that does get in can drastically lower the cost of management, greatly improve your capacity to control it and significantly reduce the impact it might have on your harvestable crop.

Some pests can fly and/or be carried on air currents, for example thrips, aphids and whiteflies. Spores of fungal diseases can also be carried by the wind. Most diseases are also carried and spread by water including run-off and rain splash.

Many pests can walk or crawl short distances so if they are near-by, they can easily find their way into the greenhouse.



Pests and diseases can come from lots of different places and get into your crop.

Pests and diseases are also carried on plant material such as new seedlings or prunings and in soil or substrate. A lot of diseases survive for a period of time on surfaces such as containers, tools and covering materials and in soil and crop debris.

Some diseases are carried by certain pests, on people and clothes as well as on tools including items like a mobile phone.

The choice of crop that you grow is not only an essential business decision, it is also an important management decision in terms of pests and diseases.

You need to know what plant family the crop you are growing belongs to. For example, crops such as cucumber, zucchini, squash and melon are all cucurbits and belong to the Cucurbitaceae family.

Tomato, capsicum, chillies and eggplant are all in the Solanaceae family. Many common weeds also belong to the same families as key greenhouse crops and some diseases are specific to certain crops or plant families.

This information is useful when planning and using preventative pest and disease management practices.

The first step in reducing the risk of pests and diseases is to be aware of plant sources and non-plant sources in or around the greenhouse from which pests and diseases can come.

Plant sources of pests and diseases

All plants and plant material can be a source of pests and diseases.

Weeds are one of the most significant sources of pests and diseases. There is a very high risk that pests and diseases that enter your crop will come from weeds in and around your greenhouse. Weeds provide shelter and food for pests and act as a host for diseases.

“weeds are one of the most significant sources of pests and diseases”

There are many species of plants which harbour pests around the farm. In general, any plants of the same family as the crops you are growing should be considered a source of pests and diseases (for example blackberry nightshade is the same family as tomato and capsicum). Flowering plants generally harbour a number of pests, especially thrips.

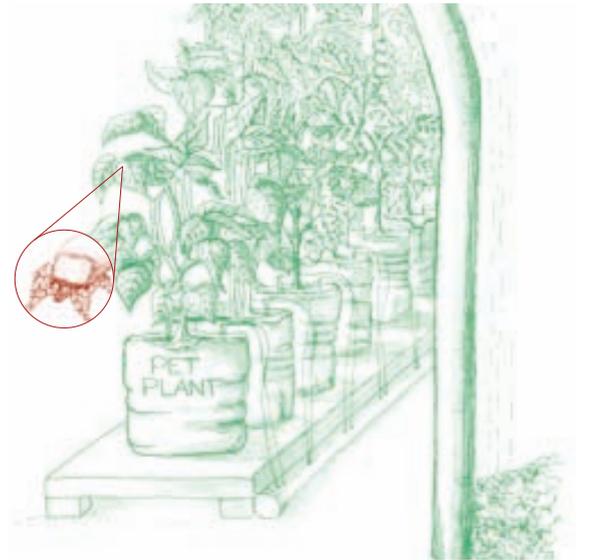
At the back of this document (Appendix 2) is a list of some important weeds and their photographs that will help you identify common weeds and the pests and diseases they might conceal on your farm.

Other crops in a nearby greenhouse and on neighbouring properties need to be considered a risk to your crop. This is especially important if nearby crops are in the same plant family as the crop you are growing because they may host pests and diseases that will affect your crop.

Older crops left in a greenhouse when you plant a new crop, can give refuge to a number of pests and diseases too. Plants in or near your greenhouse, including old crops and weeds, are one of the most significant sources of pests and diseases and can be the main reason for the majority of pests getting into your new crop.

Personal or “pet” plants such as an occasional herb at the end of a row are equivalent to weeds. These plants can act as a source of pests and diseases to the crop and should never be grown in the commercial greenhouse.

Crop debris can harbour a lot of pests and diseases giving them a safe place to wait around before moving into another crop. Crop debris includes all the old plants that have been removed from the greenhouse as well as prunings and other plant material taken from a crop during the growing period. It also includes discarded fruit. Leaves and old fruit left in the greenhouse can provide a safe haven for pests and diseases until the new crop is established.

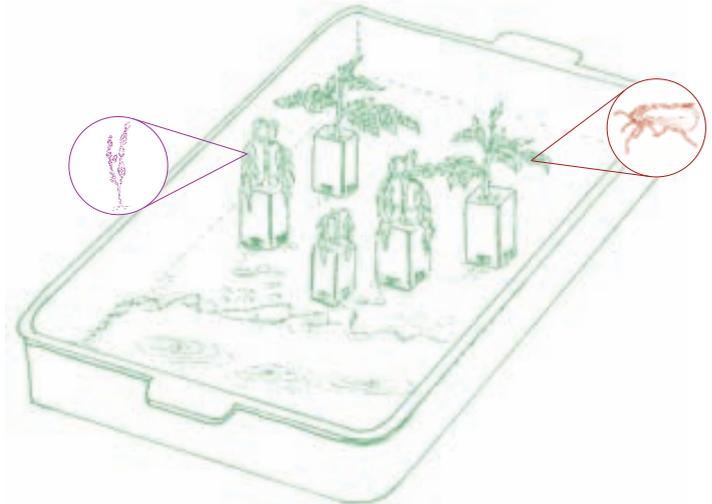


“Pet” plants in the greenhouse might be convenient but they can be very costly



Leaves and discarded fruit harbour pests and diseases

Seedlings are a significant source of pests and diseases. Seedlings have come from another area outside of your production greenhouse, either from your own propagation area or from a nursery. This means that they are a potential source of pests and diseases getting into your greenhouse.



Seedlings are a very common source of pests and diseases

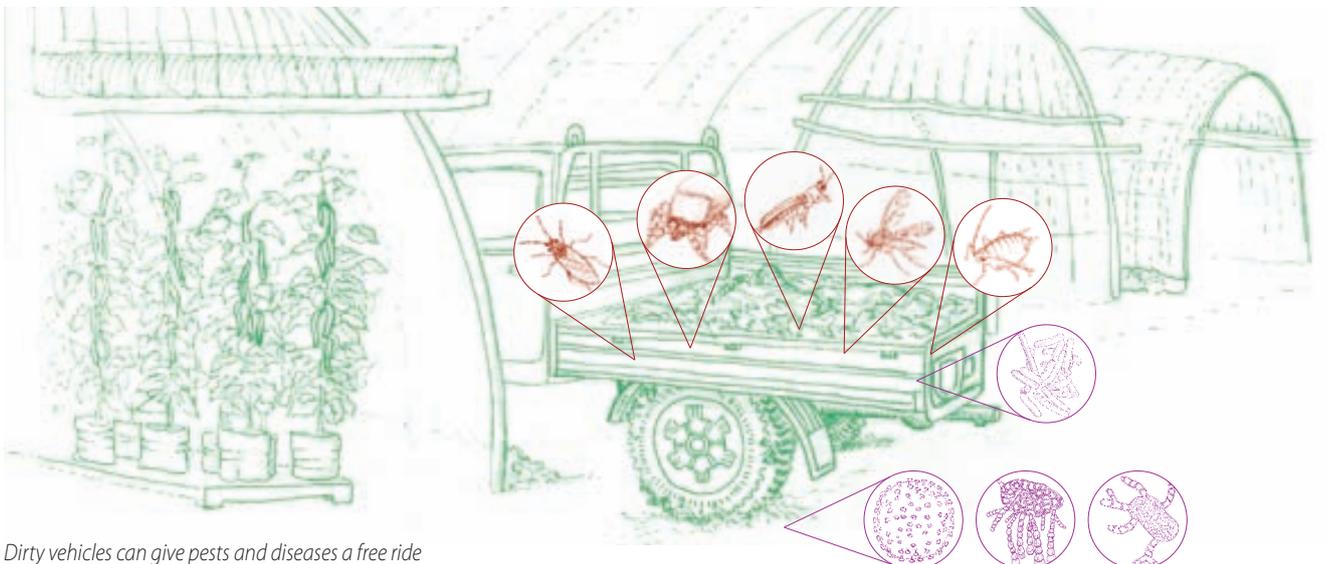
Non-Plant sources of pests and diseases

All people and objects can be a source of pests and diseases.

People are a big source of pests and diseases if good farm hygiene and quarantine is not followed. People (employees and visitors) entering and moving around your production area can be like a public transport system for pests and diseases. Pests and diseases can be carried on clothes, people's hands and especially shoes. People can, as well as introducing pests and diseases into the greenhouse, also carry them around within the crop.

Tools such as secateurs and pegs and even mobile telephones can carry diseases in and around the farm.

Vehicles are often overlooked when considering where pests and diseases can come from, but can be an important source of problems. Plant debris and soil are the main ways that pests and diseases get carried on vehicles.

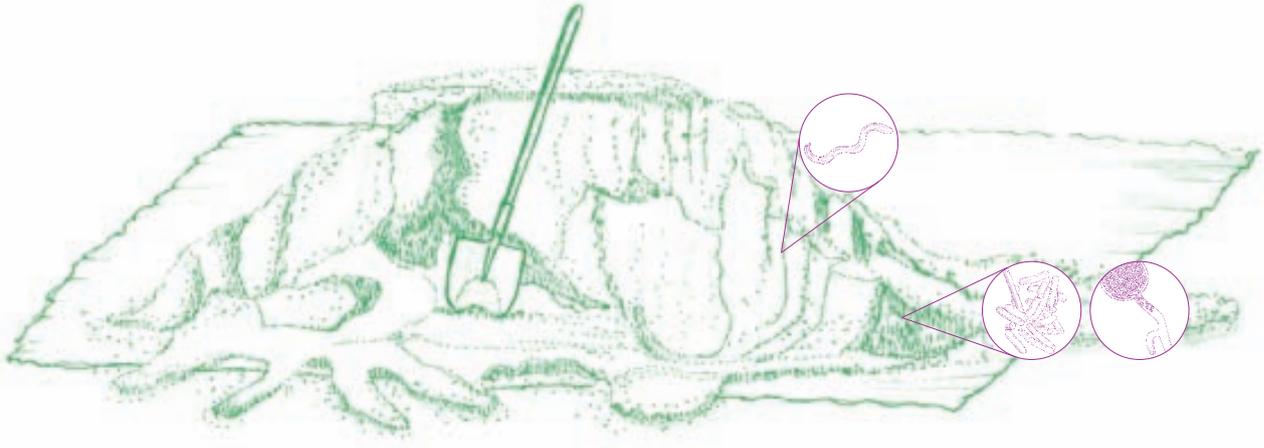


Dirty vehicles can give pests and diseases a free ride

Rubbish piles can be a problem on many farms. Rubbish is often contaminated with soil and plant debris which can harbour pests and diseases. Rubbish piles also provide protection for these pests and diseases enabling them to survive longer and giving them more chances to get into your crop.

Hydroponic substrates can be a source of pests and diseases. One of the key advantages of hydroponics is that substrates free from soil borne diseases can be used, however, many soil borne diseases can survive in substrates if they become contaminated. Organic materials such as compost, potting mixes and sawdust are a higher risk. Inorganic substrates like rockwool and perlite can generally be considered to be disease free on delivery. Pre-packaged coir fibre, though it is organic, is also generally disease free on delivery.

Bulk supply of loose substrates increases the risk of diseases because it is rare that the supply depot, delivery vehicles, on-farm storage and potting/bagging areas will be clean and free from diseases. The use of bulk loose organic substrates is a very high risk for root rot diseases. Even when clean substrate is purchased, if it comes into contact with weeds or soil or is open to the air before being used, pests and diseases can hitch a ride into your greenhouse and onto a new crop.



Bulk, loose organic substrates are a high risk for root rot diseases and nematodes

Soil is almost certain to contain plant diseases which can cause root rots and other problems. Every effort and care needs to be taken to make sure that soil is not carried into the greenhouse. If soil gets into the greenhouse or the substrate comes into contact with soil, diseases can be introduced.

Soil can get into the greenhouse on shoes and equipment such as trolleys or buckets or machinery. If large areas of dirt surround the greenhouse, wind can blow dust (carrying diseases) inside the greenhouse. Root rot diseases that get into your greenhouse or hydroponic system will almost always enter via soil.

Some greenhouse growers still use the soil as the production system. Where this is the case, special attention has to be given to the health of the soil. A healthy soil contains many organisms in a balance. Many of these organisms have a role in disease suppression.

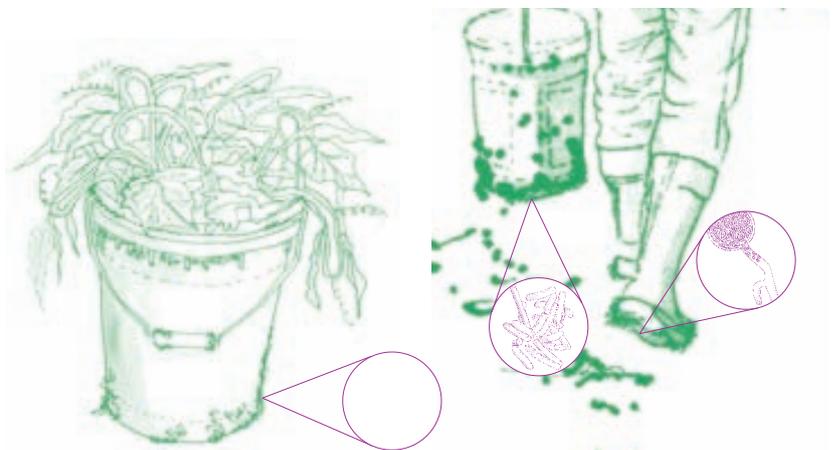
Boxes, buckets and bags used in the greenhouse can be a source of pests and diseases. Containers can be contaminated with crop debris, substrate and soil once they have been used or taken outside the greenhouse. Never return a container to the greenhouse until after it has been cleaned and disinfected. It is important that only clean equipment is taken into a greenhouse.

Water can carry many diseases, especially bacteria and root rot fungi. All water to be used in the greenhouse for irrigation, cleaning and cooling is a high risk and has to be disinfected if it can come into contact with soil at any point before it is used, for example, if it is stored in a dam, pumped from a creek or held in an open tank. Mains water supplies are already treated with chlorine and do not need to be disinfected (though residual chlorine levels and pH need to be monitored). Bore water is usually free from plant diseases, but should be tested to make sure. Contact a diagnostic laboratory for information about water testing for soil borne diseases.

Disinfected water that is being stored needs to be in a closed tank to minimise the risk of dust or debris causing recontamination.

There are a number of methods that can be used to disinfect water. (These are described in Appendix 3).

Poor drainage that results in run-off water entering the greenhouse during a rain storm for example, can bring in diseases. Water splashing into the greenhouse from rain hitting the ground or from a vehicle driving through a puddle is also likely to be a way for diseases to get in. Minor flooding can cause even greater problems.

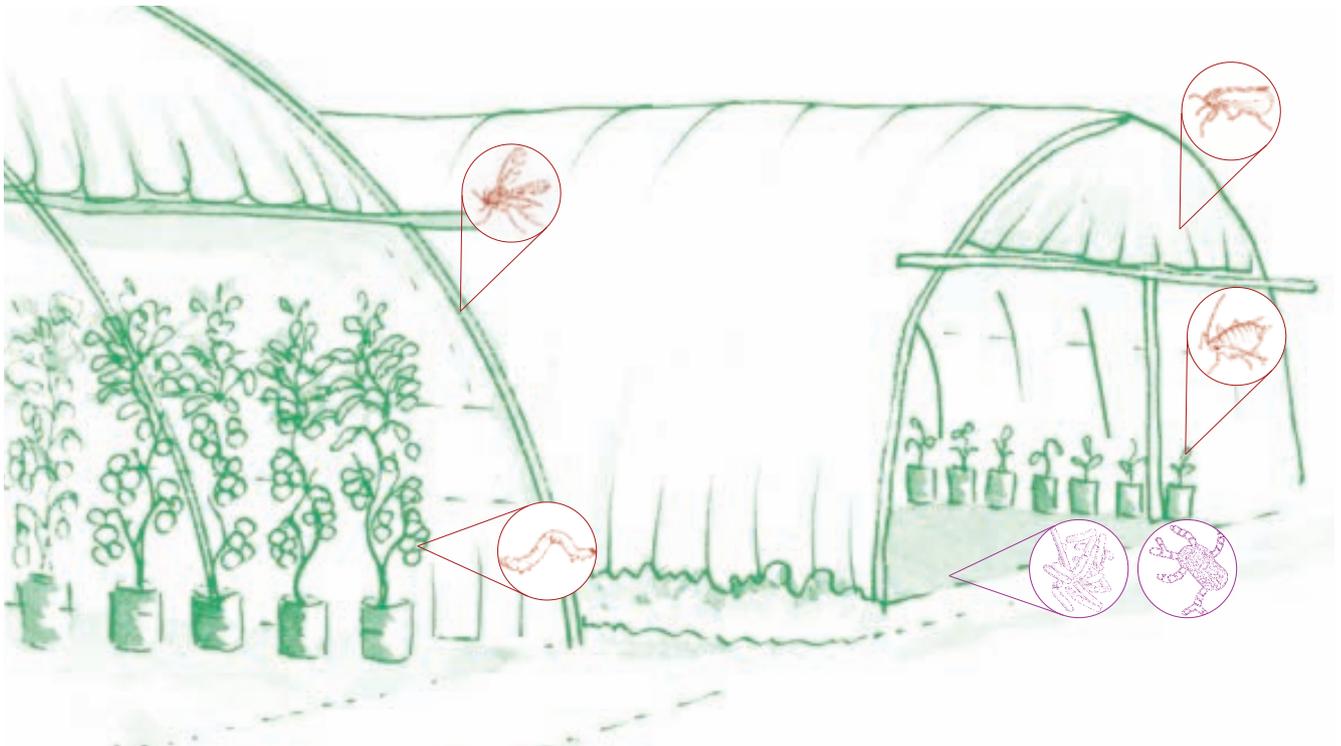


Soil on buckets, boots and any other items is a risk for root rot diseases. Only take clean equipment into the greenhouse

Irrigation systems can be an important source of some diseases. If water is recirculated, then it needs to be disinfected otherwise there is a large risk that from a few infected plants, the nutrient solution will spread a disease right through the crop. Run-off from the crop can also carry diseases down a row so if a plant has its roots in contact with the nutrient run-off from other plants, there is a significant chance that they will also become infected.

If an irrigation system is not cleaned between crops, it is likely to carry diseases over from one crop to the next.

Greenhouse covers and the structure can be a potential source of pests and especially diseases and provide a way for pests and diseases to carry over from one crop into the next. **Crop strings** will carry diseases from an old crop to a new one if they are not replaced or disinfected thoroughly.



Pests and diseases can hide and wait on materials and structures

What preventative actions and practices can you take?

Even though there are a lot of ways for pests and diseases to get into your greenhouse and affect your crops, there are clear, low cost and very effective ways to significantly reduce pest and disease problems. These can be broadly put into 2 groups: 1) how your farm and greenhouse is set up and 2) the work practices that you and your employees follow.

“ there are clear, low cost and very effective ways to significantly reduce pest and disease problems ”

Preventative pest and disease management involves good organisation, good sanitation and good quarantine.

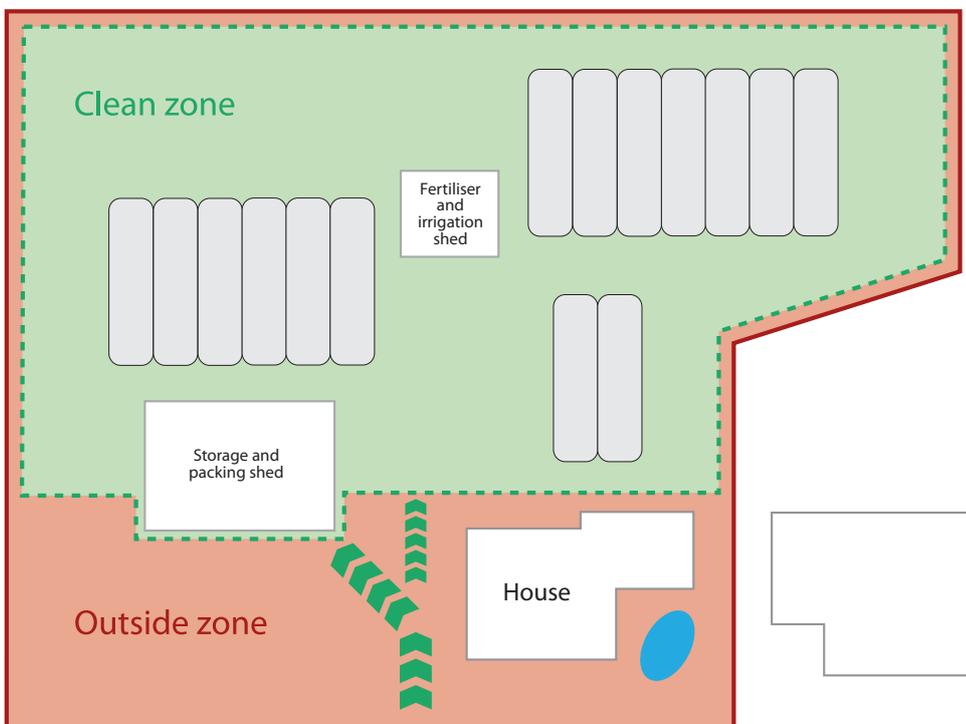
General farm management to reduce pests and diseases

Not only does a well organised farm have fewer pest and disease problems, but it will also be cheaper to run. It is very important to plan the layout of your farm and all the activities in a way that minimises the risk that problems will be carried onto the farm and between crops on the farm.

Establish a ‘clean’ zone

Separate your farm into two (2) zones - a ‘clean’ zone and an ‘outside’ zone. The ‘clean’ zone is the most important part of your farm. A clean zone is space around your greenhouse and production area which you use to create a barrier to pests and diseases. The clean zone includes all the greenhouses, shadehouses and hydroponic tables and the area immediately surrounding these production areas. It also includes the packing shed, any equipment or storage sheds as well as the areas and roadways between these structures. In the clean zone there must be no weeds, no crop debris and no rubbish. Pathways and roadways should be covered. Vehicles, tools and all equipment in the clean zone need to be kept free from soil, crop debris and rubbish. Anything being taken into the clean zone must be cleaned first.

The ‘outside’ zone is the remainder of your property, including your house and driveway and everywhere off-site. This area should also be kept clean and tidy to reduce the risk of pests and diseases getting into the clean zone and into the greenhouse.



Divide the farm into a ‘clean’ zone and an ‘outside’ zone

? Essential practice

Is the greenhouse in a ‘clean’ zone which is quarantined from the ‘outside’ zone of the farm?

Y N

Check and control points and work procedures

The aim of having two zones is so that you can clean up the production area and remove pest and disease problems and then control the movement of people, vehicles and materials into the production area (the 'clean' zone) so that you can effectively intercept and minimise pest and disease threats. This is done by having check and control points on the boundary between the two zones. A check and control point may be a vehicle washing bay, a cleaning station or footbath, for example. In this way, the 'clean' zone is quarantined from everywhere else.

? Essential practice

Do you use check and control points to control the movement of people, vehicles, plants and materials into the 'clean' zone?

Y N

Movement of staff/workers and visitors around the farm is a very common way for pests and diseases to spread. It is important to have and to follow work procedures on the farm which minimise the risk that a person will carry problems into a crop.

Work procedures need to cover every task that is involved in working within crops or in the greenhouse as well as when moving between crops or greenhouses and other structures. Work procedures also need to include when and how often a job must be done. The valuable thing about a work procedure is that by writing one, it helps you think about what you are doing or asking someone else to do, why you are doing it and what risks are involved.

There are a lot of different tasks that need to be completed around the farm and in the greenhouse. A work procedure needs to be developed to cover each and every job. Although it can seem like a lot of work initially, work procedures save time and money and reduce the risk of problems. Often you will not need more than a couple of lines or dot points to describe what has to happen and in what order.

A **general farm work procedure** might state that the roadways and buffer zones must be kept clean and free from plants and plant material. It might also state that all check and control points such as using footbaths and wash bays or vehicle restrictions must be observed by everyone when entering the 'clean' zone or going into a greenhouse.

Tasks to be covered with work procedures could include:

- Moving around the farm
- Transporting crop waste
- Taking delivery of materials
- Maintaining the buffer areas
- Mowing the grass
- Controlling weeds around the farm
- Moving product to the packing shed

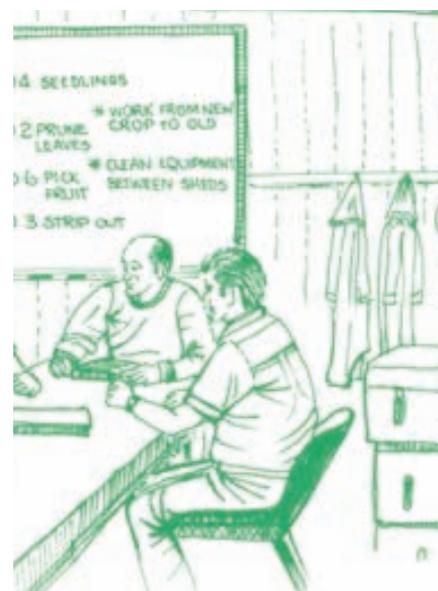
A **greenhouse work procedure** might identify the order in which crops are worked, how crops are to be managed, what the target growing conditions are, when and how a pest and disease check is conducted and what needs to be done when taking something into the greenhouse.

A greenhouse work procedure can be as simple as stating that greenhouses must be worked in the listed work order and that the list must be checked each day before work starts. A list of the order in which crops or greenhouses are to be accessed is then provided and kept up to date. This list might be written on a large whiteboard in the packing shed, for example. In this way, the order can be changed when needed (such as when a disease outbreak is found in one greenhouse) and is easily viewed by all staff or contractors.

An effective work order procedure involves working in the cleanest crop first then the next cleanest and so on. By doing this, the chance of spreading a problem is reduced. A work order list needs to be kept up to date according to what pests and diseases have been found in each crop. When there have been no observations of pests or diseases in any crop, the order needs to be from the youngest crop to the oldest.



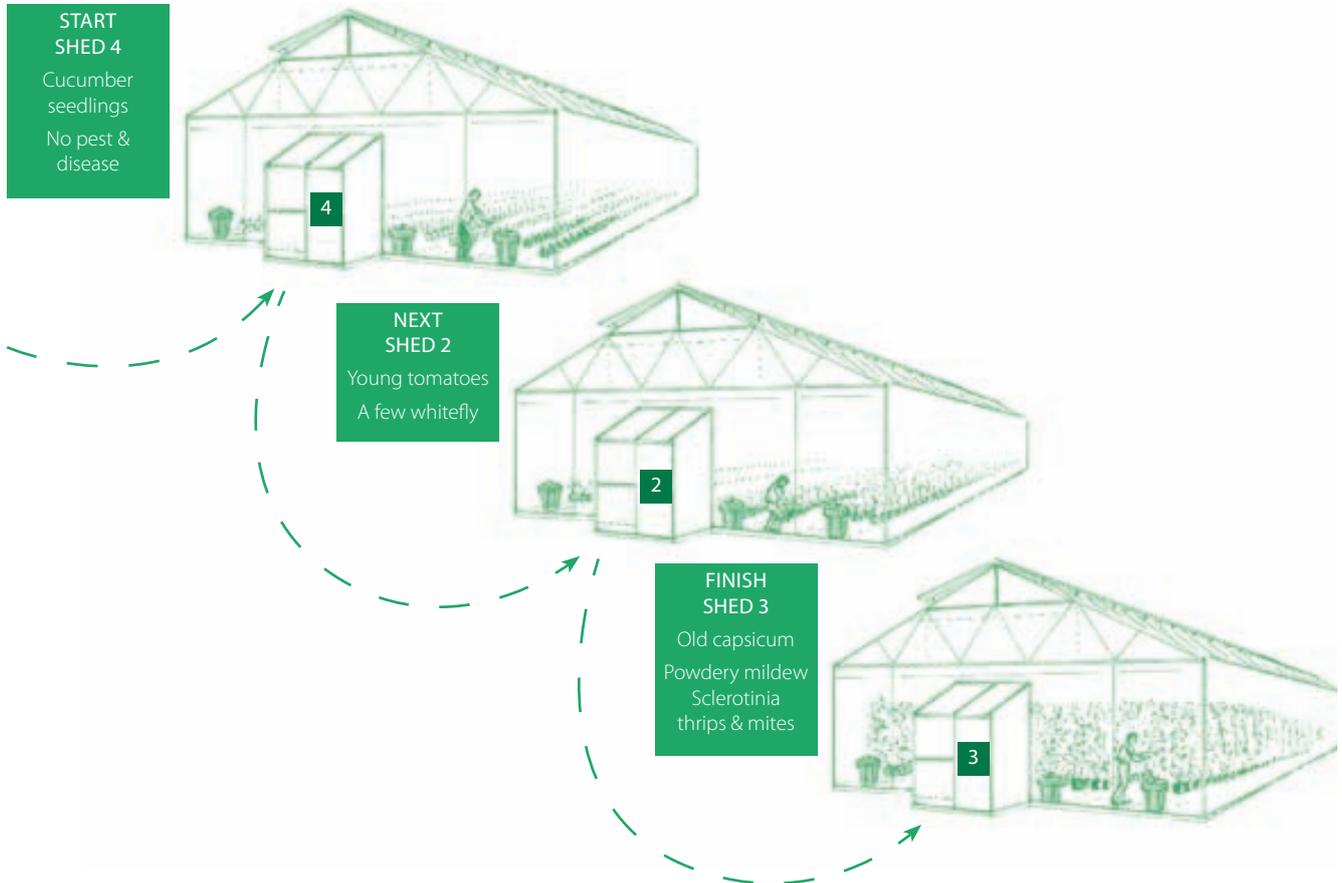
People moving around the farm is a common way for pests and diseases to spread



Good staff management reduces pest and disease risks

Simple work order plan:

- Work in cleanest crop first
- Work in youngest crop first
- Do all the 'dirty' tasks last in the day



A simple work order plan can reduce the spread of pests and diseases

It is important to make sure that all crops or greenhouses are prioritised for all jobs including monitoring and spraying tasks as well as general plant management activities.

If an area of a crop or greenhouse has an outbreak of a pest or disease, the contaminated area should be the last area to be worked on in that crop.

If the presence of pests or diseases is found in a crop during a work activity, it has to be reported and the work order list needs to be reviewed. It is a good idea for all workers to carry with them a couple of large coloured pegs or a roll of flagging tape so that an area can be easily marked.

A good idea, if feasible, is to do a routine pest and disease check before starting any job in the greenhouse that involves a lot of contact with plants such as pruning or harvest. See page 107 for information on monitoring.

When a job is completed in an infested or diseased crop (or part of a crop) the greenhouse work procedure needs to ensure that all tools are cleaned and disinfected and clothes are changed (or overalls and boot covers are replaced) before a person goes into the next crop.

The greenhouse work procedure can include more details to describe how tasks are done and what to do if a problem is found. Your greenhouse work procedure may cover tasks such as:

- Pruning and training
- De-leafing
- Harvesting
- Conducting a pest and disease check
- Batching nutrients
- Monitoring and recording electrical conductivity and pH of feed and drain solutions

- Reporting a pest or disease in a greenhouse
- Cleaning and disinfecting tools
- Cleaning and disinfecting the greenhouse
- Cleaning and disinfecting the hydroponic system

You also need to make sure that there is someone responsible for each job that needs to be done. For example, who is responsible for cleaning and refreshing footbaths? What process do you have to check that this is done?



Do you have written work procedures for all jobs that need to be done in and around the greenhouse and have you explained and provided these to your employees?

Y

N



Do you and your employees always work in the cleanest, youngest crop first and complete the 'dirty' tasks last in the day?

Y

N

Vehicles and deliveries

Vehicles coming onto a farm are a high risk for introducing a pest or disease. Delivery vehicles often travel from one farm to the next which creates a lot of opportunities for pests and diseases to hitch a ride onto your farm and into your crop.

All vehicles including trucks, tractors, trolleys and trailers used for transporting equipment or other items that will be taken into the greenhouse have the potential to spread pests and diseases. This can occur by the direct transfer of contaminated material from the wheels or other parts of the vehicle directly into the production area.

A vehicle management plan is needed. The access of vehicles has to be practical, but it also needs to reduce the risk that pests and diseases will be brought into your crop. There are basically two (2) strategies.

Either:

1. Do not permit any vehicle that has been off-farm, to enter the 'clean' (production) zone.
2. Completely wash down any vehicle that has been off-farm, before it enters the 'clean' (production) zone.

The most effective approach is to set up the farm so that vehicles which move on and off the property are never driven into the 'clean' area of the farm. The most common reasons for vehicles coming onto a property are employees and visitors, deliveries of farm inputs such as fertilisers, fuel, substrate and seedlings and transport of produce from the farm.

Visitors and workers do not need to drive into your 'clean' zone. Provide a parking area away from the production part of your farm, such as near the house where you park your own vehicle. Use signs to direct visitors and, if feasible, a closed gate to prevent anyone accidentally driving into the 'clean' zone.

The delivery of farm inputs and loading of produce needs to be carefully planned. You need to be able to stop the delivery vehicle (including your own vehicles) from entering the 'clean' zone but the materials themselves need to be unloaded or loaded. The best method to achieve this is to set up a stopping bay for all vehicles on the edge of the 'clean' zone. The deliveries can be made without the vehicle itself moving into the 'clean' zone. There are different ways of doing this.

A double entry storage and/or packing shed is a very good method. One entry faces the stopping bay for vehicles travelling off-site so that goods can be unloaded into the shed and produce can be loaded from the shed. The second entry faces the production area so that materials can be moved to and from the greenhouses and shed. The shed in this situation is the quarantine boundary between the 'clean' zone and the 'outside' zone.

If it is not practical to have a double entry shed, the same process can be used with an open-air loading bay marking the boundary between the 'clean' zone and the 'outside' zone.

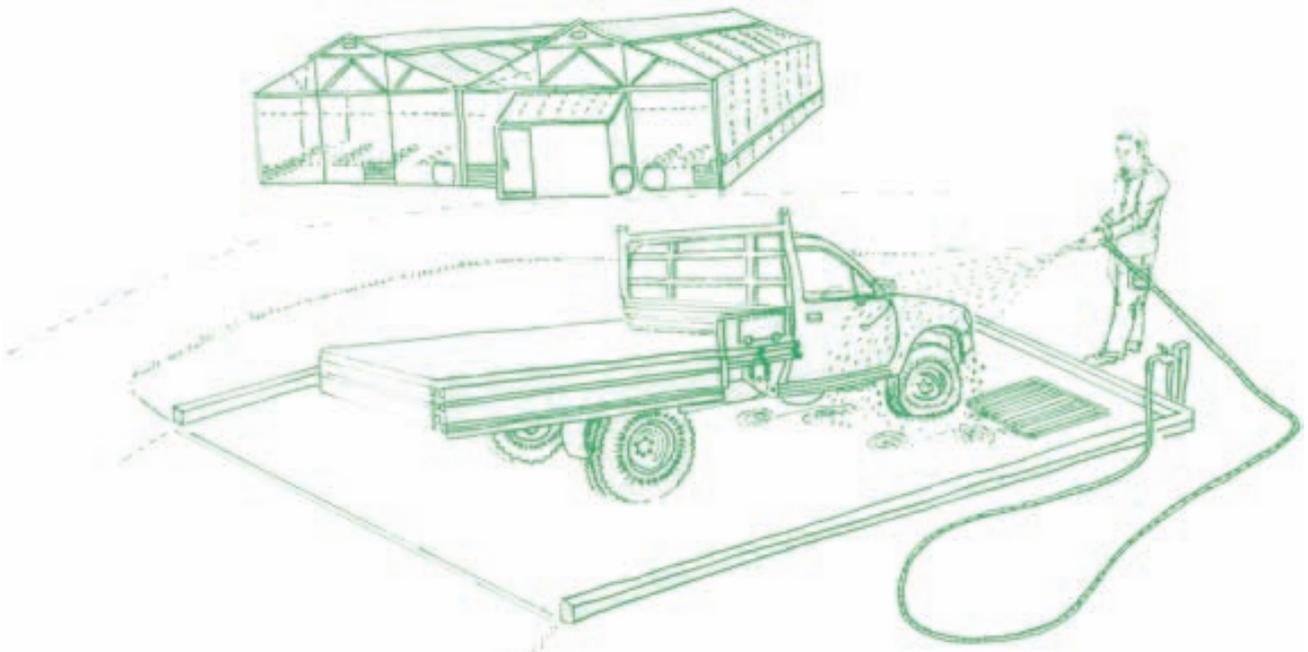
The access for gas or other fuels that may be delivered has to be carefully considered. The fuel storage tank needs to be located on the boundary between the 'clean' zone and the 'outside' zone or entirely in the 'outside' zone so that deliveries can be made without these vehicles entering the production area.

If it is not feasible to stop vehicles that have travelled off-site from entering the 'clean' zone, then it is essential that a wash down bay is set up on the boundary between the two zones.

Any vehicle that is used in or near the greenhouse or that will enter the production area must go into the washing bay and be thoroughly cleaned down before moving into the 'clean' zone.

Remove all rubbish and materials from the vehicle. A high pressure hose or steam cleaner needs to be used to remove soil and crop debris from the wheels and the undercarriage of the vehicle. Tray tops and flat beds should be swept clean and hosed off with clean water. If a vehicle has been in an area that is infected with a disease, it should be disinfected as well.

The washing bay needs to be a concrete slab large enough for the whole vehicle and a source of clean, high pressure water. Sufficient drainage is required to drain the wash water and plant and soil debris away from the production area. This wash water will need to be contained on-site. It could be used to irrigate gardens or grassed areas outside of the 'clean' zone. Tyres, wheels and the undercarriage of the vehicle need to be cleaned with high pressure water to remove all soil and plant material.



Thoroughly clean down all vehicles before moving them into the 'clean' zone

? Do you have a parking area for employee and visitor vehicles in the 'outside' zone of the farm? Y N

? Are all vehicles in the 'clean' zone kept free from soil, plant debris and rubbish? Y N

? Are all vehicles that travel off-farm ('outside' zone) always cleaned before entering the 'clean' zone? Y N

Buffer areas

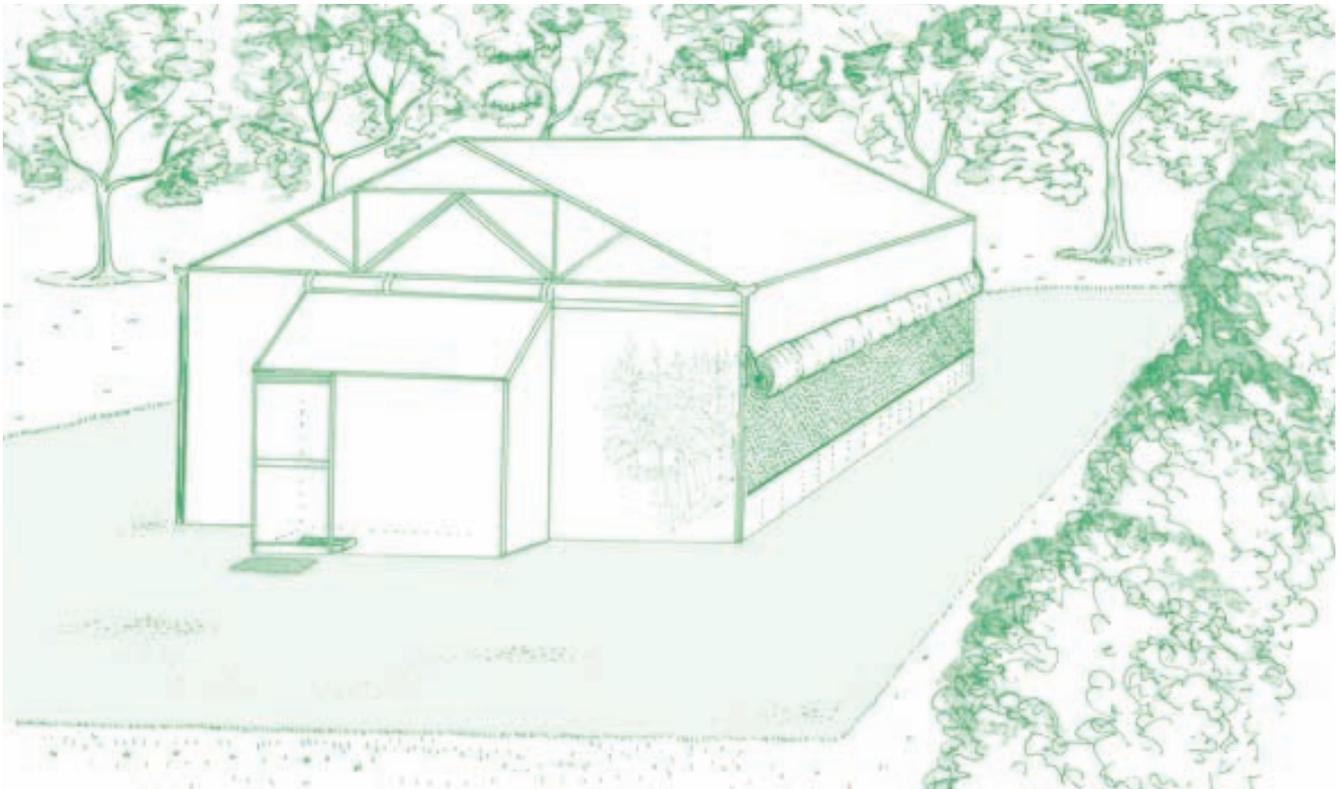
Buffer areas are an important and relatively low cost management strategy that reduces the risk of pests and diseases affecting your crop. A buffer area is a space that is kept clean or clear of things which could shelter pests or diseases. A 5-10 metre buffer area needs to be established around every greenhouse on the farm. The buffer area surrounding a greenhouse must be kept free of all plants, rubbish, old substrate and crop residues. This area should be sealed, covered in gravel or mulched.

" a 5 -10 metre buffer area is needed around every greenhouse on the farm "

? Essential practice

Do you maintain a 5 – 10 metre wide clean buffer area around every greenhouse?

Y N



Buffer areas are a very effective and low cost way to reduce pests and diseases

Weeds

Many plants found around farms are hosts of pests and diseases that can affect common crops. A weed management plan is a critical part of preventing pests and diseases causing damage to crops. Effective weed management involves knowing which plants are weeds and not allowing them to grow. Any plant in or near your greenhouse that is not the current crop, is a weed.

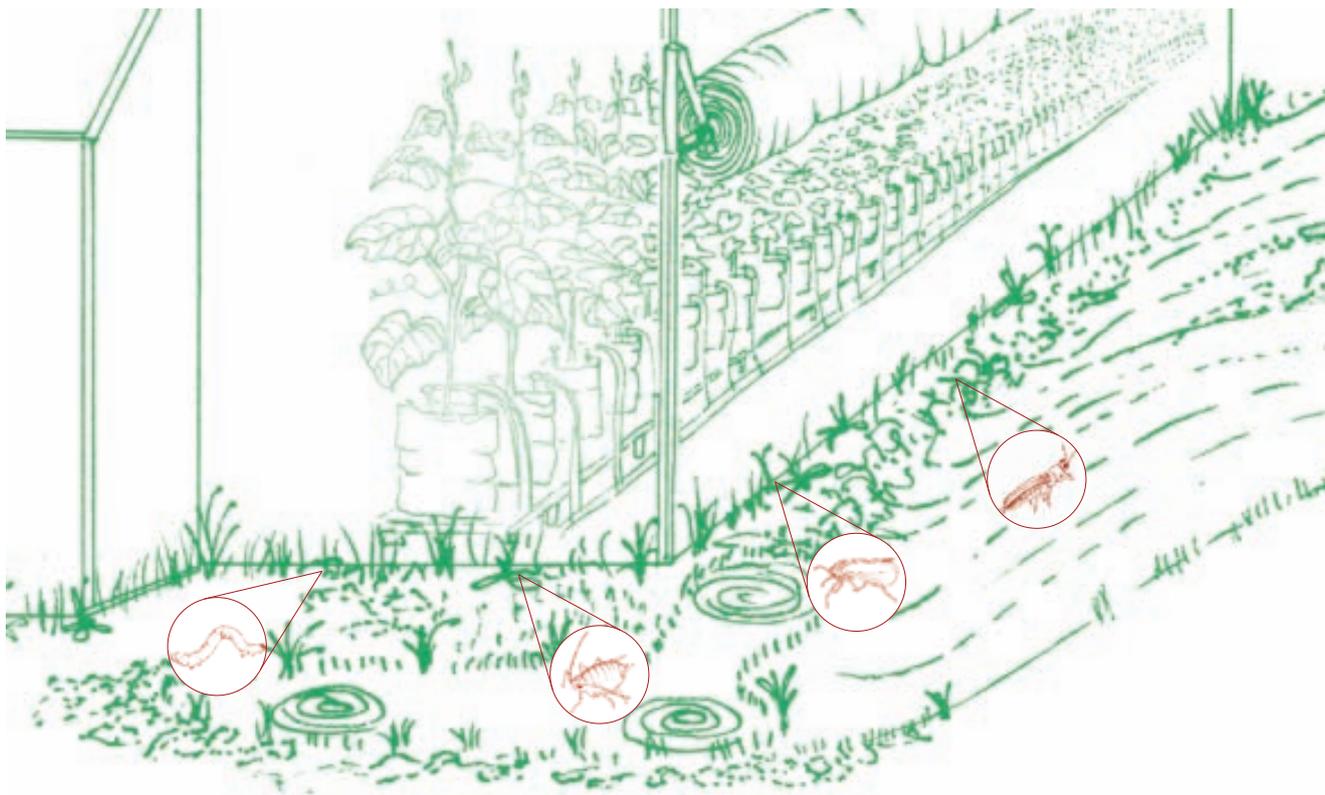
A list of common weeds and the pests or diseases that they can support is provided in Appendix 2. Volunteer crops which might grow from discarded crop debris and fruit are very serious weeds. There may also be some plants that are designated weeds in your region and need to be suppressed or eradicated even if they do not pose a direct problem for your crop.

