KEY PEST CONTROL STRATEGIES

If you would like to improve pest management results and cut costs it is important to identify areas where effective changes and improvements can be made to your pest control program.

This section contains some information that can be used to help you go through this process and come out with come clear decisions about what to work on.

A good Pest Management program includes a range of management areas working together as a plan. These need to include….

A) Farm hygiene, seedling care and greenhouse design features are used to reduce pest pressure and the need for insecticides wherever possible

B) Routine pest monitoring improves decision making about when to take (or avoid) action with insecticides, and measures the effectiveness of any action taken

C) A top notch spray program ensures that when insecticides are called for they are effective, at minimum cost and are used in a way that prevents insecticide resistance and unnecessary loss of beneficial insects from the farming system

D) A good understanding of the presence and effect of beneficial insects and the impact of chemicals on their populations enables growers to conserve the natural enemies of their pests

It is often found that spray programs have weaknesses that need to be addressed before sustained control of key pests like WFT can be achieved. These include resistance to chemicals, wrong chemical used, poor timing of applications, mixing of incompatible compounds in the spray tank, and spray coverage. Growers who addressed these issues have improved their pest control to very acceptable outcomes, with greatly reduced reliance on chemicals !

These growers, should they wish to, are in a good position to consider using biological control. Several tomato growers and one capsicum grower have adopted biological control and their crop protection has actually improved, partly because well managed natural enemies are active every day, rather than only when sprayed.

EXAMPLE OF A PEST MANAGEMENT CYCLE

(based on managing western flower thrips)

There are 6 key steps in developing an effective pest management program:

- Get hold of diagnostic information about your key pests and diseases
- Take action to reduce unnecessary pest and disease pressure
- Develop and implement a crop monitoring program
- Make sure you know enough about the effective use of pesticides
- Get expert help when needed
- Consider supporting biological control agents in your crop

1. GET INFORMATION ON KEY PESTS & DISEASES

This section outlines important information on the following greenhouse pests:

- Western Flower Thrips (WFT)
- Greenhouse Whitefly (W/fly)
- Two Spotted Mites (2SM)
- Broad mites (BM)
- Aphids (Aph)

OTHER IDENTIFICATION RESOURCES

Pocket Guide – Pests, Diseases, Beneficials and Disorders of Vebetables
An excellent field identification guide available for vegetables covering pests, beneficial insects, diseases and disorders with colour photographs. It is produced by NSW DPI as a pocket field guide

Keep it Clean manual (pdf files only, no hard copies left)
This resource has additional information on pests and diseases, including their lifecycles and conditions favouring their reproduction. This resource is also produced by NSW DPI.

There are many other fact sheets produced under levy funding including information on tospoviruses by Dr, Denis Persley. Most of these should be available from the DPI web sites.

FACT SHEET

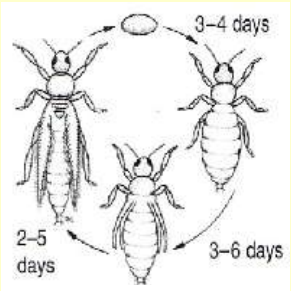
Prepared by Gabriella Caon and Tony Burfield (SARDI Entomology 2006)

1) Western Flower Thrips (WFT)
Frankliniella occidentalis (Pergande)
Thripidae, THYSANOPTERA

Western Flower Thrips
Plague thrips
Onion thrips
Tomato thrips
Photo: Glenys Wood SARDI

Description and life cycle

WFT looks like any other thrips to the naked eye. They are very small (1-2cm) thin insects, yellow to pale brown in colour. Adults can fly and have 2 pairs of wings that sit down and straight along the body when at rest. Males are smaller than females and lighter in colour.



Author unknown

The WFT life cycle is mostly continuous. Thrips can be found year-round, at all stages of growth. In greenhouses they may produce 12 – 15+ generations per year. A generation of WFT varies from about 9 days in summer to 15-20dys or more in winter. A female WFT lives 30 - 45 days and can produce 150 to 300 eggs in this time.