Although knockdown herbicides might be used as a short term strategy to remove weeds from a property and reduce the seed bank of weeds, spraying weeds occasionally to kill them off is not an effective way of reducing the risk of pests and diseases affecting your crop. This is because as the weeds grow they provide a place for pests to breed and diseases to survive and so become a source of pests and diseases. Using a knockdown herbicide on grown weeds can then result in the problems simply moving into the greenhouse crop. The regular use of herbicides also tends to discourage grasses (that are a lesser threat) and encourage shallow rooting broadleaf weeds which can be a major problem. In addition, there is a high risk of herbicide drift causing problems in the crop if they are used around a greenhouse.

For many areas around the farm, regular mowing is preferred as it favours the grasses. Always keep the grass short and free of broad leaf and flowering plants.

Around the greenhouse, a weed free area is needed – not even weed seedlings. This may just be a 5 - 10 metre clean buffer area adjacent to the greenhouse which is kept completely plant free. Seal surfaces and remove all plants. For small areas between greenhouses or other structures, cover the ground with gravel, weed matting or mulch to prevent plants from growing. For even better results, maintain a larger weed free area, especially on parts of the property that are in the direction of prevailing summer winds.

A valuable strategy is to plan and work with neighbours to establish an area-wide weed management program. In some regions native revegetation strategies have been developed using selected species of plants that are not a refuge for pests.



Always keep the greenhouse and farm surrounds weed free

? Essential practice

Do you keep the greenhouse and farm surrounds weed free?

Y N

? Do you have a neighbourhood agreement for managing weeds?

Y N

Windbreaks and vegetative screens

Many pests and diseases are spread by the wind. Putting windbreaks around the farm or production area can reduce the levels of pests and diseases which might be carried into the greenhouse. A windbreak could be a structure such as a screen fence or more commonly, a hedgerow of plants. There are specific ways in which to construct or plant an effective windbreak. There are a couple of simple guidelines.

When planting a windbreak, aim to use 3 rows of plants. Use a mix of appropriate evergreen species, preferably native to your area. A vegetative windbreak will provide protection for about 6 times the height of the plants. For example, a 3m tall hedgerow will provide wind protection in an area about 18m wide on the leeward side.

To avoid shading, the windbreak needs to be a distance 2 – 3 times the height of the plants away from the greenhouses. This will vary depending on the topography of the site.

Vegetative windbreaks may also provide habitat for beneficial organisms such as birds, spiders and predatory insects that can help reduce pests on your farm. It is important to think carefully about the types of plants which are used to avoid creating problem areas. The windbreak needs to be kept free of problem weeds.

A grower guidebook for using native vegetation, produced by the South Australian Research and Development Institute (SARDI) is a good starting point. While the species of plants identified are particularly suitable for growers in South Australia, for growers in other regions, the idea is important and hopefully, suitable native species will be identified for all growing regions. The SARDI grower guide can be downloaded from the SARDI website.

http://www.sardi.sa.gov.au/pages/ento/hort_pests/reveg.htm:sectID=212&tempID=1

Generally grasses offer less of a habitat for key pests and diseases. Clumping bamboos may be good options for windbreaks closer to the greenhouse in some areas.

An artificial structure such as a screen fence may be suitable in some situations. It is important to note that an effective windbreak can not be a solid structure because this will actually cause wind to drop material onto the area behind the windbreak. A windbreak needs to filter wind and slow it down – not completely block it.



Do you have windbreaks established around the farm or greenhouse?

Y

N

Maintain clean surfaces

Depending on the size of your property you may have a number of internal roads, laneways and paths. These provide access to all areas of your property and need to be kept clean and in good condition. Wherever feasible, roadways should be sealed. At a minimum, roads need to be constructed from compacted road-base or other material. The highest priority is roadways in the 'clean' zone and then the main driveway which delivery vehicles use. Exposed soil around the greenhouse greatly increases the risk of pests and diseases entering the crop. If it is not possible to seal a road in the 'clean' zone, consider covering it with gravel, weed matting or even a thick layer of wood chips or bark mulch.

Roadways and pathways can be used as part of the 5 - 10 metre clean buffer area around greenhouses. Roads and paths must be kept free of plants, plant material, soil and other debris. Make sure that there is good drainage so that soil and other debris does not wash onto roads. Keeping roadways and pathways clean minimises the risk that vehicles, trolleys and people will carry problems around the farm and into the greenhouses.



Are the roadways and pathways in the 'clean' zone sealed or covered?

Y

N



Are the roadways and pathways in the 'clean' zone free from soil and mud, weeds, plant debris and rubbish?

Y

N

The greenhouse

Sealed surfaces are easier to clean and keep clean than old and damaged materials. The floor of a greenhouse should be covered so that it is easily swept and washed. Plastic floor covering is ideal. White plastic is more expensive and improves light levels reaching the crop and is better for temperature management. Weed matting is the most commonly used covering material.

Breaks, tears and gaps in covering materials, such as weed matting, greatly reduce your capacity to effectively manage pests and diseases. It is very important to always keep floor coverings well maintained.



Are the floor and other surfaces in your greenhouse covered for easy cleaning?

Y

N

Sheds and other structures

Sheds are essential infrastructure on any farm. Sheds are used for storage, packing crops for market and protection for pumps and equipment. It is important that they are well-maintained and kept clean and tidy so that these areas do not become a source of pests and diseases of your crop. Floors should be cement, or of another solid cleanable surface. Keep floors completely free of all plant debris, soil and substrate. Regularly sweep out sheds.



Are floors and other surfaces of all the sheds in the 'clean' zone sealed or covered for easy cleaning and regularly cleaned?

Y

N

Water and drainage

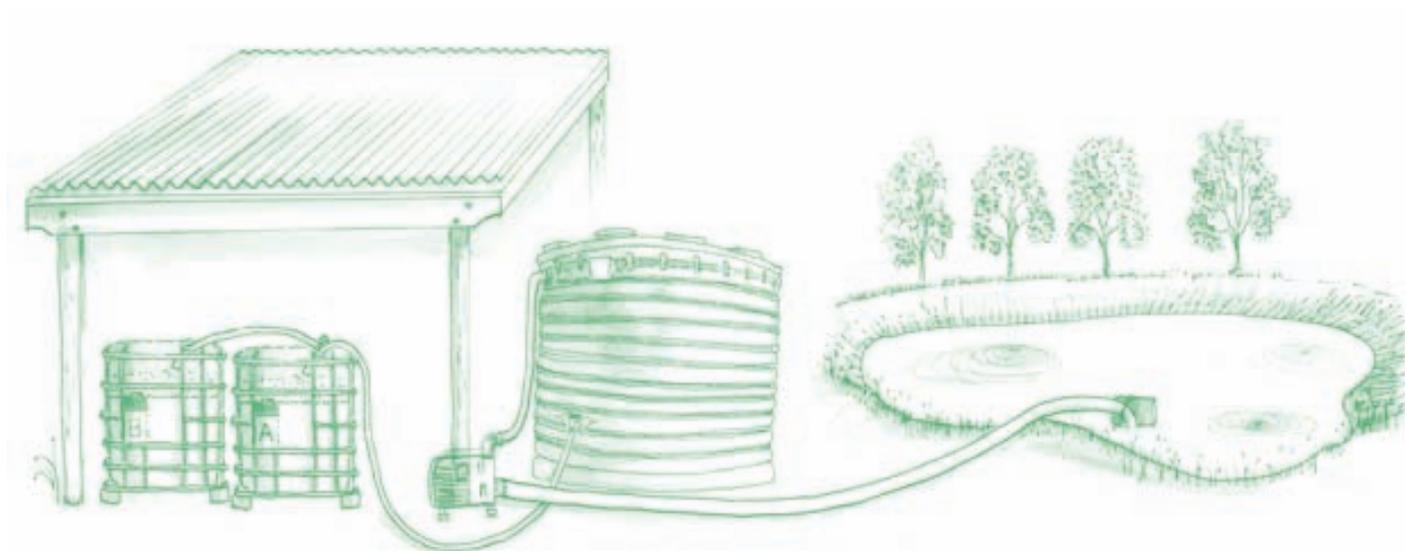
Clean water supply

Water is a very important part of any farm. How it is managed on the property and delivered to the crop has an impact on pest and disease management. A reliable supply of clean, quality water is necessary.

Only water that has been disinfected should be used in the 'clean' zone. This includes all water used for irrigation, cleaning and cooling. New and recycled water must be disinfected with the exception of municipal water supplies which have already been treated with chlorine.

It is good practice to have a clean water storage capacity on the farm as well so that supply can be maintained even if there is a temporary problem with incoming water or the disinfection system. When storing disinfected water, make sure that the tank or reservoir is closed to minimise the risk of dust or debris causing recontamination of the water.

There are a number of methods for disinfecting water. These range from the simple addition of chlorine through to the use of other chemical sanitisers and ultra violet (UV) radiation. When selecting a disinfection system, you need to consider factors such as set up and operating costs, reliability, maintenance, safety and environmental impact as well as the level of disinfection achieved (and the type of diseases removed). There is more information on water disinfection in Appendix 3.



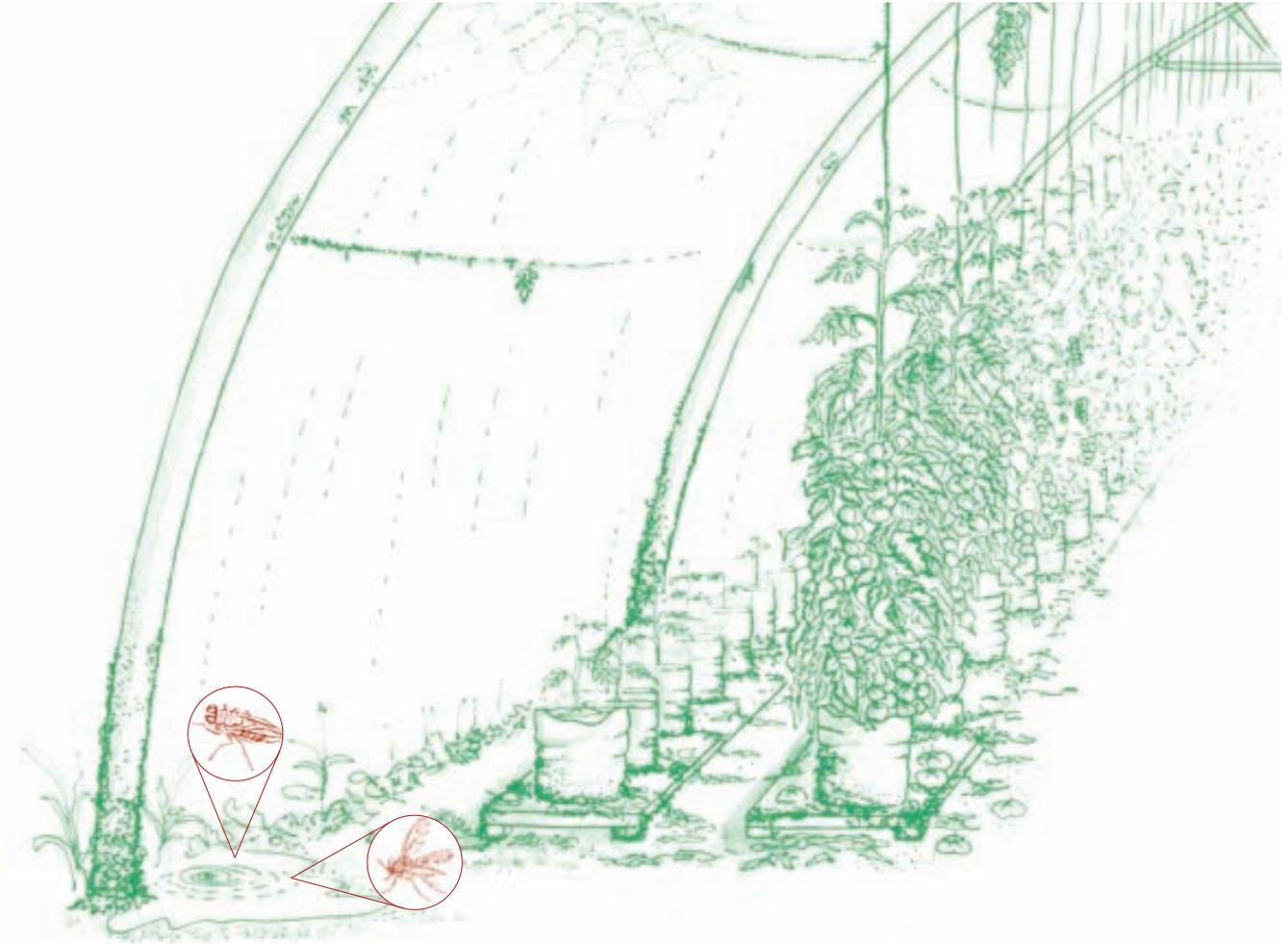
Only water that has been disinfected should be used in the 'clean' zone

Drainage and waste water

Good drainage around the greenhouse is important in reducing the risk that diseases will get into the greenhouse. Drainage needs to be planned in the context of the roadways and farm topography. Make sure that surface run-off and storm water can not wash dirt or debris into the greenhouse or onto roadways. Prevent algae from growing in drains, channels and in other areas of the greenhouse.

It is important to not have wet boggy areas or puddles in the 'clean' zone. Puddles and muddy areas are a breeding ground for some pests and diseases. These need to be drained or filled in. This also makes the farm much easier to keep clean. Maintain roadways and paths around greenhouses to prevent puddles forming and keep drains clear to avoid flooding.

Run-off from the crop also needs to be drained away from the crop. Treating and recycling water in the greenhouse can have large cost savings.



Wet or muddy areas are a breeding ground for some pests and diseases

? Is all the water to be used in the 'clean' zone disinfected and is disinfected water stored so that it can not be contaminated?

Y N

? Does your farm drainage ensure that there are no puddles or wet areas in the 'clean' zone and surface run-off does not wash into the greenhouse?

Y N

Manage rubbish

Rubbish includes crop debris, plastics and packaging and other rubbish, old and broken equipment and used substrate. All types of waste can provide pests and diseases with refuge from where they can then affect your crop. Not managing waste on the farm also causes a lot of other problems including environmental pollution, safety issues and gets in the way of farm work – costing you time and money.

Minimise the amount of rubbish that is allowed to collect on the property before disposal. Always make sure you have a specific place – well away from the greenhouses – where material can be neatly stored until disposal. A large waste bin (eg skip bin) which is regularly emptied is a good practice.

Never leave rubbish and used materials in the buffer zone around the greenhouse or production area or inside the greenhouse.

Remove and dispose of crop debris as soon as possible after pruning and harvest. Do not pile plant material near the greenhouse. Dispose of crop debris out of and away from the 'clean' zone. Crop debris can be buried if done immediately. Do not stockpile it. If you are composting crop debris on-site, shred the material to reduce the volume and speed up decomposition. Keep compost piles well away from the clean zone.

Solarisation

Crop debris can also be solarised. Solarisation is a process in which the plant material is sealed in plastic and exposed to the sun for several weeks which essentially cooks it. The radiation from the sun is converted to heat and the plant material is heated to more than 60°C which kills many pests and diseases and speeds up the decomposition of the crop debris.

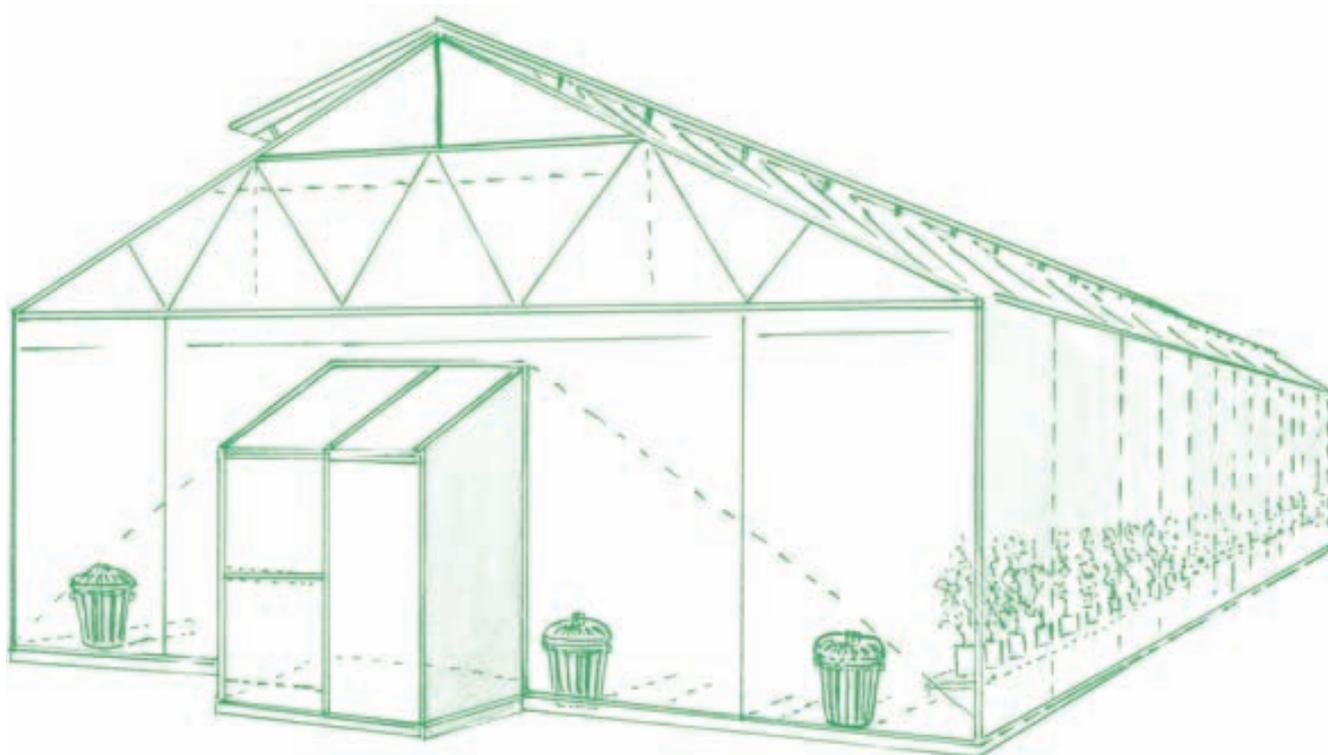
For small amounts of material such as a few individual plants that have been removed from the greenhouse because of infection (rogued), a sealed garbage bag can be used.

For large quantities of plant material, such as after a crop has been cleaned out of the greenhouse, make a pile of material and cover the pile with clear plastic film. A freshly removed crop would normally contain sufficient moisture for solarisation to be effective, however, if conditions are very dry or the plant material is dry, dampen the plant material or ground under the pile before covering with plastic and seal the edges. It is important that there are no gaps, leaks or holes to allow air to escape. Large, intact sheets of old greenhouse cladding can be used for solarisation.

If a greenhouse is not being used for a period of time over summer, it can be cleaned, left damp and closed up to achieve a degree of solarisation as well. This may help to disinfect a greenhouse if used in addition to cleaning and chemical disinfection if a crop has had a severe disease problem, but solarisation should not be relied upon as the only method of disinfection.

Bins

Bins are one of the simplest and cheapest yet very effective ways of reducing pest and disease problems. Put a small 'day' bin with a lid in convenient locations such as near entry ways to every greenhouse and shed and work area. Use these bins for rubbish and small amounts of crop debris that might be collected in between pruning tasks. Use a plastic bag in the bin so that it can be easily taken out, sealed and disposed of and the bin stays clean. If you operate a very large greenhouse, consider having bins located conveniently around the greenhouse. Nothing should ever be dropped on the ground – it should always be put in a bin.



Bins are one of the simplest and cheapest yet very effective ways of reducing pest and disease problems

The greenhouse 'day' bins must be emptied frequently to avoid a breeding place for pests and diseases. A good practice is to empty the bins as the last task of the day in each greenhouse. Have a supply of plastic bags nearby so that they can be replaced easily.

Use 'pruning' bins. A 'pruning' bin is a small bin that can be moved along the crop rows during the pruning jobs. One of the simplest methods is to fasten a garbage bin to a small trolley or use a small 'wheelie' bin. When pruning, put plant material directly into the bin or a bag for disposal – not on the ground. Pruning bins need to be emptied at the end of the pruning task for each greenhouse. If a pruning bin is used in more than one greenhouse, it needs to be emptied and cleaned before being used in the next greenhouse.

Bins can also be very useful when removing whole plants that are heavily affected by pests or disease. Using a bin with wheels (or on a trolley), position the bin next to the plant to be removed. Cut the base of the stem and put the hanging plant into the bin then remove the support clips or cut the string so that the plant, with all the pests and disease, is captured in the bin. This avoids dragging the plant across the floor of the greenhouse and spreading the problem further.

? Essential practice

Is crop debris removed and stored/disposed of outside of the 'clean' zone and away from the greenhouse?

Y N

? Is all rubbish removed and stored/disposed of outside of the 'clean' zone and away from the greenhouse?

Y N

? Do you have a waste bin located away from the greenhouse for management of bulk waste and which is emptied regularly?

Y N

? Do you have small 'day' and 'pruning' bins located conveniently in or near the greenhouse and which are emptied frequently?

Y N

Greenhouse sanitation

Sanitation is the cleaning and disinfecting (sanitising) of surfaces to remove or kill diseases. It is an essential part of pest and disease management because many pests and diseases can remain alive in the greenhouse between crops and then get into the new crop when it is planted.

Greenhouses must be completely cleaned and disinfected between each production cycle.

“ cleaning and disinfecting are essential for good pest and disease management ”

Everything inside the greenhouse needs to be cleaned and kept clean. Sanitation is a simple and affordable control strategy that has proven and substantial benefits. This means that unless sanitation is used as a primary part of your pest and disease management strategy, it is rarely economical to use any last resort strategies such as pesticides.

Sanitation is about doing everything you can to make sure that all equipment and every surface inside the greenhouse are free of pests and diseases before planting a crop. **Sanitation is essential even if you did not notice any pests or diseases in the previous crop.**

It is not possible to thoroughly clean and disinfect a greenhouse if the crops are grown in soil. A hydroponic production system on sealed or covered floors is easier to keep clean. If changing to hydroponics is not feasible (or desirable), then you will need to look at other strategies such as adding compost to increase organic matter in the soil and using suitable biological additives to the system to suppress diseases and their impact on plants.

Disinfection

Disinfection is a key part of sanitation and keeping a greenhouse clean. There are a range of disinfectants available. How well a disinfectant works is affected by a number of different factors including the concentration of the product, the pH, the time the disinfectant is in contact with the target microorganisms (contact time), the humidity and temperature and importantly, how much organic matter is present.



Everything inside the greenhouse needs to be cleaned and kept clean

No single disinfectant is effective in all situations. When selecting a disinfectant to use, it is important to consider:

- The target diseases
- The surface type to be disinfected and whether there are any potential interactions between the disinfectant and the materials to be cleaned
- The amount of contact there will be between the disinfectant and the disease
- The length of effective contact time available
- The concentration to be used

To disinfect a greenhouse prior to planting a new crop, it is essential that the surfaces to be disinfected are cleaned of organic matter and soil. Most disinfectants, especially chlorine are rapidly deactivated by organic matter.

Items or equipment removed from the greenhouse, including those used for cleaning (for example brooms, buckets and hoses), must also be decontaminated before being taken back inside the greenhouse.

The floor of a greenhouse, if not concrete, needs to be covered in plastic sheeting or at a minimum, weed matting. The type of surface can have a big impact on how effective disinfection will be. A smooth plastic surface is ideal for disinfection.

Things to consider

Organic matter

Make sure all organic matter (crop residues, algae and used substrate) as well as soil is cleaned out of the greenhouse before using a disinfectant. Most disinfectants are deactivated or are generally less effective if there is organic material present.

Temperature

When using a disinfectant, high temperatures can speed up the evaporation of the product which in turn reduces the contact time and therefore the efficacy. Avoid extremely hot conditions when disinfecting.

pH

The pH of the water can affect disinfectants. For example, chlorine is most effective at a pH range of 6 – 8. Make sure the water used to mix up the disinfectant is suitable.

Health, safety and the environment

Always consider the dangers and risks of a chemical including disinfectants. Some disinfectants may be harmful to people or animals, especially fish. When selecting and using a disinfectant, make sure you have considered and managed issues such as run-off into drains and waterways.

Information about the various types of disinfectants is provided in Appendix 3.

? Is appropriate disinfectant used for sanitising the greenhouse, tools, shoes and other equipment?

Y N

The greenhouse *clean out*

The greenhouse clean out needs to be done as soon as the crop is finished. It is a very important job. The old crop and the growing substrate are completely removed from the greenhouse. All plant material – leaves, stems, dropped fruit, weeds – is also removed.

The clean out activity creates an immediate break between crops which helps to reduce the carry-over of pests and diseases.

The greenhouse *clean out*

(as soon as crop is finished)

1. Remove old crop and dispose of material away from greenhouse
2. Remove and dispose of items that will not be reused including substrate, bags, twine.
3. Remove from greenhouse all equipment, tools, plant containers, bins, clips and truss supports, plant hangers, dripper stakes and emitters and other items that will be reused.
4. Sweep down walls, floors and all internal structures. Remove all plant material.

? Are old crops completely removed from the greenhouse at the end of the crop?

Y N

? Is used substrate completely removed from the greenhouse at the end of the crop?

Y N

The greenhouse *clean up*

The clean up activity provides a fresh starting point for the next crop and ensures that there are no pests or diseases carrying over from the previous crop. It is an extremely important job.

It is essential to have a work procedure for the greenhouse clean up that describes each step in cleaning the greenhouse. This can then be followed by everyone, each and every time the greenhouse is cleaned. Make sure that who ever is in the greenhouse when any disinfectant is used, wears personal protective equipment – including a respirator.

Everything must be washed and everything must be disinfected. A pressure washer is a very good idea. Pressure washers are more water efficient, do a better job at cleaning than a normal hose and cleaning products can be injected into the water.

The greenhouse *clean up* (before a new crop is planted)

1. Wash the walls, floors and all internal structures, including drains with a high pressure hose and detergent.
2. Rinse walls, floor and all internal structures with clean water.
3. Clean and disinfect the hydroponic (irrigation) system.
4. Open up greenhouse and allow surfaces to dry.
5. Wash walls, floors and all internal structures with a 0.5 – 1.0% chlorine solution or other appropriate disinfectant (wear personal protective equipment including a respirator).
6. Rinse walls, floor and all internal structures with clean water.
7. Close up greenhouse with just a small amount of vent opening and leave to dry.
8. Wash and refill footbaths.
9. Clean all equipment, tools, plant containers, bins and other items to be returned to greenhouse.
10. Disinfect all equipment, tools, plant containers, bins and other items to be returned to greenhouse.
11. Set up greenhouse for next crop making sure that no items, tools or equipment get contaminated.

? Essential practice

Is the greenhouse always cleaned and disinfected before planting new crop?

Y N

? Are all equipment, tools, containers, bins and other items completely removed from the greenhouse before the clean up?

Y N

The hydroponic (irrigation) system *clean up*

The whole hydroponic system has to be cleaned and disinfected before a new crop is planted. The cleaning needs to include the tanks, pipes, emitters, all the plant containers, bags or channels as well as the drainage lines. This needs to be part of the greenhouse cleaning plan (Step 3 in the example work procedure for greenhouse clean up above).

In set ups where plant containers or bags sit on a surface such as raised boxes or the greenhouse floor, a sheet of plastic should be used under the containers or bags so that it can be replaced or readily cleaned between crops.

Growing substrate

All substrate and growing containers need to be completely removed from the greenhouse before cleaning. If reusing a substrate, it needs to be steam sterilised before putting it back into the greenhouse. Reusing a substrate without steam sterilising it first significantly increases the risk of pest and disease problems in the next crop.

? Is the hydroponic (irrigation) system always cleaned and disinfected before planting a new crop?

Y N

The hydroponic clean up

(Step 3 of greenhouse clean up)

1. Remove pH and EC and any other sensors from the irrigation system.
2. If nutrient concentrate tanks are empty, wash them with a high pressure hose and detergent then rinse with clean water. Wash with a 0.5 – 1.0% chlorine solution (wear personal protective equipment including a respirator), then rinse with clean water.
3. Flush irrigation lines with phosphoric acid (pH of 1.5 – 1.8). Hold acid solution in irrigation lines for 12 – 24 hours, if possible. (Keep greenhouse vents open when acid washing irrigation lines).
4. Rinse irrigation lines with clean water.
5. Soak all dripper stakes and emitters overnight in a chlorine solution (0.5 – 1.0%), phosphoric acid solution or other appropriate disinfectant.
6. Flush irrigation lines with chlorine solution (0.5 – 1.0%) or a phosphoric acid solution. (Wear personal protective equipment including a respirator).
7. Rinse irrigation lines with clean water.
8. Rinse dripper stakes and emitters with clean water and return them to the greenhouse and refit.
9. Conduct an irrigation distribution uniformity test on the system.

Quarantine and Exclusion

After investing time and money in cleaning your greenhouse and hydroponic system and installing barriers to make it harder for pests and diseases to get in, it is vital that the risk of carrying pests and diseases in is also minimised. This comes down to quarantine and exclusion. The check and control points identified as part of the farm set up are the basis to excluding pests and diseases.

Do everything you can to reduce the chance that anyone or anything going into your greenhouse may be carrying a pest or disease. Everything going into the 'clean' zone and again everything going into the greenhouse must be checked, cleaned and disinfected first. You need to be especially careful with any item that is not new. If you are reusing anything used with a previous crop, it must be well cleaned and disinfected.

Plants

Seedlings

If buying seedlings, inspect them upon delivery – before they are moved into the clean zone. If any plants have disease symptoms, tell the delivery person and supplier immediately. Remove the diseased looking plants and submit them for diagnostic testing. Have a special designated clean, insect-screened area or quarantine greenhouse away from your production greenhouse in which to store seedlings prior to transplanting them. Seedlings need to be placed on raised benches or racks – never on the ground.

“ do not plant out any seedlings that are diseased or infested with pests ”



If propagating your own seedlings, have a separate quarantine nursery greenhouse away from your production greenhouse. Before moving any plants into the production greenhouse, check them for signs of pests or diseases. Do not plant out any seedlings that are, or appear to be, diseased or infested with pests.

“Pet” plants

Personal or “pet” plants should never be grown in the commercial greenhouse. Like weeds, these plants can act as a source of pests and diseases, making prevention more difficult and costly.

Each greenhouse needs to be run as a ‘single crop’. This means that all plants in a structure need to be of the same species and same age. Grow pet plants in the garden instead.

Root zone separation

Many pests and particularly diseases spread easily from one plant to the next one in the root zone. Maintaining a quarantine barrier between plants is valuable.

Make sure all run-off water drains directly to a drainage channel and out of the greenhouse. The way a substrate hydroponic system is set up is very important. All surfaces and drainage channels need to be designed so that the run-off from plants in one bag or container can not touch the roots of other plants. Plant containers should be held above the drainage channels to make sure that there is good drainage.



Say “no” to pet plants in the greenhouse

? Essential practice

Are all seedlings checked and found free of pests and diseases before they are planted out?

Y N

? Do you only grow a single crop at a time in each greenhouse and keep the greenhouse free from non-crop plants such as “pet” plants?

Y N

? Does the hydroponic set up prevent plant to plant contact of run-off water?

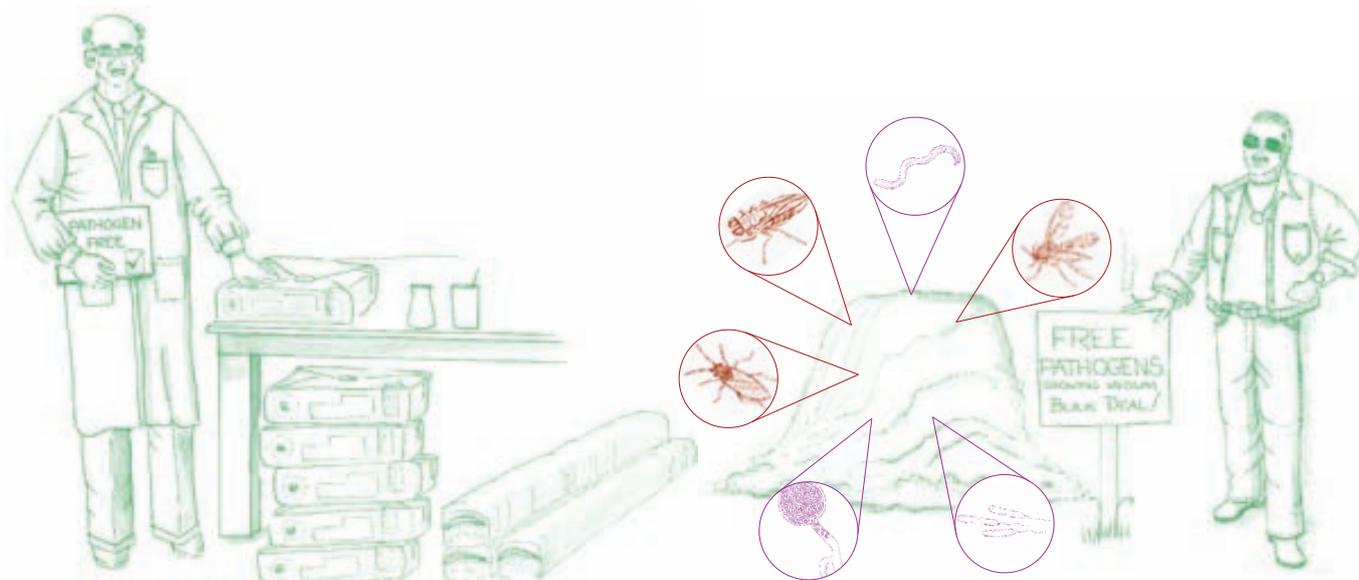
Y N

Substrate, plant containers and soil

Only ever use a clean, pest and disease free substrate. If in doubt, do not use it.

Some substrates including perlite, rockwool and foam are sterile and therefore, as long as the bags are not soiled, they can be moved straight inside the greenhouse. Some substrates such as cocopeat, are typically free of pests and diseases so again, unless the bags are soiled, they can be moved straight inside the greenhouse.

“ only ever use a clean, disease free substrate ”



Any substrate that is purchased in loose bulk loads and bagged onsite, for example cocopeat and sawdust, must be kept clean. An undercover, soil free storage and bagging area is essential. Do not store substrate outside or exposed to wind, rain or surface water or near crop waste. Make sure that the delivery vehicle does not contaminate the storage area.

When setting up for a new crop, it is absolutely essential that all containers to be used in the greenhouse are clean and disinfected before being taken inside. Grow-bags and slabs must also be clean. Containers and bags need to be filled and transported to the greenhouse without becoming contaminated. This means that they should never be placed on the ground or left exposed to wind and rain.

If anything has been in contact with the ground outside or remained exposed to wind and rain for a period of time, it needs to be cleaned before being taken into the greenhouse.

Reusing substrates increases the risk of disease problems, and some pest problems, in a new crop. If you are going to reuse a substrate, it must be steam sterilised before taking it back into the greenhouse. If the substrate has lost more than 10% of its original height, it should not be reused because its physical structure has deteriorated.

Sawdust needs to be replaced with every crop. Compost and potting mixes should only be used if they have a suitable physical structure and are guaranteed free of plant diseases. Compost and potting mixes need to be replaced with every crop.

Cocopeat can be used for 2 – 3 crops, perlite and rockwool slabs can be reused for 3 – 4 crops provided they are steam sterilised before reuse (10 minutes at 100°C or 20 minutes at 75°C). Avoid reusing a substrate from a crop that had a significant disease problem.

Soil

Growing in soil is a major challenge with respect to greenhouse hygiene. Many crop diseases survive for long periods of time in soil and a lot of pests live in or on soil at some stage during their lifecycle. Grafting onto disease resistant rootstocks can provide another disease management strategy.

A large amount of resources need to be invested in making sure that the soil is healthy, pest and disease lifecycles are disrupted (for example, with crop rotations) and the biological, chemical and physical properties of the soil are appropriate for the crops you are growing. This includes careful fertiliser and irrigation management and maintaining sufficient organic matter levels in the soil.

When significant pest or particularly disease problems exist, unlike in hydroponics where the substrate is easily replaced, soil may need to be fumigated.

Hydroponics offers a significantly more efficient way to grow in greenhouses and substantially improves your capacity to preventatively manage pests and diseases.

If soil in a greenhouse needs to be fumigated, a certified contractor must be used. Remove all the equipment and materials from the greenhouse and remove as much of the old crop as possible then thoroughly plough in the residue. Allow plenty of time for the crop debris to decompose otherwise the fumigation may not be effective. Never fumigate soil that is too cold, too wet or too dry.

? Do you only use clean, pest and disease free substrate (new or sterilised) for each new crop? Y N

? If growing in soil, are the biological, chemical and physical properties of the soil appropriate for the crop? Y N

? If growing in soil, is it solarised or fumigated with an appropriate and registered product between crops? Y N

Clean tools and equipment

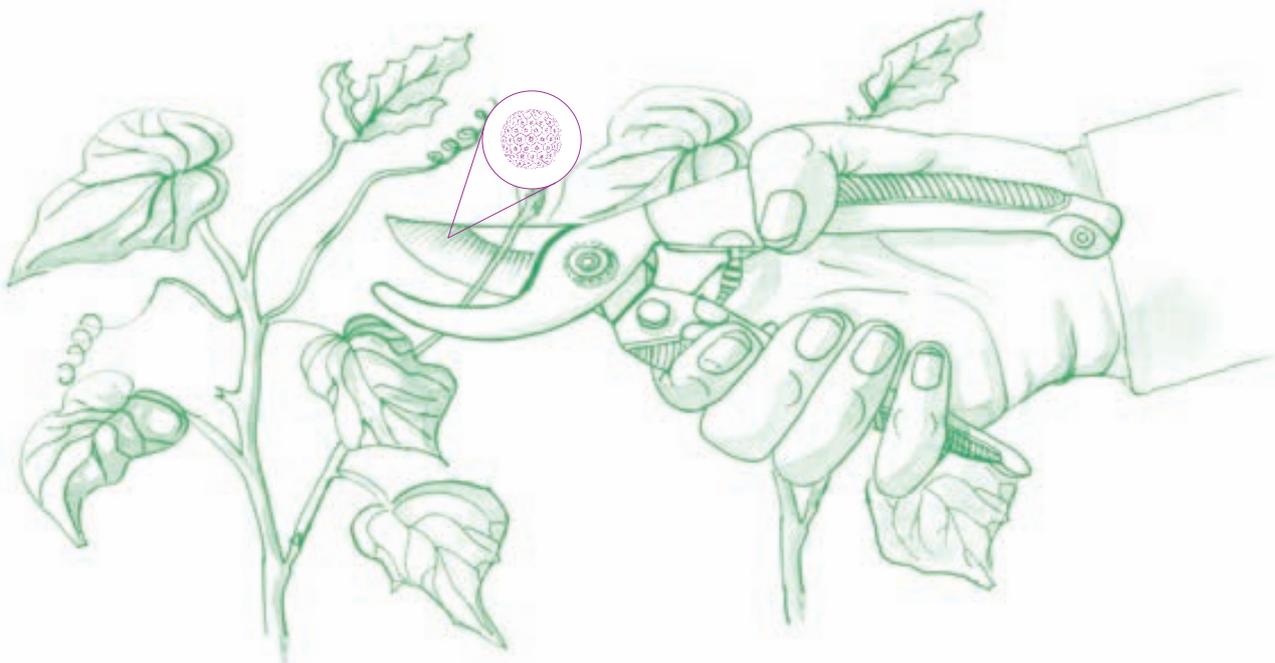
All tools and equipment being used in a crop need to be cleaned and disinfected before being taken into the greenhouse. Because tools and some equipment are often moved around, a cleaning station needs to be set up at each greenhouse entry way in a convenient central position. This is an easy way that helps ensure all tools and equipment are cleaned before being taken inside. Common items that are frequently taken into and out of a greenhouse include knives and secateurs, picking buckets and pruning bins as well as pollinators, brooms and trolleys. Mobile telephones and other personal items are also a risk.

A cleaning station is a covered bench or cupboard that is kept stocked with clean rags and suitable disinfectant such as trisodium phosphate. All tools and other items can be quickly wiped down before being taken into the greenhouse.

If feasible, for equipment such as brooms, ladders and trolleys, consider having a separate set for each greenhouse.

When using pruning tools in a crop, it is important to routinely disinfect them. This needs to be done every 5 – 10 plants. Use a tool belt with a container of disinfectant (such as trisodium phosphate) so that secateurs and knives can be easily dipped and disinfected.

Do not move tools or other equipment from an area of a crop which has a pest or disease problem into the remainder of the crop without cleaning and disinfecting them.



When using pruning tools in a crop, routinely disinfect them

Containers and materials

All materials and containers that you will use in the greenhouse need to be cleaned and disinfected before they are taken into the greenhouse. This includes seedling trays, pallets and picking boxes. Containers such as boxes or bins used to hold pruning waste and discarded fruit must also be cleaned and disinfected before being taken into the crop. Hose off containers to remove all soil, substrate and plant material. Soak in a solution of chlorine (0.5%), phosphoric acid or another appropriate disinfectant overnight. Allow to drain and dry in a clean area.

Do not allow cleaned containers and equipment to be put on soil or other dirty surfaces.

Crop support twine must be clean. Never reuse twine from a diseased crop. If you are reusing twine, it needs to be disinfected. Reusing twine creates an increased risk of disease problems in a new crop.



Set up a cleaning station at the greenhouse entry or other convenient location

? Is a cleaning station set up at the greenhouse entry or other convenient location for sanitising tools before taking them into the greenhouse? Y N

? Are all containers (bins, boxes, tubs, buckets and trays) and other materials (eg twine and crop supports) to be used in the greenhouse cleaned and disinfected before being returned to the greenhouse? Y N

? Are all tools and equipment (eg knives, secateurs, brooms and trolleys) to be used in the greenhouse cleaned and disinfected before being returned to the greenhouse? Y N

? Are pruning tools regularly disinfected during the pruning task and when used in a diseased area of a crop, cleaned and disinfected before being taken into a healthy area of a crop? Y N

? Is the crop support twine new, or cleaned and disinfected before use in the greenhouse? Y N

Greenhouse structures and surrounds

Using physical barriers to keep out as many pests and diseases as possible is a very effective strategy.

Entry ways

Controlled entry is one of the cheapest ways of quarantining your greenhouse. It is important to be aware that diseases and pests are easily carried on clothing, shoes and equipment. The fewer people entering the greenhouse, the smaller the chance that diseases and pests will be carried into the crop. Minimise the number of access points to the greenhouse. Where ever it is feasible, have only one door per structure.

More access points may be used to assist in removing old crops and cleaning the structure between crops, but during production you need to prevent workers and visitors moving into the greenhouse through multiple points.

Never allow a fully open side to the greenhouse. Everyone can get forgetful and it only takes one short cut to bring a pest or disease into the greenhouse which will cost you money and maybe even make you lose your whole crop. If your greenhouse has fully open sides, rope or fence off access so that people don't forget to use the doorway. Preferably, install a plastic splash skirt and insect screening on the open sides.

The fewer the doorways, the cheaper and easier it is to maintain quarantine.

Footbaths

Install and maintain a foot bath at every entrance to each and every greenhouse. Footbaths and wheel baths are important and cheap quarantine barriers to assist in keeping a greenhouse clean and disease free but they need to be used properly.

Incorrect use and maintenance of footbaths is a common waste of time and money.

Key problems associated with footbaths are that the activity of many disinfectants (for example hypochlorite) is reduced when there is organic matter and soil present. Exposure to sunlight will also deactivate disinfectants. In addition, many disinfectants require a minimum contact time.

When using footbaths, combination disinfectants utilising a blend of potassium peroxymonosulfate compounds, inorganic salts, organic acids and surfactants are suggested (for example, but not limited to products such as Trifectant® or Virkon-S®).

The footbath must be deep enough to cover shoe treads and the footbaths need to be refilled daily. In very dirty conditions or where there is a lot of organic matter, footbaths need to be cleaned and refilled more often.

It is good practice to also have a heavy duty doormat and/or boot brush on which footwear can be cleaned before using the footbath. Another cheap but useful tactic is to use dedicated footwear for all employees such as gumboots. Having a pair of gumboots for each employee can further reduce risk. Disposable shoe covers are another option, especially for visitors.

Commercially manufactured foot baths are available. Alternatively, a shallow water proof plastic container with a piece of foam can be used. The foot bath is filled with a disinfectant solution. If the footbath is dirty or muddy, and at least every 2 – 3 days, every footbath must be emptied, washed and refilled with new disinfectant solution. If chlorine is used as the disinfectant in the footbath, it will need to be emptied, washed and refilled with new chlorine solution daily.

Make sure that the footbath is protected from rain to avoid excessive dilution of the disinfectant.

Every person entering the greenhouse must place both feet into the footbath each and every time that they enter the greenhouse. It is also good practice to place both feet into the footbath each and every time that you leave the greenhouse because this further reduces the risk of carrying something into another area of the farm.

“ every person entering the greenhouse must place both feet into the footbath each and every time that they enter ”

If you move equipment such as trolleys, spray rigs or other vehicles out of the greenhouse, they must be cleaned before taking them back inside. If this is a regular activity, you will need to make sure that the footbaths are long enough and designed so that the wheels of the equipment can rotate a full circle through the disinfectant when being moved into the greenhouse. Wheel baths are specialised disinfection points installed to make sure that equipment and machinery entering the greenhouse is disinfected.

The alternative is to have separate trolleys for inside and outside, however, this may require more manual lifting and carrying of picking containers and other items as well as larger set up costs.



Install and maintain a foot bath at every entrance to each and every greenhouse

Double-door entries

The use of a double-door entry to the greenhouse, especially when combined with an outwards blowing fan, greatly reduces the opportunity for pests to get into the crop when the door is opened.

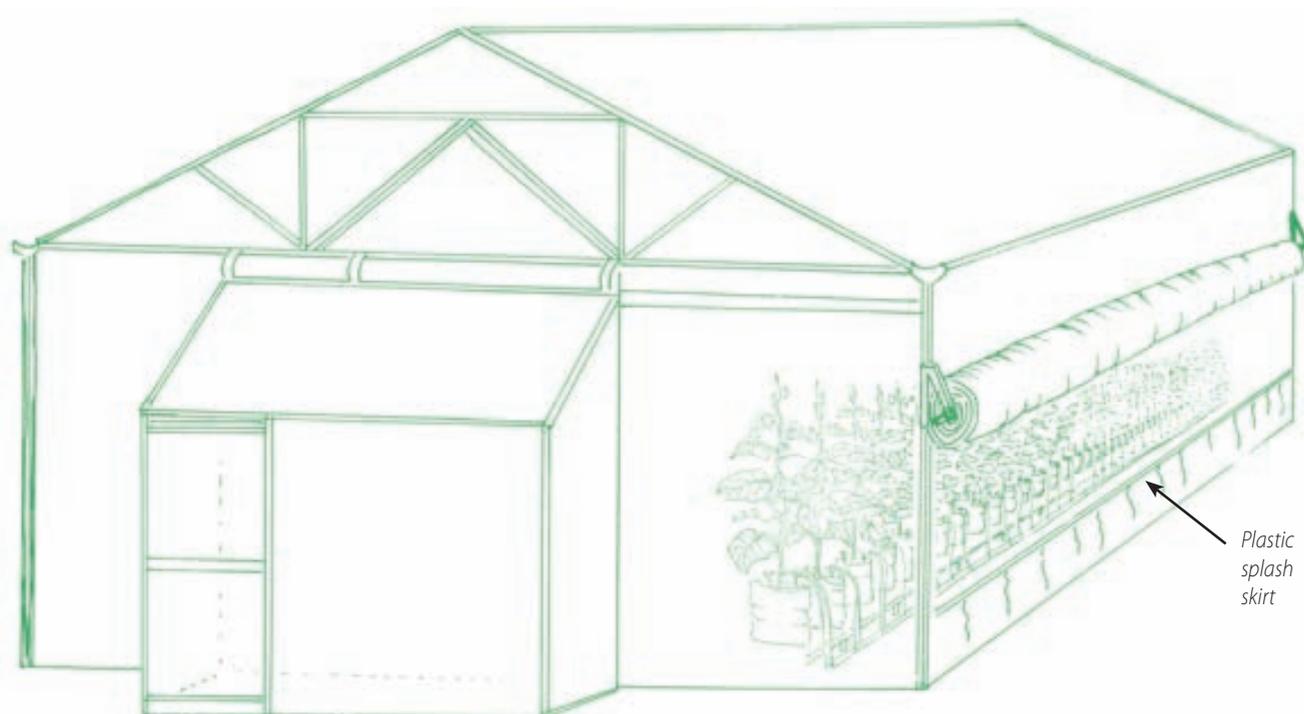
An alternative is a double curtained doorway. This uses two plastic or screen 'curtains' which are fastened on opposite sides of the doorway and overlap almost completely. To enter the greenhouse you have to push between the two 'curtains'.

Covering materials

The greenhouse itself with its covering materials such as glass or plastic, provides an effective barrier to many pests and diseases. Covering materials need to be well maintained. Breaks and tears should be fixed as soon as possible. The walls and roof of greenhouses need to be cleaned regularly. This should occur with every pre-crop clean.

Plastic splash skirts

Plastic skirts on the lower 0.6 – 1 m of the walls need to be installed on any greenhouse in which the side walls open for venting. These skirts significantly reduce the risk of mud and water splashing into the greenhouse and stop a lot of pests such as thrips and whitefly which can tend to gather in larger numbers nearer the ground around greenhouses.



Plastic splash skirts need to be installed on all open sides

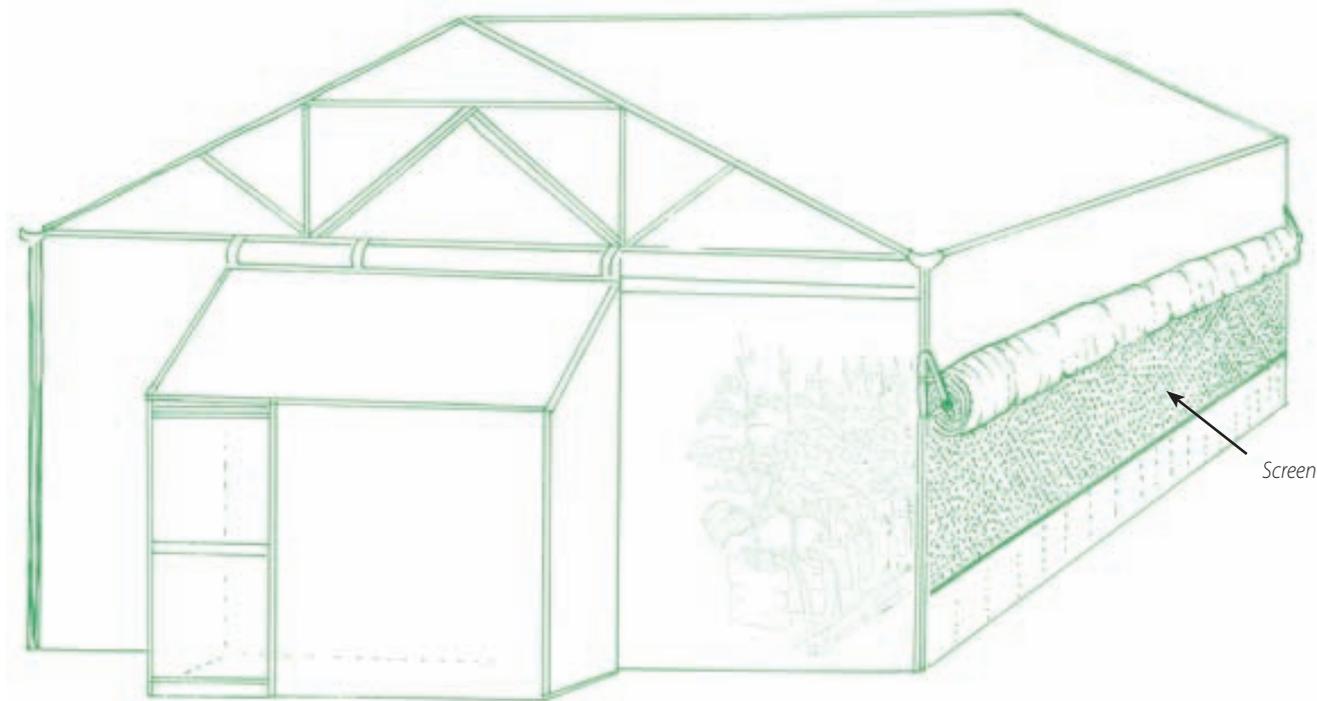
Furrows or trenches

A trench, such as a drain, with a vertical edge on the greenhouse side can prevent some insect pests such as swarming juvenile Rutherglen bugs from getting to the greenhouse.

Insect screening

Insect screens are a very good way of preventing pests and some diseases from getting into the greenhouse. Install insect screens over all openings in your greenhouse. There are different types of insect screens which are categorised on the basis of the size of the holes and therefore which pests they keep out. "Thrips grade" screens are the finest (smallest holes) but do not keep out all thrips. Be aware that screens reduce the flow of air and will impact on the venting capacity of the structure. The smaller the size of the holes, the less air can flow into and out of the greenhouse, which can reduce your capacity to manage the growing environment.

There are insect screens available that are classed as “whitefly grade” but which also have a deterrent effect on thrips, making them a useful option.



“ insect screens are a good way to prevent pests and diseases getting in ”

Vent management

Under some conditions, it is possible to restrict vent openings to minimise the risk of pests blowing into the greenhouse. For example, closing vents on the windward side during warm windy conditions can reduce the risk or levels of pests such as thrips getting into a greenhouse. Overall venting is maintained by opening the leeward vents more. A greenhouse that has double roof vents provides this flexibility.

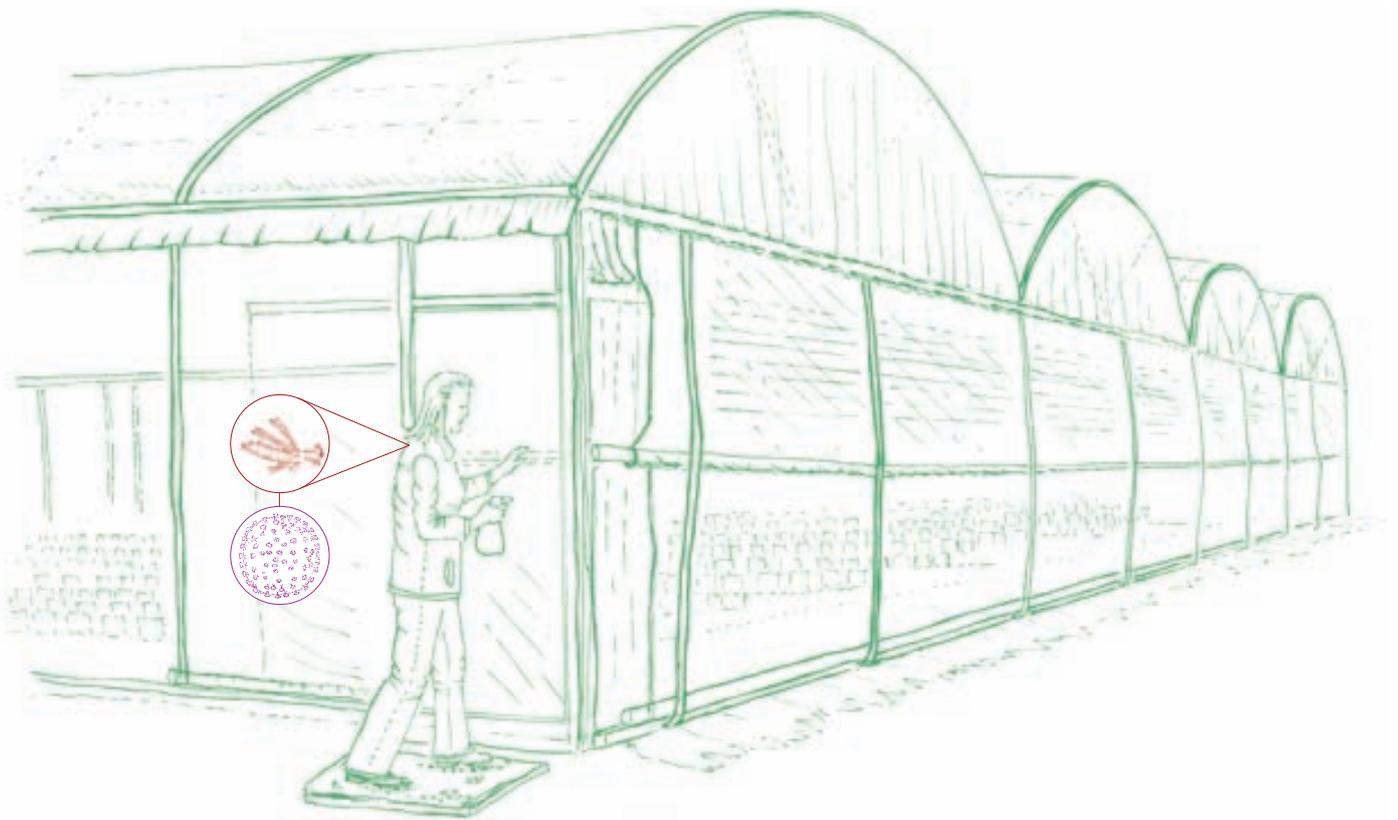
Vector management

Some diseases are spread by specific pests. The pests that spread diseases are known as vectors. By keeping out the pests, the diseases they can carry are also stopped. Therefore, an important strategy in managing some diseases is to exclude the pests (or vectors) which spread them.

One of the best examples of this is tomato spotted wilt virus (TSWV). This disease is spread by some species of thrips. Once a plant is infected, it can not be cured, but making sure that thrips are properly managed will also help control this disease.

The reverse control is also important. Because many virus diseases that are carried by insect vectors have a range of host plants which can act as a source of the disease, controlling the host plants (especially weeds) within and around a crop can significantly reduce the impact of a disease, even if there is a large population of the vector.

“ pests that spread diseases are known as vectors ”



Some pests also spread diseases

Another common example is fungus gnats which can spread root rot and wilt diseases including *Pythium* and *Fusarium*. Fungus gnats may also spread *Botrytis* and Gummy stem blight. Fungus gnats are best managed with good drainage and irrigation practices. Biological control agents are available and very effective.

It is also possible for some fungi to be the vector for a virus. This occurs, for example, with Lettuce Big Vein Virus and there is some evidence to suggest that a fungus may also be a vector of a virus that can infect capsicum.

? Have you minimised the number of entry points into the greenhouse? Y N

? Are footbaths (or wheel baths) and doormats installed and being used correctly at all entry points to the greenhouse? Y N

? Are double-door entries (and fan) or a double curtain installed at all entry points? Y N

? Are the greenhouse covering materials kept clean and well maintained? Y N

? Are splash skirts installed on all opening walls of greenhouse? Y N

? Are furrows or trenches (such as a gutter or drain) used to stop crawling pests? Y N

? Are insect screens installed on opening sides?

Y N

? Are insect screens installed on roof vents?

Y N

? Is windward vent opening restricted during warm windy conditions if feasible?

Y N

? Are potential insect vectors excluded or appropriately managed?

Y N

Worker and visitor hygiene

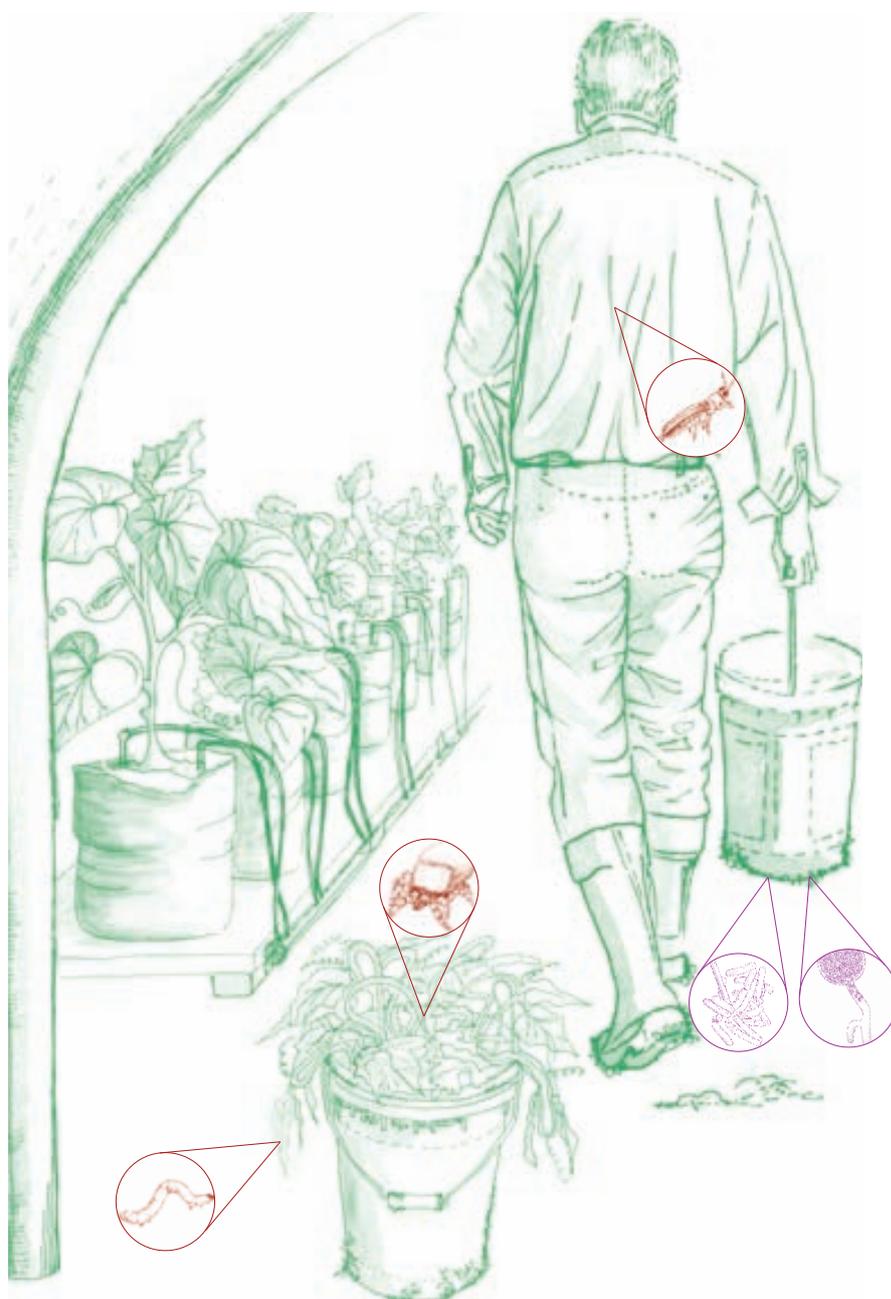
People are one of the most likely ways that pests and diseases will enter a greenhouse. All workers on the farm need to be responsible for not bringing potential problems into the greenhouse.

Instruct workers not to visit another greenhouse before coming to work. When work begins for the day, workers must not come from another farm unless they have changed clothes or overalls and have disinfected hands, boots and all tools before entering your greenhouse.

Clean clothes need to be worn every day. A good practice is to provide every worker with clean overalls. These could be cool cotton overalls that are washed regularly or single-use disposable overalls. Low cost, disposable paper 'lab coats' are a good choice.

Many insects are attracted to certain colours, particularly yellow. Sticky traps which are used for monitoring flying insects are made in yellow and blue for this reason. Many flying insects are attracted to yellow. Thrips are also readily attracted to blue and white. Insects can easily hitch a ride into a greenhouse or through a crop on people's clothing. To reduce the risk of this happening, yellow, mid-blue and white clothing should be avoided.

Disposable gloves need to be worn. A box of disposable gloves should be placed at every entry to the greenhouse. Everyone going into or working in the greenhouse needs to wear them. When working in the crop, change gloves regularly, such as at the end of every row and when you take a break. Put the used gloves into a bin.



Wear clean clothes. Wash and disinfect hands, boots and all tools before entering the greenhouse

Rubber boots (gum-boots) should be considered as footwear to improve the efficacy of footbaths.

Always try to complete activities in the youngest and healthiest crops before going into older crops. If a greenhouse has a medium to high level of a pest or disease, make sure that all workers change their overalls and gloves before entering another greenhouse.

When people are visiting, have them wear disposable overalls and step through the footbath. Avoid having visitors who have come directly from another greenhouse. Do not be embarrassed about telling a visitor that they can not enter your greenhouse - it is your livelihood at stake! If visitors are going to move between different crops, always take them from the youngest and healthiest crop plantings through to the older crops (that may be infected) to reduce the risk of spreading problems.

Tobacco can carry some diseases that infect greenhouse crops. If employees or visitors are permitted to smoke on your premises, make sure that they wash their hands before entering the greenhouse.

? Essential practice Y N
Employees and visitors do not visit another greenhouse before entering your greenhouse?

? Do all employees and visitors wear disposal gloves when in the greenhouse and change them frequently? Y N

? Does every employee have a clean change of clothes/overalls every day for greenhouse work and change clothes/overalls after working in a 'dirty' greenhouse? Y N

? Is dedicated footwear or are disposable shoe covers used when working in or entering the greenhouse? Y N

? Does every employee wash their hands and disinfect personal items (eg mobile telephone) after working in a 'dirty' greenhouse? Y N

? Does every employee and visitor who smokes wash their hands after smoking before entering the greenhouse? Y N

? Is bright yellow, mid-blue and white coloured clothing avoided when working in or entering the greenhouse? Y N

Limiting the spread of pests and diseases

Farm planning, sanitation and exclusion are effective ways to significantly reduce the risk that pests and diseases will get into your greenhouse or crop. Despite this, it is very difficult to completely remove all the risk and therefore you need to plan for limiting the spread of pests and diseases once they get into the crop as well.

There are a number of strategies that can be used in combination to do this including managing the growing environment, manipulating plant growth, monitoring for early detection and using a variety of actions to kill or suppress pest and disease populations.

It is also critical that if any chemical control (including copper) is used, the efficacy is regularly assessed to check whether there are any developing resistance issues or control failures. Any use of any chemical control must be done with reference to a resistance management plan.

Resistance is a situation where a pest or disease develops the capacity to tolerate or otherwise survive the use of a chemical which would normally be expected to control it. Pesticide resistance is a very serious problem.

All of these strategies only work if you regularly check for pests and diseases (a pest and disease check), properly identify what is in and near the crop and make the right decision about what to do and when.

? Essential practice

Are you able to correctly identify pests and diseases (or have them identified for you) and do you routinely conduct a pest and disease check to ensure early detection and correct identification of problems?

Y N

? Essential practice

Have you determined action points and do you use pest and disease check information for all decision making including chemical, biological, whole crop and hot-spot treatments?

Y N

What localised strategies can be used?

Plant management

Plant management is the use of cultural management strategies at the individual plant level. Practices that can be used to limit the spread of pests or diseases include de-leafing, plant thinning and truss or flower pruning. These practices not only influence plant growth and balance, but can directly impact on the growing environment around plants such as air circulation, light, temperature and humidity which in turn can have an effect on pest and disease development.

Diseased foliage and fruit and critically infected plants need to be removed from the greenhouse. This reduces the opportunity for diseases to spread. Place material directly into bags or bins and take it out of the greenhouse.

Roguing

When a diseased plant (for example, infected with a virus), is found in the greenhouse it can be removed to reduce the risk of the disease spreading in the crop. This is called roguing. It is most often used in preventing viruses spreading or becoming established in a crop. It can also be an effective strategy to prevent the spread of other diseases, for example when a disease such as bacterial canker is first found in a crop.

“ roguing is a very effective way of controlling localised outbreaks of some diseases ”

When roguing, it is very important to maintain quarantine of the diseased plant during its removal. While wearing disposable plastic gloves, place the diseased plant carefully into a plastic garbage bag, put the gloves into the bag and then seal the bag.

Depending on the disease, you might also decide to remove adjacent plants. Put on another pair of gloves and place the neighbouring plants into another garbage bag and pick up all leaves and plant parts that may have fallen on the ground. Put the gloves into the bag and then seal this bag. Take the bags out of the greenhouse and avoid touching other plants on the way out. Immediately, take the bags to the waste storage area and put in the bin.

For some diseases (not viruses), you may also be able to disinfect or otherwise treat the immediate area after the infected plant has been safely removed.

? Are infected plants (bagged before removal) removed from the greenhouse (roguing)? Y N

Pruning and 'handling' plants

Pruning and training are essential practices to produce a healthy and productive crop. Pruning includes removal of any part of a plant. Normally, pruning and training is done to manage crop growth, plant balance and yield and maintain air circulation within the crop. Pruning is also used to remove unmarketable fruit from a plant. Pruning and training practices are useful tools in managing pests and diseases. It is very important to not fall behind in pruning and training plants. Practices including de-leafing and thinning can be used to deal specifically with problems associated with high humidity, for example, or a localised disease outbreak.

Tissue damage from pruning and picking wounds predisposes a plant to infection. A sharp blade ensures that the wound is clean and tools can be easily disinfected and are better than using hands. Any tools that are used need to be disinfected regularly with bleach (0.5%), trisodium phosphate or 70% ethyl alcohol. A belt holder with a container of disinfectant is practical. Tools can be readily dipped every couple of plants.



“ put pruned material directly into a bag or bin ”

Place pruned material directly into a bag or bin and dispose of it appropriately. Dropping material onto the ground and sweeping it up later can spread diseases around the greenhouse. Some diseases can develop spores on plant debris.

? Do you prune and train all plants appropriately and use sharp, clean blades? Y N

? Is all pruned plant material put directly into a 'pruning' bin or bag and disposed of appropriately? Y N

? Do you use de-leafing, selective pruning and thinning to reduce pest and disease risk? Y N

Spot treatments

Spot treatment is a good technique for localised control of some pests and diseases. Spot treatments are often cheaper and save time and can prevent larger outbreaks of pests or diseases. Spot treatments include spot spraying with an appropriate pesticide and applying biological controls to a specific problem area or "hot-spot". If you have to use chemicals, spot treatments significantly reduce the amount of chemical needed which is better for the crop, the environment and the business.

Spot biological treatment

Biological management strategies include the appropriate use of biological control agents. Biological control agents or biocontrols are beneficial organisms which naturally control specific pests or diseases. Biocontrols may be naturally occurring in and around your farm or commercially produced.

Spot biological treatment is a useful strategy to limit the spread of pests using biological control agents. This practice involves treating a small problem area or section of a crop when an infestation is limited to just a couple of plants or rows in part of the greenhouse.

Monitoring data is used to define what area needs to be treated. High numbers of the appropriate biological control agent are released in and around the localised infestation. (Biological management can also be used on a whole crop basis.)

When using biocontrols, pest and disease monitoring must be used to make decisions about when and how biological controls will be used.

Commercially produced biocontrols can be purchased and released into your crop to manage specific problems. They are not pesticides and can not be used in the same way. They are most effective when they are introduced while pest numbers are low and in this way can be used to prevent pest outbreaks occurring.

Some chemicals are harmful to biocontrols and so biological management will only work if you are very well informed and thorough when selecting and using pesticides. Some pesticides are not harmful to biocontrol agents and these are referred to as IPM compatible or 'soft' chemicals. Chemicals permitted in organically grown crops are not necessarily safe for biological control organisms.

Spot spraying

Chemical management strategies include the appropriate use of chemical pesticides with a focus on low toxicity, pest specific chemistries.

Unlike whole of crop spray applications, spot spraying can be used to just treat a small area or section of a crop. This might be just a couple of plants that have an infestation or could be a couple of rows in part of the greenhouse, for example, near a doorway or under a vent. Monitoring data is used to define what area needs to be treated.

Spot spraying has enormous advantages over whole of crop spray application when pest or disease incursions are localised. Significantly less time, money and pesticide is required. Spot spraying can involve using oils, soft pesticides or other registered products.

“pesticides should only be used in conjunction with other preventative management practices”

Spot spraying can also involve treating pruning wounds to prevent disease.

Pest and disease monitoring must be used to make decisions about when and how chemical controls will be used. Spot chemical treatments need to be used in conjunction with other preventative management practices. If chemicals are used on their own, poor management occurs and costs can escalate rapidly without significantly reducing losses or damage.

Early detection of disease and a quick response as well as preventative spray applications when risk factors are high are a key aspect to effective disease management. Many diseases can increase very rapidly from a low infection level. For some diseases once an outbreak level of infection is reached, there is very little opportunity to contain infections.

Both bacteria and fungal spores of diseases can be spread inside the greenhouse with a moving spray mist created when applying pesticides. If the disease is resistant to the fungicide, the act of spraying can make the problem worse. Copper fungicides have a reputation for failing because of this situation.

When chemical controls are used, the correct rate and frequency of application must be followed. The target pest or disease has to be correctly identified. The treatment needs to target the vulnerable stages of the pests or diseases. (Refer to the key pest and diseases sections). Doing these important things ensures the best possible results are obtained and the chemicals remain effective. Resistance to pesticides by pests and diseases is a serious threat to all growers.

Spray application equipment needs to be accurately calibrated.

It is also very important to distinguish between different types of chemicals. The way a chemical works affects how it must be used. For example, fungicides (used to manage fungal diseases) may be protectant or curative. Protectant chemicals stay on the surface of plants and they need to have contact with diseases to achieve any effect. As new growth needs to be protected, growing plants need on-going protectant spray applications. These chemicals generally control a wide range of fungal diseases but plant coverage needs to be thorough and even. These types of chemicals are used to prevent infection or spread of a disease.

Curative fungicides are systemic chemicals which are absorbed by plants. They can provide some effect against diseases some distance away from where the chemical droplets land on the plant. These chemicals may move into new growth in which case they do not need to be applied as often as protectant chemicals. Systemic fungicides are specific to the type of fungi they control. Their continued or over-use can lead to resistance developing in the fungal population. This has occurred with Downy mildew, Powdery mildew and Grey mould for some chemicals.

There are also different types of insecticides. For example, a pesticide may be 'knock-down' or 'residual' as well as being either 'contact' or 'systemic'. Some chemicals may only affect specific life stages so the way they are used depends on their characteristics.

? Do you use spot treatments when appropriate?

Y N

? Are chemical controls assessed for any resistance issues or control failures and is a resistance management plan is used?

Y N

What whole crop strategies can be used?

Cultural management

Cultural management is the first and most important whole crop strategy in limiting the spread of pests and diseases in the greenhouse. The aim of any greenhouse grower should be to provide the optimal environment for the crop they are growing.

This requires good management of the greenhouse environment, the hydroponic (irrigation) system and the plants themselves. It is important to understand how a greenhouse works and to invest carefully to ensure that your growing system works well. The greenhouse design, the size of vents, heating, fans, type of covering materials and screens are just some of the key parts of a greenhouse which can have an impact on how well you manage pests and diseases.

Large variations in growing conditions and environmental extremes can reduce plant productivity and increase pest and disease problems.

Monitor and manage growing environment

Temperature and Humidity

Managing the temperature and humidity in the greenhouse is a very important part of greenhouse growing. Every greenhouse must have temperature and humidity sensors appropriately located in the greenhouse.

For most crops, day time air temperatures need to be between 20 – 25°C to get the best performance from the plant. Crop productivity and plant health will decline if temperatures vary too much above or below this range. Minimum night temperatures for many crops need to be between 15°C and 20°C depending on the crop.

The relative humidity needs to be maintained around 60-80%. If it is too high or too low, pests and diseases can flourish. For optimal crop production, relative humidity needs to be closely managed. Ideally the greenhouse environment should be managed for a vapour pressure deficit of between 3 – 7 grams/m³.

Managing the greenhouse environment can involve making conditions more favourable for the crop and/or less favourable for pests or diseases. Good temperature and humidity management are essential to minimising disease in greenhouse crops, particularly for Downy mildew, Powdery mildew and *Botrytis*.

Temperature and humidity are also very important when using biological control agents (beneficial organisms). Most biocontrol agents require temperatures between 20°C and 30°C and a relative humidity over 60%.

Condensation in the greenhouse is a critical problem and needs to be avoided. It occurs when temperature and humidity management is not adequate. Heating is essential to properly manage the greenhouse environment and can be used in combination with venting to purge hot moist air from a greenhouse as well as simply to increase temperature and reduce humidity.



Every greenhouse must have temperature and humidity sensors

“condensation in the greenhouse needs to be prevented”

In the late afternoon, as much of the warm humid air in the greenhouse as possible should be vented. This draws in cooler air from outside. When this is then heated, the air becomes drier and the lower humidity minimises the development of many diseases.

Condensation can also affect fungicide activity by diluting fungicide applications. Over time, this may actually contribute to the development of resistance by diseases to particular pesticides.

Tissue damage due to chilling injury or heat damage also predisposes plants to infection and needs to be avoided.

? Do you properly manage (including monitoring) the temperature and humidity and avoid temperature and humidity extremes in the greenhouse? Y N

? Do you have adequate and adjustable venting capacity in the greenhouse? Y N

? Do you have adequate heating capacity in the greenhouse? Y N

? Do you use overhead sprinklers/misting/fogging (if appropriate and feasible) to maintain humidity levels? Y N

Air movement

Air movement into and within the greenhouse has a big influence on pests and diseases. Insect screens and venting capacity are very valuable aspects of any greenhouse and influence air movement through the structure. The heating system and internal fans can also greatly influence air circulation.

Good air circulation within the crop is important in maintaining a uniform growing environment. This prevents pockets of high or low temperatures or humidity levels forming which could otherwise lead to pests or diseases becoming established in the crop. Plant density is a critical factor. It is essential that adequate plant spacing is maintained to enable air to flow sufficiently around plants and through the whole crop. Poor air circulation can encourage diseases such as *Botrytis*, *Alternaria* and Downy mildew. Horizontal airflow (HAF) fans are a useful piece of equipment in any greenhouse. These fans reduce variation in the greenhouse and should operate continuously during periods of high humidity, that is, on cloudy wet days and every night.

Excessive air movement, however, can rapidly spread pests and diseases into and within the greenhouse. Windbreaks can be used to slow down air around the greenhouse during windy conditions. Blowers used in pollination of some crops can quickly spread pests and disease spores through a crop and should be avoided if possible. Vibrating pollinators are a better option. The blast from spray equipment will also cause excessive air movement. Applying any sort of spray (including foliar fertiliser applications and pesticides) in the crop can potentially spread pests and diseases around the greenhouse.

Many diseases require moist plant surfaces to germinate, infect or grow. By keeping foliage dry, the risk of disease is reduced.

? Are air circulation fans installed and do you manage air movement in the greenhouse? Y N

? Do you use vibrating pollinators instead of blowers if pollinating crops? Y N

? Do you minimise the number of whole crop foliar sprays applied? Y N

Light and radiation

The level of light and the quality of light in the greenhouse influences crop growth. Certain conditions can also affect pests and diseases. Some diseases require ultraviolet radiation (UV) for different stages of development such as spore germination or sporulation. By using covering materials that absorb UV radiation, these diseases can be suppressed. For example, the spread of *Alternaria*, *Botrytis* and *Sclerotinia* could be reduced by filtering out (absorbing) UV radiation.

Polycarbonate sheeting absorbs a significant proportion of UV, glass absorbs up to two-thirds while basic polyethylene films are practically transparent to UV and so will have no effect.

The behaviour of some pests such as greenhouse whitefly, thrips and aphids can also be affected by using covering materials that block UV radiation in the crop.

Low light levels can favour some diseases including *Pythium*, Powdery mildew and Gummy stem blight while also stressing the crop and making plants more susceptible to attack.

? Is UV blocking greenhouse covering material used (if appropriate and feasible) to disrupt pest behaviour?

Y N

Nutrition

Good plant nutrition is important in maintaining a healthy and productive plant. Plants which become stressed are more susceptible to infection or attack from pests. Follow a suitable recommended fertiliser program and test your water supply regularly to make sure that the nutrient program is appropriate for the water quality.

Plant nutrition and the pH of the root zone can have a significant impact on some diseases. For example, a nutrient program using a higher proportion of nitrate nitrogen (compared to nitrogen in the ammonium form) may help reduce *Fusarium* wilt in tomato. This form of nitrogen results in a small increase in pH in the root zone solution. A higher pH can help reduce *Fusarium* wilt and *Botrytis*. There is some suggestion that Bacterial wilt of tomato might be reduced with a higher substrate pH.

You need to make sure that mistakes are avoided when batching nutrients. You need to constantly monitor the hydroponic solutions (or soil fertility if growing in soil).

Excess nitrogen can make plants more susceptible to pests and diseases.

Measure and record the electrical conductivity (EC) and pH of both the feed and drain solutions. This needs to be done at least daily. Watch for trends and maintain root zone conditions according to plant balance and the growing environment.

Making sure that calcium levels are optimal is necessary to help guard against blossom end rot (a disorder) and may also contribute to reducing the incidence of Bacterial wilt.



? Are you providing a balanced and appropriate nutrient regime to the crop?

Y N

? Are feed and drain EC and pH managed (monitored and recorded) at least daily?

Y N

Irrigation

Irrigation needs to be based on the needs of the plant. Too much or too little moisture in the root zone can contribute to pest and disease problems. When there is excess water in the root zone, oxygen levels are reduced and this causes damage to roots. Not only do the damaged roots result in poorer crop growth and performance and make plants vulnerable to extreme conditions, but damaged roots are more easily infected by some diseases. High substrate moisture favours the development of key root rot diseases including *Phytophthora* and *Pythium* as well as providing favourable conditions for pests such as fungus gnats.

Guttation, caused by high root moisture pressure, is an important way in which diseases can infect greenhouse crops. When guttation occurs, diseases are picked up off the leaf surface by the exudate from the leaf and then can be sucked into the plant during the day.

The amount of nutrient solution needed by a crop will vary. There are a number of factors which influence how much water is needed. These include:

- Level of solar radiation
- Temperature
- Relative humidity / vapour pressure deficit (VPD)
- Age of crop / leaf area
- Type of crop (and variety)
- Fruit load
- Type of substrate
- Water quality

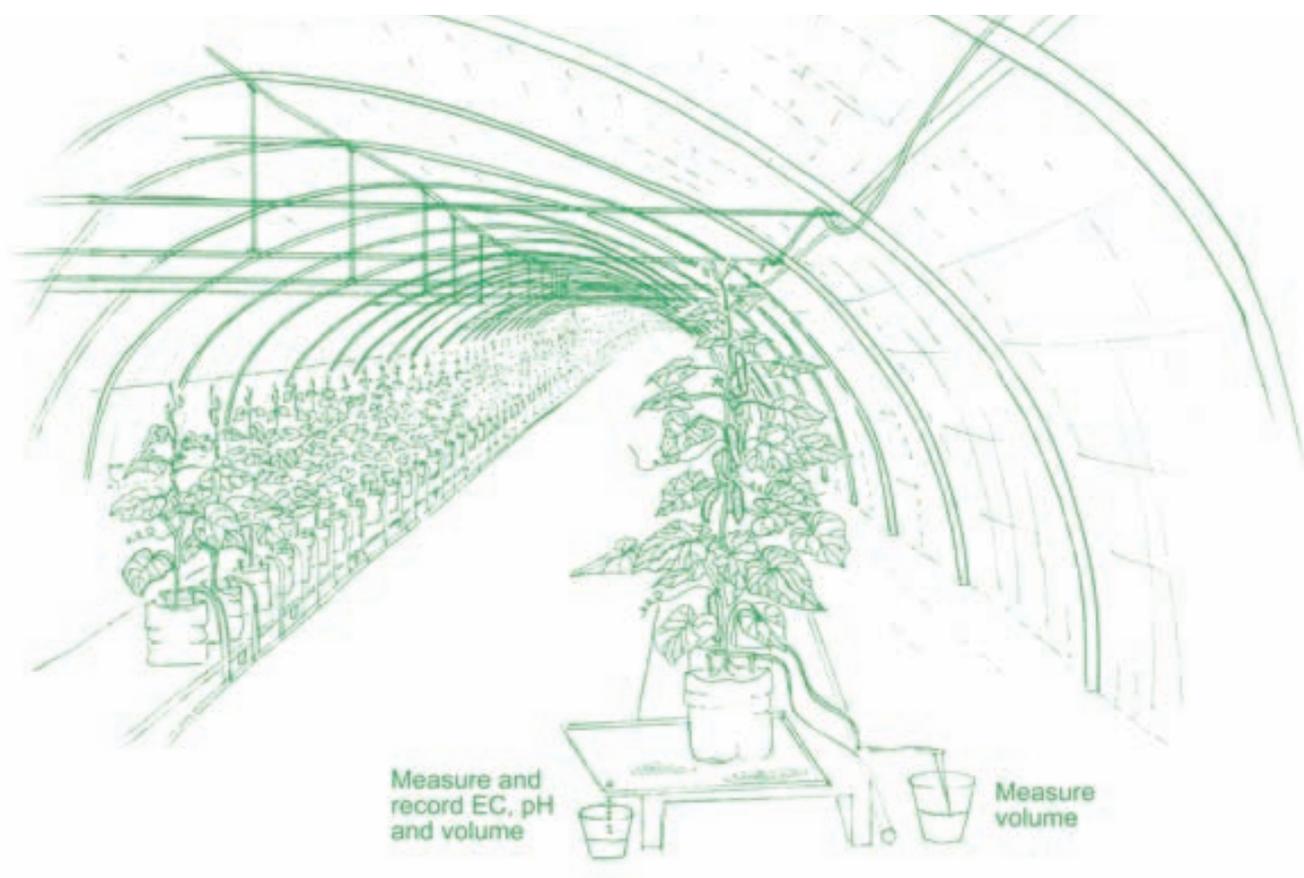
As the growing conditions change, the volume and frequency of irrigation need to be changed. If growing in a substrate (or soil), it is important that the level of water in the substrate is monitored to better regulate the irrigation. The growing conditions and the crop type and stage can be used to estimate the expected water demand but regular monitoring is needed. An irrigation system should be flexible so that you can alter the supply of water when needed.

Run-off targets are a useful way of monitoring the amount of irrigation to apply. This is done in conjunction with managing electrical conductivity (EC) and pH of the run-off. Target a run-off volume of between 10% and 30% depending on your growing conditions, crop and substrate. A higher run-off volume will use more water and fertilisers and result in the EC and pH being closer to the feed EC and pH. It will also direct the plant to be more vegetative. Excessively vegetative plants are more prone to attack by some diseases. A high run-off target can also be used to manage poorer water quality.

A lower target run-off is more water and fertiliser efficient but will also result in greater differences between feed and drain solutions. It will tend to direct the plant to be more generative.

Monitor run-off at least daily. A simple tray system can be used to collect water.

Ensuring uniform irrigation in the greenhouse is a critical preventative management practice. Always undertake an **irrigation distribution uniformity** check before planting a new crop.



Monitor run-off at least daily. Check and record EC, pH and volume.

? Are feed and drain irrigation volumes managed (monitored and recorded) at least daily? Y N

? Do you complete an irrigation distribution uniformity test on the irrigation system before a new crop is planted? Y N

? Do you make sure that good root zone drainage is maintained? Y N

Reducing plant risks

Crop rotation

Crop rotation is an important strategy in preventing a build-up of crop specific pests and diseases if substrates are reused, or crops are grown in soil.

Allowing a greenhouse to remain empty of all plants for a short period between crops is extremely useful in breaking pest and disease cycles. A longer period of time is needed for soil grown crops, especially if fumigation is required.

? Do you use a crop break or rotation plan for the greenhouse? Y N

Variety selection

A key strategy in preventing diseases (and some pests) is to select cultivars or varieties which have resistance or tolerance to key diseases. This option may not always be available or suit your markets, but should always be considered. Grafting onto tolerant rootstocks should be considered if available and feasible.