The eggs are laid individually, just under the epidermis (skin) of the soft younger parts of leaves, stems, flowers and inside the buds. The eggs hatch in 3 - 4 days, depending on temperature, and the larvae move into more protected areas of the plant to commence feeding. There are four immature stages, two active larval stages, feeding on leaves and in flowers, and two non-feeding pupa stages, usually in the soil. The adults that emerge from the soil are sluggish for the first 24 hours, but become active as they mature. There are usually more females than males in a population. Females do not need to mate to produce fertile eggs. Unfertilised eggs only give rise to male thrips.

Crops attacked and problems caused

This thrips feeds on almost any flowering plant including capsicum, cucumber, lettuce, potatoes tomatoes, strawberries, pome and stone fruit and a very wide range of ornamentals.

WFT affects crop production in two ways:
1) Direct damage from feeding thrips.
Major symptoms of WFT feeding damage on foliage, flowers and fruit include:

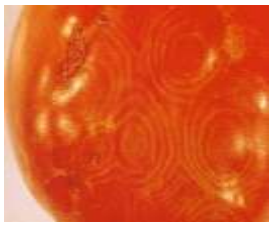
- foliage discolouration or silvering
- deformed new growth or flower buds
- halo-spotted foliage - small dark scars surrounded by white tissue

2) Transmission of tomato spotted wilt virus.
WFT is a vector of tomato spotted wilt virus (TSWV). Other thrips can transmit this virus but are generally easier to control. The larval stages of WFT pick up the virus while feeding on infected plants; the resultant adult stage is then able to pass the virus on to uninfected plants after about 5 minutes or less of feeding on a plant.

TSWV is known to infect a broad range of vegetables. Plants infected with TSWV can either have no symptoms or they can have a variety of symptoms, depending on plant species, growing conditions and virus strain. Symptoms vary greatly from leaf spots or ring patterns to yellowing, dead tissue, distortion or stunt, reduction in plant vigour, and in some cases plant death.

TSWV is only spread by WFT, Tomato Thrips, Onion thrips in South Australia. Not plague thrips or any other insects. It is no spread by pruning and does not live in the soil.

Some images of TSWV affected vegetables:

Infected Tomato leaves and fruit

Infected capsicum leaves and fruit

Infected lettuce

Reducing the threat of invasion and attack

Reduce the chance of getting TSWV by managing potential sources of infection especially by thoroughly controlling/removing weeds and infected plants. Do not leave old crops, especially if they are already infested with thrips. They will almost certainly allow thrips to colonise new crops and infect them with TSWV at an early stage.

There are some further simple things that can be done to avoid high WFT numbers:

- Avoid introducing any infested plant material into the crop
- Use seedlings that have been grown away from WFTW and TSWV infested areas, i.e. start with a clean crop.
- Promptly remove TSWV infected plants to reduce the spread of virus – only spread by thrips
- Avoid moving thrips around the crop on staff moving from infested to clean areas.
- Use a fallow period, if possible, when no crop is grown to clear thrips and TSWV levels.
- Use fine mesh/netting to restrict thrips entry if growing in a Greenhouse (400microns or less). Cover all doors (double doors are even better) and vents if the crop is likely to be invaded by thrips from outside. Rolls of yellow sticky tape may be useful in some greenhouse designs if placed near entry points and hot spots.

Monitor thrips populations for early control. Use yellow sticky cards to alert you of new infestations and scout plants by turning leaves to look for adults and larvae and signs of thrips feeding damage. Control is simpler and less expensive when plants are young and spray coverage is not an issue.

Crop monitoring:

MAKE INSPECTIONS ROUTINE AND KEEP GOOD RECORDS !

- Get into the habit of walking right through your crops in a set pattern (a M or Z)
- Check about (about 1%) of your plants very carefully
- Hunt for thrips and symptoms of virus disease
- Check underside of leaves for feeding larvae and adults
- Blow gently into flowers or shake flowers over white paper to find more thrips
- Keep good records of pest levels and treatments used

Monitoring with sticky traps (only adults with wings are caught on traps)*:*

For insecticide-based control programs economic thresholds need to be worked out from monitoring and spray records using sticky traps, flower checks and virus counts. Decide on a threshold level for thrips in your crop, above which you must spray and below which you can safely withhold spraying.

- Plan the layout of traps to identify hot spots and estimate overall thrips levels
- Place traps just above the plant tops
- Do a weekly count of thrips on each trap and look for virus infected plants. Mark infected plants with tape for removal and replace sticky traps.
- Note any thrips or virus hot spots and check thrips numbers in flowers on nearby plants to find the size of hot spots.
- Check thrips numbers in flowers 1-2 days after spraying to check results
- If able, count the proportion of adult to young thrips in flowers (young thrips, but no adults = spray worked, but high breeding levels still in the crop; adults only = new flight; both adults & larvae = thrips not killed by spray applications indicates resistance/coverage issues)
- Record trap, virus and flower details
- If thrips numbers are above the threshold you must spray ASAP to prevent loss of control

Note:

- ***If you can spot isolated hot spots early you may only need to spray a small area!***
- ***Plan to introduce biological control agents as soon as thrips are found***

Chemical control

Chemical control of WFT and TSWV outbreaks has been difficult due a number of factors:

- WFT behaviour - hiding in flowers and buds creates difficulties for good spray coverage.
- WFT life cycle – egg and pupal stages not susceptible to chemical control
- High level of resistance to many horticultural insecticides.
- Nearby weed and crop host plants harbouring both WFT and TSWV

Many chemicals originally tested and used have now been removed from permit lists including synthetic pyrethroids and most organophosphates due to resistance and OH&S issues.

Include a resistance management strategy into your spray program to reduce the chance of WFT becoming resistant – i.e. correct spray application with rotation of chemical groups after 3-4 sprays. There should be at least a 3 week break (<20 deg C) or a 2 week break (>20 deg C) before another series of sprays is applied. If monitoring indicates the need to spray earlier, then insecticide resistance, inappropriate spray application or inadequate farm hygiene should be suspected and expert advice sought.

Effective spray frequency/intervals depends on temperature

Daytime Av temp	Length of life cycle	Days between sprays
10-20oC	25-35days	6
20-30oC	15-25 days	3-5

Spray crop after pruning and training plants to maximise chemical application by improving penetration into the crop.

Current permits are listed on the NSW Department of Primary Industries / Agriculture site: http://www.agric.nsw.gov.au/reader/thrips/wft-insecticide-mgt-plan.htm#Chemicals

Relevant beneficial insects

Orius !!

Natural enemies have been investigated and biological control programs using predatory mites and other beneficial insects have been developed. They are very effective if environmental thrips pressure is not too great and they are cared fro properly in the crop.

Predatory mites are now available for use in greenhouses. *Typhlodromips montdorensis* and *Neoseiulus cucumeris* are the preferred predators for thrips control in protected environments. These mites are most effective at preventing thrips build-up when applied early in the growing season at the first sign of thrips. These light coloured predatory mites search for prey on the underside of leaves along the veins or inside mature flowers if conditions are not too hot and dry.

Hypoaspis miles mites are used primarily for control of fungus gnats, but they also help with western flower thrips control. Hypoaspis is a generalist predator/scavenger that feeds on small, soil inhabiting insects and mites. It is primarily a predator of fungus gnat larvae in the soil, but it also consumes thrips pupae on the floor and soil surface of the greenhouse. It can also survive by feeding on soil debris in the absence of thrips pupae and fungus gnat larvae. They are a native soil mite and can adapt to a variety of different growth media. They are less than 1 mm (1/20 inch) in size, light brown in colour, and can be seen moving quickly on the soil surface and base of plants.

Commercial suppliers of bio-control agents in Australia can be found listed at the Goodbugs site: http://www.goodbugs.org.au/. The suppliers on this page will help you develop an IPM program suitable for your crop and situation. Many also provide IPM monitoring services.

You can also boost the numbers of wild beneficial insects in your crop naturally by holding back on broad spectrum insecticides, providing safe plant species as habitat near the crop and maintaining higher levels of organic soil carbon using composted green and animal waste.