? Do you use resistant or tolerant varieties when feasible? Y N

Section 2

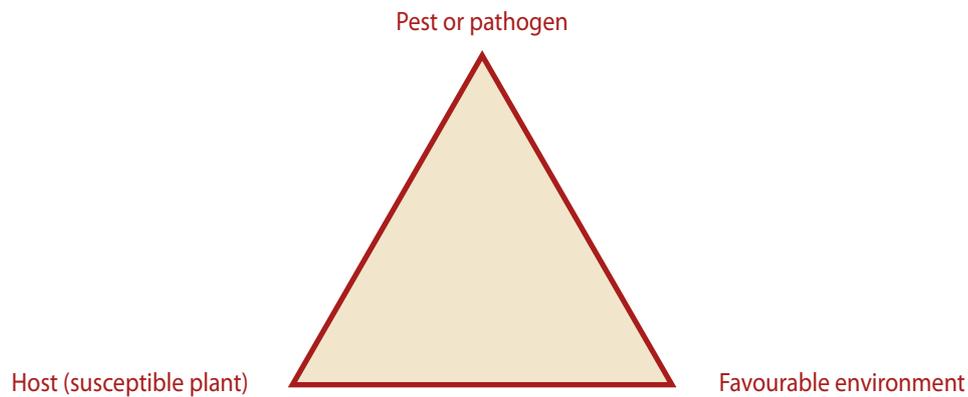
Implementing effective
pest and disease
management

Implementing effective pest and disease management

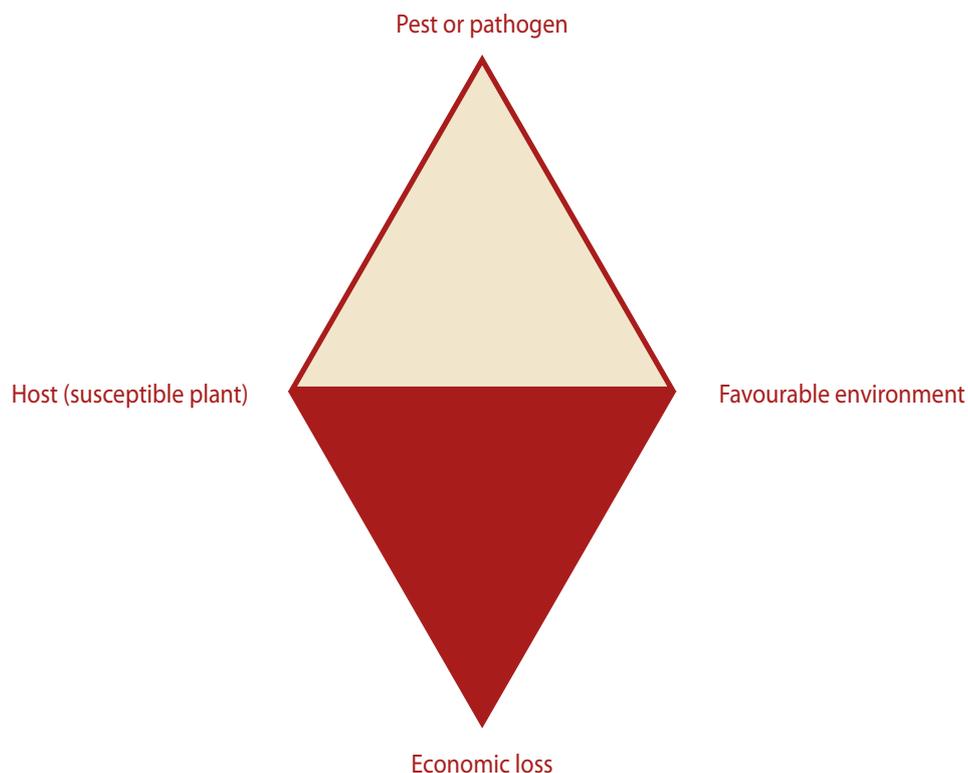
Effective pest and disease management requires the use of multiple tactics – using most, if not all, of the preventative practices listed in this manual.

A useful process in managing pests and diseases is to imagine a triangle with its 3 points representing the 3 conditions that must occur: the pest or disease has to be present, the plant must be susceptible to it and the environmental conditions must be favourable for the pest or disease.

Preventative practices can be used to impact on one or more of these conditions. Effective management of pests and diseases only requires removing one of these conditions.



The key to minimising the cost of pest and disease management is to extend this triangle into a diamond. The fourth point represents a critical condition – an economic loss has or will be caused by the pest or disease.



If any one of the 4 conditions can be removed or avoided, the pest or disease is no longer a problem.

It is unlikely to be feasible to implement all the potential practices in one go so you need to know which practices to do immediately, and which you need to plan to incorporate over time.

There are ten (10) *Essential Management Practices*. These need to be done by all growers because they are essential for effective management of any pest or disease. These practices can cost almost nothing to implement yet provide enormous benefits in pest and disease management.

Essential Management Practices

1. Be able to correctly identify pests and diseases (or have them identified for you) and routinely conduct a pest and disease check to ensure early detection and correct identification of problems
2. Action points are determined and pest and disease check information is used for all decision making including chemical, biological, whole-crop and hot-spot treatments
3. The greenhouse is within a 'clean' zone which is quarantined from the 'outside' zone of the farm
4. Check and control points are used to control movement of people, vehicles, plants and materials into the 'clean' zone
5. Employees and visitors do not visit another greenhouse before entering your greenhouse
6. All seedlings are checked and found free from pests and diseases before they are planted out
7. A 5 - 10 metre wide clean buffer area is maintained around every greenhouse
8. The greenhouse is always cleaned and disinfected before planting new crop
9. The greenhouse and farm surrounds are kept weed free
10. Crop debris is removed and stored/disposed of outside the 'clean' zone and away from the greenhouse

There are also a number of *Critical Management Practices* that are important in managing specific pests and diseases. These are listed for each pest and disease group. To work out which practices are priorities for your farm, a risk assessment is used. A risk assessment is a simple technique that can be used to gauge the level of risk that a particular problem poses. If a pest or disease is found to be a high risk, then the *Critical Management Practices* for that pest or disease need to be given priority.

After all the *Critical Management Practices* for high risk pests and diseases are in place, you can then implement the practices identified for medium risk and then lower risk problems.

By doing this, you can systematically implement all the necessary preventative practices for your farm, starting with the ones that will give you the greatest benefit first.

It is most likely that you will have some of the practices already in place. Well done. Move onto the next practice on the list.

Assessing the risk of pests and diseases

Pest and disease risk management is the process of looking at each pest and disease in the greenhouse and around the farm that could cause damage or loss and thinking about how much damage or loss the pest or disease may cause. With this information you can then prioritize the preventative practices that you can implement.

“prioritize the preventative practices that you can implement”

There are specific steps involved in risk management:

1. Correctly identify the pest or disease.
2. Decide how serious the pest or disease is. This is called a risk assessment.
3. Implement the preventative practices according to how serious the pest or disease is.
4. Check regularly that the risk assessments you have done are still current and relevant.

Risk assessments

A risk assessment is made for each pest or disease, for each type of crop and for the key season in which the pest or disease occurs. For example, you may need to assess the risk of thrips in cucumber in summer.

Use the priority table below to work out whether a pest or disease is **high risk**, **medium risk** or **lower risk**.

How much damage or loss could this pest or disease cause?	How likely is it that this pest or disease will occur?		
	Very likely (could happen in every crop)	Likely (could happen in most crops)	Unlikely (could happen in some crops)
	A	B	C
Will cause a lot of damage to product. Will kill or cause damage to a lot of plants. Will significantly reduce yield and/or quality. A	1 High risk	1 High risk	2 Medium risk
Will cause some damage to product. Will kill or cause damage to some plants. Will reduce yield and/or quality. B	1 High risk	2 Medium risk	3 Lower risk
Will cause damage to some plants and may have a little loss in yield and/or quality. C	2 Medium risk	2 Medium risk	3 Lower risk

STEP 1

For each pest or disease that is found to be **high risk**, the critical management practices listed for that pest or disease should be implemented. This level of risk is a very high priority as the pest or disease in this category will be costing you a lot of money.

STEP 2

When all the **high risk** pests and diseases have been covered, move onto the **medium risk** pests and diseases. For each pest or disease that is found to be **medium risk**, the critical management practices listed for that pest or disease should be implemented.

STEP 3

When all the **medium risk** pests and diseases have been covered, move onto the **lower risk** pests and diseases. For each pest or disease that is found to be **lower risk**, the critical management practices listed for that pest or disease should be implemented.

There may be some practices that are not feasible for your property at this point in time. These practices need to be incorporated into future farm developments or upgrades. When completing your annual budget or working out future capital investments, consider implementing any remaining preventative practices. The risk assessment table can be used to help decide the priority for implementation.

Recognising key pests and diseases

Effective management of pests and diseases depends on knowing the problem. Not only is correct identification critical, but you need to understand the life cycle of the pest or disease, at what stages they are most vulnerable and what specific environmental conditions favour them.

“effective management of pests and diseases depends on knowing the problem”

A pest is an organism that has the capacity or potential to cause economically significant damage to your crop, product or production system. Damage could be caused directly or indirectly. A pest may be an insect or mite, a disease, a weed or even animals such as rodents and birds. A pathogen is an organism that can cause disease. A disease is when the plant's normal functioning or development is adversely affected.

It is important to be aware that not all pests are equal. For example, Western Flower Thrips (WFT) is a vector of the Tomato Spotted Wilt Virus (TSWV) and it also has a high level of resistance to many insecticides. Consequently, it is a more significant threat than plague thrips which do not transmit the virus.

Correct diagnosis of pests and diseases is very important. Getting the identification wrong can result in a costly waste of the money and time from implementing a management action that has no real positive effect.

Excess use of pesticides is one of the quickest ways to build resistance in the pest or disease population and incorrect use of pesticides is not only expensive, but can lead to more problems with pests and diseases.

Taking care not to confuse beneficial and/or benign insects with pests is another important consideration. Be aware that a lot of money can be wasted trying to control an insect that is not even a problem and in fact, might be beneficial!

Some plant symptoms which may look like a disease can have other causes, for example, nutritional deficiencies or toxicities, poor growing conditions, environmental effects and damage from chemicals (crop burn).

When plants are grown under optimal conditions, they are mostly only at risk from diseases that need living tissues to develop (obligate parasites) such as powdery mildew. However, when plants are stressed, they become more susceptible to a wider range of diseases including ones that have the ability to survive under different conditions and which can survive on non-living organic matter (facultative parasites) such as *Botrytis* and *Pythium*.

The following sections on pests and diseases have been included to provide a basic overview of key pests and diseases. They are not intended to be a comprehensive guide to pests and diseases. There are a lot of other publications and resources available that provide more detailed information, including;

- Integrated Pest Management in Greenhouse Vegetables – Information guide and the companion Field Identification guide
- Integrated Pest Management in Ornamentals – Information guide and the companion Field Identification guide

There are also many other pest and disease management resources available, including on-line resources.

Diagnostic samples

Effective management of diseases depends on being able to quickly recognise symptoms and correctly identify the cause. Be careful when attempting to diagnose diseases from pictures or descriptions – you may have an uncommon or new disease that superficially looks like another or the symptoms may be a result of growing conditions or other factors.

At the first sign of an unfamiliar symptom, sufficient samples should be sent for diagnosis by an expert. Not only will this ensure that you apply the correct and lawful method of control, but new diseases can be identified early.

Correct diagnosis requires a plant sample that shows the full range of symptoms present on the crop. When sending plant specimens, include several affected plants that range from early symptoms on younger plants to some with severe or 'full-blown' symptoms if possible. It is useful to also include an apparently healthy plant.

Samples should, ideally, consist of whole plants including roots and some attached growing substrate. Keep samples as fresh as possible by wrapping in moist newspaper. Refrigerate them if they are to be kept overnight. Hand deliver, courier or send the sample by Express Post. Clearly mark your name and address on the package. Material dispatched by post or courier should be sent early in the week to avoid being held up during the weekend.

There are several plant health diagnostic laboratories around Australia. Unfamiliar pests should also be submitted for identification. Some organisations, for example, NSW Department of Primary Industries, have insect sampling kits available to make it easy to get pests identified.

Digital photography can be a useful tool to get feedback about potential problems. Photographs of plants with and without problems can be sent by email to appropriate professionals or diagnostic services for a preliminary diagnosis.



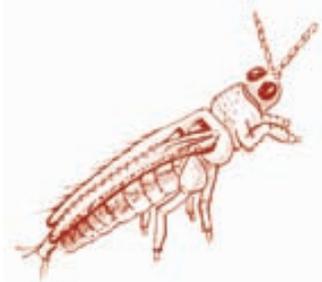
Knowing and preventing your key pests

Types of pests

Effective pest management depends on knowing which pests are in and around your crop. Adult insects have 6 legs. Adult mites have 8 legs. There are a couple of key types of pests that you need to be able to recognise.

Thrips

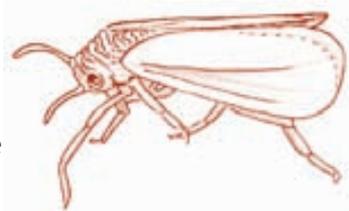
Thrips are small, slender insects about 1 – 2mm long. Adult thrips have wings. Young stages of thrips look similar to adults but do not have wings.



Thrips can cause direct damage to crops when they feed. Some species of thrips also carry the Tomato spotted wilt virus. Thrips have a very wide host range and so will affect most crops and can live on a lot of different weeds and garden plants.

Whiteflies

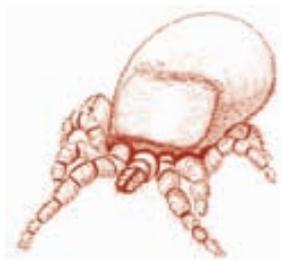
Whiteflies are readily recognised. Adults are small white coloured flies. These insects tend to flutter around a plant when disturbed before quickly landing back on the plant.



Whiteflies feed on plant sap. They also excrete honeydew which leads to the growth of black sooty mould on the leaf surface. Greenhouse whitefly can transmit lettuce yellows virus and the Silverleaf whitefly can transmit tomato leaf curl virus.

Mites

Mites are very small oval shaped organisms. Adult mites have 8 legs. Young mites look like smaller versions of the adults. They are very small and can increase to very large numbers and cause lot of damage before they are even noticed.



Caterpillars

Caterpillars are the larval stages (juveniles) of moths and butterflies. These pests cause direct and significant feeding damage on a range of crops.



Flies

Fungus gnats and shore flies are small, black flies. They are weak fliers and tend to 'run' or 'jump' along the substrate surface or ground. Fungus gnat larvae cause damage by feeding on roots. Fungus gnats and shore flies can spread fungal diseases.



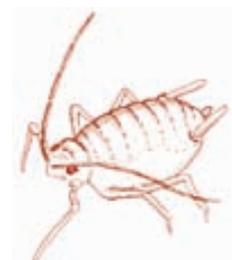
Bugs

There are various bugs which can be pests in some crops, though they tend to be minor or uncommon problems in the greenhouse. Rutherglen bugs are one of the more common seasonal bug pests. These native insects cause direct and significant feeding damage on a range of crops. Rutherglen bugs are sap suckers.



Aphids

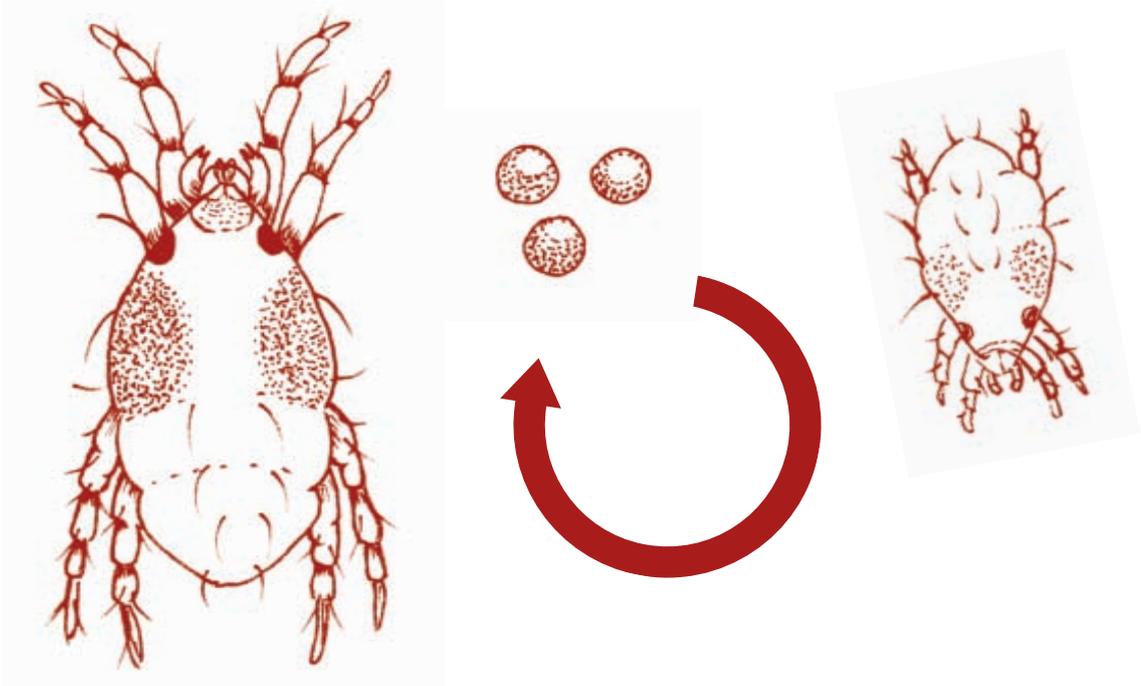
Aphids are small pear-shaped insects. They have soft bodies 1.5 – 3.5mm long. Some adults may have wings. Aphids have relatively long legs and antennae. Aphids can also carry some viruses.



Life cycles

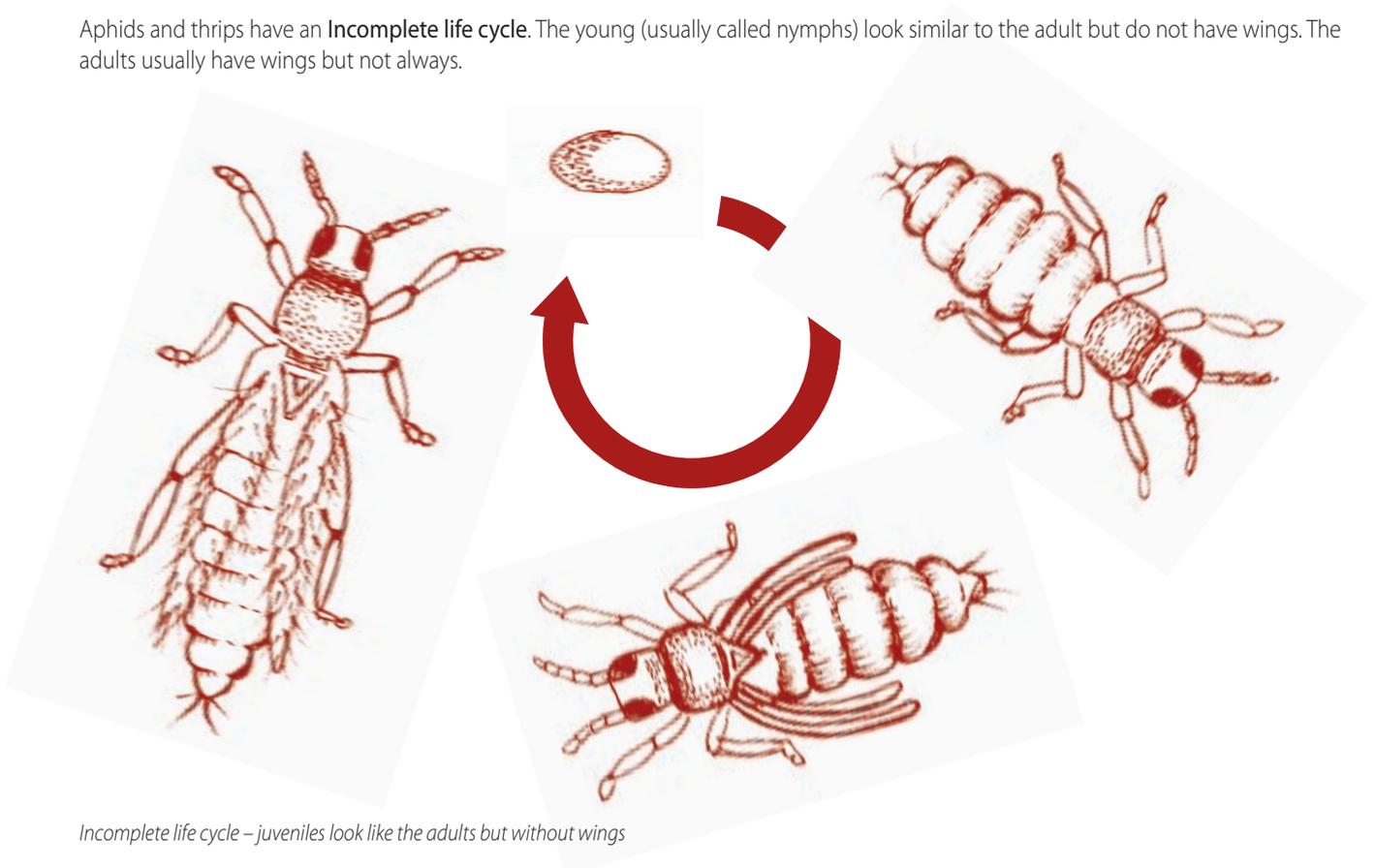
Both insects and mites go through different life stages. It is important to be able to recognise the different stages, not only in order to correctly identify the problem, but also because some management strategies, for example pesticides, may only work when a pest is at a certain life stage. There are 3 types of life cycle.

For pests which have a **Simple life cycle**, for example mites, the young and adult mites look similar except for their size. The pest does not have wings at any stage.



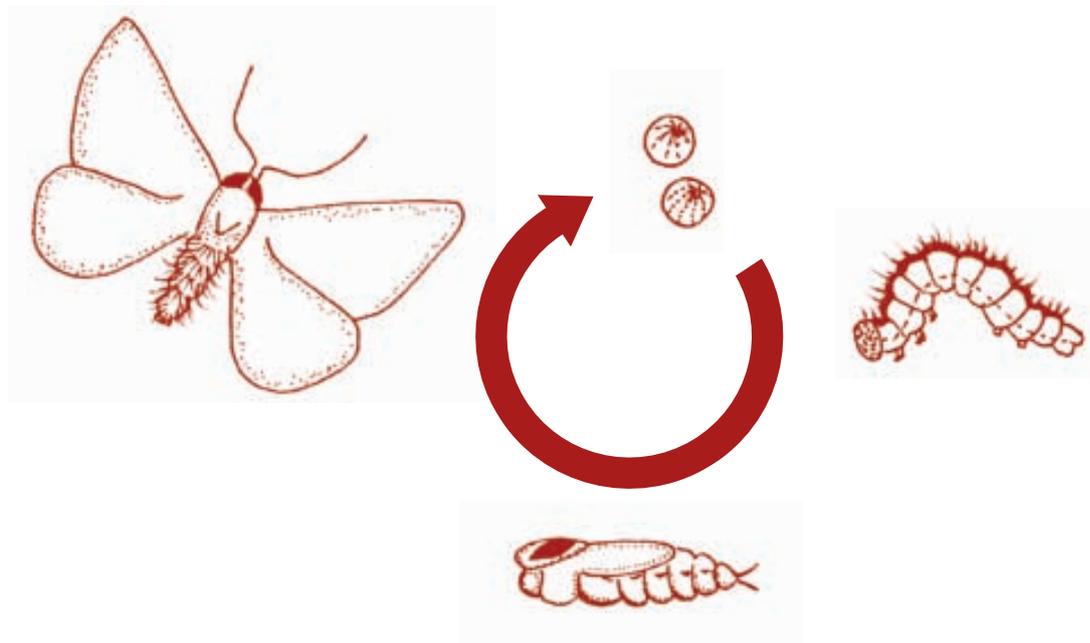
Simple life cycle – juveniles and adults look the same

Aphids and thrips have an **Incomplete life cycle**. The young (usually called nymphs) look similar to the adult but do not have wings. The adults usually have wings but not always.



Incomplete life cycle – juveniles look like the adults but without wings

Some pests including moths, whiteflies and fungus gnats have a **Complete life cycle**. The young look completely different to the adult. The young may be called larvae, maggots, caterpillars or grubs depending on the species. The young will go through a dramatic change in form (metamorphosis) during the pupal stage before emerging as an adult.



Complete life cycle – juveniles look completely different to the adults

Critical Management Practices that need to be considered are identified for each of the following pests or pest groups:

- THRIPS
- APHIDS
- SPIDER MITES
- BROAD MITES
- TOMATO RUSSET MITES
- WHITEFLIES
- CATERPILLARS
- FLIES – FUNGUS GNATS, SHORE FLIES, QUEENSLAND FRUIT FLIES
- RUTHERGLEN BUGS

For each pest or pest group a lifecycle diagram has been included to show the different life stages of the particular pest. The types of practice (preventative, biological or chemical) that are available for each pest at a particular life stage are indicated (with a white dot) in the relevant lifecycle diagrams.

The practices that you implement will depend on the level of risk that each pest poses to your business. Ultimately, you should aim to implement all the preventative practices.

THRIPS

Thrips are small, slender insects. They have soft bodies ranging from 1 – 2mm in length. Adult thrips have two pairs of narrow wings fringed with long hairs. Immature thrips are pale yellow to white in colour. Adults can be pale to dark. Eggs are laid in leaves or petals. The larval stages and adults can be found in flowers and buds as well as on leaves.

Host range

Thrips feed on almost any flowering plant including capsicum, cucumber, lettuce, tomato and strawberry as well as pome and stone fruit and a very wide range of ornamentals.

Thrips are sap suckers. They can physically damage plants causing malformations in new growth and bronzing and scarring of leaves, flowers and fruit from their feeding. When thrips larvae feed on small developing fruit especially cucumber, they cause small scars. As the fruit grows, the scars restrict growth causing bending or curling in the case of cucumbers.

Thrips prefer warm, dry conditions so they tend to be more active from spring through to autumn, though they can also be a winter problem in some greenhouses.



Check for thrips under leaf axils, in flowers, on the underside of leaves and in new growth



Photo J. Badgery-Parker

There are several species; most of which transmit tomato spotted wilt virus (TSWV). The larval stages pick up the virus while feeding on infected plants and then as adults, they pass the virus on to uninfected plants (after only about 5 minutes of feeding on the plant).

Western flower thrips (*Frankliniella occidentalis*) is a key pest in Australia. Adult females are yellowish on the head and thorax and brown on the upper abdomen. They can be darker in winter. Adult males are smaller and pale yellow. Immature stages are wingless and have bright red eyes. Adults are found in flowers and both adults and larvae can be found on the undersides of leaves, on fruit and in the growing tips on the plant.

WFT have high levels of resistance to many insecticides. This makes them very difficult to control using chemicals. This species is the main carrier of TSWV in most greenhouse systems.

Onion thrips (*Thrips tabaci*) are a key pest in the Eastern states. Adults are smaller than WFT, pale yellow to dark brown – not as two-toned. Immature stages are yellowish and do not have wings. This species transmits TSWV. Adults and larvae are mostly found on the lower leaves, though they may also be in flowers, on fruit and leaves and in the growing tips on the plant.

Melon thrips (*Thrips palmi*) are a key pest in Queensland. These are small, yellow-orange thrips with dark fringed wings. Immature stages are yellowish. Melon thrips can transmit TSWV and Capsicum Chlorosis Virus (CaCV) in sub-tropical climates. This species of thrips are usually on the underside of leaves and in the growing tips.

Tomato thrips (*Frankliniella schultzei*) can be yellow to a dark brown colour and though they are generally a minor pest of greenhouse crops, this species can transmit both TSWV and CaCV. This species is usually found hiding in flowers and foliage.

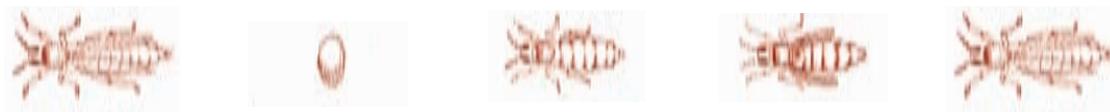
Plague thrips (*Thrips imaginis*) are an occasional pest of greenhouse crops. They are found feeding on flowers and young leaves.

Critical management practices

- The number of greenhouse entry points has been minimised
- Double entry doors (and fan) or a double curtain installed at all entry points
- Bright yellow, mid-blue and white coloured clothing is avoided when working in or entering the greenhouse
- Insect screens are installed on opening sides
- There is a neighbourhood agreement for managing weeds
- Used substrate completely removed from greenhouse at the end of the crop
- Crop work done in cleanest, youngest crops first and dirty tasks are completed last in the day
- Overhead sprinkler/misting/fogging used (if appropriate and feasible) to maintain humidity levels
- Windbreaks are established around the farm or greenhouse
- Windward vent opening restricted during warm windy conditions if feasible

Risk factors	
Temperature	20 – 35°C
Low humidity (<60%)	✓
Air currents / wind	✓
Poor hygiene (hands, clothes, tools, equipment)	✓
Weeds	✓
Crop debris	✓
Infested plants	✓
'Pet' plants	✓
Old crops	✓
Soil	✓
Substrate	✓
Pesticide resistance	✓
Cucurbits (eg cucumber, zucchini)	✓
Solanaceae (eg tomato, capsicum, eggplant)	✓

In a greenhouse there can be up to 15 generations of thrips per year



Warm conditions		2–5 days		3–6 days		1–4 days		30–35 days	
Cool conditions		5–10 days		6–14 days		5–9 days			
	ADULT	→	EGG	→	LARVA	→	PUPA	→	ADULT
	Leaves Flowers Buds		Leaves Petals		Leaves Flowers Buds		Soil Substrate		Leaves Flowers Buds
Preventative controls	○		○		○		○		○
Biological controls	○				○		○		○
Chemical controls	○				○				○

* A full circle indicates relevant management controls are available. A half circle indicates only partial control is available.

APHIDS

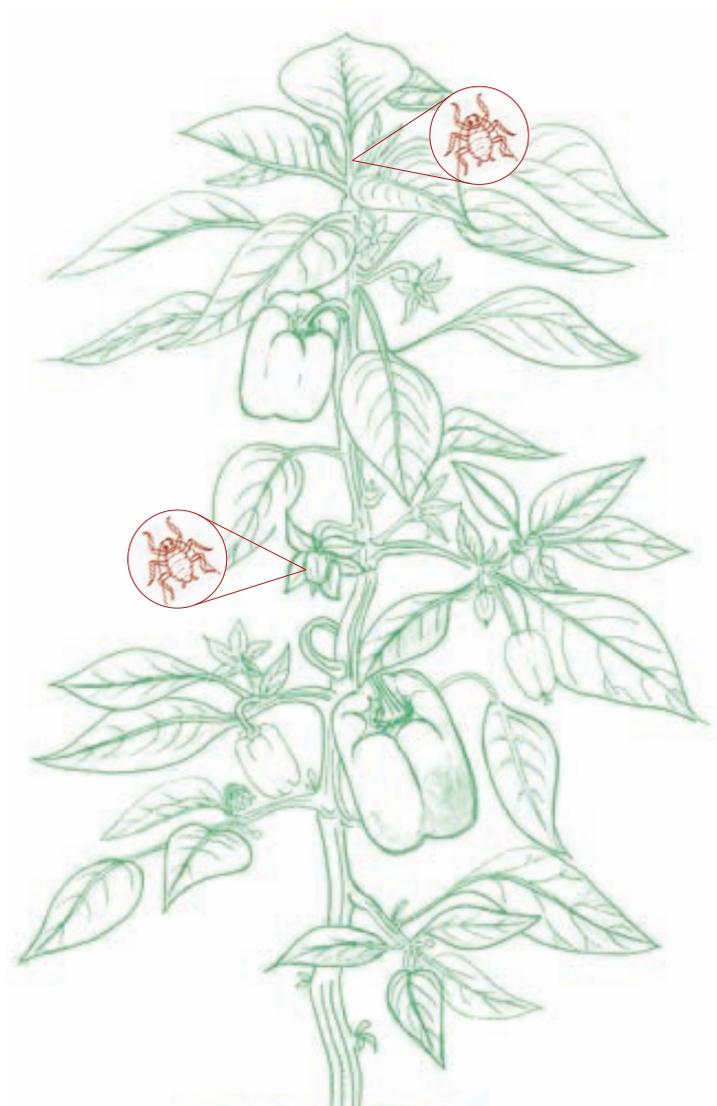
Aphids are small (2-3mm) soft bodied insects. They have a pear shaped body, ranging in colour from light olive green or pinkish to dark green and black. There are usually 4 nymphal stages. These look the same as the adult but are smaller and sometimes lighter in colour. Some colonies can have aphids of two colour types. There are also winged and wingless adult forms which occur in the same colony. Aphids usually give birth to live young (which can already have their own young developing).

Host range

Most crops are susceptible to attack by at least one species of aphid. Herbaceous weeds are also common hosts of aphids. They are a common pest in greenhouses (especially green peach aphid), though usually easily controlled. Some aphids have primary and secondary hosts.

Aphids are sap suckers. They reduce plant vigour and yield and fruit quality can suffer. Feeding damage can cause distortion of newer shoots and fruit buds. Heavy infestations can severely weaken plants.

Honeydew, which is excreted by feeding aphids onto the plant foliage can result in the growth of sooty mould that spoils fruit appearance and may even lead to stunting, defoliation and poor yields.



Check for aphids on new growth, particularly young stems and under fruit axils.



Photo M. Steiner

Aphids prefer warm conditions so they tend to be more active in spring and autumn, though they can also be a winter problem in some greenhouses. Some species produce eggs to over-winter in cold climates.

There are several species. In some crops, aphids can transmit viruses.

The **green peach aphid** (*Myzus persicae*) is a key pest. This species transmits over 100 plant viruses including the cucumber mosaic virus (CMV). The wingless adult and the nymphs are light green to pink with red eyes. The cornicles (a distinctive pair of protrusions at the insect's rear) have dark tips. Winged females have a black patch on the upper surface of the abdomen and a dark head and thorax.

The **cotton aphid** (*Aphis gossypii*) is another key pest and can also transmit several plant viruses including CMV. The small wingless adult and the nymphs of this species vary from light yellow to greenish black. They have long black cornicles. Winged females are black.

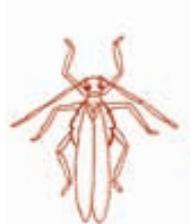
The **potato aphid** (*Macrosiphum euphorbiae*) is a less significant pest but it can also transmit several plant viruses including CMV. The wingless adult and the nymphs vary from pink to green. They have long cornicles. Winged adult females are black.

Critical management practices

- Crop work done in cleanest, youngest crops first and dirty tasks completed last in the day
- Small 'day' and 'pruning' bins are located conveniently in or near the greenhouse and are emptied frequently
- Old crops completely removed from greenhouse at end of crop
- Roadways and pathways in the 'clean' zone are free from soil and mud, weeds, plant debris and rubbish
- The number of greenhouse entry points has been minimised
- Double entry doors (and fan) or a double curtain installed at all entry points
- Insect screens are installed on opening sides
- Feed and drain EC and pH is managed (including monitored and recorded) at least daily
- Only a single crop is grown at a time in the greenhouse and the greenhouse is kept free of non-crop plants including "pet" plants
- UV blocking covering material used (if appropriate and feasible) to disrupt pest behaviour

Risk factors	
Temperature	22 – 33°C
Air currents / wind	✓
Weeds	✓
Crop debris	✓
Infested plants	✓
'Pet' plants	✓
Old crops	✓
Excess nitrogen	✓
Cucurbits (eg cucumber, zucchini)	✓
Solanaceae (eg tomato, capsicum, eggplant)	✓

In a greenhouse there can be up to 35 generations of aphids per year



Warm conditions	25–35 days	5–7 days	5–7 days	25–35 days	
Cool conditions	7–10 days		7–10 days		
	WINGED ADULT	↔	NYMPH	↔	WINGLESS ADULT
	Leaves Flowers Buds Shoots	↙ ↘	Leaves Flowers Buds Shoots	↖ ↗	Leaves Flowers Buds Shoots
		EGG (rare) Leaves Flowers		EGG (rare) Leaves Flowers	
Preventative controls	●	●	●	●	●
Biological controls	●		●	●	●
Chemical controls	●		●		●

* A full circle indicates relevant management controls are available. A half circle indicates only partial control is available.

SPIDER MITES

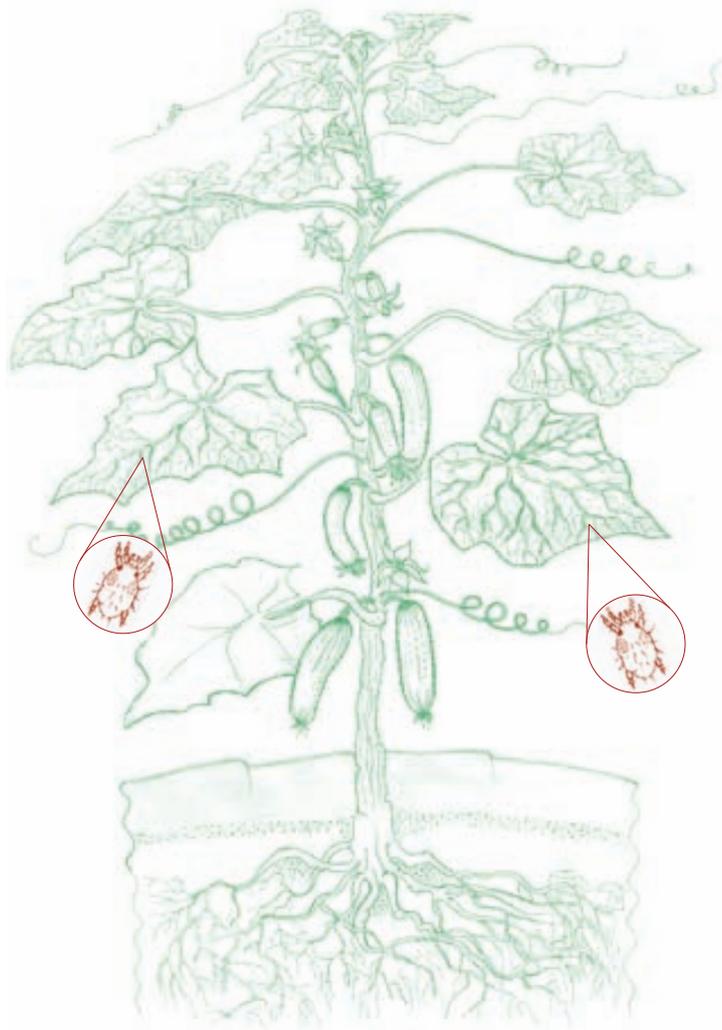
Mites are very small, oval shaped pests, only up to about 0.5mm in length. The males tend to become narrower towards the tail end of their body. Mites are very difficult to see so you need to look for the symptoms or damage they cause such as bronzing or mottling of leaves.

Host range

Mites attack a wide range of crops and many broad-leafed weeds are hosts. These pests are sap suckers and cause leaf yellowing and mottling as well as reduced plant vigour. Flower and leaf buds can become distorted.

Mites prefer warm to hot conditions so they tend to be more active from spring through to autumn, though they can also be a winter problem in some greenhouses. Two-spotted mite and bean spider mite prefer hot dry conditions. High humidity can reduce numbers of these species.

The **two-spotted mite** (*Tetranychus urticae*) is a key pest in all areas. It feeds on the underside of leaves and causes leaf cells to die resulting in a speckled pattern. Heavier infestations cause a yellowing of interveinal leaf area with prominent green veins and a lot of webbing. The two-spotted mite (TSM) has a very broad host range including cucumbers and has increasing resistance to several pesticides/miticides. Adults and nymphs are yellowish-green with two dark green or black spots on their backs. In winter the female will lose its spots and turn an orange colour. Eggs are small, round and white. TSM thrives in hot dry conditions. Infested leaves can rapidly become bronzed and shrivel and may drop and cause the plant to die.



Check for spider mites on the underside of leaves.



Photo J. Badgery-Parker

The **bean spider mite** (*Tetranychus ludeni*) is a key pest in New South Wales and Western Australia. Adult females are about 0.5mm long and are dark red. Nymphs can be a light greenish colour with dark patches on their backs. Eggs are small and round with a reddish tinge. Bean spider mites (BSM) mainly feed on the underside of leaves though will sometimes also be found on the upper side. When BSM feed, the damage causes leaves to become mottled and bleached. These symptoms are similar to some nutritional disorders such as magnesium deficiency or zinc toxicity so monitoring for this pest is critical to avoid misdiagnosis.

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Critical management practices

- Crop work done in cleanest, youngest crops first and dirty tasks completed last in the day
- Employees have a clean change of clothes/overalls everyday for greenhouse work and clothes/overalls are changed after working in a 'dirty' greenhouse
- Temperature and humidity in the greenhouse is properly managed (including monitoring) and temperature and humidity extremes in the greenhouse are avoided
- Only a single crop is grown at a time in the greenhouse and the greenhouse is kept free of non-crop plants including "pet" plants
- Pruned plant material put directly into a 'pruning' bin or bag and disposed of appropriately
- All containers (bins, boxes, tubs, buckets and trays) and other materials (eg twine and crop supports) to be used in the greenhouse are cleaned and disinfected before being taken into the greenhouse

- The number of whole crop foliar sprays are minimised
- Vibrating pollinators used in preference to blowers if pollinating crops
- A waste bin is located away from the greenhouse for management of bulk waste and is emptied regularly
- Spot treatments are used when appropriate

Risk factors	
Temperature	>25°C
Low humidity (<60%)	✓
Air currents / wind	✓
Poor hygiene (hands, clothes, tools, equipment)	✓
Weeds	✓
Crop debris	✓
Infested plants	✓
'Pet' plants	✓
Old crops	✓
Pesticide resistance	✓
Cucurbits (eg cucumber, zucchini)	✓
Solanaceae (eg tomato, capsicum, eggplant)	✓

In a greenhouse there can be up to 28 generations of spider mites per year



Warm conditions		3-5 days		4-7 days		14 days	
Cool conditions		5-10 days		7-12 days		21 days	
	ADULT	→	EGG	→	IMMATURE	→	ADULT
	Leaves Flowers Buds		Shoots Fruit		Shoots Fruit		Shoots Fruit
Preventative controls	●		●		●		●
Biological controls	●		●		●		●
Chemical controls	●		◐		●		●

* A full circle indicates relevant management controls are available. A half circle indicates only partial control is available.

BROAD MITES

Broad mites (*Polyphagotarsonemus latus*) are a key pest in all the Eastern states, especially warmer regions and in warm humid seasons. They are very small (0.25 – 0.3mm) oval shaped pests, pale white to yellow-green in colour. The nymphs are pale and have a white stripe along the top of their back but otherwise resemble the adults. Mites are very difficult to see so you need to look for the symptoms or damage they cause such as bronzing or distortion of leaves.

Host range

Broad mite attacks a wide range of crops but favours capsicum. Many broad-leaved weeds are hosts. Broad mites can be common in herbs such as basil and parsley.

Mites are sap suckers that cause leaf yellowing and mottling and reduced plant vigour. Flower and leaf buds can become distorted.

The broad mite prefers warm, humid conditions so they tend to be more active in spring and autumn, though they can also be a winter problem in some greenhouses. They are found in the growing tips of plants. This species feeds on both the upper and lower surfaces of newly emerged leaves and flowers and remains still when feeding. When disturbed, it moves slowly. Leaves become bronzed, russetted and distorted with downward curling leaves. The symptoms can be mistaken for viral or herbicide damage so monitoring for this pest is critical.

Broad mites can be carried by whiteflies.



Check for broad mites on new leaves and growing tips of plants.

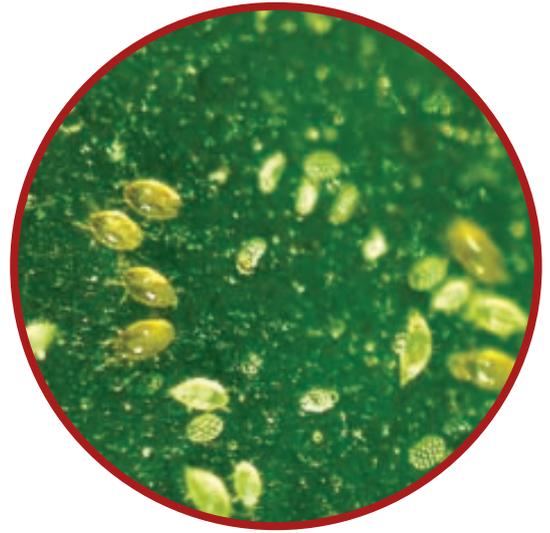


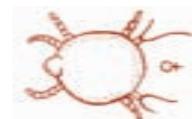
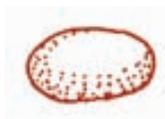
Photo M. Steiner

Critical management practices

- Crop work done in cleanest, youngest crops first and dirty tasks completed last in the day
- Employees have a clean change of clothes/overalls everyday for greenhouse work and clothes/overalls are changed after working in a 'dirty' greenhouse
- Temperature and humidity in the greenhouse is properly managed (including monitoring) and temperature and humidity extremes in the greenhouse are avoided
- Only a single crop is grown at a time in the greenhouse and the greenhouse is kept free of non-crop plants including "pet" plants
- Pruned plant material put directly into a 'pruning' bin or bag and disposed of appropriately
- All containers (bins, boxes, tubs, buckets and trays) and other materials (eg twine and crop supports) to be used in the greenhouse are cleaned and disinfected before being taken into the greenhouse
- All tools and equipment (eg knives, secateurs, brooms and trolleys) to be used in the greenhouse are cleaned and disinfected before being taken into the greenhouse
- Vibrating pollinators used in preference to blowers if pollinating crops
- Potential insect vectors are excluded or appropriately managed
- Spot treatments are used when appropriate

Risk factors	
Temperature	>25°C
High humidity (>80%)	✓
Air currents / wind	✓
Poor hygiene (hands, clothes, tools, equipment)	✓
Weeds	✓
Crop debris	✓
Infested plants	✓
'Pet' plants	✓
Old crops	✓
Whiteflies	✓
Pesticide resistance	✓
Cucurbits (eg cucumber, zucchini)	✓
Solanaceae (eg tomato, capsicum, eggplant)	✓

In a greenhouse there can be up to 28 generations of broad mites per year



Warm conditions		1 day	2 days	2-4 days	10 days		
Cool conditions		1-2 days	3 days	4 days			
	ADULT	→	EGG	→	IMMATURE	→	ADULT
	Leaves Flowers Buds		Shoots Fruit		Shoots Fruit		Shoots Fruit
Preventative controls	●		●		●		●
Biological controls	●				●		●
Chemical controls	●				●		●

* A full circle indicates relevant management controls are available. A half circle indicates only partial control is available.