FACT SHEET

Prepared by Gabriella Caon and Tony Burfield (SARDI Entomology 2006)

2) White fly

Greenhouse whitefly

Trialeurodes vaporarium (Westwood)

Aleyrodidae, HEMIPTERA

Dominant in the Southern states

Silverleaf whitefly

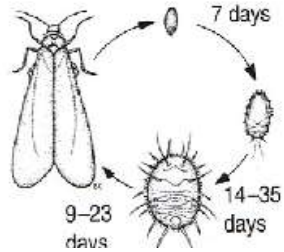
Bemsia argentifolii (Bellows and Perring)

Aleyrodidae, HEMIPTERA

Queensland, Northern NSW and WA. Not known to occur in the southern states

Silverleaf whitefly

Description and life cycle



Author unknown

Whitefly feed, mate and lay numerous eggs on the underside of leaves. The adult whitefly are small white insects, 1.5mm long. The crawlers that emerge do not move far and after 2-4 weeks of feeding turn into pupae.

Greenhouse whitefly are normally identified at the pupal stage. They are scale like, oval shaped and only 1.5-2mm long. Under magnification they have a flat top and box like sides with waxy filaments emerging from the top edge. The adult whitefly that emerges from these pupa cases are small white insects, 1.5mm long with four powdery white wings. They disperse mainly onto the underside of young leaves where they feed, mate and lay eggs. The eggs are bullet shaped and laid vertically onto the leaf in a semi circle shape. When first laid the eggs are creamy white, but they turn purplish as they mature and are difficult to see without a 10X hand lens. The crawlers that emerge from the egg are the only motile (moving) juvenile stage, but they do not move far from where they were laid, usually staying on the same leaf. Within a few days the crawler settles down and begins actively feeding, soon looking more like a scale than a bug. As it progresses through two scale-like larval instars, its outer covering hardens giving it extra protection. The pupa then forms under this scale-like covering and the adult emerges 12 - 23 days later, from a T shaped slit made in this hardened covering.

Silverleaf whitefly pupa are smaller than Greenhouse whitefly pupa, their profile is flatter and dome shaped and they do not have the waxy filaments around the top edge. The eggs are still bullet shaped and laid vertically, but they scattered on the leaf and do not turn as dark as greenhouse whitefly. Silverleaf whitefly has a similar life cycle to that of greenhouse whitefly, but it prefers a hotter climate and is a pest in northern Australia. Silverleaf whitefly adults hold their wings tent-like over their body with the body visible down the centre, while greenhouse whitefly hold their wings flatter over the body with no part of the body showing.

Crops attacked and problems caused

Greenhouse Whitefly are serious pests of most greenhouse vegetables and many ornamentals.

Whitefly are sap-sucking insects in both the adult and immature stages. The scale like immature nymphs are the most damaging. Their feeding can cause yellowing and mottling on leaves. Honeydew excreted by the feeding insect onto the plant foliage can cause sooty mould to grow, which detracts from the plant and harvested fruits' appearance. Heavy infestations will reduce the overall plant vigour and cause stunted growth, defoliation and poor yields.

Reducing the threat of invasion and attack

Greenhouse and silverleaf whitefly have a wide host range of about 250 plant species, mostly in the families Cruciferae, Leguminosae, Malvaceae, and Solanaceae. Capsicum, cucumber, eggfruit are members of these families, but so are many broad leaf weeds including mallow, sow thistle and verbena. Controlling these weeds well ahead of planting out a new crop is very important. Use a fallow period, if possible, when no crop is grown to clear whitefly populations. Use seedlings or cuttings that have been grown away from whitefly infested areas and are free of whitefly i.e. start with a clean crop. DO NOT LEAVE OLD CROPS, ESPECIALLY IF THEY ARE ALREADY INFESTED WITH WHITEFLY.

There are some further simple things that can be done to avoid high WFT numbers:

- Use seedlings that have been grown away from infested areas, i.e. start with a clean crop.
- Avoid introducing any infested plant material into the crop
- Avoid moving whitefly around the crop on staff moving from infested to clean areas.
- Use a fallow period, if possible, when no crop is grown to clear pest populations
- Use fine mesh/netting if growing in a Greenhouse (400microns or less). Cover all doors (double doors are even better) and vents if the crop is likely to be invaded by whitefly from outside.
- Rolls of yellow sticky tape may be useful in some greenhouse designs if placed near entry points and hot spots.