TOMATO RUSSET MITES

Tomato russet mites (*Aculops lycopersici*) are a major pest of tomato. They are very small (0.15 – 0.2mm) torpedo shaped pests, white to pale yellow in colour. The nymphs are similar to the adults but even smaller. Mites are very difficult to see so you need to look for the symptoms or damage they cause such as bronzing or russetting of leaves.

Host range

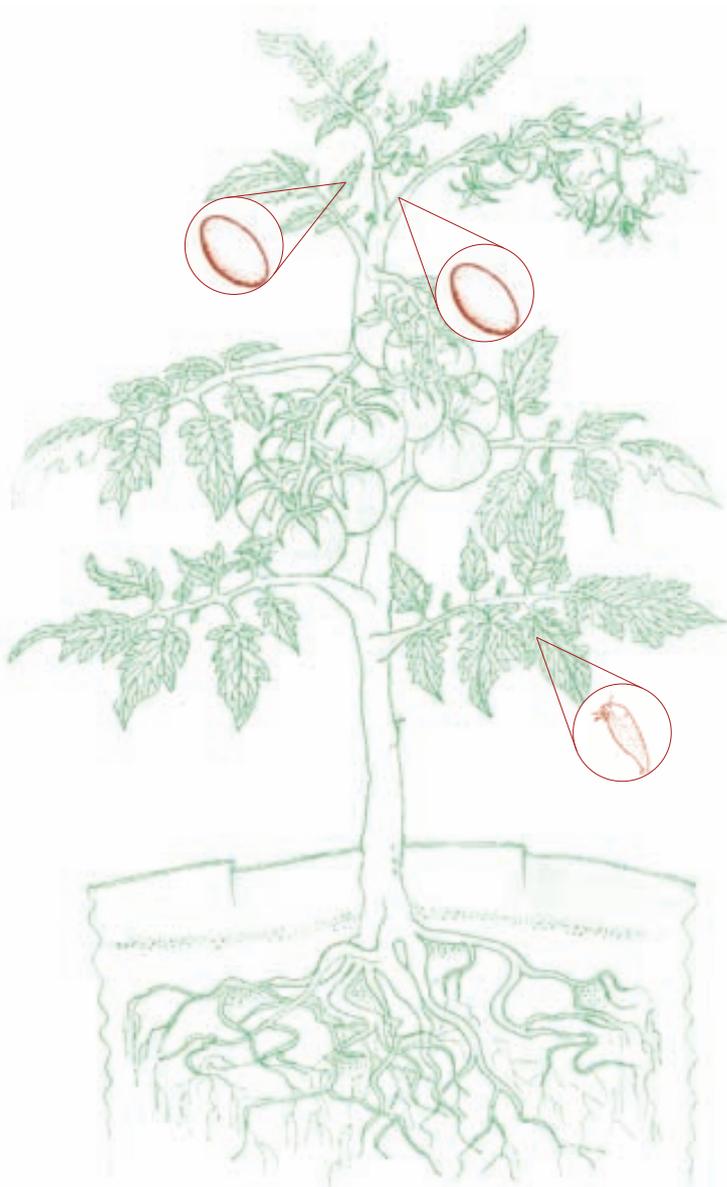
Tomato russet mite attacks tomatoes and other Solanaceae crops. A number of weeds including nightshade are hosts to this pest. They are found around leaf veins and the greatest numbers are seen just above the obvious damage areas.

Russet mites cause a silvering of lower leaves which soon turn bronze and drop. Infestation tends to start on lower leaves and spread upwards. The lower stems of tomato plants will lose their hairs and become smooth and shiny and develop a brown rust colour.

Fruit can become more susceptible to sunscald as the plants lose leaves. The skin of fruit can become leathery with pale halo shaped blotches and small cracks develop at the stem end.



Photo M. Steiner



Check for tomato russet mites on lower leaves. Eggs are laid on upper stems and new leaves.

The russet mite prefers warm to hot conditions and low humidity though they can still be a problem under more humid conditions.

These mites are spread on the wind, plant debris, clothing and equipment.

Critical management practices

- Crop work done in cleanest, youngest crops first and dirty tasks completed last in the day
- Employees have a clean change of clothes/overalls everyday for greenhouse work and clothes/overalls are changed after working in a 'dirty' greenhouse
- Temperature and humidity in the greenhouse is properly managed (including monitoring) and temperature and humidity extremes in the greenhouse are avoided
- Pruned plant material put directly into a 'pruning' bin or bag and disposed of appropriately
- All containers (bins, boxes, tubs, buckets and trays) and other materials (eg twine and crop supports) to be used in the greenhouse are cleaned and disinfected before being taken into the greenhouse
- All tools and equipment (eg knives, secateurs, brooms and trolleys) to be used in the greenhouse are cleaned and disinfected before being taken into the greenhouse
- Vibrating pollinators used in preference to blowers if pollinating crops
- A crop break or rotation plan is used for the greenhouse
- Windbreaks are established around the farm or greenhouse
- Spot treatments are used when appropriate

Risk factors	
Temperature	20 – 30°C
Low humidity (<60%)	✓
Air currents / wind	✓
Poor hygiene (hands, clothes, tools, equipment)	✓
Weeds	✓
Crop debris	✓
Infested plants	✓
'Pet' plants	✓
Old crops	✓
Pesticide resistance	✓
Solanaceae (eg tomato, capsicum, eggplant)	✓

In a greenhouse there can be up to 30 generations of russet mites per year



Warm conditions		2 days	2 days	3 days	16-22 days		
Cool conditions		2 days	2-3 days	3-5 days			
	ADULT	→	EGG	→	IMMATURE	→	ADULT
	Leaves Flowers Buds		Shoots Fruit		Shoots Fruit		Shoots Fruit
Preventative controls	●		●		●		●
Biological controls	●				●		●
Chemical controls	●				●		●

* A full circle indicates relevant management controls are available. A half circle indicates only partial control is available.

WHITEFLIES

Whiteflies are small, white insects. They have soft bodies ranging from 1.5 – 2mm in length. When disturbed, they tend to flutter near the plant and resettle quickly on leaves. Heavy infestations give the appearance of white clouds when they are disturbed and flutter about.

Greenhouse whitefly (*Trialeurodes vaporariorum*) is a key pest in most areas. Adults are usually on the underside of leaves, towards the top of the plant. Eggs are found on the underside of new foliage. Immature whiteflies (nymphs and pupae) are scale-like and are generally found on older foliage.

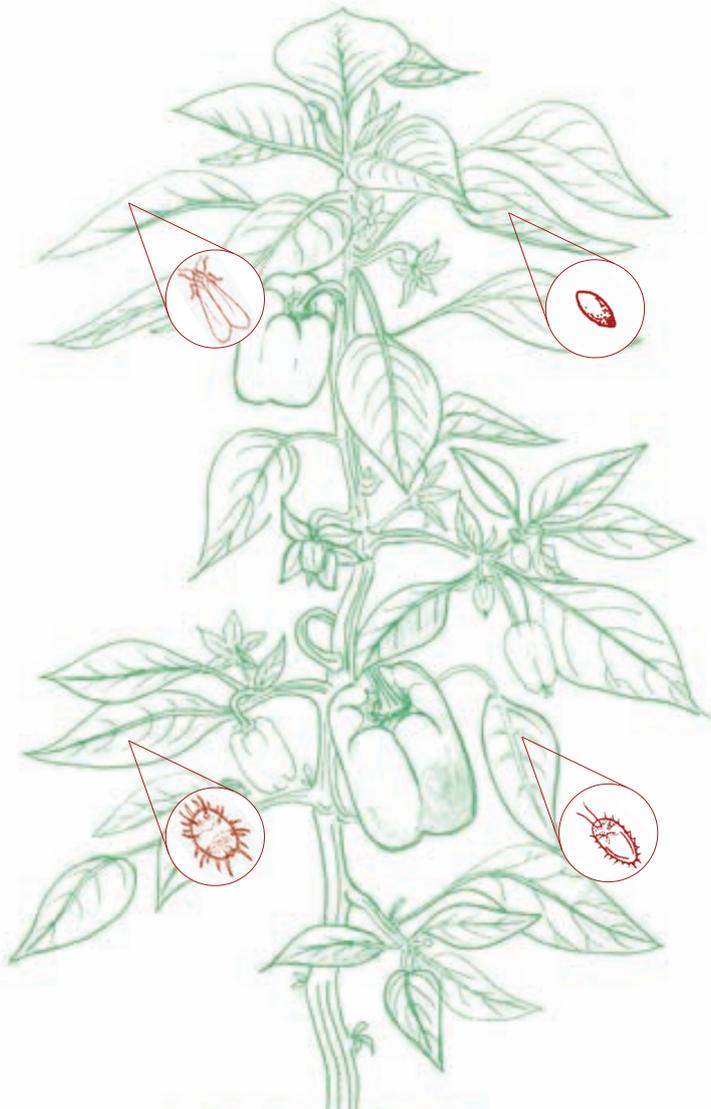
Silverleaf whitefly (*Bemisia argentifolii*) is a key field problem in tropical zones of Western Australia, Queensland and northern NSW and is likely to become a significant pest of greenhouse crops in most areas. The adult has a smaller body than greenhouse whitefly (GWF) and holds its wings on a steeper angle - more tent-like than GWF. Silverleaf whitefly (SLW) has a yellow body that is visible between its wings. It also sucks sap resulting in reduced plant vigour, poor growth, leaf yellowing and leaf drop. It can transmit viruses including tomato yellow leaf curl virus.



Photo J. Badgery-Parker



Photo M. Steiner



Check for whiteflies on the underside of leaves, especially towards top of plant. Eggs are laid on upper stems and new leaves.

Host range

Whiteflies feed on a wide range of crops. Greenhouse whitefly favours tomatoes. A large number of weeds are whitefly hosts, including sow thistle, verbena and mallow. Milk thistle is a common host of whiteflies, especially Silverleaf whitefly.

Whiteflies suck plant sap as they feed. Direct feeding damage by adults and immature stages causes leaves to yellow and die prematurely. Heavy infestations reduce plant vigour. Adults have the potential to transmit viruses. They also excrete honeydew which encourages the growth of sooty mould on leaves and fruit.

Whiteflies prefer warm to hot conditions so they tend to be more active from spring through to autumn, though they can also be a winter problem in some greenhouses. Silverleaf whitefly prefers hotter conditions.

Critical management practices

- The number of greenhouse entry points has been minimised
- Double entry doors (and fan) or a double curtain installed at all entry points
- Insect screens are installed on opening sides
- Small 'day' and 'pruning' bins are located conveniently in or near the greenhouse and are emptied frequently
- Pruned plant material put directly into a 'pruning' bin or bag and disposed of appropriately
- De-leafing, truss or flower pruning and thinning used to reduce pest and disease risk
- Old crops completely removed from greenhouse at end of crop
- Roadways and pathways in the 'clean' zone are free from soil and mud, weeds, plant debris and rubbish
- Spot treatments are used when appropriate
- UV blocking covering materials used (if appropriate and feasible) to disrupt pest behaviour

Risk factors	
Temperature	18 – 24°C
Air currents / wind	✓
Poor hygiene (hands, clothes, tools, equipment)	✓
Weeds	✓
Crop debris	✓
Infested plants	✓
'Pet' plants	✓
Old crops	✓
Cucurbits (eg cucumber, zucchini)	✓
Solanaceae (eg tomato, capsicum, eggplant)	✓

Greenhouse whitefly

In a greenhouse there can be up to 12 generations of whitefly per year



Warm conditions		1 day	7 days	14 days	9 days				
Cool conditions		3 days	10 days	35 days	23 days				
	ADULT	→	EGG	→	NYMPH	→	PUPA	→	ADULT
	Underside of higher leaves		Middle and lower leaves		Middle and lower leaves		Lower leaves		Underside of higher leaves
Preventative controls	●		●		●		●		●
Biological controls	●				●				●
Chemical controls	●		◐		●				●

* A full circle indicates relevant management controls are available. A half circle indicates only partial control is available.

Silverleaf whitefly

Warm conditions		7 days	8 days	4 days	9 days				
Cool conditions		10 days	16 days	6 days	16 days				
	ADULT	→	EGG	→	NYMPH	→	PUPA	→	ADULT
	Underside of higher leaves		Middle and lower leaves		Middle and lower leaves		Lower leaves		Underside of higher leaves
Preventative controls	●		●		●		●		●
Biological controls	●				●				●
Chemical controls	●		◐		●				●

* A full circle indicates relevant management controls are available. A half circle indicates only partial control is available.

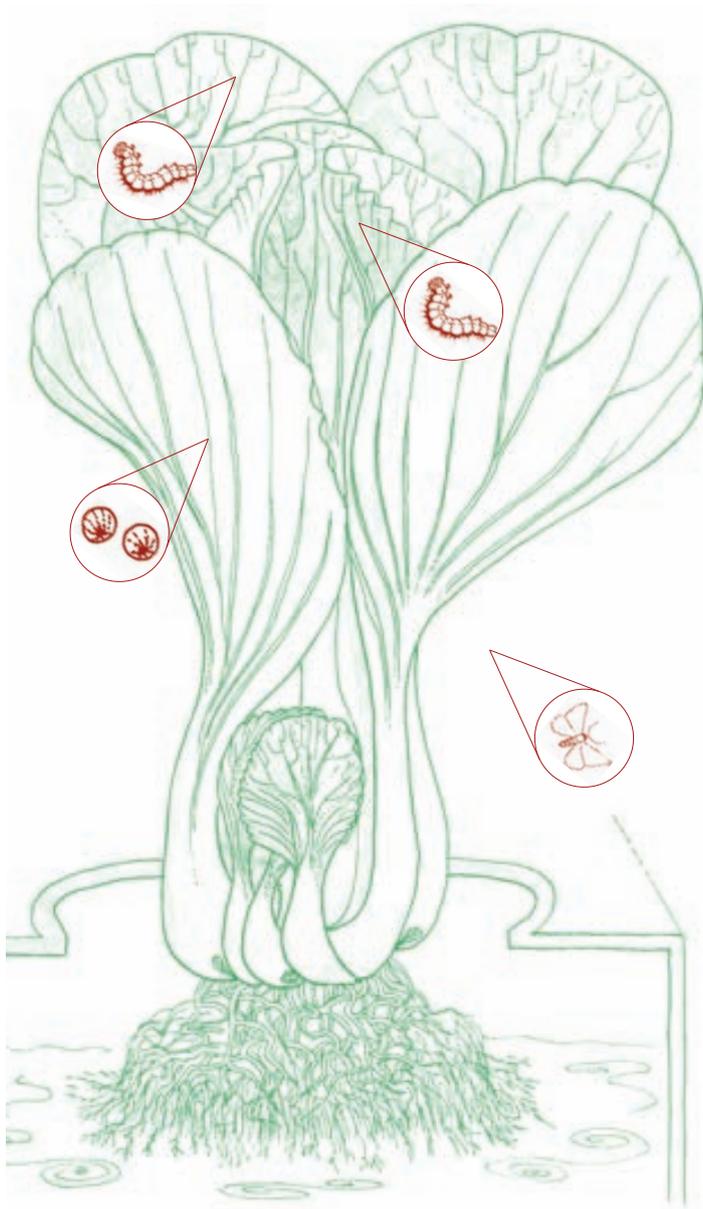
CATERPILLARS

A number of caterpillar, larvae or grub life stages of adult moths are minor or major pests in most greenhouse crops. Caterpillars cause damage by feeding directly on leaves, young stems, buds and flowers.

There are several key species.

Budworms (*Helicoverpa punctigera* and *H. armigera*), previously known as *Heliothis*, are a key pest. The dome-shaped, finely striped egg is small (0.5mm) and laid singularly on buds and growing tips. It is white when first laid, but gradually changes to yellow then brown as it gets closer to hatching.

Young caterpillars or larvae are pale with a dark brown head. Older caterpillars grow to 40 to 50mm long and are yellow-green to red-brown in colour. They have yellowish stripes along the side of their bodies and a darker one along their back. Besides destroying plant foliage, buds and flowers, *Helicoverpa* also chews holes in fruit. The adult moths are grey to reddish brown and have a 40mm wingspan and feed only on nectar. They are active at night and fly towards lights.



Check for caterpillars and moth eggs on leaves and stems.



Photos J. Badger-Parker

The **Cluster caterpillar** (*Spodoptera litura*) lays its eggs in clusters. They are covered with buff-coloured scales.

Young caterpillars feed in clusters on the underside of leaves and skeletonise leaves. Older larvae are solitary. They feed on flowers, leaves and growing points of the plant. Caterpillars grow to 40 to 50mm long. They are commonly brownish purple in colour, though they can be green. The Cluster caterpillar has a row of dark triangles and a distinctive yellow line along either side of the body. The adult moths have dark forewings and light hind wings.

Looper caterpillars (*Chrysodeixis* spp.) have a small, round pale egg which is laid singularly or in small clusters on the underside of leaves.

The caterpillars of this species grow to 30 to 40mm long and are usually green, but can be brown. They are smooth and slender. They feed on the underside of leaves and can skeletonise or chew holes in them. Large populations can defoliate plants. Loopers move in a looping motion. The adults are active at night and fly towards lights.

The **potato moth** (*Phthorimaea operculella*) caterpillar grows to just 10 to 12mm long. They are pinkish white with a dark thorax and narrower, brown head. The body colour can vary from whitish to greyish pink and even green when feeding on leaves and stems. The larvae bore holes into stems, shoots and fruit. Damage is most severe on lower leaves and on fruit. Large numbers can kill seedlings. The brownish grey moth has a wingspan of up to 16mm and is active at dusk.

Critical management practices

- The number of greenhouse entry points has been minimised
- Insect screens are installed on opening sides
- Greenhouse covering materials are kept clean and well maintained
- Double entry doors (and fan) or a double curtain installed on all entry points
- A waste bin is located away from the greenhouse for management of bulk waste and is emptied regularly
- Windward vent opening restricted during warm windy conditions if feasible
- Pruned plant material put directly into a 'pruning' bin or bag and disposed of appropriately
- Spot treatments are used when appropriate
- Greenhouse floor and other surfaces kept covered for easy cleaning

Risk factors	
Temperature	20 – 30°C
Air currents / wind	✓
Weeds	✓
Crop debris	✓
Infested plants	✓
'Pet' plants	✓
Old crops	✓
Pesticide resistance	✓
Cucurbits (eg cucumber, zucchini)	✓
Solanaceae (eg tomato, capsicum, eggplant)	✓

In a greenhouse there can be up to 12 generations of caterpillars per year



Warm conditions	1–4 days		2–7 days		14–28 days		8–14 days		14–21 days	
Cool conditions	5–12 days				18–42 days		12–14 days			
	ADULT	→	EGG	→	LARVA	→	PUPA	→	ADULT	
	Leaves Flowers Buds Stems		Leaves Flowers Buds Stems		Leaves Flowers Buds Stems		Leaves Buds Stems		Leaves Flowers Buds Stems	
Preventative controls	●		●		●		●		●	
Biological controls			●		●		●		●	
Chemical controls	●		●		●		●		●	

* A full circle indicates relevant management controls are available. A half circle indicates only partial control is available.

FLIES – FUNGUS GNATS, SHORE FLIES AND QUEENSLAND FRUIT FLIES

There are several small flies that are pests of many greenhouse crops.

Fungus gnats (*Bradysia* spp. (*Sciaridae*)) are a key pest in all areas. These pests are small black flies with long legs and antennae. They have a single pair of dusky wings and can look like a small mosquito. The veins on the wings make a Y-pattern at the end of the wing.

Very small whitish eggs are laid in the hydroponic substrate around the roots of the plant and in cracks and crevices in the greenhouse floor. The larvae are legless and white to clear in colour. They have a worm-like body (5 to 8mm long) and a small, shiny black head.

The larvae feed on root hairs, roots, organic matter and the base of the stem. Algae are also a food source. Feeding damage can cause loss of plant vigour, wilting and collapse, particularly in young plants. Large larvae can enter the stem just below the substrate surface. Adults and larvae can spread a number of plant diseases such as *Pythium*, *Rhizoctonia* and *Fusarium*. Adult fungus gnats can spread *Botrytis* and Gummy stem blight.

Adults are weak fliers and can usually be seen running about on the substrate or soil surface. Adult fungus gnats do not feed on plants.

Shore flies (*Scatella australiae*) are only minor pests. They can be mistaken for fungus gnats. Small, white oval eggs are laid in moist substrate or on algae. The larvae are small white maggots with no distinct head. They are found in the top layer of substrate. Algae is also a host on which they feed.

The adults are brown-black and have five pale spots on their smoky coloured wings. They can look like a very small house fly or fruit fly. Shore flies do not hover. They have a typical short flight which makes them look like they are jumping. Adults cause 'fly spotting' damage by leaving excrement on foliage and fruit. Adults and larvae are suspected of spreading some key plant diseases such as *Pythium* and *Phytophthora*.



Fungus Gnat. Photo J. Badgery-Parker



Shore fly. Photo J. Badgery-Parker



Check for fungus gnats and shore flies in wet areas and in substrate.

Queensland fruit fly (*Bactrocera tryoni*) is a key pest in Queensland and New South Wales and seasonal incursions may occur in some areas. Adults are brown to red-brown with yellow markings along their sides. They are 5 to 8mm in length. The larvae are creamy white with tapering ends and are legless. Adults sting fruit and lay eggs into it and the flesh around that section of fruit can ripen prematurely, rot and fall. Sometimes a corky scab can be produced at the sting site. In humid conditions, a gum-like exudate may be produced at the wound site. Rotting fruit is usually the first sign of fruit fly infestation.

Cucumber fly (*Bactrocera cucumis*) may also be a minor pest in some areas.

Critical management practices

- Drainage ensures that there are no puddles or wet areas in the 'clean' zone and surface run-off does not wash into greenhouse
- Good root zone drainage is maintained
- Irrigation uniformity test done before planting new crop
- Feed and drain irrigation volume is managed (including monitored and recorded) at least daily
- Only clean, pest and disease free substrate (new or sterilised) used for each new crop
- Used substrate completely removed from greenhouse at the end of the crop
- Hydroponic (irrigation) system always cleaned and disinfected before planting new crop
- Greenhouse floor and other surfaces kept covered for easy cleaning
- Roadways and pathways in the 'clean' zone are free from soil and mud, weeds, plant debris and rubbish
- All vehicles in the 'clean' zone are kept free from soil, plant debris and rubbish

Risk factors	
Temperature	20 – 30°C
Air currents / wind	✓
Poor hygiene (hands, clothes, tools, equipment)	✓
Run-off	✓
Wet areas	✓
Algae	✓
Weeds	✓
Crop debris	✓
Infested plants	✓
'Pet' plants	✓
Old crops	✓
Soil	✓
Substrate	✓
Poor drainage / high root zone moisture	✓
Cucurbits (eg cucumber, zucchini)	✓
Solanaceae (eg tomato, capsicum, eggplant)	✓

In a greenhouse there can be up to 14 generations of fungus gnat per year



Warm conditions		2–3 days	4 days	7–9 days	5–7 days	25–35 days			
Cool conditions		6 days		10–14 days	6–8 days				
	ADULT	→	EGG	→	LARVA	→	PUPA	→	ADULT
	Anywhere on plant, often on substrate		Soil Substrate		Soil Substrate		Soil Substrate		Anywhere on plant, often on substrate
Preventative controls	●		●		●		●		●
Biological controls			●		●				
Chemical controls									

* A full circle indicates relevant management controls are available. A half circle indicates only partial control is available.

RUTHERGLEN BUGS

Rutherglen bug (*Nysius vinitor*) is a native insect which attacks a wide range of plants. The adult female has a narrow, 5mm long grey-brown body with black eyes. The wings are silvery.

Eggs are small (1mm) and cream coloured when first laid, but gradually change to amber over about a week as they get closer to hatching. Small clusters of about 6 eggs are laid in spring on flower heads, weeds, plant debris and on soil.

Nymphs are pear shaped and amber when they first hatch but become darker brown. There are five nymph stages. Wing buds appear on the last stages. The adults can over-winter in weeds and crop debris.

Rutherglen bugs suck plant sap as they feed causing leaves to wither. They will migrate as the plants they are feeding on dry off, particularly winter weeds as they dry off in spring and during summer. Swarms can arrive in large numbers with storm fronts, which can make chemical control of adults difficult.

They prefer drier conditions as moist conditions can lead to a fungal disease which can kill large numbers.



Photo J. Badger-Parker

Critical management practices

- Windbreaks are established around the farm or greenhouse
- Roadways and pathways in the 'clean' zone are sealed or covered
- Roadways and pathways in the 'clean' zone are free from soil and mud, weeds, plant debris and rubbish
- Furrows or trenches (such as a gutter or a drain) used to stop crawling pests
- Splash skirts are installed on all opening walls of greenhouse
- Greenhouse covering materials are kept clean and well maintained
- Insect screens are installed on opening sides
- Insect screens are installed on roof vents
- Windward vent opening restricted during warm windy conditions if feasible
- Rubbish removed and stored/disposed of outside of 'clean' zone and away from greenhouse



Check for Rutherglen bugs on leaves. Swarms can arrive with storm fronts.

Risk factors	
Temperature	20 – 35°C
Low humidity (<60%)	✓
Air currents / wind	✓
Weeds	✓
Crop debris	✓
Infested plants	✓
'Pet' plants	✓
Old crops	✓
Soil	✓
Cucurbits (eg cucumber, zucchini)	✓
Solanaceae (eg tomato, capsicum, eggplant)	✓

There is typically only 1 generation of Rutherglen bug each year, however there may be several swarms of adults during the summer months.



Warm conditions		10–14 days		16–20 days		50+ days	
Cool conditions		14–18 days		18–22 days			
	ADULT	→	EGG	→	NYMPHS	→	ADULT
	Flowers Buds Leaves		Soil Flowers Leaves		Flowers Buds Leaves		Flowers Buds Leaves
Preventative controls	●		●		●		●
Biological controls							
Chemical controls	◐				●		◐

* A full circle indicates relevant management controls are available. A half circle indicates only partial control is available.

OTHER PESTS

It is fairly likely that in some seasons or some regions, there will be other pests that have not been included. It is important to correctly identify unknown pests. Once you know what it is, you can find out its lifecycle, risk factors and complete a risk assessment for it with respect to your greenhouse. If standard preventative practices that you have implemented are not working, more information about the pest will always identify new tactics and practices that can be used.

Never assume that all insects and mites in your greenhouse are pests. You need to find out what they are and whether they are a problem or not. Some insects can be helpful. Others may have no affect at all. Some could be a pest to people, such as mosquitoes or house flies, but they are not crop pests.

Knowing and preventing your key diseases (and the pathogens that cause them)

Types of pathogens

A pathogen is an organism that causes a disease. There are different types.

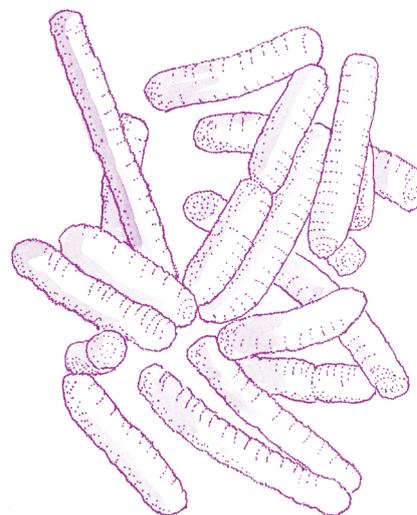
Bacteria

Bacteria (and bacteria-like organisms) are single celled microorganisms and can not be seen with the naked eye on plants. Bacteria can multiply extremely quickly under favourable conditions. Bacteria usually infect plants through wounds or natural openings in the plant. Most bacteria can survive for long periods in soils and substrates and on dead plant material.

Bacteria are commonly spread in water, for example when water splashes from one plant to another or even from the infected part of a plant to somewhere else on the same plant. Condensation dripping onto plants is one way bacteria can spread. Bacteria can also spread from the water used to apply pesticides or foliar fertilisers.

Drainage water and nutrient solution can also spread bacteria as well as pruning and other activities undertaken in the crop. All bacteria can be spread in water, on contaminated equipment and tools as well as on people's hands. This often results in infections moving down plant rows.

Seed from plants infected with some diseases, such as bacterial canker, may also carry bacteria resulting in future infected plants.



Bacteria can multiply very quickly under favourable conditions

Fungi

Fungi (and fungi-like organisms) are microscopic organisms but they develop structures which can be seen unaided and their fruiting bodies can be seen with a hand lens or microscope.

Fungi produce spores (like seeds) and this is the most common way for fungi to spread. A spore is too small to see with the naked eye but when there are millions of them together they can be more easily seen. Spores can be carried on air currents and in water as well as on people, clothes, equipment, plant material and in soil and substrates.

The spores, like plant seeds, require specific conditions to germinate. Many need moisture such as rain, dew, condensation or high humidity to germinate and infect a plant, for example Downy mildew needs a wet leaf surface. Other fungi, such as Powdery mildew likes a dry leaf surface but humid conditions. Temperature is also important. Most fungi germinate best between 15°C and 30°C, but they all tend to have an optimum temperature. For example, *Botrytis* germinates best between 18 and 24°C.



Fungi are very small but develop structures and fruiting bodies which can be seen more easily.

Some fungi can also produce sclerotia. Sclerotia are masses of fungal growth which darken and can look like small stones or dung. These growths form a hard skin which protects the fungal growth on the inside. This enables these fungi to survive long periods of very tough conditions.

Viruses

Viruses (and virus-like organisms) are extremely small, microorganisms that can infect plants and animals. They can only be seen with specialised equipment. Viruses can only reproduce inside a living organism such as a plant.

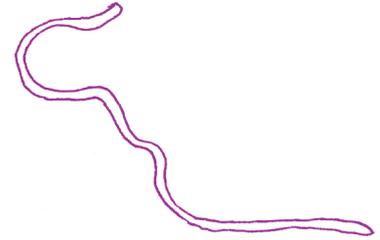
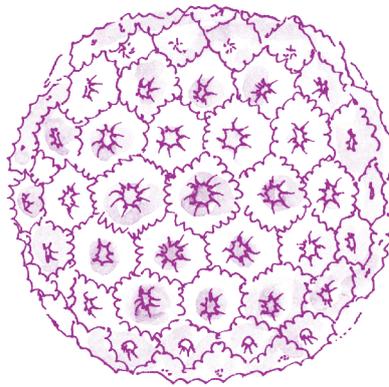
All the viruses which can infect your crop need other things to spread them such as sap sucking insects. Some viruses only have one way to spread while other viruses can spread in several ways.

Many viruses are spread by insects including thrips, aphids, whiteflies and leafhoppers. Some viruses have specific vectors. Cucumber mosaic virus (CMV) is carried by various aphid species while Tomato spotted wilt virus (TSWV) is spread by several thrips species.

When an insect feeds on a virus infected plant, it picks up the virus. When it then feeds on a healthy plant, the insect can transfer the virus to the healthy plant. Some insects (for example thrips) can carry a virus for their entire lives. Other insects (for example aphids) may only carry a virus for a defined period of time after feeding on an infected plant.

Some viruses can be spread through plant material. For example, cuttings and grafting can transfer a virus to the new plant.

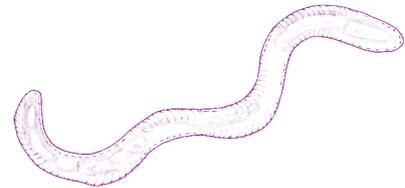
Others, for example cucumber mosaic virus, can be spread mechanically. This means that tools such as secateurs and knives as well as people's fingers can spread viruses in plant sap from one plant to another.



Viruses are too small to see and can often be spread by pests, people and on tools

Nematodes

Nematodes are very small worm-like animals that are too small to be seen with the naked eye. These organisms can spread in soil, crop debris, weeds and water.



Nematodes are tiny worm-like organisms

Critical Management Practices that need to be considered are identified for each of the following groups of diseases:

- FUNGAL MOULDS AND MILDEWS
- FUNGAL LEAF SPOTS, BLIGHTS AND CANKERS
- FUNGAL WILTS AND ROOT ROTS
- BACTERIAL LEAF SPOTS AND BACTERIAL SOFT ROTS
- BACTERIAL WILTS
- VIRUSES
- NEMATODES

The practices that you implement will depend on the level of risk that each disease poses to your business. Ultimately, you should aim to implement all the preventative practices.

FUNGAL MOULDS AND MILDEWS

Botrytis or **grey mould** is caused by the fungus *Botrytis cinerea* on a wide range of crops. This disease is spread by crop debris, air, clothing, tools and fungus gnats. It is usually seen in winter and spring when humidity in the greenhouse is high and temperatures are cooler. *Botrytis* is favoured by temperatures between 18 and 24°C.

Several parts of a plant can be attacked. Fruit is infected through dying flower petals. Other infection sites are through aborted fruit and wounded tissue (such as pruning cuts). The disease develops rapidly as a slightly sunken, water-soaked, greyish green area with a definite margin. In humid conditions grey spore masses form on infected areas.

On green tomato fruit *Botrytis* spores can cause an aborted infection symptom called 'ghost spots'. They are white to yellow pale ring markings (3 – 6cm in diameter) on the surface of otherwise healthy fruit.



Botrytis. Photo K. Ferguson



Check for the grey fluffy growth of *Botrytis* on flowers and small fruit and pruning wounds

Downy mildew of cucurbits is caused by the fungi *Pseudoperonospora cubensis* and is usually seen in spring.

This disease is spread by air, people, tools and crop debris. It can only survive for a short period without a host plant.

On cucumbers, infected leaves first show a light mottle that develops into yellow leaf spots which soon turn brown. The spots are markedly angular and can be confused with angular leaf spot - a bacterial disease. A fine white to grey fluffy growth develops on the lower surface and turns grey to purple as spores form in humid conditions. If there are many spots, the leaf shrivels inwards and dies. Severe infections result in defoliation, stunting and poor fruit development.



Downy mildew. Photo K. Ferguson



Check for the yellow angular spots of Downy mildew on older leaves, with fluffy growth on underside of leaves.

Leaf mould of tomatoes is caused by the fungus *Cladosporium fulvum* (syn. *Fulvia fulva*). This disease is spread by water, air, soil, equipment, crop debris, tools, hands and on seed. It can survive without a host plant for a long period in soil and substrate and on plant debris.

Leaf mould appears as yellow blotches on the upper surfaces of tomato leaves. A characteristic buff-brown and velvety mould develops on the underside, corresponding with the yellow blotches.

Severe infections result in mould developing on both leaf surfaces and stems, causing leaves to die, and the fungal growth turns purple. Infected flowers fail to set fruit.



Leaf mould. Photo NSW DPI image library



Check for the yellow blotches of Leaf mould on upper surface of leaves, with brown velvet growth on underside of leaves.

Powdery mildew is caused by *Sphaerotheca fuliginea* (on cucumbers), *Leveillula tarruca* (on solanaceous crops) which has an asexual stage called *Oidopsis sicula*, and *Oidium* spp. which also infects tomatoes. Cucumber cultivars have varying levels of resistance to this disease.

This disease usually appears on older leaves first and can be a problem at any time of the year.

These diseases are spread by air, tools, hands and clothing. They can only survive without a host plant for a short period.

Initial symptoms vary depending on host and species of fungus. For cucumbers, white powdery leaf spots appear firstly on the lower surfaces of the older leaves within 3-7 days of initial infection, and may later spread to cover both leaf surfaces and the stems. Older leaves gradually turn yellow and die, while vines become stunted.

Leveillula tarruca on tomatoes and capsicums causes light green to yellow leaf lesions. White powdery spores develop initially on the lower leaf surface, but will extend to the upper surface during severe infections. Lesions become brown and whole leaves eventually die. *Oidium* on tomato develops white powdery spots mainly on the upper surface which eventually cover entire leaves (both surfaces), petioles and stems. Affected leaf tissue yellows and dries out, and defoliation results.



Powdery mildew on cucumber. Photo K. Ferguson



Powdery mildew on tomato. Photo J. Badgery-Parker



Check for the white powdery growth of Powdery mildew on topside and underside of leaves.

Sclerotinia rot or **white mould** is caused by the fungi *Sclerotinia sclerotiorum* (on cucurbits and solanaceous crops) and *Sclerotinia minor* (on tomatoes). It is usually seen in winter and spring when humidity in the greenhouse is high and temperatures are cooler.

These diseases are spread by air, soil, substrate and crop debris. They can survive without a host plant for up to 5 years in soil and substrate.

Leaves, stems and fruit can be infected. White and cottony growth covers infected plant parts and a soft watery rot develops. Plants eventually wilt and die.

Sclerotinia sclerotiorum produces black resting bodies (sclerotia) up to about 1 cm long that develop on infected tissue or inside infected stems. They have the appearance of rat dung. *S. minor* has smaller and rounder sclerotia that are the size of a match head.



Sclerotinia on cucumber. Photo K. Ferguson



Check for the white fluffy growth of *Sclerotinia* on leaves, stems and fruit.

Critical management practices for fungal moulds and mildews

- Temperature and humidity in the greenhouse is properly managed (including monitoring) and temperature and humidity extremes in the greenhouse are avoided
- Resistant or tolerant varieties are used when feasible
- Crop work done in cleanest, youngest crops first and dirty tasks are completed last in the day
- Greenhouse has adequate and adjustable venting capacity
- Greenhouse has adequate heating capacity
- Greenhouse coverings are kept clean and well maintained
- Balanced and appropriate nutrient regime is provided
- Pruned plant material is put directly into a 'pruning' bin or bag and disposed of appropriately
- All equipment, tools, containers, bins and other items completely removed from the greenhouse before the clean up
- All containers (bins, boxes, tubs, buckets and trays) and other materials (eg twine and crop supports) to be used in the greenhouse are cleaned and disinfected before being taken into the greenhouse

RISK FACTORS	Botrytis (grey mould)	Downy mildew	Leaf mould	Powdery mildew	Sclerotinia (white mould)
Temperature	18 – 24°C	25 – 30°C	20 – 27°C	20 – 25°C	12 – 20°C
High humidity	✓	✓	✓		✓
Low humidity				✓	
Wet leaves	✓	✓	✓		
Air currents / wind	✓	✓		✓	✓
Poor hygiene (hands, tools, equipment)	✓	✓	✓	✓	
Dirty water			✓		
Rain splash	✓	✓	✓		
Run-off					
Postharvest wash					
Insect vector	✓				
Weeds	✓	✓	✓	✓	✓
Crop debris	✓	✓	✓	✓	✓
Infected plants	✓	✓	✓	✓	✓
Infected seed			✓		
Soil			✓		✓
Substrate			✓		✓
Lush growth	✓	✓		✓	
Over ripe fruit					
Low light				✓	
High root zone EC (>3.5 mS/cm)					
Poor nutrition		Excess N		Low K, P, Mg Excess N	
Root damage					
Poor drainage / high root zone moisture					
Plant wounds / injuries	✓				
Cucurbits (eg cucumber, zucchini)	✓	✓		✓	✓
Solanaceae (eg tomato, capsicum, eggplant)	✓		✓	✓	✓

FUNGAL LEAF SPOTS, BLIGHTS AND CANKERS

Alternaria leaf spot is caused by the fungi *Alternaria cucumerina*, *Alternaria alternata* (leaf blight and leaf spot on cucurbits) and *Alternaria solani* (target spot and early blight on solanaceous crops). Various *Alternaria* species cause black mould and fruit rots.

Alternaria is spread by air, water and crop debris and it can be carried on seed. This disease can survive without a host plant under warm, dry conditions for several months. It can also survive intermittent wetting and drying.

On cucumbers, small circular spots develop on the upper surface of leaves. These turn brown, enlarge and may cover entire leaves.



Alternaria. Photo L. Turton



Check for the small round spots of *Alternaria* on the upper surface of leaves.

On solanaceous crops like tomato, typical target spot symptoms include brown concentric rings that form from initial small brown spots. These occur on leaves (usually older leaves), stems and fruit.

Black-mould affected fruit develop sunken brown spots. Under humid conditions and in transit or storage these spots become covered with a black powdery mat of fungal spores. Black mould often forms on fruit that is damaged by other factors, for example where fruit is affected by blossom-end rot or chemical injuries.



Target spot. Photo NSW DPI image library



Check for the brown concentric rings of *Alternaria* on leaves and stems.

Anthracnose leaf spot is caused by the fungi *Colletotrichum orbiculare* (anthracnose on cucumbers) and *Colletotrichum coccodes* (anthracnose and black root rot on solanaceous crops). Various *Colletotrichum* species have a wider host range.

This disease is spread by water, people and equipment. Resting spores can survive in soil, substrate, on crop debris (especially fruit) and on seed for up to two years.

Leaves, stems and fruit may be affected. Red-brown to black spots occur on leaves, while long, dark, sunken spots appear on stems. These lesions may completely encircle stems, causing runners to wilt and die. Masses of pink spores ooze from lesions under humid conditions. Fruit have characteristic round, sunken spots with masses of pink spores. Fruit which is unblemished when picked may develop symptoms in transit. The disease develops rapidly on ripening fruit.



Anthracnose. Photo D. Letham



Check for the dark sunken spots of Anthracnose on stems and leaves and round sunken spots on fruit.

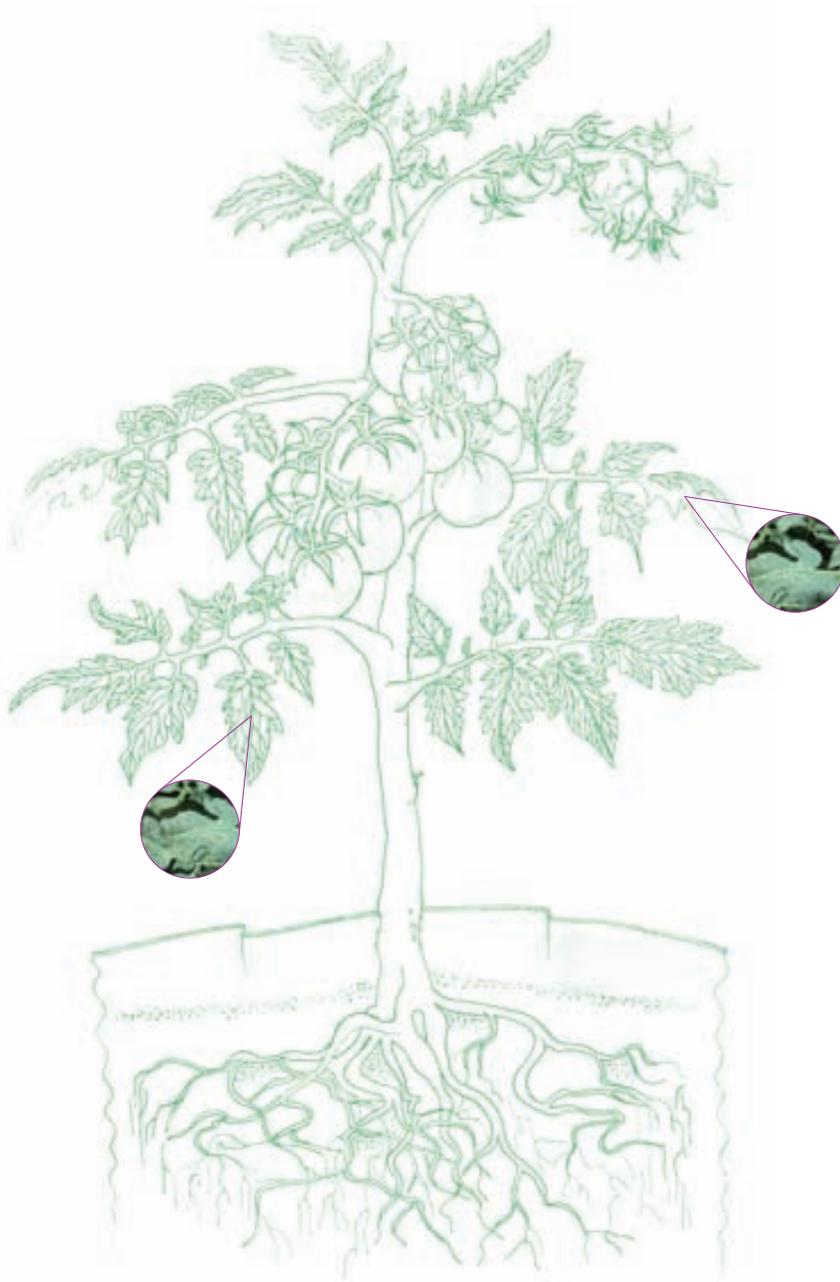
Grey leaf spot of tomatoes is caused by the fungus *Stemphylium solani* (and possibly other species).