Monitor pest populations for early control. Use yellow cards to alert you of new infestations (only adults with wings are caught on traps) and scout plants by turning leaves to work out were they are. Control is simpler and less expensive when plants are young and spray coverage is not an issue.

Crop monitoring

MAKE INSPECTIONS ROUTINE AND KEEP GOOD RECORDS !

Monitor for early detection and control of whitefly. Control of whitefly is simpler and less expensive when plants are young and spray coverage is not an issue. Whitefly adults and eggs are usually found on the under side of young upper leaves, while the larval and pupa stages are found on lower older leaves. Use yellow cards to alert you of new infestations and scout plants by turning leaves to work out were they are.

- Get into the habit of walking right through your crops in a set pattern (a M or Z)
- Check about (about 1%) of your plants very carefully
- Check underside of leaves for feeding larvae, adults and eggs
- Keep good records of pest levels and treatments used

Monitoring with sticky traps (only adults with wings are caught on traps)*:*

For insecticide-based control programs economic thresholds need to be worked out from monitoring and spray records using sticky trap and plant leaf checks. Decide on a threshold level for whitefly in your crop, above which you must spray and below which you can safely withhold spraying.

- Plan the layout of traps to identify hot spots and estimate overall pest levels
- Place traps just above the plant tops
- Do a weekly count of pests on each trap and look for signs of pest activity. Mark affected plants with tape and check nearby plants to determine the size of hot spots.
- Check pest numbers on plants 1-2 days after spraying to check results
- If able, count the proportion of adult to larvae (larvae but no adults = spray worked, but high breeding levels still in the crop; adults only = new flight; both adults & larvae = pests not killed by spray applications indicates resistance/coverage issues)
- Record trap and plant results
- If pest numbers are above the threshold you must spray ASAP to prevent loss of control

Note:

- ***If you can spot isolated hot spots early you may only need to spray a small area!***
- ***Plan to introduce biological control agents as soon as thrips are found***

Chemical control

Chemical control of this pest has been difficult due a number of factors:

- Resistance to insecticides is fairly common
- Nearby weed and crop host plants readily reinfest new crops

A resistance management and prevention strategy needs to be in place to reduce the chance of whitefly becoming resistant. Although pupae are not susceptible as with WFT, the precise chemical strategy is a bit different because some new whitefly chemistry acts very differently, takes longer to kill and has minimal impact on adults.

The five distinct life cycle stages (adult, eggs, crawler, larvae (scale) and pupa) differ in their tolerances to insecticides but all stages can be on a single plant at the same time. It is very important to find out what stage of the whitefly lifecycle is susceptible to each chemical being used. Some of the "soft" moulting inhibiting chemicals will only kill larval/nymph stages and not effect the adults! The adult and crawler stages are the most susceptible to contact insecticides but the egg, scale and pupa vary in their resistance to these chemicals. **A single spray of any chemical will only kill the susceptible stages present at the time of**

treatment or during the time the chemical remains active. All other stages will survive and continue their life cycle. Thus clusters of 2-3 applications are usually required during the cropping period.

Whitefly feed on the underside of leaves and it is important to remember that it is difficult to obtain thorough coverage with sprays to these parts of the plant and this often leads to repeated failures to control this pest. Spray crop after pruning and training plants to maximise chemical application by improving penetration into the crop. If monitoring indicates the need to spray frequently, then insecticide resistance, inappropriate spray application or inadequate farm hygiene should be suspected and expert advice sought.

Relevant beneficial insects

There is a good biological control option. *Encarsia formosa* a small parasitic wasp has been extensively used as a biological control for greenhouse whitefly especially in protected environments such as greenhouses. The adult wasp lays its eggs in the 3rd or 4th larval stage of the whitefly but the adults also feed on the young scale like larvae. The parasitised larvae turn black as they mature and a small wasp emerges leaving a small round emergence hole. An average daily temperature of 23oC (15oC or higher at night) is required for good whitefly control by Encarsia.

If using biological control by introducing *Encarsia formosa* for Greenhouse whitefly do it early and encourage parasite activity by only using soft sprays and only pruning leaves after parasites have emerged. The exotic parasitoid, *Eretmocerus hayati*, has been released for Silverleaf whitefy by CSIRO and Growcom staff on Queensland grower farms in the summer of 04/05. The parasitoid has established readily at most locations. Toxic broad spectrum sprays should be avoided to encourage this parasites' activity and spread into other growing areas. For more information: www.growcom.com.au/media/March05/March_23_05.html

Whitefly are also preyed upon by lacewing larvae, and other general predators. As with WFT can also boost the numbers of wild lacewings and other beneficial insects in your crop naturally by holding back on broad spectrum insecticides, providing safe plant species as habitat near the crop and maintaining higher levels of organic soil carbon.

The only other natural enemy is a fungal pathogen *Veticillium lecanii* but more research is needed on formulations which will improve the effectiveness of *V. lecanii* in controlling whitefly. It is important to prolong the period of its effectiveness. At present, the ‘conidial solution’ is capable of infecting target insect pests only for a short time after it is applied to crops.

Commercial suppliers of bio-control agents in Australia can be found listed at the Goodbugs site. http://www.goodbugs.org.au/. The suppliers on this page will help you develop an IPM program suitable for your crop and situation. Many also provide IPM monitoring services. Fungal pathogens are supplied by companies dealing in microbial products. One example of these companies can be found at http://www.nutri-tech.com.au/products/microproducts.htm

FACT SHEET

Prepared by Gabriella Caon and Tony Burfield (SARDI Entomology 2006)

3) Broad Mite
Polyphagotarsonemus latus (Banks)
Tarsonemidae, ACARINA

Author unknown

Description and life cycle
The egg stage is the most easily identified microscopically, they are clear, oval shaped with the surface covered in white pimples or tubercles making a spotted pattern. They are usually found in the growing tips on the underside of newly formed leaves and under the calyx of flowers and fruit or in protected depressions. The life cycle through egg, two nymphal stages to adult takes between 4 to 10 days depending on temperature, with up to 20-30 generations a year if conditions are favourable. Adults are oval, tapering slightly toward the rear end. Females are very small approx 0.3mm long, barely visible without magnification, males are slightly smaller, they are both transparent to yellowish green in colour, stationary when feeding, moving slowly when disturbed, the nymphal stages resemble the adults. Adult broad mite only live from 5 to 13 days the female broad mites laying 30 to 76 eggs over this period.

Crops attacked and problems caused
Broad mite is a major pest in the warmer parts of Australia and favours capsicum plants. It is a minor pest in temperate Australia but will cause severe damage when conditions are favourable. Broad mite usually attacks the young growth of a wide variety of vegetable crop plants especially capsicums or peppers and many ornamentals by injecting a toxin from their saliva as they feed so that a few mites can cause a lot of damage. It has been known for many years as a pest in glasshouses and of summer grown vegetables and ornamentals. Mite damage is often reported when conditions are warm and humid. High humidity (80 to 90%) and temperatures above 25oC are favourable.

Feeding by the mite may cause leaves to bronze and thicken, become brittle, corky or cupped downward and narrower than normal. Young stem growth may be distorted and stunted with young terminal buds so distorted that flowers do not open; heavy feeding can cause young terminal buds to die and drop off. Severely damaged plants could die. The symptoms of broad mite feeding are often confused with viral symptoms or hormonal herbicide damage.
Be aware of early symptoms, with careful crop inspection so that action can be taken quickly. With effective treatment to control the mites new plant growth is healthy with no long term damage unless an initial severe infestation has seriously weakened the plants.

Reducing the threat of invasion and attack
Reduce the chance of pest invasions by managing potential sources of outbreaks by thoroughly controlling/removing weeds and infested plants. DO NOT LEAVE OLD CROPS, ESPECIALLY IF THEY ARE ALREADY INFESTED WITH PESTS THAT CAN COLONISE NEW CROPS.

Broad mites are so small (~0.3mm) that they are difficult to see even with a good hand lens but they tend to crowd into crevices and buds. They can enter the crop undetected from nearby host pants or infected plant material imported into the crop. Infected plants are usually not noticed until damage is severe and by this time the mites could have moved onto other plants. Citrus is a very good host.