This disease is spread by water, air, soil, substrate, tools and equipment, crop debris, on hands and on seed. It can survive without a host plant for a long period in soil and substrate and on plant debris.

Grey leaf spot shows as small dark specks which develop into grey-brown spots (1 – 3mm in diameter), sometimes with a slight angular margin and/or a yellow halo. The centre of the spot dries and cracks. The whole leaf may yellow with severe infections. Stems and fruit are generally not affected.



Grey leaf spot. Photo NSW DPI image library



Check for the small dark specks and grey-brown spots of Grey leaf spot on leaves.

Gummy stem blight of cucurbits is caused by the fungus *Didymella bryoniae*.

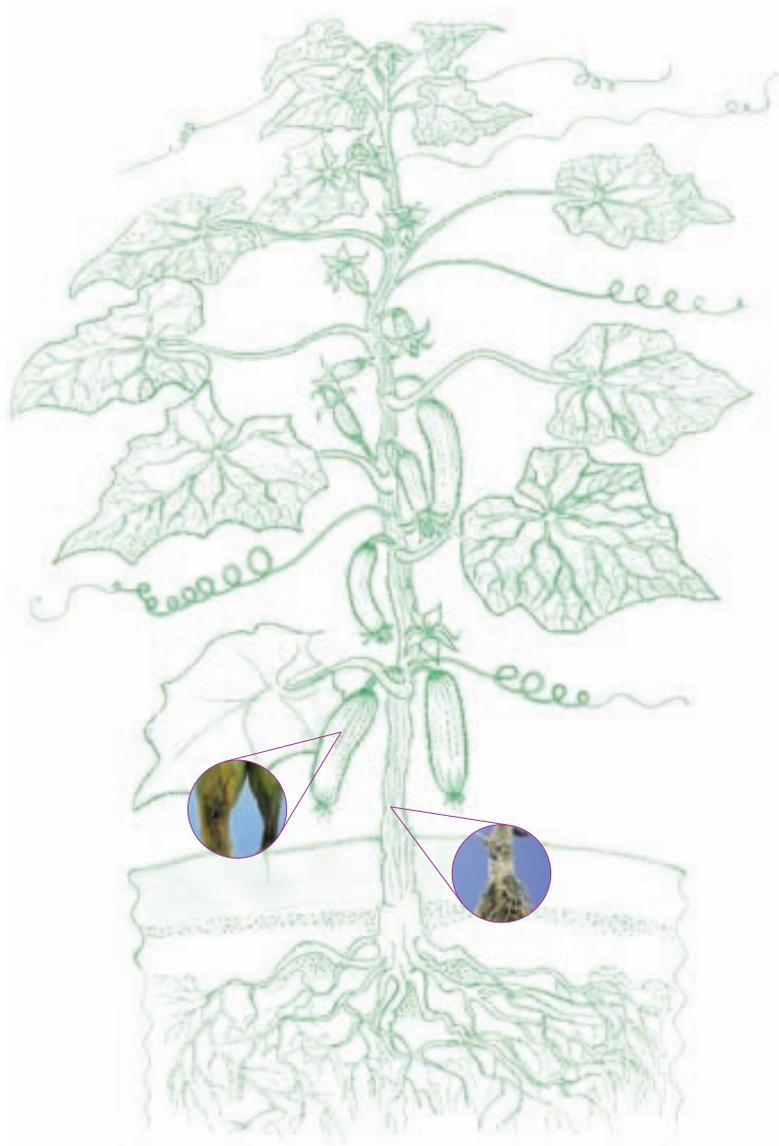
This disease is spread by air, tools, equipment, crop debris and insects and will survive on crop debris as well as on seed.

Stems, leaves and fruit may be affected. The stem is most frequently attacked, particularly around the crown. Water-soaked cankers develop and may become light brown or whitish and sunken. They are covered with small black dots, which are the fruiting bodies of the fungus. The cankers may split open and exude a reddish gum. If the canker encircles the stem, the runner wilts and dies. Spots on the leaves are black and may contain small black fruiting bodies.

Round or irregular sunken spots are formed on the fruit. These often have a black leathery appearance and a relatively fine texture. This black rot stage of the disease may cause losses in the field, in transit or in storage.



Gummy stem blight. Photos L. Turton



Check for the light brown to white canker of Gummy stem blight on the lower stem near the crown. Black spots may occur on leaves and fruit.

Critical management practices for fungal leaf spots, blights and cankers

- Disposable gloves worn when in the greenhouse and are changed frequently
- Crop work done in cleanest, youngest crops first and dirty tasks are completed last in the day
- Plants are pruned and trained appropriately and sharp, clean blades are used
- Temperature and humidity in the greenhouse is properly managed (including monitoring) and temperature and humidity extremes in the greenhouse are avoided
- Greenhouse has adequate and adjustable venting capacity
- Air circulation fans are installed and air movement is managed in the greenhouse
- Splash skirts are installed on all opening walls of greenhouse
- Employees have a clean change of clothes/overalls everyday for greenhouse work and clothes/overalls are changed after working in a 'dirty' greenhouse
- Greenhouse coverings are kept clean and well maintained
- All containers (bins, boxes, tubs, buckets and trays) and other materials (eg twine and crop supports) to be used in the greenhouse are cleaned and disinfected before being taken into the greenhouse

RISK FACTORS	Alternaria leaf spot	Anthracnose leaf spot	Grey leaf spot	Gummy stem blight
Temperature	15 – 21°C	20 – 24°C	24 – 27°C	Cool nights
High humidity		✓	✓	✓
Low humidity				
Wet leaves	✓	✓	✓	✓
Air currents / wind	✓		✓	✓
Poor hygiene (hands, tools, equipment)		✓	✓	✓
Dirty water	✓	✓	✓	
Rain splash	✓	✓	✓	✓
Run-off		✓	✓	✓
Postharvest wash				
Insect vector				✓
Weeds	✓	✓	✓	
Crop debris	✓	✓	✓	✓
Infected plants	✓	✓	✓	✓
Infected seed	✓		✓	✓
Soil		✓	✓	
Substrate		✓	✓	
Lush growth	✓			
Over ripe fruit		✓		
Low light				
High root zone EC (>3.5 mS/cm)				
Poor nutrition				
Root damage				
Poor drainage / high root zone moisture				
Plant wounds / injuries	✓	✓		✓
Cucurbits (eg cucumber, zucchini)	✓	✓		✓
Solanaceae (eg tomato, capsicum, eggplant)	✓	✓	✓	

FUNGAL WILTS AND ROOT ROT

Black root rot of cucurbits is caused by the fungus *Phomopsis sclerotioides*.

Black root rot is spread by soil, crop debris, shoes and equipment. Resting spores can survive in soil, substrate and on crop debris. There is a possibility that it also survives and is spread on seed.

Plants infected with this disease are stunted, leaves are cupped downwards and they begin to wilt in the middle of the day. Infected roots and the tap root turn brown with black lines, rings and spots on their surfaces. These markings are formations of fungal structures called sclerotia. Plants wilt and eventually die, particularly with the stress induced during fruit setting. Some plants linger, but small fruit abort or fail to mature.



Black root rot. Photo L. Turton



Black root rot. Photo NSW image library



Check for the dark lines and spots of Black root rot on the roots of stunted and wilting plants.

Damping off root rots are caused by a number of fungi including *Rhizoctonia solani* and several species of *Pythium*, *Phytophthora* and *Fusarium*. A wide range of plants can be affected.

These diseases are spread by water, soil, equipment, tools, footwear, crop debris and fungus gnats. They are also common soil organisms and survive in soil.

A water-soaked lesion occurs at the soil level, and seedlings wilt and collapse. *Pythium* spp. and *Phytophthora* generally cause rotting roots to have a watery grey or brown appearance, particularly the finer feeder roots.

Phytophthora infection of tomatoes can spread up the stem causing a dark brown discolouration and rot just above ground level. Plants often wilt and die.

Rhizoctonia is not an important disease of larger plants, but can cause a dry brown rot of the roots and crown tissue.

Root rot fungi often occur together and in association with other organisms (disease complexes) that cause premature plant death after the first few fruit have set.



Damping off. Photo NSW DPI image library



Check for the water-soaked lesion of Damping off at the base of the stem and the watery grey or brown roots of stunted and wilting plants.

Fusarium root rots and wilt are caused by various *Fusarium* fungi. Some species have a wide host range, while others are very specific to a particular host. Most tomato cultivars are resistant to *Fusarium oxysporum* which causes Fusarium wilt.

These diseases are spread by water, soil, equipment, crop debris, seed and some insects such as fungus gnats. They can survive without a host plant for a long period in soil and substrate.

Stunting, yellowing, wilting and death of plants can occur. Brown discolouration of the vascular tissue of the stem may be seen near the base of the plant. These fungi can be associated with damping off of young seedlings in cool conditions and are often associated with other fungal diseases, causing plants to become stunted and eventually die soon after the first fruit have set.

Maggots and compost flies and soft rotting bacteria become numerous in lesions at the bases of plants as the disease develops, though they do not cause the disease.



Fusarium wilt of cucumber. Photo K. Ferguson



Check for stunting, yellowing and wilting of *Fusarium* infected plants and pale yellow to brown rot near the base of the stem.

Verticillium wilt is caused by the fungus *Verticillium* spp.

These diseases are spread in soil (directly as well as on footwear, containers and vehicles). They are common soil organisms and survive for a long time in soil.

Yellow blotches on the lower leaves can be the first symptom. V-shaped lesions are common. Veins may turn brown and eventually dark brown dead spots will be seen. These do not have concentric rings. Wilting can occur, typically late in the day. Wilt is not common in tomatoes under good growing conditions. Infected plants have internal discolouration (browning) in the stems.



Verticillium wilt on eggplant. Photo L. Tesoriero



Critical management practices for fungal wilts and root rots

- Only clean, pest and disease free substrate (new or sterilised) used for each new crop
- Good root zone drainage is maintained
- Footbaths (or wheel baths) and doormats installed and used correctly at every entry point
- Dedicated footwear or disposable shoe covers are used when working in or entering the greenhouse
- All water in the 'clean' zone is disinfected and disinfected water is stored so that it can not be contaminated
- All containers (bins, boxes, tubs, buckets and trays) and other materials (eg twine and crop supports) to be used in the greenhouse are cleaned and disinfected before being taken into the greenhouse
- Hydroponic set up prevents plant to plant contact of run-off water
- Splash skirts are installed on all opening walls of greenhouse
- Feed/drain irrigation volume is managed (including monitored and recorded) at least daily
- Feed and drain EC and pH is managed (including monitored and recorded) at least daily
- If growing in soil, soil has appropriate biological, chemical and physical properties for the crop being grown

RISK FACTORS	Black root rot	Damping off (root rots)	Fusarium	Verticillium
Temperature (root zone)	12 – 18°C	18 – 24°C	25 – 30°C	13 – 28°C
High humidity				
Low humidity				
Wet leaves				
Air currents / wind			✓	
Poor hygiene (hands, tools, equipment)		✓	✓	
Dirty water	✓	✓	✓	✓
Rain splash	✓	✓	✓	✓
Run-off		✓	✓	✓
Postharvest wash				
Insect vector		✓	✓	
Weeds	✓	✓	✓	✓
Crop debris	✓	✓	✓	✓
Infected plants	✓	✓	✓	✓
Infected seed	✓?		✓	
Soil	✓	✓	✓	✓
Substrate	✓	✓	✓	✓
Lush growth				
Over ripe fruit				
Low light		✓		
High root zone EC (>3.5 mS/cm)		✓	✓	
Poor nutrition				
Root damage		✓	✓	✓
Poor drainage / high root zone moisture		✓	✓	✓
Plant wounds / injuries				
Cucurbits (eg cucumber, zucchini)	✓	✓	✓	
Solanaceae (eg tomato, capsicum, eggplant)		✓	✓	✓

BACTERIAL LEAF SPOTS AND SOFT ROT

Angular leaf spot of cucurbits is caused by the bacteria *Pseudomonas syringae* pv. *lachrymans*. This disease likes warm, humid conditions.

On leaves the disease first appears as small, water-soaked spots which enlarge to about 3mm in diameter. The spots become tan on the upper surface and gummy or shiny on the lower surface due to a bacterial ooze, which dries out and turns white.

The spots are an angular shape because they are limited by the leaf veins. The centre of the spots may drop out. Spots can also develop on leaf stalks, stems and fruit, which become covered with a white, crusty bacterial exudate. A brown rot can develop in the fleshy tissue beneath the fruit.

Angular leaf spot is spread by water, hands, clothing, crop debris and seed. It can survive on crop debris for more than 2 years.



Angular leaf spot. Photo J. Badgery-Parker



Check for the water-soaked spots of Angular leaf spot on leaves. The upper surface of spots become tan coloured and the underside is shiny or may have dry white crust.

Other **Bacterial spots** are caused by the bacteria *Xanthomonas campestris* pv. *vesicatoria* (of solanaceous crops) and *Xanthomonas campestris* pv. *cucurbitae* (of cucurbits).

Bacterial leaf spots (3mm in diameter) are characterised by dark spots usually surrounded by yellow haloes on stems, flower stalks and fruit. *Xanthomonas* generally causes spots which appear water-soaked and greasy.

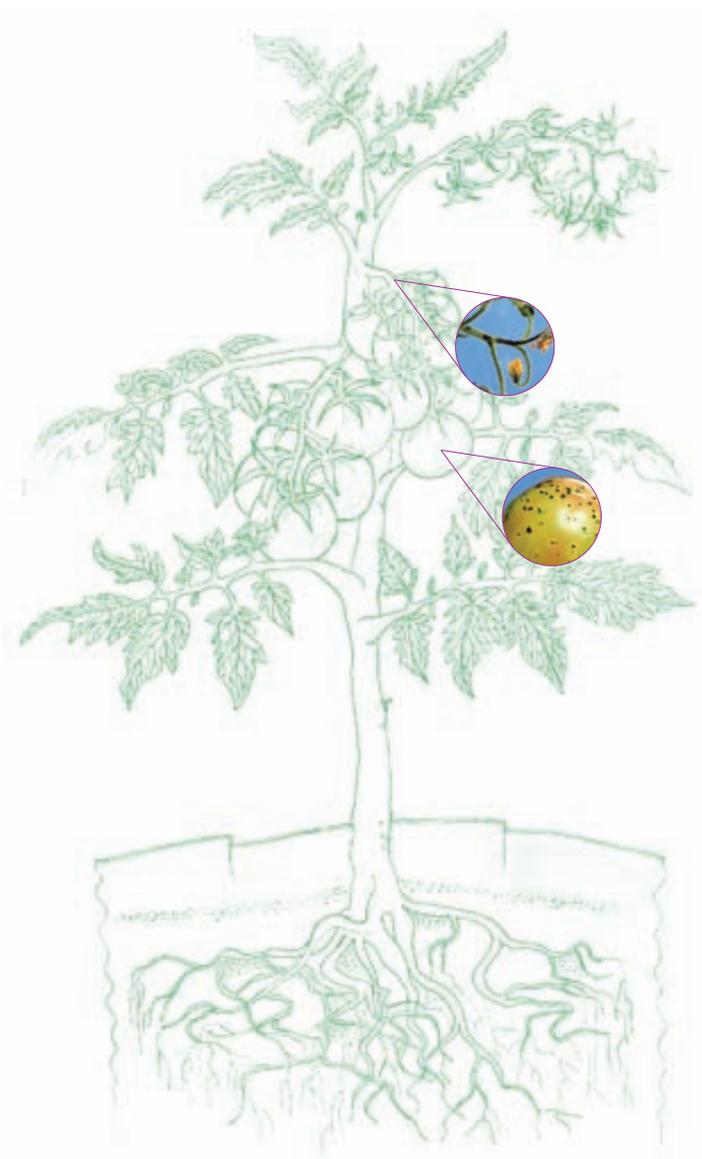
Bacterial speck of tomatoes is caused by the bacteria *Pseudomonas syringae* pv. *tomato* and another *Pseudomonas* species has been detected in association with a leaf spot of capsicums.

Bacterial Speck causes smaller spots (1mm in diameter). Affected leaves, flowers and young fruit may wither and fall. Fruit lesions are dark and slightly raised and scab-like.

These diseases are spread by water, on hands, tools, equipment, crop debris and on seed. These bacteria can survive for a long period of time in soil and substrate.



Bacterial speck. Photos NSW DPI image library



Check for the dark spots with a yellow halo of Bacterial spots and very small spots of Bacterial speck on leaves, stems and fruit.

Bacterial soft rot of cucumber, tomato and capsicum can be caused by *Erwinia carotovora* subsp. *carotovora*. Soft rots occur after harvest but can occur on damaged fruit still on the plant. The rot is soft and wet and smells putrid.

This disease is spread by water, on hands, tools, equipment, crop debris and on seed and it can also be spread by insects. These bacteria can survive for a long period of time in soil and substrate.



Check fruit for soft, wet marks



Bacterial soft rot. Photo R. Weir

Critical management practices for bacterial leaf spots and soft rots

- Pruned plant material is put directly into a 'pruning' bin or bag and disposed of appropriately
- Pruning tools are regularly disinfected during the pruning task and when used in a diseased area of a crop are cleaned and disinfected before being taken into the greenhouse
- A cleaning station is set up at the greenhouse entry or other convenient location for sanitising tools before taking them into the greenhouse
- Employees wash hands and disinfect personal items (eg mobile telephone) after working in a 'dirty' greenhouse
- Only clean, pest and disease free substrate (new or sterilised) is used for each new crop
- Plants are pruned and trained appropriately and sharp, clean blades are used
- Splash skirts are installed on all opening walls of greenhouse
- Temperature and humidity in the greenhouse is properly managed (including monitoring) and temperature and humidity extremes in the greenhouse are avoided
- Greenhouse has adequate and adjustable venting capacity
- Air circulation fans are installed and air movement is managed in the greenhouse

RISK FACTORS	Angular leaf spot	Bacterial spot	Bacterial speck	Bacterial soft rot
Temperature	24 – 27°C	24 – 30°C	18 – 24°C	
High humidity	✓	✓	✓	✓
Low humidity				
Wet leaves		✓	✓	✓
Air currents / wind				
Poor hygiene (hands, tools, equipment)	✓	✓	✓	✓
Dirty water	✓	✓	✓	✓
Rain splash	✓	✓	✓	✓
Run-off	✓	✓	✓	✓
Postharvest wash				✓
Insect vector				✓
Weeds	✓	✓	✓	
Crop debris	✓	✓	✓	✓
Infected plants	✓	✓	✓	✓
Infected seed				
Soil	✓	✓	✓	✓
Substrate	✓	✓	✓	✓
Lush growth				
Over ripe fruit				
Low light				
High root zone EC (>3.5 mS/cm)				
Poor nutrition				
Root damage				
Poor drainage / high root zone moisture				
Plant wounds / injuries		✓	✓	✓
Cucurbits (eg cucumber, zucchini)	✓	✓		✓
Solanaceae (eg tomato, capsicum, eggplant)		✓	✓	✓

BACTERIAL WILTS

Bacterial canker of solanaceous crops is caused by *Clavibacter michiganensis* subsp. *Michiganensis* and is a very serious disease and can cause large losses in crops. It likes warm and very humid conditions.

Infected seedlings may be stunted or die in trays, or may be symptomless until transplanted. Older plants have leaves that turn yellow and wilt only on one side. Light brown scab-like cankers (slightly raised spots 3-6mm in diameter) develop on stems and occasionally on leaves. Fruit may also develop cankers surrounded by white haloes which are referred to as 'bird's eye spots'. Vascular tissue (the ring of water-conducting tissue) inside stems becomes discoloured, followed by portions of the central (pith) tissue. Plants may eventually wilt and die.

Bacterial canker is spread by water, on hands, tools, equipment, crop debris and seed. It can survive for a long period in soil and substrate.



Bacterial canker. Photo L. Forsyth



Check for the light brown scabs of Bacterial canker on stems and leaves, and small scabs with white haloes (bird's eye spots) on fruit.



Bird's eye spots. Photo A. Young



Canker symptoms on tomato. Photo L. Forsyth

Bacterial pith necrosis is associated with *Pseudomonas corrugate* as well as other *Pseudomonas* species and *Erwinia carotovora* subsp. *carotovora*. These diseases are spread by water, on hands, tools, equipment, crop debris and seed and can survive in soil and substrate.

Pith necrosis is generally associated with tomatoes, though these bacteria have a broad host range and are common in soil.

The first symptom of bacterial pith necrosis is normally a slight yellowing and wilting of leaflets. Bumps appear on lower stems as plants try to produce adventitious roots. Pith tissue inside stems becomes brown and collapses. Dark necrotic streaks appear on surface of stems. Plants may wilt and die, though they can survive if they only have a minor infection.



Bacterial pith necrosis. Photo NSW DPI image library



Check for the slight yellowing and wilting of leaflets of Bacterial pith necrosis and bumps along lower stems. The inside of infected plants is brown.

Bacterial wilt of solanaceous crops is caused by the bacteria *Ralstonia solanacearum* which is spread by water, on hands, tools, equipment, crop debris and seed and it can survive in soil and substrate.

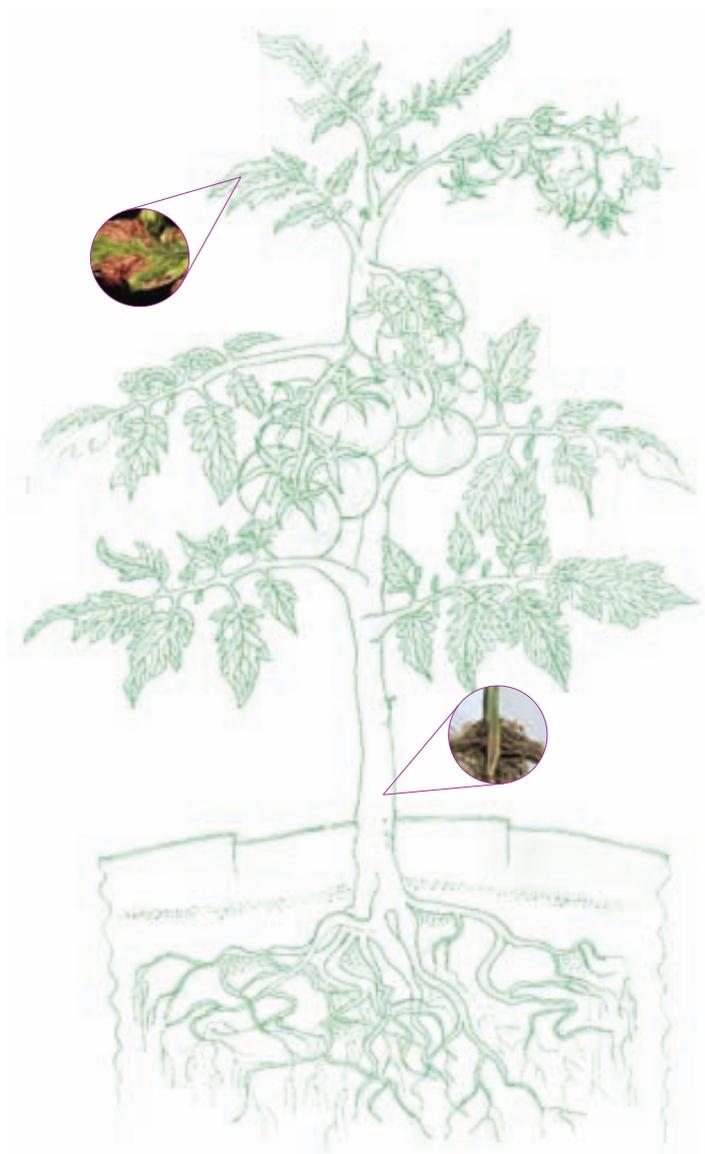
Plants infected with this disease can wilt rapidly and die without any spotting or distinct yellowing of leaves. Vascular tissue (particularly near ground level) appears brown and water-soaked.



Bacterial wilt. Photo NSW DPI image library



Bacterial wilt. Photo L. Tesoriero



Check for the wilting and death caused by Bacterial wilt without any distinctive symptoms. The inside of infected plants is brown.

Critical management practices for bacterial wilts

- All vehicles that travel off-farm ('outside' zone) are always cleaned before entering the 'clean' zone
- Footbaths (or wheel baths) and doormats installed and used correctly at every entry point
- Employees have a clean change of clothes/overalls everyday for greenhouse work and clothes/overalls are changed after working in a 'dirty' greenhouse
- Disposable gloves worn when in the greenhouse and are changed frequently
- Pruning tools are regularly disinfected during the pruning task and when used in a diseased area of a crop are cleaned and disinfected before being taken into a healthy area of a crop
- Plants are pruned and trained appropriately and sharp, clean blades are used
- Hydroponic set up prevents plant to plant contact of run-off water
- All containers (bins, boxes, tubs, buckets and trays) and other materials (eg twine and crop supports) to be used in the greenhouse are cleaned and disinfected before being taken into the greenhouse
- Infected plants (bagged before removal) are removed from the greenhouse (rouging)
- Chemical controls are assessed for any resistance issues or control failures and a resistance management plan is used

RISK FACTORS	Bacterial canker	Bacterial pith necrosis	Bacterial wilt
Temperature	18 – 24°C	25 – 35°C	21 – 32°C
High humidity	✓		
Low humidity			
Wet leaves			
Air currents / wind			
Poor hygiene (hands, tools, equipment)	✓	✓	✓
Dirty water	✓	✓	✓
Rain splash	✓	✓	✓
Run-off	✓	✓	✓
Postharvest wash			
Insect vector			
Weeds			
Crop debris	✓	✓	✓
Infected plants	✓	✓	✓
Infected seed	✓	✓	✓
Soil	✓	✓	✓
Substrate	✓	✓	✓
Lush growth	✓	✓	
Over ripe fruit			
Low light			
High root zone EC (>3.5 mS/cm)			
Poor nutrition	Excess N	Excess N	
Root damage			✓
Poor drainage / high root zone moisture			✓
Plant wounds / injuries	✓	✓	✓
Cucurbits (eg cucumber, zucchini)			
Solanaceae (eg tomato, capsicum, eggplant)	✓	✓	✓

VIRUSES

Mosaic viruses

Mosaic viruses can infect and survive in a wide range of plants, including many weeds. Once a plant is infected with a mosaic virus, it can not be cured and becomes a source of the virus. There is also a high risk that there may be virus or virus-like diseases that are not even known yet. Any unusual symptoms need to be properly checked out.

Symptoms can vary depending on the host and the environmental conditions but generally leaves have distinct yellow or light and dark green markings and are misshapen. Plants tend to be stunted. Fruit may be malformed or have bumps and mosaic patterns.

Cucumber mosaic virus (CMV) infects cucurbits and solanaceous crops. In tomatoes, CMV causes leaves and shoots to become narrow and thick with curled edges. This condition is known as Fern leaf. CMV can be spread by aphids, on tools, hands and equipment.

Tomato mosaic virus (ToMV) infects solanaceous crops. In tomatoes, it causes leaves and shoots to become narrow and thick with curled edges. This condition is known as Fern leaf. It also causes fruit to develop brown sunken patches. ToMV can be spread on tools, hands and equipment and also on seed so can survive on seed from infected plants.

Potato Virus Y (PVY) infects solanaceous crops. PVY causes brown spotting on the underside of leaves and stems as well as a downward curling of young shoots which eventually shrivel up and die. This is called Leaf shrivel.

Solanaceous crops are also infected by **Alfalfa mosaic virus (AMV)** which is spread by aphids.



Check for the narrow, thick and distorted stems of Mosaic viruses. Leaves have lighter and darker patterns. Look for aphids.



Mosaic virus. Photo D. Letham



Mosaic virus. Photo L. Turton

Tomato spotted wilt virus

Tomato spotted wilt virus (TSWV) infects an enormous range of plants. Some plants such as cucumber can be infected and be a source of the virus but do not show symptoms. Symptoms can take up to 3 weeks after infection before they appear.

TSWV infection causes a variety of symptoms. The upper surfaces of young expanding leaves on tomato plants develop a bronze colour with small spots and ring patterns. Plants become stunted as the developing shoot tissue is affected. Shoot tips often become blighted and young plants may die. Expanded leaves develop dark spots and ring spots that may join together, blacken and cause the tissue to shrivel. Leaves may also yellow and wilt. Black spots and streaks also develop on stems. Fruit can develop a variety of symptoms, ranging from circular yellow blotches to brown necrotic rings.

Capsicum plants are stunted with a yellow-green look to the leaves. Some leaves may be distorted and have spots and ring markings. Shoots may be blighted. Some cultivars display only vague leaf symptoms. Fruit on all cultivars can be severely affected with yellow blotches and sometimes brown spots, streaks and ring markings. Symptoms become more noticeable as fruit ripen.

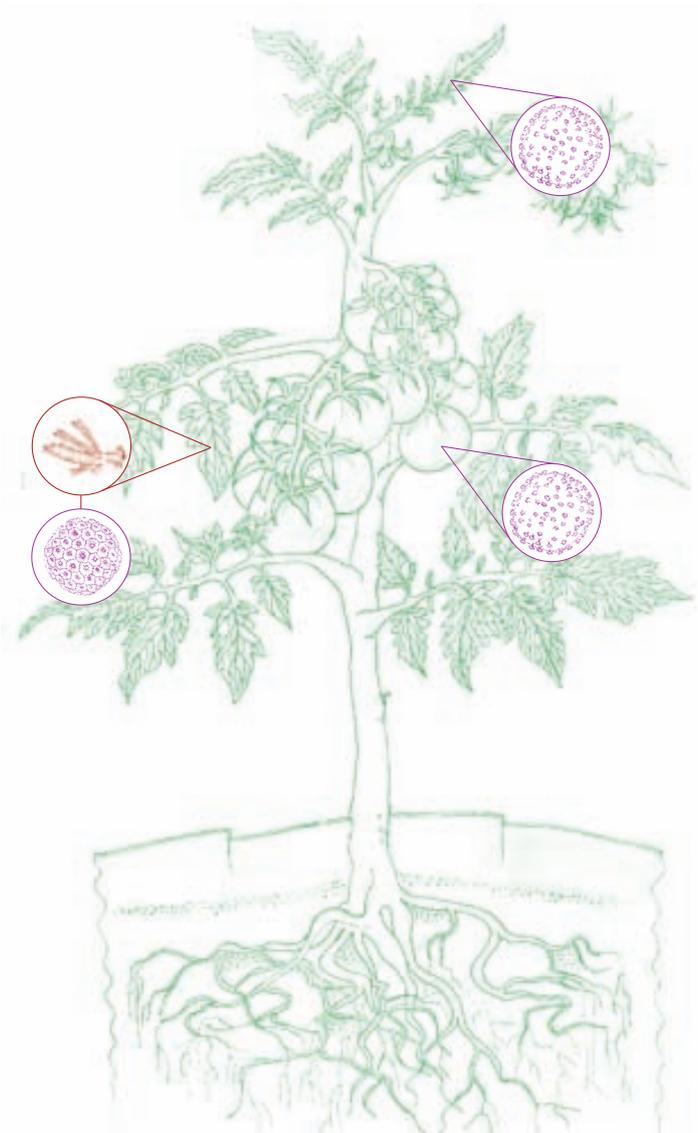
TSWV is spread by several species of thrips including Western flower thrips, tomato thrips and onion thrips.



TSWV on capsicum fruit. Photo K. Ferguson



TSWV on capsicum. Photo K. Ferguson



Check for the bronzed young leaves of Tomato spotted wilt virus infected plants and blotches and rings on fruit. Look for thrips.

Cucumber yellows virus (Beet pseudo-yellows virus)

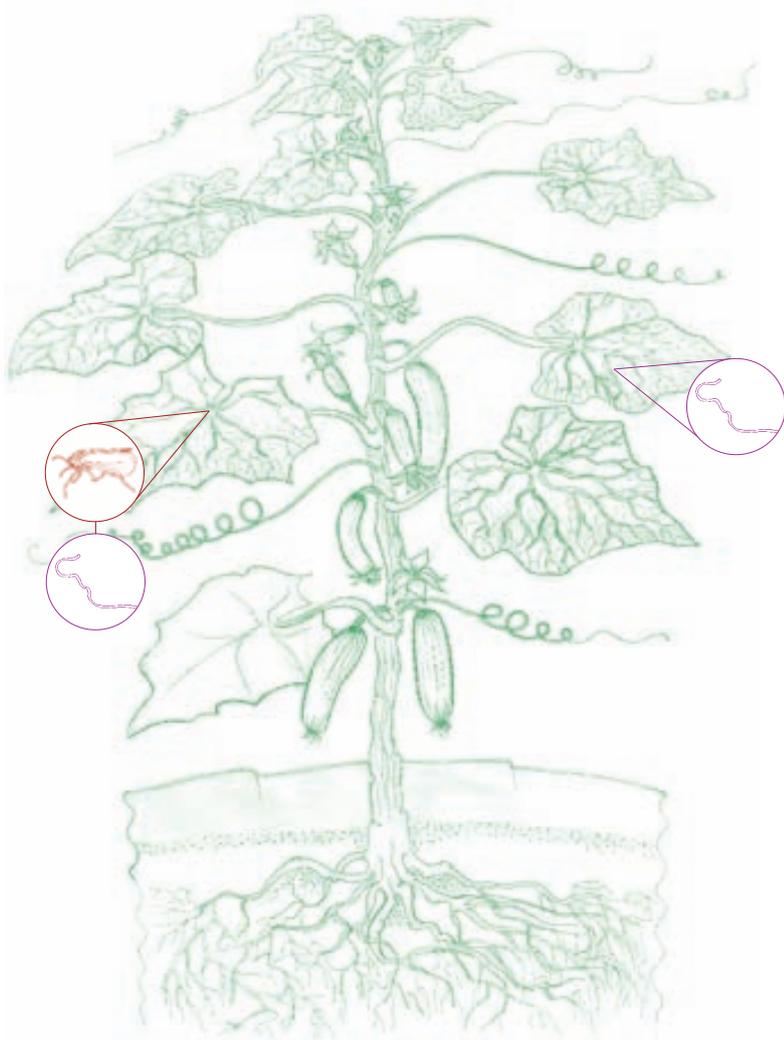
Cucumber yellows virus (CYV) can infect several species including cucumbers, melons, lettuce, spinach and beets as well as some weed species including groundsel and shepherds purse. This virus has only recently been confirmed in cucumbers in Australia.

CYV is spread by greenhouse whitefly.

Cucumber yellows virus causes yellowing between the veins on leaves. Leaves become thickened, brittle and curl down at the edges. Leaves may become puckered. Plant growth is slowed and yield is reduced. Fruit are not affected, though developing fruit may be aborted on badly affected plants. The leaf yellowing is very similar to nutritional deficiency symptoms, in particular magnesium.



Cucumber yellows virus. Photo L. Turton



Check for the yellowing between the leaf veins of Cucumber yellows virus infected plants and puckered leaves. Look for greenhouse whitefly.

Critical management practices for viruses

- Infected plants (bagged before removal) are removed from the greenhouse (roguing)
- Disposable gloves worn when in the greenhouse and are changed frequently
- Pruning tools are regularly disinfected during the pruning task and when used in a diseased area of a crop are cleaned and disinfected before being taken into a healthy area of a crop
- Potential insect vectors are excluded or appropriately managed
- Only a single crop is grown at a time in the greenhouse and the greenhouse is kept free from non-crop plants including “pet” plants
- Resistant or tolerant varieties are used when feasible
- Insect screens are installed on opening sides
- Double entry doors (and fan) or a double curtain installed on all entry points
- Roadways and pathways in the ‘clean’ zone are free from soil and mud, weeds, plant debris and rubbish
- Pruned plant material put directly into a ‘pruning’ bin or bag and disposed of appropriately

RISK FACTORS	Mosaic viruses	Tomato spotted wilt virus	Cucumber yellows virus
Temperature	25 – 30°C	22 – 35°C	25 – 30°C
High humidity			
Low humidity		✓	
Wet leaves			
Air currents / wind	✓	✓	
Poor hygiene (hands, tools, equipment)	✓		
Dirty water			
Rain splash			
Run-off			
Postharvest wash			
Insect vector	Aphids	Thrips	Greenhouse whitefly
Weeds	✓	✓	✓
Crop debris	✓	✓	✓
Infected plants	✓	✓	✓
Infected seed	✓		
Soil		✓	
Substrate		✓	
Lush growth			
Over ripe fruit			
Low light			
High root zone EC (>3.5 mS/cm)			
Poor nutrition			
Root damage			
Poor drainage / high root zone moisture			
Plant wounds / injuries	✓		
Cucurbits (eg cucumber, zucchini)	✓	✓ No symptoms	✓
Solanaceae (eg tomato, capsicum, eggplant)	✓	✓	

* risk factors for vector

NEMATODES

Nematodes are uncommon in hydroponic production provided clean substrate is used for each new crop. In soil production, root knot nematode can be a problem.

Root knot is caused by root knot nematodes of the genus *Meloidogyne*. These nematodes can infect a wide range of vegetables, ornamental plants, fruit trees and weeds.

This nematode is spread by soil, water, substrate, crop debris, other crops, equipment and footwear. It is common in soil and survives for a long time in soil.

Symptoms include root swellings (galls) and stunting and yellowing of plants. Galls can range from little more than an insignificant swelling to large club-like structures (>1cm in diameter).

Death may follow, but often plants struggle on with reduced yields and quality. Roots commonly become infected by a range of secondary bacteria and fungi.



Root knot nematode. Photo L. Turton



Check for the root swellings of nematodes on stunted and yellowing plants.

RISK FACTORS

RISK FACTORS	
Temperature (root zone)	Warm
Poor hygiene (hands, tools, equipment)	✓
Dirty water	✓
Rain splash	✓
Run-off	✓
Weeds	✓
Crop debris	✓
Infected plants	✓
Soil	✓
Substrate	✓
Cucurbits (eg cucumber, zucchini)	✓
Solanaceae (eg tomato, capsicum, eggplant)	✓

Critical management practices

- Only clean, pest and disease free substrate (new or sterilised) used for each new crop
- Foot baths (or wheel baths) and doormats installed and used correctly at every entry point
- Soil is solarised or fumigated with an appropriate and registered product between crops
- Drainage ensures that there are no puddles or wet areas in the 'clean' zone and surface run-off does not wash into the greenhouse
- Splash skirts installed on all opening walls of greenhouse
- Roadways and pathways in the 'clean' zone are sealed or covered
- Roadways and pathways in the 'clean' zone are free from soil and mud, weeds, plant debris and rubbish
- All vehicles that travel off-farm ('outside' zone) are always cleaned before entering the 'clean' zone
- All vehicles in the 'clean' zone are kept free from soil, plant debris and rubbish
- A parking area for employee and visitor vehicles is in the 'outside' zone of the farm

Monitoring and checking for pests and diseases

Monitoring the crop regularly and routinely enables you to find pests and diseases early. This greatly improves the type and number of control strategies available to you and how well they will work. Knowing the problem early gives you more options and this means that you can choose the most cost effective strategy.

“ monitoring the crop regularly enables you to find pests and diseases early ”

Early detection and correct identification achieved through regular and routine monitoring is the single most important part of any pest and disease management program.

The more monitoring that you do, the better the information that you will have available when you make important business and crop management decisions.

In particular you need to monitor to assess pest/disease levels before and after any treatment is used. This enables you to check that the treatment is effective and to identify any possible failures in control so that they can be fixed.

You need to make sure that some effective monitoring is done every week in all your greenhouses. If it is feasible, a consultant or dedicated employee should be used to monitor your crops and record the information for you. If not, you must do it yourself.

Monitoring for pests and diseases needs to include both the routine inspection of plants and the routine checking of sticky traps.

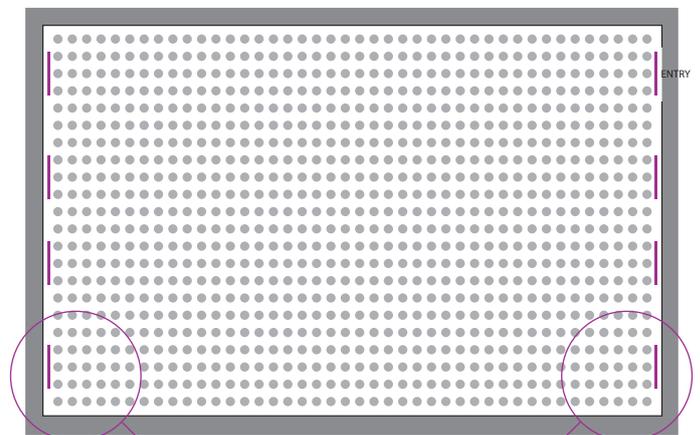
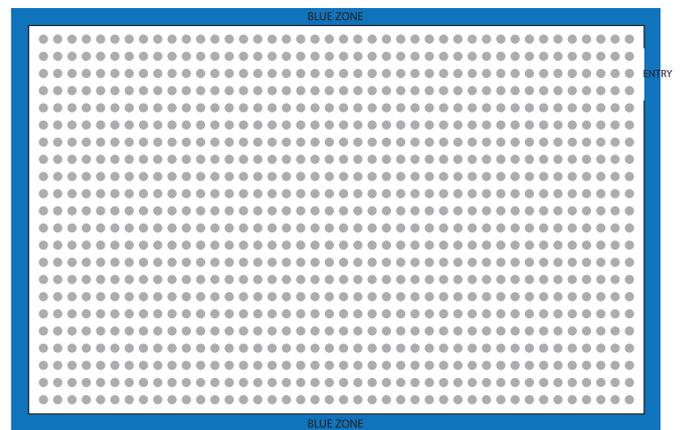
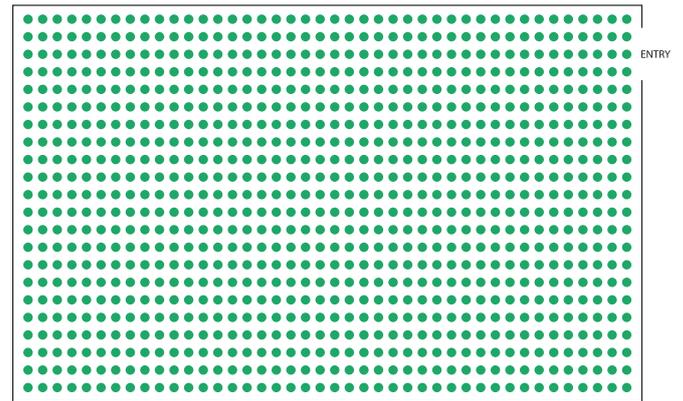
The pest and disease check

The pest and disease check is one of the simplest ways to monitor for pests and diseases. The check is done in every greenhouse 2 times per week in summer and once per week in winter. It only takes 20 – 30 minutes. Doing more than this – if you can – gives you even better information on which to make decisions.

The simplified pest and disease check is easy to complete because the greenhouse is set up in advance. Places to monitor are marked (check zones) and pre-prepared charts are ready on which to make your record. The charts are only one method of keeping a record. Use any method you prefer, but make sure that you always make a written record.

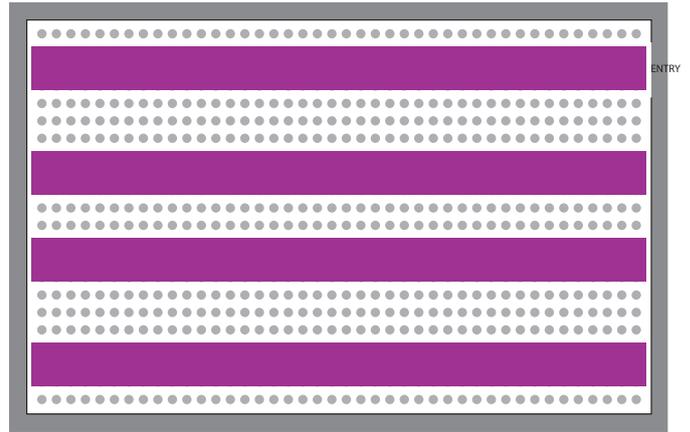
Setting up check zones in the greenhouse

1. Each greenhouse is set up for pest and disease checks. This only needs to be done once. Imagine you are looking at your greenhouse from above
2. First, mark out the blue zone. This is a 5 – 10 metre buffer zone around the outside of each greenhouse. This area needs to be kept clean and free from weeds, crop residues and rubbish.
3. Next, mark out the four purple zones. These are pairs of adjacent rows spaced fairly evenly through the greenhouse. Use some paint to mark the purple zones by drawing a line on the floor across the two inter-rows at each end of every purple zone. You could also use coloured flagging tape or large coloured clothes pegs to mark the zones.

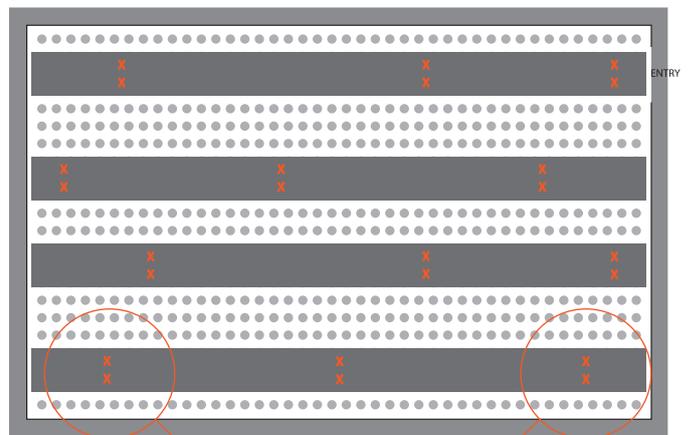


Purple zone

The purple zones run the full length of the greenhouse. Three rows of plants are included in each zone. In this way, there are two inter-rows (pathways) in each purple zone.



- Each purple zone contains 3 orange zones which are spaced along the length of the greenhouse. With orange coloured paint or tape, mark the location of the orange zones with a cross (X) in the middle of each pathway or a piece of tape or peg on a post or support wire.

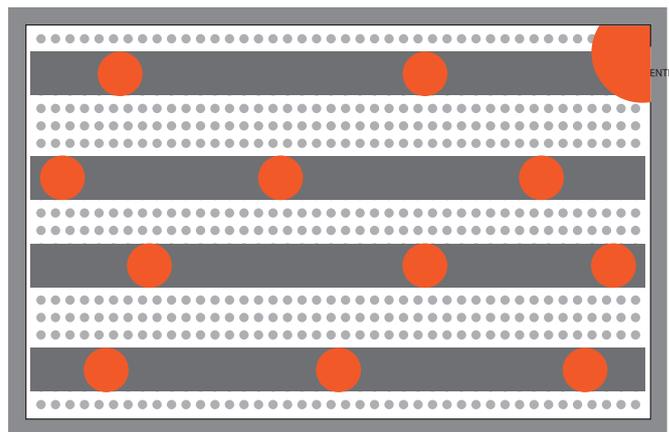


Orange zone

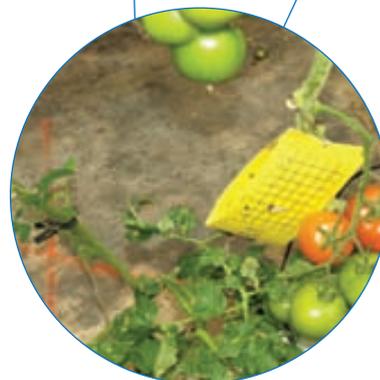
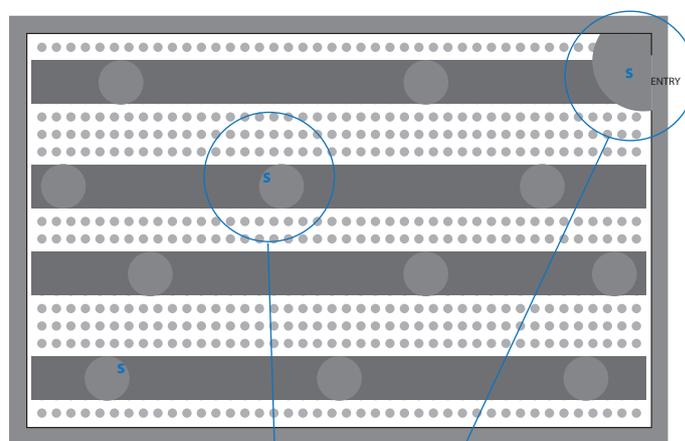
- The first orange zone is put at the entry. If there is more than one entry, mark an orange zone at each entry. If a known trouble spot exists in the greenhouse, such as a shaded corner that always gets pests or diseases, then an orange zone needs to be marked at the trouble spot.



The rest of the orange zones are spaced roughly evenly through the greenhouse.



6. Finally, mark out where sticky traps (S) will be placed. Use at least 3 traps per greenhouse or, if possible 1 trap per 200m². Place one in the pest and disease check zone near the entry and the other traps in other orange zones in the greenhouse. Again, if there is a known problem area for pests, place a sticky trap in this area.



Sticky trap

Conducting a simplified pest and disease check

When conducting a pest and disease check, take your time. Look closely at the plants you inspect. Work your way from the top down to the bottom or bottom up to the top. Check both sides of every leaf, check buds, flowers and leaf axils. Check fruit, especially under the calyx.

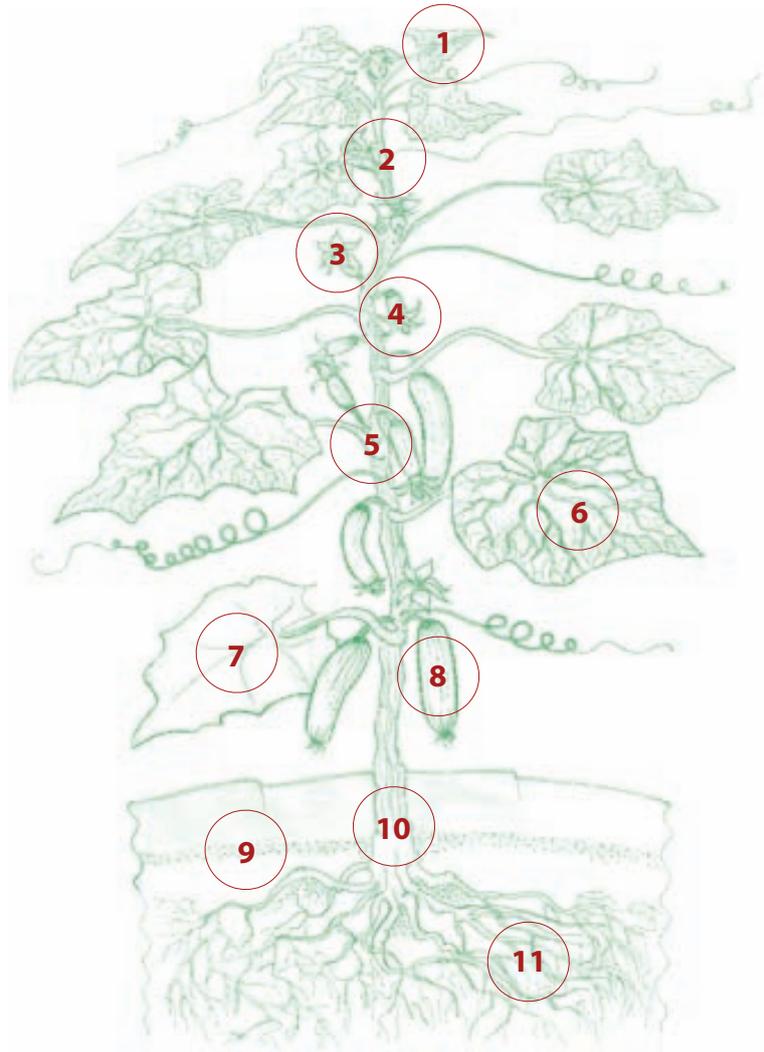
Use a magnifying lens.

Mark each pest chart with a dot (•) for the number of pests of that type which you find. Mark each disease chart with a dot (•) for the number of plants that have symptoms of that disease.

Charts are one method of keeping a record. You may prefer a record sheet. Use any method you prefer, but make sure that you always make a written record. Some sample charts are included in Appendix 4.

Carefully check the sticky traps. Mark each pest chart with a cross (x) for the number of that pest you count. (Replace the sticky trap on every second inspection.)

- | | |
|----------------------------|------------------------------------------|
| 1. Check new growth | 7. Check underside of leaves |
| 2. Check stems | 8. Check older fruit |
| 3. Check inside flowers | 9. Check substrate |
| 4. Check new fruit | 10. Check base of stem |
| 5. Check pruning wounds | 11. Check roots if you suspect a problem |
| 6. Check topside of leaves | |



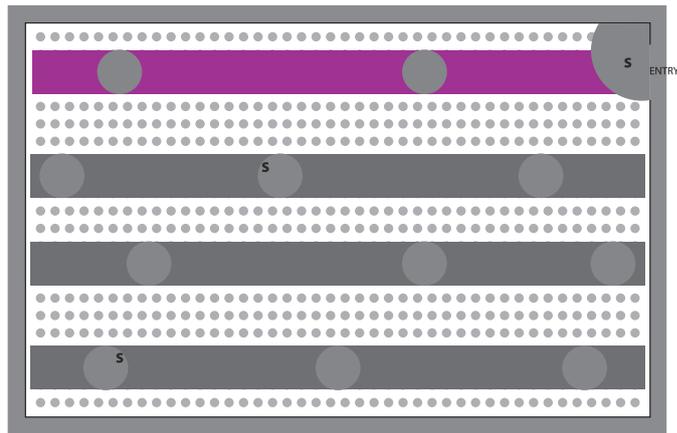
When you start the pest and disease check, as you enter the greenhouse, you are in the first orange zone and there will be a sticky trap (blue S). Use a hand lens to inspect the sticky trap. Look closely at the trap and mark each pest chart with a cross (x) for the number of that pest you count. (Replace the sticky trap on every second inspection.) Record the number of each pest you find on the appropriate chart or record sheet. This trap inspection will give you an idea of what you may find in the crop.

Select one of the near-by plants (marked blue). Carefully inspect this plant from the top down, or bottom up. Take your time. Use a hand lens. Look on the top and underside of every leaf. Look in flowers and leaf axils. Look at the fruit. Look at the whole stem.

Record the number of each pest you find on the appropriate chart or record sheet. Record any diseases you find on the appropriate chart or record sheet.



Now slowly walk along one of the rows in the purple zone. As you walk, look for any signs of problems or diseases. If you see something, stop and take a closer look. Record any diseases you find on the appropriate chart. If you see other problems, make a note of it and come back later to fix it.

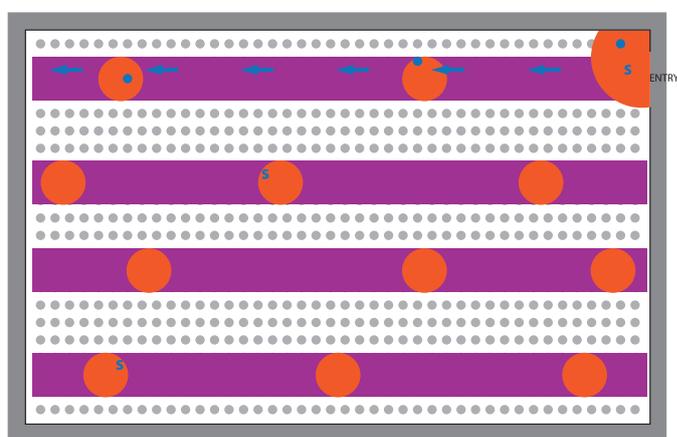


Stop when you come to the next orange zone (marked by the X on the ground). If you have put a sticky trap in this zone use a hand lens to inspect the sticky trap. Record the number of each pest you find on the appropriate chart.

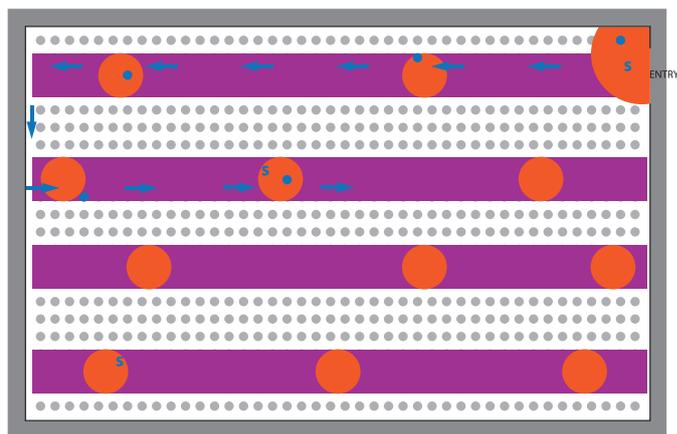
Now, select one of the near-by plants (marked blue). Carefully inspect this plant from the top down, or bottom up. Take your time. Use a hand lens. Look on the top and underside of every leaf. Look in flowers and leaf axils. Look at the fruit. Look at the whole stem. Record the number of each pest you find on the appropriate chart. Record any diseases you find on the appropriate chart.



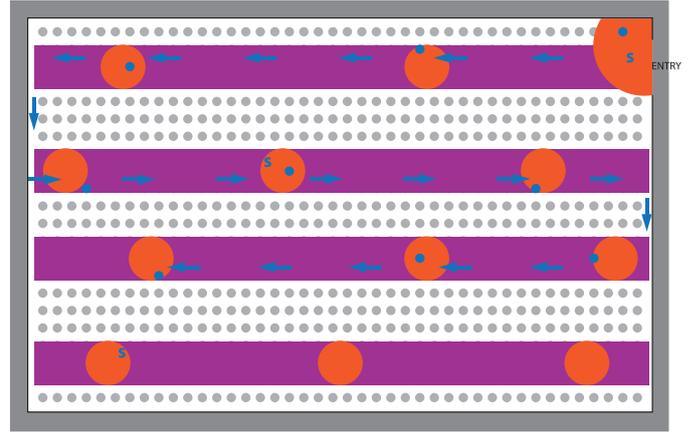
When you have finished inspecting the chosen plant, continue slowly walking down the row. Again, as you walk, look for any signs of problems or diseases. If you see something, stop and take a closer look. Record any diseases you find on the appropriate chart. If you see other problems, make a note of it and come back later to fix it. Each time you reach an orange zone, stop and carefully inspect one of the plants. Record any pest or disease you find on the appropriate chart. Then continue along the row.



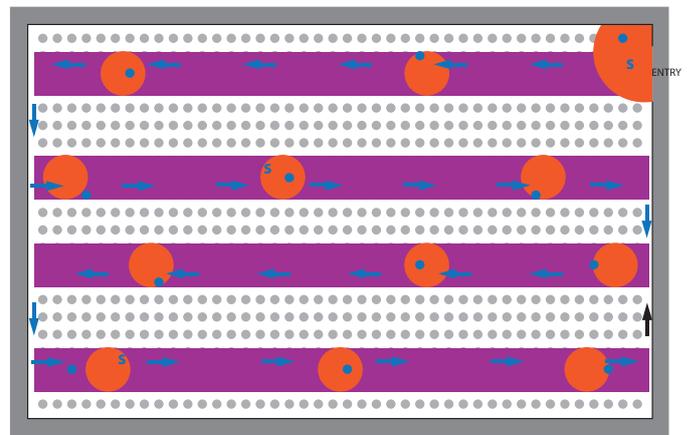
When you reach the end of the row, turn and walk down to the next purple zone. Select one of the rows and slowly walk along the row looking for any signs of a problem. Again, when you reach an orange zone, stop and carefully inspect a plant. Record what you find.



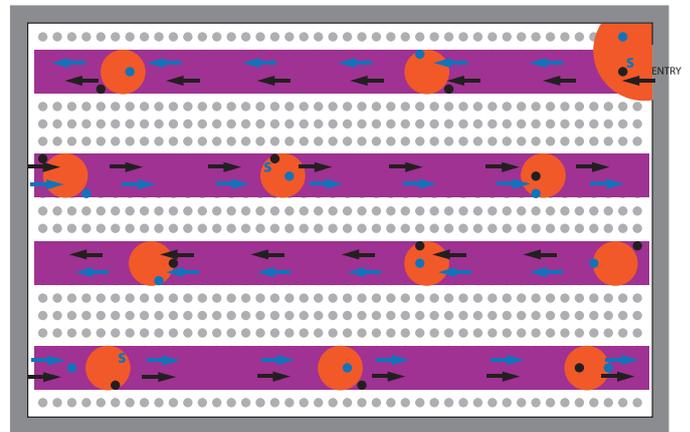
Continue through the greenhouse. Slowly walking along the purple zones and look for signs of any problem. Stop at each orange zone and carefully inspect sticky traps when you come upon them and carefully inspect a plant in each orange zone. Always record what you find.



At the end of the pest and disease check, you will have walked down 4 rows looking at the plants and stopped and carefully inspected at least 12 plants.



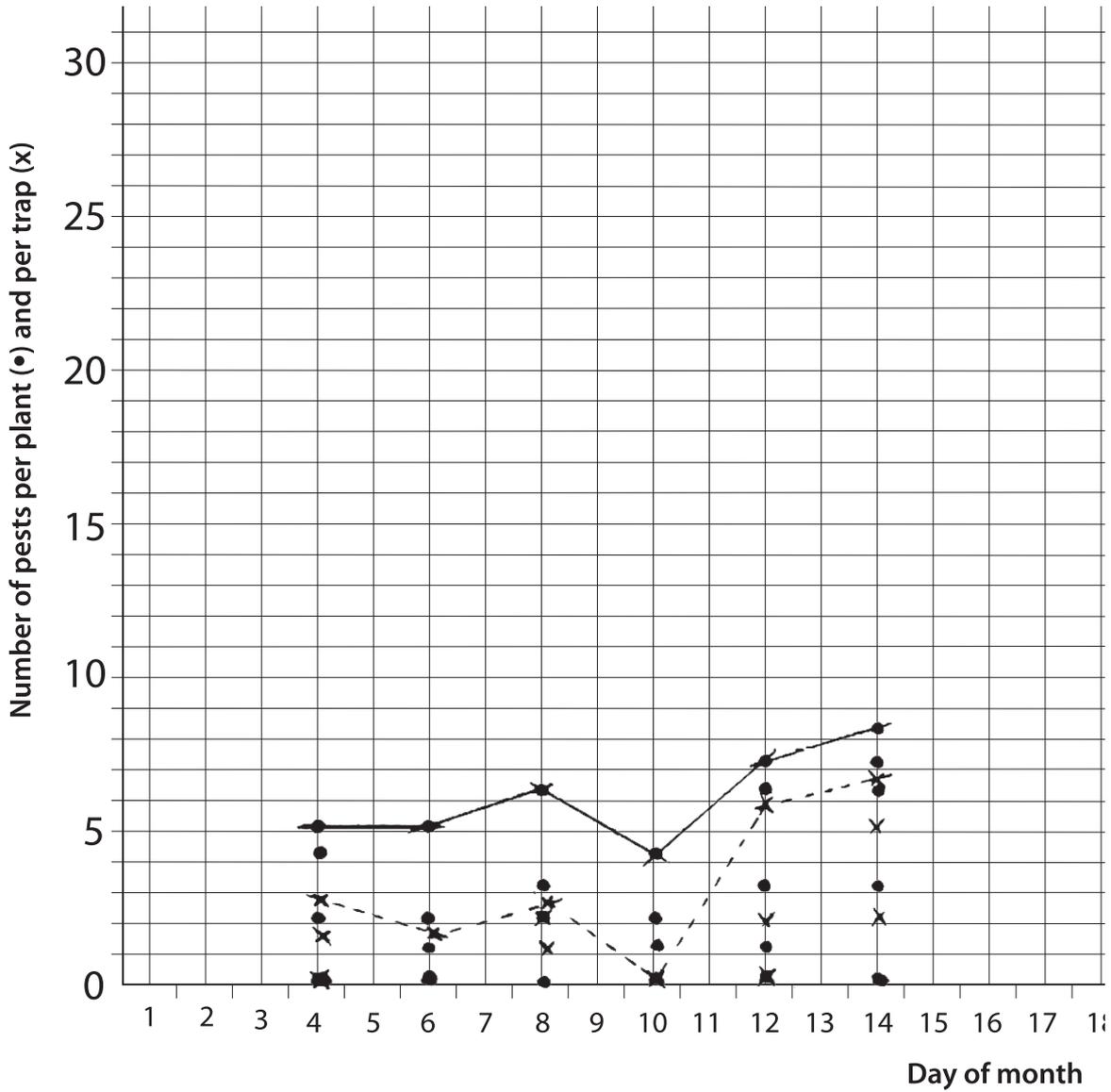
Every second time you do the pest and disease check, walk down the other row in each purple zone, looking for anything suspicious. Stop at each orange zone and select a different plant to the one you inspected last time. When you get to a sticky trap, inspect it carefully and record the results. You will then need to replace the trap with a new one. (Traps are replaced on every second inspection)



Completing your record

After you have finished your pest and disease check and attended to any urgent actions that are necessary, for example, bagging and removing a virus infected plant, it is important to complete the record. Use a ruler to connect the highest dot on each chart to the highest from the previous check. If you are using a computer record, enter the results.

Look at the charts. Are there any significant changes in the numbers of pests or disease infected plants? It is best to look at the trend over a few days. How do the numbers detected compare with your threshold (action) levels?



Record sheet example

Action points (threshold levels)

It is important to have clear action points for pests and diseases. An action point is the level of pests or disease at which point you implement an active treatment strategy. These are set points that you use to make decisions about what, if any, management action you need to take. They may also be called threshold levels. An action point or threshold is the number of a certain pest per plant in your greenhouse above which you will implement a control action. Or, an action point is the number of plants infected with a certain disease above which you will implement a control action.

There are different ways that you can use to describe an action point. You also need to plan what the action will be. The action points and the selected action need to be thought about and planned before you plant your crop.

Example 1

The action point for pest X is 10 insects on any one plant. The action might be to release low numbers of an appropriate predatory insect.

In this example, when you or your scout conducts your pest and disease check, if you find 10 or more of pest X on a plant, you would release the predetermined number of predatory insects.

Example 2

The action point for pest Y is 5 insects on 5 plants throughout the greenhouse. The action might be to use a whole crop application of an appropriate insecticide.

In this example, when you or your scout conducts your pest and disease check, if you find 5 or more of pest Y on at least 5 plants, you would apply a whole crop application of an appropriate insecticide.

Example 3

The action point for fungal disease Z is 10 plants in a greenhouse. The action might be to use a whole crop application of an appropriate fungicide.

In this example, when you or your scout conducts your pest and disease check, if you find 10 or more plants showing symptoms of fungal disease Z, you would apply a whole crop application of an appropriate fungicide.

For some pests or diseases, you might want to have more than one action point, with different actions.

Example 4

- a. The first action point for pest X is 10 insects on any one plant in the greenhouse. The action might be to release low numbers of an appropriate predatory insect and to check more plants to find out how widespread the pest is.
- b. The second action point for pest X is 15 insects on 5 plants throughout the greenhouse. The action might be to use a whole crop application of an appropriate insecticide.

In this example, when you or your scout conducts your pest and disease check, if you find 10 insects on any one plant in the greenhouse, you would release the predetermined number of predatory insects and conduct an additional pest check on more plants in the greenhouse but if you find 15 or more of pest X on at least 5 plants you would go straight to the second action and apply a whole crop application of an appropriate insecticide.

Action points are linked to the life cycle of pests and diseases, the effective control periods, the cost of the planned action and the potential loss if no action is taken.

Action points can vary for different types of management actions, seasons and production systems. Action points also vary depending on whether a problem is a direct pest or an indirect pest. A direct pest or disease is one which directly damages the part of the plant that is the marketed product or is required for the marketed product to develop. For example, thrips would be a direct pest of cucumbers because they cause direct damage to developing fruit. An indirect pest or disease is one which damages a plant but not the harvestable part of the plant. For example, Downy mildew might be considered an indirect pest of cucumber because it damages the leaves and can stunt overall growth but does not directly damage fruit.

The action point for direct pests is generally lower than that for indirect pests because the economic loss caused by the pest or disease is more immediate and occurs at lower levels of pests or disease.

The best management practice is to act only when necessary to avoid a loss that would be greater than the cost of the action, or to prevent a minor problem from becoming unmanageable. You do not want to act too soon, nor do you want to act too late.

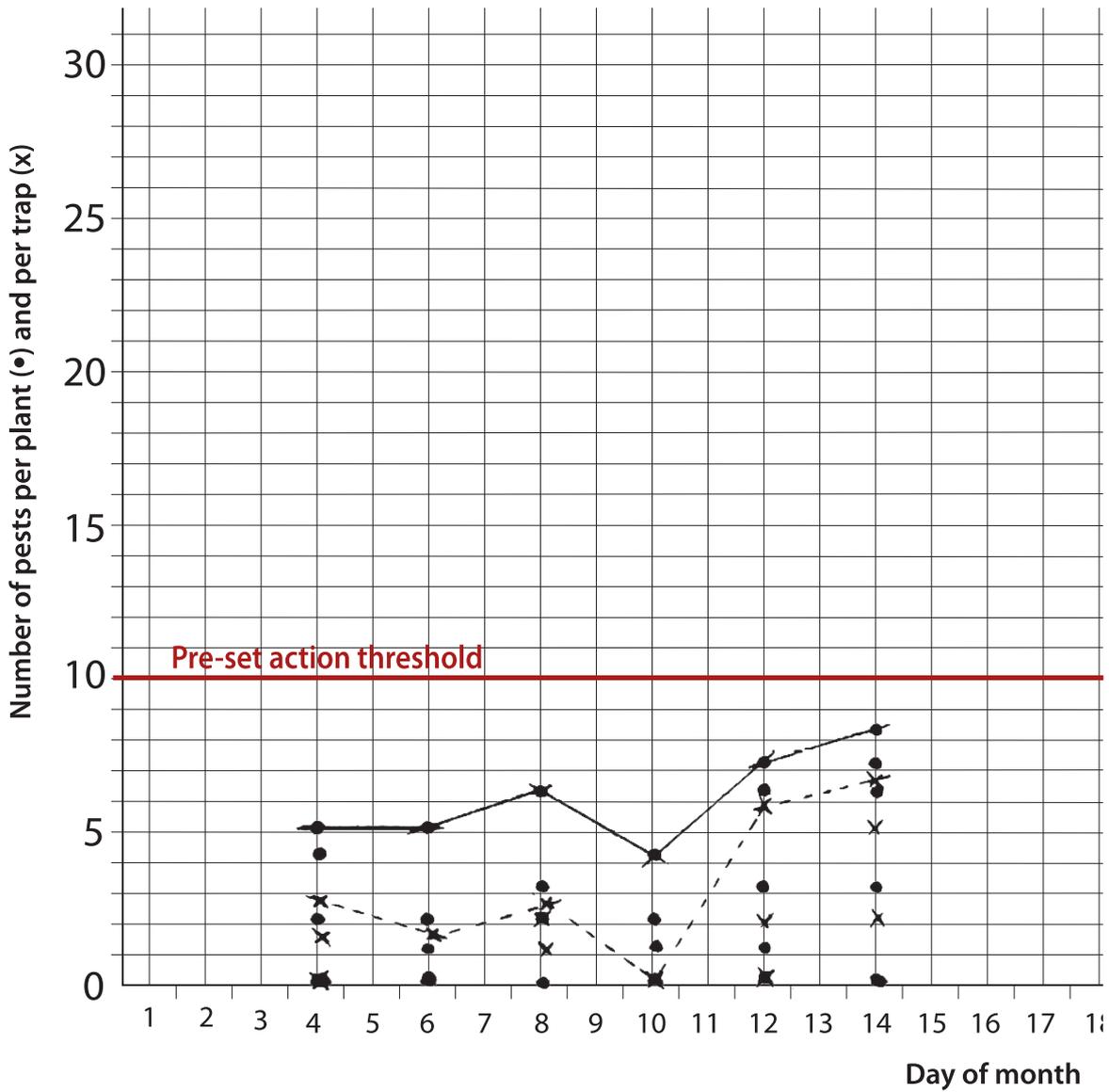
Setting action points or threshold levels

Setting action points for your farm is an extremely important and powerful skill. Growers who learn to make action points specific for their greenhouse will save a lot of money and greatly improve their success in pest and disease management.

“ the more accurate your action point, the more cost effective your management of pests and diseases will be ”

When first starting out, set a basic action point or threshold as a guide to when to take action. You might set this by talking with a consultant, extension officer or researcher and other growers. Remember, this is just a place to start. A simple way to plan your action points is to draw up a basic table (like the example below) and complete it for each of the pests and diseases.

Pest	Action point (threshold)	Action
X	10 on a plant	<ul style="list-style-type: none"> • release preventative numbers of predatory insect A • check an extra 12 plants in the greenhouse
	15 on 5 plants	<ul style="list-style-type: none"> • apply a whole crop application of insecticide B
Y	8 on a plant	<ul style="list-style-type: none"> • apply a spot application of insecticide D on target plant and surrounding plants
	15 on 5 plants	<ul style="list-style-type: none"> • apply a whole crop application of insecticide D
Disease	Action point (threshold)	Action
Z	10 plants infected	<ul style="list-style-type: none"> • apply a whole crop application of fungicide E



Record sheet example

During the growing period of your crop and after the crop has finished, the pest and disease charts and the actions you took need to be carefully looked at to see how well the thresholds worked. This process allows you to use your actual experience to make the thresholds more accurate. You may be able to increase a particular threshold if you found that a pest or disease was extremely well managed. Or you may have had problems with a pest or disease getting out of control, in which case you may need to lower your threshold for that pest or disease to give you earlier and better control next time.

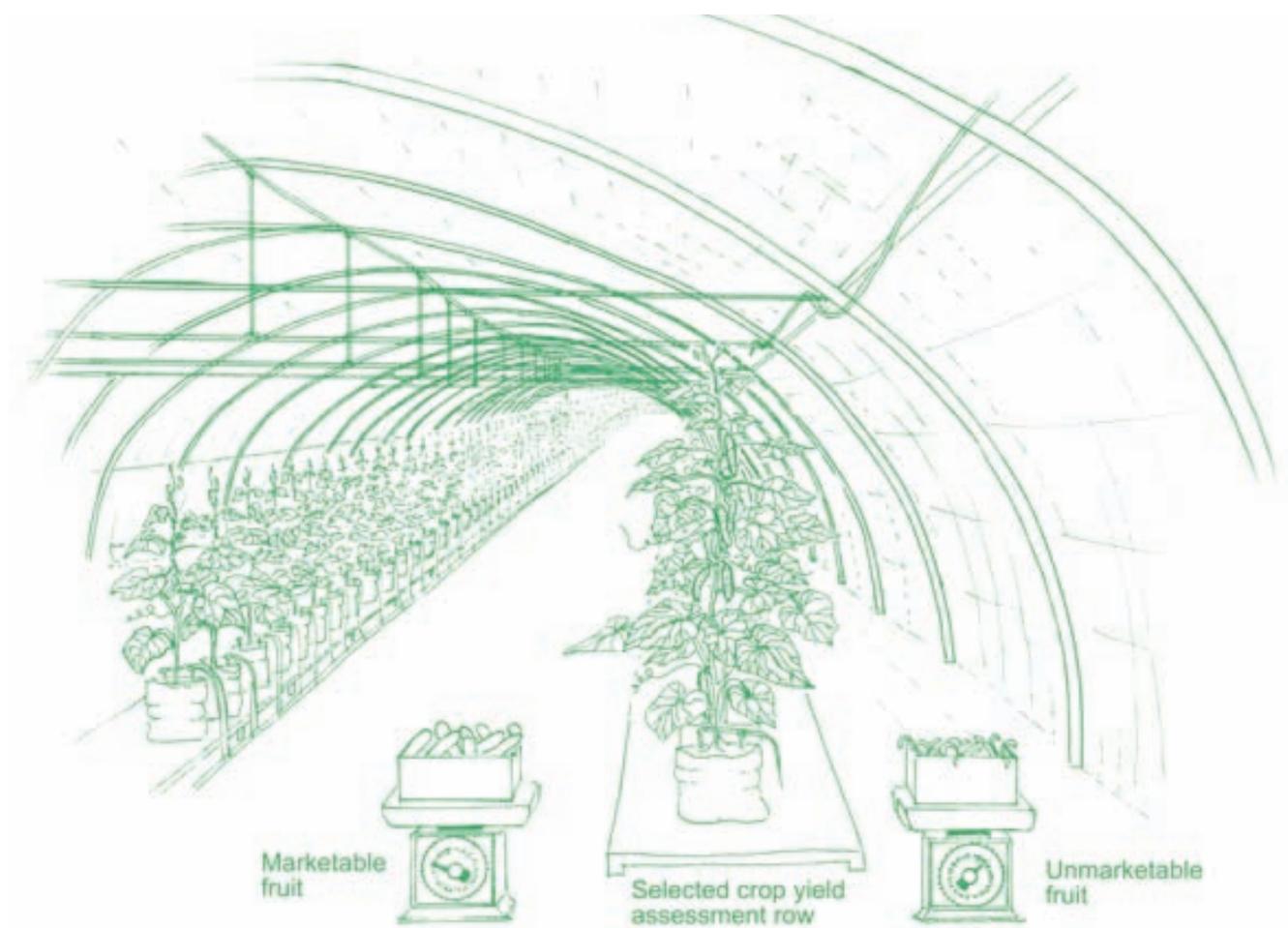
Measuring the impact of pests and diseases

Improving management decisions in the greenhouse is only possible when there is a way of comparing different situations. Crop yield is a valuable tool to use. By collecting and keeping crop yield information on each crop, it is possible to see which decisions and/or changes have the best effect. Over several crops, it is possible to significantly increase productivity and/or reduce costs – both of which can lead to bigger profits.

Yield measurements are also very useful for a range of management decisions for example comparing varieties, fine tuning fertiliser programs or reducing input costs.

Yield is an important factor to consider when deciding on pest and disease management strategies. Not only does yield information provide a way of working out the likely cost or loss of a pest or disease, but it also enables you to make better pest and disease as well as cultural management decisions in the future by knowing what impact a previous decision has had on yield.

While the best information comes from assessing the whole crop from a greenhouse, to simplify the process, you can just select a single row of plants in each greenhouse and use this row for your measurements. All fruit that is removed from any plant or falls off any plant in this row (or whole greenhouse) needs to be counted. Yield is described as either marketable or unmarketable.



Yield measurements are very useful for making a lot of important management decisions

Unmarketable yield

Unmarketable yield is any fruit which forms on the plant but is not picked for sale. This information gives you the clearest measure of how well your pests and diseases, and growing environment are being managed. The less unmarketable yield you get, the better your management practices.

Unmarketable yield includes immature aborted fruit and any bent, damaged or diseased fruit removed at any time. It also includes any healthy fruit that may be removed early for cultural management reasons (for example, touching the substrate) and is therefore not suitable for sale.

Throughout the cropping period, all unmarketable fruit is collected and placed in a clearly marked container such as a bucket. Only fruit prunings are put into this container. Leaves and stems are not put into this container. The container is kept at the end of the row. Each week (or more often), the contents of the container are weighed and the weight is recorded.

This fruit may also be examined to determine the reasons that the fruit are unmarketable (eg aborted, diseased, pest damage, nutritional, cultural removal).

Marketable yield

Marketable yield is all fruit which are picked and suitable for sale.

Once harvest begins, every time the crop is harvested, all marketable fruit picked off any plant in the specified row is collected and placed in a container and weighed before being included with the rest of the harvested fruit. The weight is recorded.

This fruit may also be counted and classified into grades to provide more valuable information.

Keeping records

There are many different ways to keep a record. Use whatever method you prefer. The most important thing is that a written record is made. This information is what you can use later to improve your business.

Two different methods of keeping a record for crop yield are provided as examples.

Appendix 1

Farm self review and action plan records

1. Overview of structures:
Complete for each greenhouse
2. Pest and disease risk assessment: Complete for each greenhouse
3. Preventative practices checklist: Complete for each review
4. Action plan: Complete for each problem identified

1. Overview of structures: Complete for each greenhouse

Greenhouse structure (name or ID number): _____

Area (m²) = _____

Height to gutter (m) = _____

Span width (m) = _____

Height to peak (m) = _____

Single span Multispan

Shape / features:

- Tunnel / igloo
- Gable – venlo type
- Gable – wide span
- Raised arch
- Flat arch
- Off-set arch
- Off-set gable
- Sawtooth
- Skillion
- Other _____

Technologies:

- Twin roof vents
- Single roof vent
- Wall vents
- Hydronic heating
- Hot air heating
- Insect screens
- Thermal screen
- Climate control
- Substrate culture (type) _____
- Water culture
- Soil
- Other _____

Cladding:

- Single plastic film
- Twin plastic film
- Glass (____ mm thickness)
- UV absorbing film
- Polycarbonate
- Other _____

Average yield (per m²):

Primary crop	(_____) =	_____
Secondary crop	(_____) =	_____
Tertiary crop	(_____) =	_____
	crop	yield

2. Pest and disease risk assessment: Complete for each greenhouse

Key pests

- Thrips
- Whiteflies
- Broad mites
- Russet mites
- Rutherglen bugs

Assessed Risk level (1, 2 or 3)

Key pests

- Aphids
- Caterpillars
- Spider Mites
- Flies (fungus gnats)
- Other

Assessed Risk level (1, 2 or 3)

Key diseases

- Fungal moulds and mildews
 - Botrytis (grey mould)
 - Downy mildew
 - Sclerotinia (white mould)
 - Leaf mould
 - Powdery mildew
 - Other

Assessed Risk level (1, 2 or 3)

Key diseases

- Bacterial leaf spots and soft rots
 - Angular leaf spot
 - Bacterial speck
 - Bacterial spot
 - Bacterial soft rot
 - Other

Assessed Risk level (1, 2 or 3)

Fungal leaf spots, blights and cankers

- Alternaria leaf spot
- Anthracnose leaf spot
- Grey leaf spot
- Gummy stem blight
- Other

Bacterial wilts

- Bacterial canker
- Bacterial pith necrosis
- Bacterial wilt
- Other

Fungal wilts and root rots

- Black root rot
- Damping off
- Fusarium
- Verticillium
- Other

Viruses

- Mosaic viruses
- Cucumber yellows
- Tomato spotted wilt virus
- Other

Nematodes

3. Preventative practices checklist: Complete for each review

General farm management

Establish a 'clean zone'

Y / N

- The greenhouse is within a 'clean' zone which is quarantined from the 'outside' zone of the farm
- Check and control points are used to control movement of people, vehicles, plants and materials into the 'clean' zone
- A 5-10 metre wide clean buffer area is maintained around every greenhouse
- The greenhouse and farm surrounds are kept weed free
- Work procedures for all jobs that need to be done in and around the greenhouse are written and explained to all workers
- Crop work is done in cleanest, youngest crops first and dirty tasks are completed last in the day
- A parking area for employee and visitor vehicles is in the 'outside' zone of the farm
- All vehicles in the 'clean' zone are kept free from soil, plant debris and rubbish
- All vehicles that travel off-farm ('outside' zone) are always cleaned before entering the 'clean' zone
- Windbreaks are established around the farm or greenhouse
- There is a neighbourhood agreement for managing weeds

Maintain clean surfaces

Y / N

- Roadways and pathways in the 'clean' zone are sealed or covered
- Roadways and pathways in the 'clean' zone are free from soil and mud, weeds, plant debris and rubbish
- Floors and other surfaces of sheds in the 'clean' zone are sealed or covered for easy cleaning and are regularly cleaned
- The greenhouse floor and other surfaces kept covered for easy cleaning

Water and drainage

Y / N

- All water used in the 'clean' zone is disinfected and disinfected water is stored so that it can not be contaminated
- Drainage ensures that there are no puddles or wet areas in the 'clean' zone and surface run-off does not wash into the greenhouse

Manage rubbish

Y / N

- Crop debris is removed and stored/disposed of outside 'clean' zone and away from greenhouse
- A waste bin is located away from the greenhouse for management of bulk waste and is emptied regularly
- Rubbish removed and stored/disposed of outside of 'clean' zone and away from greenhouse
- Small 'day' and 'pruning' bins are located conveniently in or near the greenhouse and are emptied frequently

Greenhouse sanitation

Greenhouse clean out

Y / N

- Old crops completely removed from greenhouse at the end of the crop
- Used substrate completely removed from greenhouse at the end of the crop

Greenhouse clean up

Y / N

- The greenhouse always cleaned and disinfected before planting new crop
- Appropriate disinfectant used for sanitising the greenhouse, tools, shoes and other equipment
- All equipment, tools, containers, bins and other items are completely removed from greenhouse before the clean up

Limiting the spread of pests and diseases

Assessing the problem

Y / N

- Be able to correctly identify pests and diseases (or have them identified for you) and routinely conduct a pest and disease check to ensure early detection and correct identification of problems
- Action points are determined and pest and disease check information is used for all decision making including chemical, biological, whole-crop and hot-spot treatments

Plant management

Y / N

- Plants are pruned and trained appropriately and sharp, clean blades are used
- Pruned plant material put directly into a 'pruning' bin or bag and disposed of appropriately
- Infected plants (bagged before removal) are removed from the greenhouse (roguing)
- De-leafing, truss or flower pruning and thinning used to reduce pest and disease risk

Spot treatments

Y / N

- Spot treatments are used when appropriate
- Chemical controls are assessed for any resistance issues or control failures and a resistance management plan is used

Quarantine and exclusion

Plants

Y / N

- All seedlings are checked and found free from pests and diseases before they are planted out
- Only a single crop is grown at a time in the greenhouse and the greenhouse is kept free of non-crop plants including "pet" plants
- Hydroponic set up prevents plant to plant contact of run-off water

Substrate, plant containers and soil

Y / N

- Only clean, pest and disease free substrate (new or sterilised) is used for each new crop
- Soil has appropriate biological, chemical and physical properties for the crop being grown
- Soil is solarised or fumigated with an appropriate and registered product between crops

Clean tools and equipment

Y / N

- A cleaning station is set up at the greenhouse entry or other convenient location for sanitising tools before taking them into the greenhouse
- All containers (bins, boxes, tubs, buckets and trays) and other materials (eg twine and crop supports) to be used in the greenhouse are cleaned and disinfected before being taken into the greenhouse
- All tools and equipment (eg knives, secateurs, brooms and trolleys) to be used in the greenhouse are cleaned and disinfected before being taken into the greenhouse
- Pruning tools are regularly disinfected during the pruning task and when used in a diseased area of a crop are cleaned and disinfected before being taken into a healthy area of a crop
- The crop support twine is new or cleaned and disinfected before use in the greenhouse

Greenhouse structures and surrounds

Y / N

- The number of greenhouse entry points has been minimised
- Foot baths (or wheel baths) and doormats installed and used correctly at every entry point
- Double entry doors (and fan) or a double curtain installed at all entry points
- The greenhouse covering materials are kept clean and well maintained
- Splash skirts are installed on all opening walls of greenhouse
- Furrows or trenches (such as a gutter or drain) used to stop crawling pests
- Insect screens are installed on opening sides
- Insect screens are installed on roof vents
- Windward vent opening restricted during warm windy conditions if feasible
- Potential insect vectors are excluded or appropriately managed

Worker and visitor hygiene

Y / N

- Employees and visitors do not visit another greenhouse before entering your greenhouse
- Disposable gloves are worn when in the greenhouse and are changed frequently
- Employees have a clean change of clothes/overalls everyday for greenhouse work and clothes/overalls are changed after working in a 'dirty' greenhouse
- Dedicated footwear or disposable shoe covers are used when working in or entering the greenhouse
- Employees wash hands and disinfect personal items (eg mobile telephone) after working in a 'dirty' greenhouse
- Employees and visitors who smoke wash their hands after smoking before entering the greenhouse

Cultural management

Monitor and manage greenhouse environment

Y / N

- Temperature and humidity in the greenhouse is properly managed (including monitoring) and temperature and humidity extremes in the greenhouse are avoided
- The greenhouse has adequate and adjustable venting capacity
- The greenhouse has adequate heating capacity
- Overhead sprinkler/misting/fogging used (if appropriate and feasible) to maintain humidity levels
- Air circulation fans are installed and air movement is managed in the greenhouse
- Vibrating pollinators used in preference to blowers if pollinating crops
- The number of whole crop foliar sprays is minimised
- UV blocking covering material used (if appropriate and feasible) to disrupt pest behaviour

Nutrition

Y / N

- A balanced and appropriate nutrient regime is provided to the crop
- Feed and drain EC and pH is managed (including monitored and recorded) at least daily

Irrigation

Y / N

- Irrigation uniformity test is completed before planting new crop
- Feed and drain irrigation volume is managed (including monitored and recorded) at least daily
- Good root zone drainage is maintained

Reduce planting and other risks

Y / N

- A crop break or rotation plan is used for the greenhouse
- Resistant or tolerant varieties are used when feasible

4. Action plan BLANK: Complete for each problem identified

Problem: (what is the problem that is causing a pest and/or disease risk?)	
[Empty space for problem description]	
Aim: (what will you aim to do to fix the problem?)	
[Empty space for aim description]	
Practices to be implemented: (select practices from checklist)	
[Empty space for practices]	
[Empty space for practices]	
[Empty space for practices]	
Strategy/action: (what action will you take? where? and how will you do it?)	
[Empty space for strategy/action]	
Resources: (what do you need? how much does it cost? and who will do the work?)	
[Empty space for resources]	
Schedule: (by when?)	Completed: (is it done?)
[Empty space for schedule and completion status]	

Action plan EXAMPLE:

Problem: (what is the problem that is causing a pest and/or disease risk?)	
<i>No records of pests and diseases available for effective decision making</i>	
Aim: (what will you aim to do to fix the problem?)	
<i>Implement a routine pest and disease check procedure for all greenhouses</i>	
Practices to be implemented: (select practices from checklist)	
<i>Be able to correctly identify pests and diseases (or have them identified for you) and routinely conduct a pest and disease check to ensure early detection and correct identification of problems</i>	
<i>Action points are determined and pest and disease check information is used for all decision making including chemical, biological, whole-crop and hot-spot treatments</i>	
Strategy/action: (what action will you take? where? and how will you do it?)	
<ol style="list-style-type: none"> 1. <i>A preferred recording system is decided upon including where records will be kept and in what form. Record sheets obtained.</i> 2. <i>Days of week that P&D check be done are decided.</i> 3. <i>Middle two rows will be purple zone for each greenhouse (2 purple zones per tunnel)</i> 4. <i>Each greenhouse is marked for P&D check with 3 orange crosses in each of 2 rows (6 orange zones per tunnel)</i> 5. <i>Sticky traps installed (2 per tunnel)</i> 6. <i>Initial action points defined for each key pest and disease</i> 	
Resources: (what do you need? how much does it cost? and who will do the work?)	
<ul style="list-style-type: none"> • <i>P&D check records</i> • <i>Sticky traps (22 needed per week in summer)</i> • <i>Hand lens</i> • <i>ID guide and posters</i> 	
Schedule: (by when?)	Completed: (is it done?)
<i>End of March 09</i>	<i>yes</i>

Appendix 2

Common weeds

COMMON WEEDS

Brassica weeds

There are a number of Brassica weeds which host several pests and diseases. These weeds produce yellow or white flowers from winter to summer.

Brassica weeds are a risk for thrips, aphids, caterpillars, cucumber mosaic virus, tomato spotted wilt virus.
Photo T. Burfield



Cobblers pegs

Cobblers pegs is a small upright bush with bright green leaves with serrated edges. It produces yellow and sometimes white flowers year-round. Slender black seeds attach readily to clothing. This weed harbours a number of problems including thrips, cucumber mosaic virus and tomato spotted wilt virus



Cobblers pegs is a risk for thrips, cucumber mosaic virus and tomato spotted wilt virus. Photo J. Badgery-Parker

Capeweed

Capeweed is a low growing herbaceous plant that produces a profusion of yellow daisy like flowers with dark centres from spring through to autumn. Capeweed hosts Western flower thrips (WFT) as well as Tomato spotted wilt virus (TSWV). Rutherglen bugs readily breed in capeweed.

Capeweed is a risk for thrips, tomato spotted wilt virus and Rutherglen bug.
Photo M. Campbell



Dock

There are a few species of dock (including curled, broad-leaved, clustered) which harbour a range of problems such as thrips, aphids, cucumber mosaic virus and tomato spotted wilt virus. Flowers occur in separate clusters along the stems rising from a rosette of leaves.

Dock is a risk for thrips, aphids, cucumber mosaic virus and tomato spotted wilt virus.
Photo J. Badgery-Parker



Clover

White clover and other clovers are hosts of thrips and tomato spotted wilt virus. They are low growing legumes with trifoliate leaves. Flowers form ball shaped clusters.

Clover is a risk for thrips and tomato spotted wilt virus.
Photo J. Badgery-Parker



Fat hen

Fat hen is an erect annual herb with silvery green leaves. It produces slender panicles of whitish flowers from summer to autumn. It is a host of thrips and tomato spotted wilt virus.

Fat hen is a risk for thrips and tomato spotted wilt virus.
Photo J. Badgery-Parker



Fireweed

Fireweed is an erect annual or biennial herb which produces small yellow daisy-like flowers. This weed harbours thrips and mosaic viruses.

Fireweed is a risk for thrips and mosaic viruses.

Photo J. Badgery-Parker



Mallow

Mallows range from low growing ground covers to small shrubs. They have gently serrated edges to their leaves which give them a pleated appearance. Flowers are pale pink in summer. Mallows host thrips and mites.

Mallows are a risk for thrips and mites. Photo J. Badgery-Parker



Flickweed

Flickweed is a slender annual herb with pinnate leaves. It produces very small white flowers and harbours thrips, cucumber mosaic virus and tomato spotted wilt virus.

Flickweed is a risk for thrips, cucumber mosaic virus and tomato spotted wilt virus.

Photo J. Badgery-Parker



Nettles

Nettles are erect herbs. Leaves are rich green and have serrated edges. Nettles host a number of pests and diseases including thrips, two spotted mites and mosaic viruses.

Nettles are a risk for thrips, mites and mosaic viruses. Photo T. Burfield



Lambs Tongue

Lambs Tongue is an annual or biennial herb with thick slender leaves. It produces a solitary flower spike on a single upright stem. Lambs tongue provides a refuge for many pests and diseases including thrips, aphids, cucumber mosaic virus and tomato spotted wilt virus.

Lambs tongue is a risk for thrips, aphids, cucumber mosaic virus and tomato spotted wilt virus.

Photo J. Badgery-Parker



Nightshades

Nightshades (Blackberry and Silverleaf) belong to the same family as Solanaceae crops such as tomatoes. These are bushy annual or short lived perennial plants. The flowers look similar to tomatoes but are purple or white. These weeds host thrips and tomato spotted wilt virus.

Nightshades are a risk for thrips and tomato spotted wilt virus. Photo J. Badgery-Parker



Oxalis

There are a number of oxalis weeds which can be annual or perennial herbs or shrubs. Many have underground tubers or bulbs. Leaves are composed of three heart shaped leaflets, a little similar to clovers. Oxalis harbours thrips.

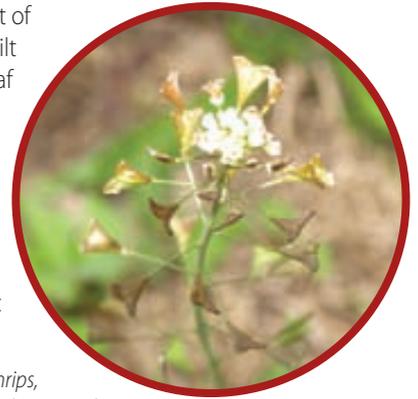
*Oxalis weeds are a risk for thrips.
Photo J. Badgery-Parker*



Shepherds purse

Shepherds purse is a host of thrips, tomato spotted wilt virus and some fungal leaf spots. It is a small erect herb. A stem grows from the centre of a rosette of leaves. It has small white flowers. As the stem grows further, it produces characteristic purse-shaped 'pods'.

Shepherds purse is a risk for thrips, tomato spotted wilt virus and fungal leaf spots. Photo J. Badgery-Parker



Paterson's curse

Paterson's curse (Salvation Jane) is an upright bush and produces curved spikes of purple flowers. Thrips, aphids and Rutherglen bug breed in this weed.

*Paterson's curse is a risk for thrips, aphids and Rutherglen bug.
Photo J. Badgery-Parker*



Thistles

Thistles (including sow thistle, scotch thistle, milk thistle) are herbaceous, upright plants. They can be annual, biennial or perennial. Some species have spines. Thistles have purple or yellow flowers. Thistles provide a refuge for many pests and diseases including thrips, aphids, greenhouse whitefly, Cucumber mosaic virus and tomato spotted wilt virus.

Thistles are a risk for thrips, aphids, greenhouse whitefly, cucumber mosaic virus and tomato spotted wilt virus. Photo J. Badgery-Parker



Pig weed

Pig weed or Pig face is a succulent plant with thick fleshy leaves. There are a number of ornamental varieties with various colours of flowers. The main weed form has purple flowers. This weed harbours thrips, tomato spotted wilt virus and Rutherglen bug.

*Pigweed is a risk for thrips, tomato spotted wilt virus and rutherglen bug.
Photo J. Badgery-Parker*



Appendix 3

Disinfectants

DISINFECTANTS

Halogens

Chlorine

Chlorine is effective against a wide variety of microorganisms and needs a relatively short contact time. It is also fairly inexpensive. At a 0.1% concentration (1000 mg/L), it can be used as a general disinfectant where there is a high disease load or short contact time. It is less effective when there is a lot of organic matter present and so the concentration must be increased (up to 0.5%) to retain activity.

Chlorine is the most commonly used method for disinfecting greenhouses and hydroponic systems. Remove all organic material by sweeping, brushing and/or washing before using chlorine.

Chlorine is also widely used for disinfecting water. A reaction period of at least 20 minutes is normally required for effective disinfection with a residual concentration of free chlorine of 3 mg/L. An initial concentration of up to 20 mg/L may be needed to achieve the required residual dose depending on water quality. When disinfecting water, prefilter the water to remove organic matter.

Chlorine is effective between a pH range of 6 – 7.5, but it is de-activated by sunlight and some metals. In high concentrations chlorine can corrode metal surfaces and bleach other materials. The efficacy of chlorine decreases with time and so a freshly made solution always needs to be used. Use it straight away. Do not bother to use an old chlorine solution.

Generally chlorine is used in the form of sodium or calcium hypochlorite. For general disinfection either form can be used, however, calcium hypochlorite is recommended when cleaning tanks or disinfecting water to avoid a build up of sodium in the hydroponic or irrigation system.

The levels of chlorine in the water can be measured with a simple test kit. To avoid potential damage to plants, the total level of chlorine in the water needs to be less than 1 mg/L prior to irrigation.

Chlorine is a very useful general disinfectant. Household bleach is dilute sodium hypochlorite.

Bromine

Bromine is a chemical similar to chlorine and is used in conjunction with chlorine in a process called chlorobromination to disinfect water supplies. Sodium bromide is added to the water (along with the chlorine) and forms hypobromous acid. This disinfectant is more stable at higher pH so is used in preference to chlorination for treating water that has a pH value greater than 7.

Chlorobromination is a relatively cheap method of disinfecting water and is a useful alternative to chlorine in some situations. This method of disinfection is corrosive and may damage metal fittings.

A bromine concentration of up to 8 mg/L for 8 minutes may be required to kill the toughest stages of key diseases in alkaline water because the chlorine is deactivated at high pH. At neutral pH, a 1 – 2 mg/L concentration of chlorine plus 1 – 2 mg/L bromine only requires a 2 minute contact time.

The levels of chemical in the water can be measured with a simple test kit. To avoid potential damage to plants, the total level of chlorine and bromine in the water needs to be less than 1 mg/L prior to irrigation.

Chlorobromination is a useful disinfectant for treating water in some situations.

Iodine

Iodine is another disinfectant in the halogen group. It is similar to chlorine but tends to be more expensive. Iodine is used in an aqueous or alcoholic solution. Iodine vapour is highly toxic and is absorbed through the skin.

Iodine is effective against a wide variety of microorganisms and needs a relatively short contact time. It is typically used at a 1% w/v concentration of free iodine. Trials conducted by NSW DPI¹ showed that at a concentration of 0.001% iodine, a treatment time of 30 minutes is required. At 0.002%, a 5 minute treatment time is needed to kill *Fusarium*. These concentrations are suitable for treating water prior to irrigation as long as the iodine is dissipated before the water is used.

Iodine is effective in a neutral to acid pH range. It is inactivated above 40°C. Iodine is not very effective when there is a lot of organic matter present and should not be used on aluminium or copper. It will stain some materials and surfaces. The efficacy of iodine decreases with time and so a freshly made solution always needs to be used.

Iodine is a useful disinfectant though there remain some practical issues in the use of this chemical.

1 Tesoriero, L (2008) Final report (project VG04012) Effective management of root diseases in hydroponic lettuce, NSW DPI

Alcohols

Ethanol (80% v/v ethyl alcohol) or 2-propanol (60-70% v/v iso-propyl alcohol) solutions are used to disinfect skin. It is typically used at a 70% concentration in water. Alcohol is fast acting and doesn't leave any residue. Alcohol is effective against fungi, bacteria and some viruses. It is limited or not effective against spores. Its efficacy is reduced in the presence of organic matter. It can damage some plastics and rubber.

Alcohol is a useful hand cleanser prior to entry into the greenhouse.

Oxidising agents

Hydrogen peroxide

Hydrogen peroxide is active against a range of microorganisms though fungi and spores require a higher concentration. A concentration of 3% w/v of hydrogen peroxide is generally used for disinfection.

There are no toxic end-products from this disinfectant making it a useful and safe product. Hydrogen peroxide is relatively expensive and is degraded by sunlight. Its efficacy is reduced when organic matter is present.

It should not be used on aluminium, copper, zinc or brass.

Hydrogen peroxide is an effective disinfectant but is not commonly used due to its cost.

Ozone

Ozone is an effective water disinfecting agent but it is destroyed quickly in water with a pH greater than 7, and where there are high levels of manganese, iron and bicarbonate ions. This reduces its potential usefulness for recirculating nutrient solutions though it is useful for disinfection of new water.

The ozone needs to be dissolved in the water to be effective so the efficiency of dissolution is a critical factor in deciding the type of ozone disinfection system to be used. A residual ozone concentration of at least 1.5 mg/L for 15 minutes would destroy key diseases. A much higher dosing rate (up to 140 mg/L) may be needed to achieve the residual concentration.

Ozone is also fairly corrosive and may damage brass and other metals, rubber and some plastics.

To avoid potential damage to plants, the total level of ozone in the water needs to be less than 1 mg/L prior to irrigation.

Ozone is useful as a water disinfectant in some situations but is not used as a general disinfectant.

Chlorine dioxide

Chlorine dioxide is another oxidizing agent. Chlorine dioxide is marketed as an alternative to chlorine. It has similar results to chlorine but has the advantage that it is less reactive to organic material and so has better efficacy under 'dirty' conditions, such as where there is a high level of organic matter.

Chlorine dioxide may be a useful disinfectant for treating water supplies. A concentration of approximately 3 – 4 mg/L is required to kill key diseases such as *Pythium* and *Fusarium*. A treatment time of 2 – 4 minutes is required to kill most diseases. An eight minute treatment time is needed for *Alternaria*. A concentration of 9 mg/L is needed to destroy the tough resting stage of *Phytophthora*.

Acids and Alkalis

Acids and Alkalis are fairly effective disinfectants against bacteria and some viruses, though their effect can be limited with fungi and fungal spores. The alkali disinfectant trisodium phosphate is a useful product for disinfecting tools. Weak acids may be useful in footbaths, while stronger acids are good for disinfecting and cleaning irrigation systems.

Combination disinfectants

Commercial blends of an inorganic peroxygen compound, inorganic salts, organic acid and anionic detergents or surfactants have been developed to produce effective and more stable disinfectants in the oxidising category. Virkon-S[®], Trifectant[®] are examples of commercial disinfectants.

They are effective against a range of fungi, bacteria and viruses even when organic matter is present. There is some variability in how effective they are against spores.

These products are suitable for disinfecting a range of surfaces and equipment, though oxidising agents can damage some metal surfaces.

These combination disinfectants are suitable for foot and wheel baths.

Peroxyacetic acid

Peroxyacetic acid (for example Oxy-Sept 333®) is a combination of hydrogen peroxide and acetic acid. It is a stronger oxidising agent than hydrogen peroxide alone.

Phenolics

Phenols can be used for disinfecting floors, walls, benches however, these chemicals are only active against bacteria and lipid-containing viruses - not against spores, fungi or non-lipid-containing viruses so their use for disease prevention in greenhouses is limited. Phenols remain active when organic matter is present and so may be suitable for use in footbaths. They are non-corrosive and effective over a wide pH range, but must not be mixed with detergents.

Phenolic compounds can cause irritation, though generally considered safe for humans. They are toxic to many pets, especially cats.

Quaternary Ammonium Compounds (Quats)

Quaternary ammonium compounds are positively charged surface-active disinfectants. They are effective against gram-positive bacteria (for example Bacterial canker) but are more limited against gram-negative bacteria such as angular leaf spot. They have some efficacy against lipid-containing viruses.

These types of disinfectants will generally not kill spores, but can help prevent spores from germinating.

Quats are effective at high temperatures and high pH (9 – 10), but they are inactivated by proteins, soap and anionic detergents and readily inactivated by organic matter.

Quaternary ammonium compounds are toxic to fish and should not be used where there is a risk that they will contaminate water courses, ponds and waterways.

Other disinfectants

Biguanides

Biguanides (for example Chlorhexidine) are generally only effective against bacteria, have a narrow working pH range and are easily deactivated by soaps. They are also toxic to fish and should not be used where there is a risk that they will contaminate water courses, ponds and waterways.

This group of disinfectants are not suitable for use in greenhouses.

Aldehydes

Aldehydes (for example Formaldehyde and Glutaraldehyde) are very effective, broad spectrum disinfectants. They are also non-corrosive but are highly irritating, toxic and carcinogenic. Aldehydes are also known to have a residual phytotoxic effect if used in a greenhouse.

Aldehydes are not suitable for use in greenhouses.

Non-chemical disinfection

Ultra-violet light

Ultra-violet (UV) light is an effective disinfectant and is commonly used to treat water prior to irrigation. A lamp is used to generate UV radiation which passes through the water and destroys the diseases. A UV dose of 200 mJ.cm⁻² is needed to kill most key diseases including *Fusarium*. *Alternaria*, may require a dose in the order of 850 mJ.cm⁻². The flow rate of the water past the lamp is an important factor and has to be considered.

Deposits on the lamp casing can be caused by iron and manganese in the water. An inspection every 6 months is required and deposits can be cleaned off. The lamps are generally replaced annually.

UV treatment is typically faster to disinfect water than chemical treatments such as chlorination and also does not require a retention period for the chemicals to dissipate.

The efficacy of UV is affected by the level of organic material and other solids in the water. To be effective, more than 60% UV transmission is required. To achieve this, prefiltration is necessary when using an ultra-violet disinfection system.

UV radiation is a useful water disinfectant and one of the most cost effective non-chemical methods.

Membrane filtration

Membrane filtration systems use hydrostatic pressure to force water against a semipermeable membrane. This membrane only allows small molecules to pass through and so contaminants including diseases are excluded. Ultrafiltration, Reverse osmosis and microfiltration are all types of membrane filtration with the difference being the size of the molecules that can pass through the filter.

Membrane filtration can also be used to improve water quality, such as reducing salt levels.

Membrane filtration is a useful method of water disinfection in some situations.

Heat

Heat is a very effective method of water disinfection. Water is prefiltered and then heated to 95°C for 30 seconds or 85°C for 3 minutes. This is quite expensive and consequently heat disinfection is not commonly used.

Concentration of disinfectants

There are 2 main ways of expressing the concentration of disinfectants.

1. Volume/Volume (V/V)

Percent volume/volume (or % v/v) refers to millilitres of a liquid disinfectant per 100ml diluted solution (eg water).

For example, if a disinfectant is to be diluted to 1% v/v then 1ml of concentrate is made up to 100ml final solution. That is, 1ml of concentrate is added to 99ml of diluent such as water.

Target concentration v/v	Amount of disinfectant	Amount of diluent (eg water)
0.1 %	0.1 ml	99.9 ml
1 %	1 ml	99 ml
5 %	5 ml	95 ml

2. Mass/Volume (M/V)

Percent mass/volume (or % m/v) refers to grams of the solid chemical per 100ml of the final solution. Parts per million (ppm) can be used for weak solutions.

Target concentration w/v	ppm	Amount of disinfectant	Amount of diluent (eg water)
0.1%	1000	0.1 g	100 ml
1 %	10000	1 g	100 ml
5 %	50000	5 g	100 ml

Comparing activity of disinfectants for cleaning¹

Type of disinfectant										
	Proteins	Acids	Alkalis	Alcohols	Aldehydes	Halogens	Oxidising Agents	Phenolic Compounds	Biguanides	Quaternary Ammonium Compounds (Quats)
Examples	Skim milk	Hydrochloric, acetic and citric acids Phosphoric acid	Sodium hydroxide, Sodium carbonate, Trisodium phosphate	Ethyl alcohol, isopropyl alcohol	Formaldehyde, Glutaraldehyde	Hypochlorite, Iodine, Chlorine dioxide	Hydrogen peroxide, peroxyacetic acid, Virkon-S [®] , Trifectant [®] , Oxy-Sept 333 [®]	Phensol [®] , Lysol [®]	Chlorhexidine [®]	Glitz [®] Pine disinfectant, Roccal-D [®]
Target pathogen										
Bacteria (Gram +ve) Eg bacterial canker		Effective	Effective	Highly Effective	Highly Effective	Effective	Effective	Highly Effective	Highly Effective	Highly Effective
Bacteria# (Gram -ve) Eg angular leaf spot, pith necrosis		Effective	Effective	Highly Effective	Highly Effective	Effective	Effective	Highly Effective	Highly Effective	Effective
Bacterial spores		Limited	Limited	Not Effective	Effective	Effective	Effective+	Not Effective	Not Effective	Not Effective
Fungi		Limited	Limited	Effective	Effective	Effective	Limited	Limited	Limited	Limited
Fungal spores		Limited	Effective	Limited	Effective	Effective	Limited	Effective	Limited	Limited
Viruses (Lipid enveloped) Eg TSWV		Effective	Effective	Effective	Highly Effective	Effective	Effective	Limited	Limited	Limited
Viruses (No lipid envelope) Eg CMV	Effective	Not Effective	Limited	Not Effective	Effective	Effective*	Limited	Not Effective	Not Effective	Not Effective
Suggested Use	Suitable for tool disinfect between plants.	Weak acids have some potential in footbaths. Cleaning irrigation system. Phosphoric acid may be useful for cleaning irrigation parts	Trisodium phosphate suitable for tool disinfect. Limited benefit for disinfection of greenhouses. Can be corrosive and potentially dangerous.	Suitable for hand disinfect before entry. 70% ethyl alcohol suitable for tool disinfect between plants (esp. if bacterial canker present), but not for all viruses	NOT SUITABLE for in greenhouses. Dangerous and can have residual phytotoxic effects.	Hypochlorite is suitable to wash floors, walls and hydroponics between crops. 0.5% for tool disinfect but damages tools. Footbaths and wheel baths.	Footbaths and wheel baths.	Limited benefit for disinfection in greenhouses. May be suitable for footbaths and wheel baths due efficacy in presence of organic matter.	NOT SUITABLE for in greenhouses. Limited use against target pathogens.	May be suitable for disinfection, especially after bacterial canker outbreak

Many bacterial pathogens of concern are gram negative.
 + peroxyacetic acid is effective against spores (hydrogen peroxide is only effective against spores at high concentrations).
 * Iodine has limited activity against non-enveloped viruses.

Comparing activity of water treatments¹

Type of disinfectant										
Heat	Ultraviolet (UV) radiation	Chlorination	Chloro-bromination	Chlorine dioxide	Iodination	Hydrogen peroxide	Ozone	Membrane filtration	Slow sand filtration	
Examples	95°C for 30 seconds	Sodium or calcium hypochlorite 3 mg/L residual for 20 minutes	Chlorine and Bromine		Iodine	3%	1.5 mg/L residual for 15 minutes			
Target pathogen										
Bacteria (Gram +ve) Eg bacterial canker	Effective	Effective	Effective	Effective	Effective	Effective	Effective 1.1 mg/L (5 minutes)	Effective	Effective	
Bacteria (Gram -ve) Eg angular leaf spot, pith necrosis	Effective	Effective	Effective	Effective	Effective	Effective	Effective	Effective	Effective	
Fungi	Effective	Effective	Effective	Effective	Effective	Effective	Effective 3.8 mg/L (2 minutes)	Effective	Effective	
Phytophthora (including chlamydospores)			1 mg/L residual for 1 minute	9 mg/L for 4 minutes						
Fusarium				4 mg/L for 4 minutes	0.002% for 5 minutes		1.1 mg/L (10 minutes)			
Pythium				4 mg/L for 4 minutes						
Colletotrichum				4 mg/L for 4 minutes						
Alternaria			3 mg/L residual for 1 hour	8 mg/L for 4 minutes						
Viruses (Lipid envelope) Eg TSWW	Effective	Effective	Effective	Effective	Effective	Effective	Effective	Effective	Effective	
Viruses (No lipid envelope) Eg CMV	Effective	Effective	Effective	Effective	Effective	Effective	Effective	Effective	Effective	
	Expensive	Cost effective. Need prefiltration. Need >60% transmission	Cheap and easy to use. Need prefiltration. pH to be <7.5.	Need prefiltration.	Need prefiltration.	Need prefiltration.	Relatively expensive Need prefiltration. Oxidises iron and manganese	Expensive set up and maintenance costs		

¹ Information on the efficacy of disinfectants and treatments against plant pathogens is sparse and incomplete. There are many discrepancies between reports, and therefore only a broad compilation of claims and reports from numerous sources has been made in this publication. As a result, the listed information is not definitive and should only be used as general guide. Sources include general information on disinfectants and treatments, online resources such as The Department of Microbiology and Immunology, University of Melbourne, Schiff Consulting (Canada) and The Center for Food Security and Public Health, Iowa State University, as well as product claims made by manufacturers.

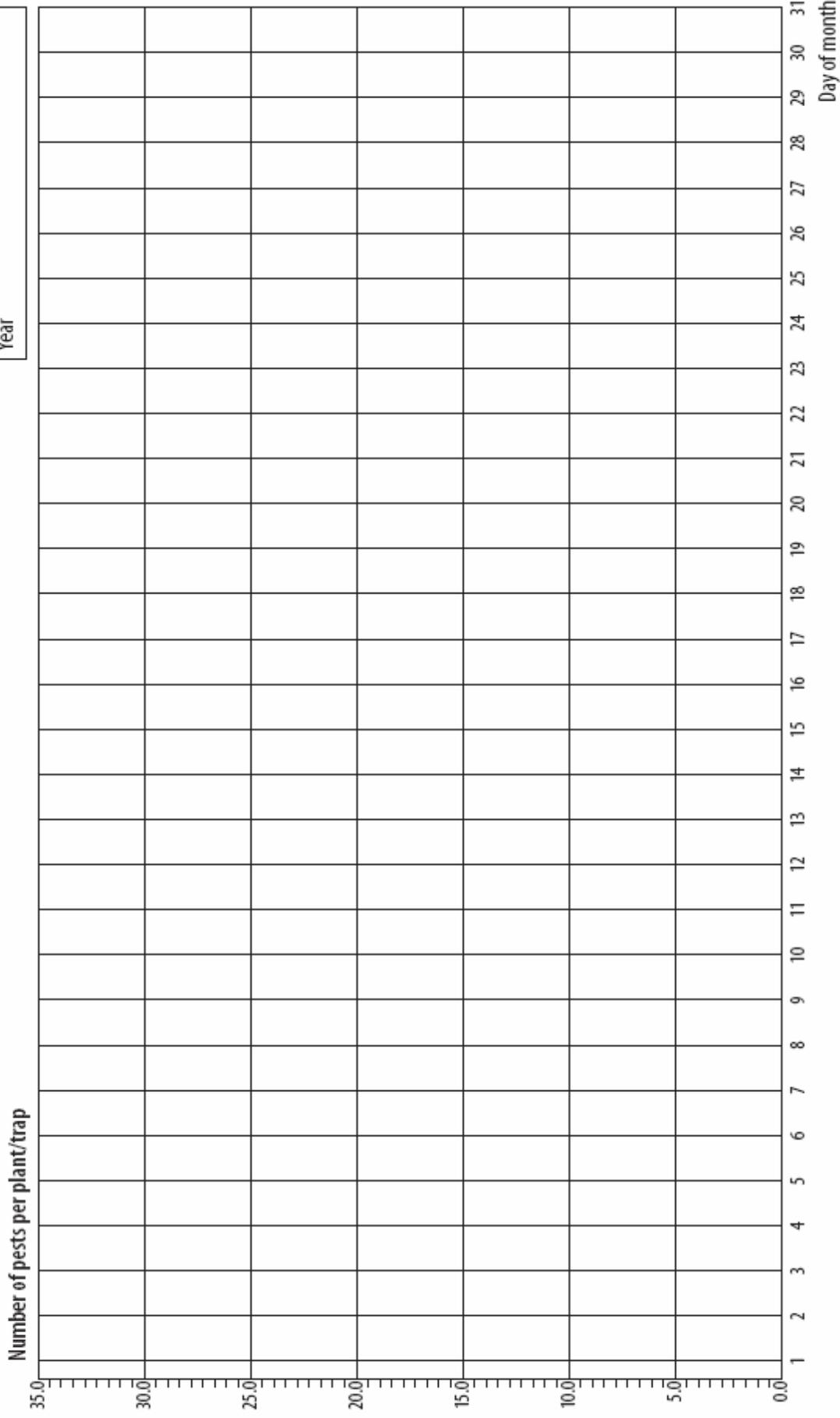
Appendix 4

Example charts

Charts are a fast and easy way to record information. Charts provide an instant picture of monitoring data to make decision making simpler. A couple of example charts are provided. These can be used for recording pest and disease check information and EC, pH and run-off volumes.

Insect pests

Crop, greenhouse
Month
Year

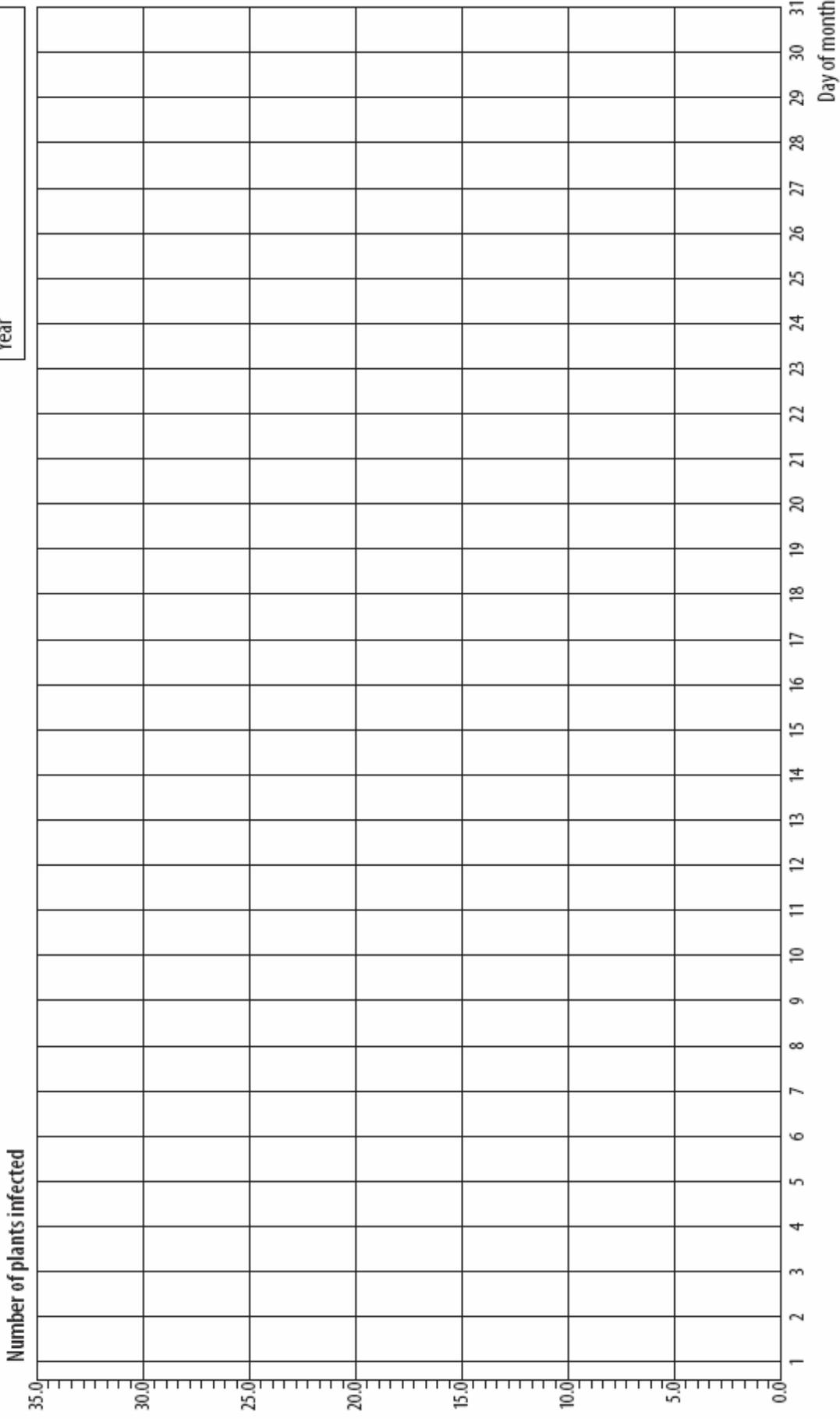


Pests on plants, pests on traps

■	XX
●	○

Disease

Crop, greenhouse
Month
Year



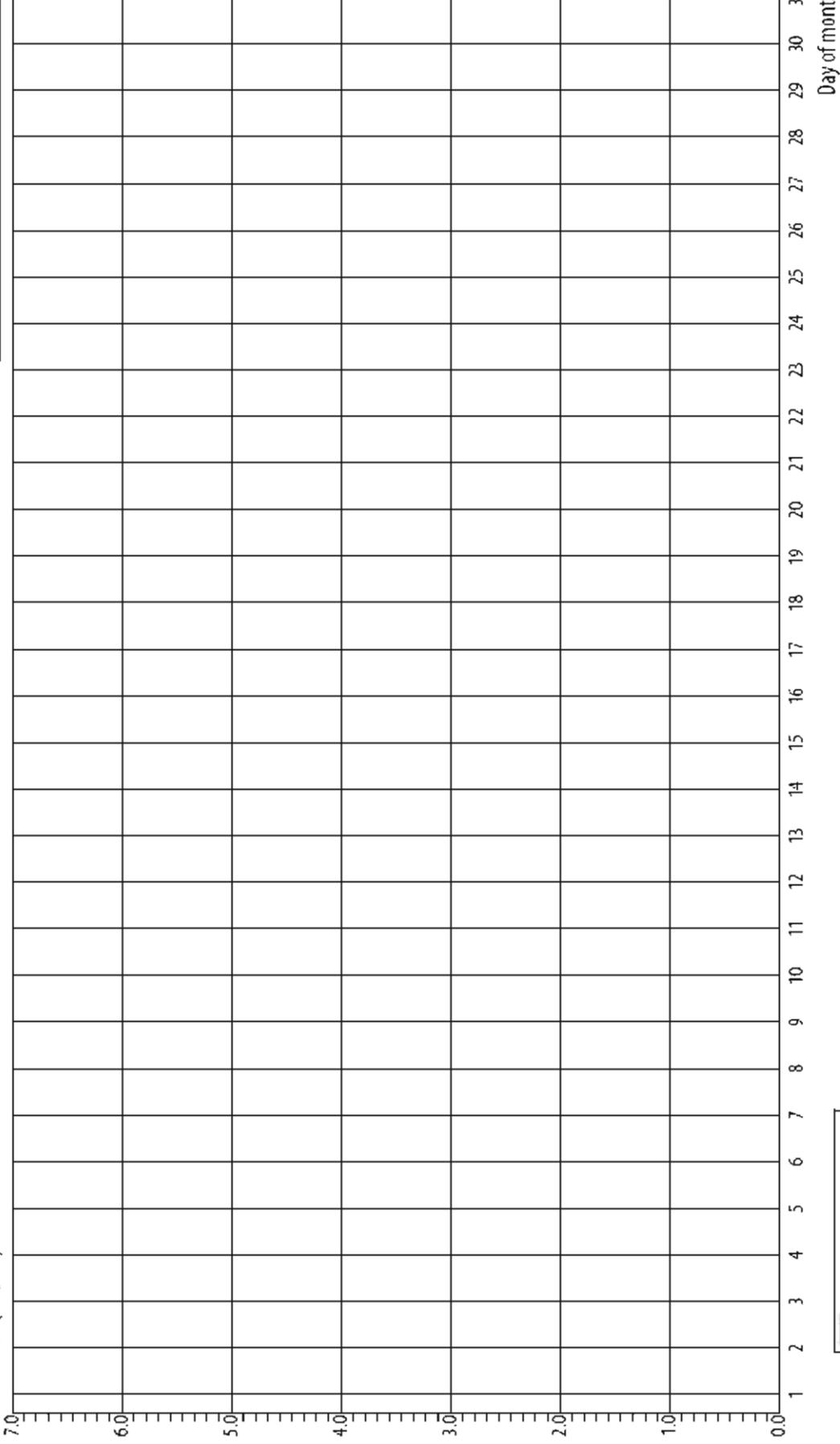
Disease

■	□
●	×

Electrical conductivity (EC)

Crop
Month
Year

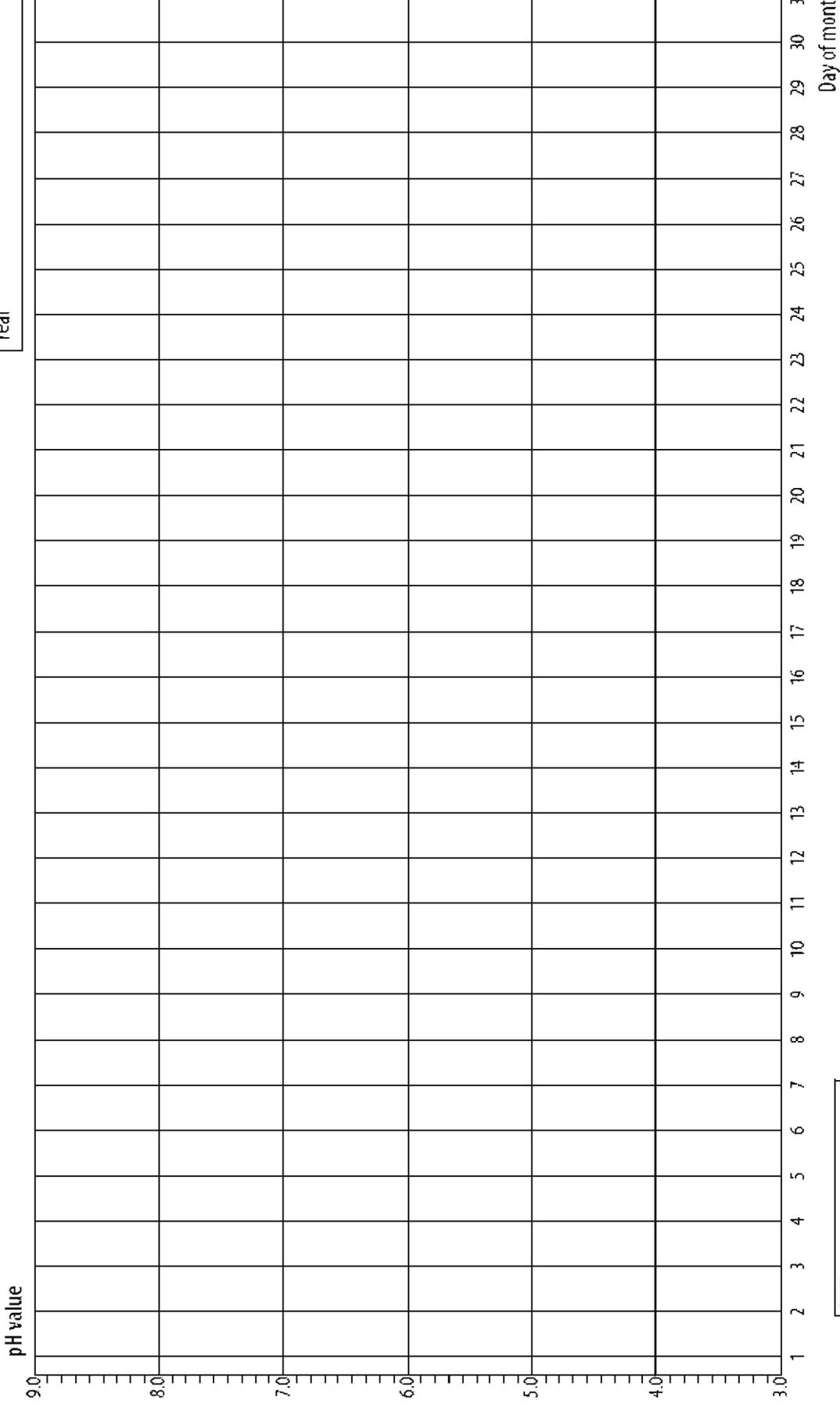
EC value (mS/cm) 10 units of = 1 EC



<input type="checkbox"/> Feed EC
<input type="checkbox"/> Drain EC

Acidity, Alkalinity (pH)

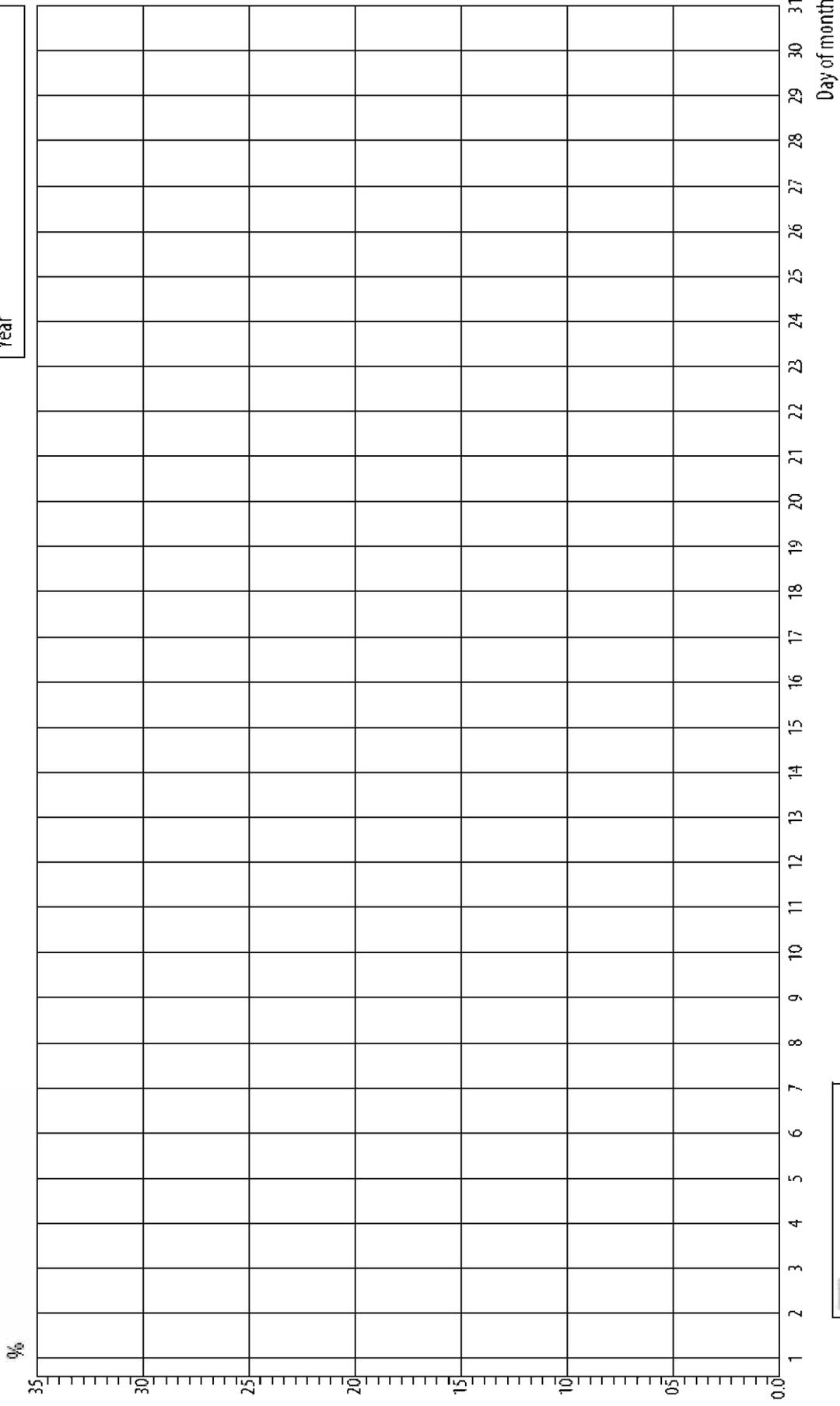
Crop
Month
Year



<input type="checkbox"/> Feed pH
<input type="checkbox"/> Drain pH

Run-off volume (pH)

Crop
Month
Year



Daily target
Daily actual

PREVENTION IS CHEAPER
THAN TREATMENT



NSW DEPARTMENT OF
PRIMARY INDUSTRIES