- Be aware of early symptoms, with careful crop inspection so that action can be taken early
- Avoid introducing infested plant material into the crop, either with seedling plants
- Avoid moved mites around the crop on staff moving from infested to clean areas.
- Use a fallow period, if possible, when no crop is grown to clear pest populations
- Use seedlings that have been grown away from infested areas, i.e. start with a clean crop
- Monitor pest levels to act early for control. Control is simpler and less expensive when plants are young and spray coverage is not an issue.

Crop monitoring:
MAKE INSPECTIONS ROUTINE AND KEEP GOOD RECORDS !
These mites are too small for the naked eye to see, but changes in the growing tips of plants are a tell tale sign:

- Get into the habit of walking right through your crops in a set pattern (a M or Z)
- Check about (about 1%) of your plants very carefully
- Look at the growing crown for signs of distortion and mottling (will not see feeding spots as for TSM). Large numbers are not required for damage to be visible.
- Keep good records of pest levels and treatments used

Note:

- ***If you can spot isolated hot spots early you may only need to spray a small area!***
- ***Plan to introduce biological control agents as soon as thrips are found***

Chemical control
Chemical control of Broad mite is not difficult but problems are encountered because there are only a few chemicals registered. Most registered chemicals do not kill the egg stage or have enough residual to kill hatching larvae. Two applications should be used at about 5 days apart to kill all stages. The chlorinated chemical dicofol and abamectin are the most effective.

Include a resistance management strategy into your spray program to reduce the chance of resistance. If monitoring indicates the need to spray earlier, then insecticide resistance, inappropriate spray application or inadequate farm hygiene should be suspected and expert advice sought.

Relevant beneficial insects
Natural enemies have been investigated and biological control programs using predaceous mites and plant bugs have been investigated. Predatory mites are now available for use in greenhouses.

The predatory mite *Neoseiulus cucumeris* is now available in Australia at Biological Services at Loxton; http://biologicalservices.com.au/ and Goodbugs; http://www.goodbugs.org.au/.

The suppliers on this page will help you develop an IPM program suitable for your crop and situation. Many also provide IPM monitoring services.

Broad mites are also preyed upon by lacewing larvae, and other general predators. As with WFT you can also boost the numbers of beneficial insects in your crop naturally by holding back on broad spectrum insecticides, providing safe plant species as habitat near the crop and maintaining higher levels of organic soil carbon.

FACT SHEET

Prepared by Gabriella Caon and Tony Burfield (SARDI Entomology 2006)

4) Two Spotted Mite (TSM)
Tetranychus urticae Koch
Tetranychidae, ACARINA

Author unknown

Description and life cycle
TSM are very small arthropods, and have an incomplete life cycle. There is no resting stage or pupa in its life cycle and in midsummer this cycle can be as short as seven days. Generally in the greenhouse the life cycle is between 7 to 12 days in summer and 12 - 21 days in winter depending on temperature. TSM loves hot and dry weather, especially between 25 and 30oC with low humidity. Interestingly high humidity will actually reduce mite numbers.

The mite population consists of males and females with females predominating. Each female produces 15-20eggs per day with a total production of about 100eggs. The adult female is 0.6mm long, round in shape, and pale yellow to greenish with two characteristic dark green to black spots on each side of the body. The male is smaller, slimmer and has a more diamond shape. The eggs are usually laid on the underside of the leaf under a thin layer of webbing, they are small and translucent becoming whitish as they mature. Nymphs resemble the adults but are much smaller, there are two nymphal stages before becoming an adult.

In late autumn some females can turn an orange red colour (the over wintering female), they stop laying eggs and feeding and search for protected sites to spend the cooler winter months. In most greenhouses small numbers will persist because they provide a suitable climate for TSM all year.

Crops attacked and problems caused
Two-spotted mite (TSM) belongs to a group of mites collectively known as spider mites, because they produce a fine web which can be seen on the surface of the infected leaf. Once the underside of a leaf is overrun with mites they will move onto the top surface where webbing and mite activity will soon become apparent. When numbers are extreme webbing can easily be seen on the whole plant especially on the growing tips.

TSM attack a broad range of plants, from most vegetable crops, ornamentals, tree crops and weeds and frequently occurs in protected environments such as glasshouses.

These mites feed by first puncturing the cell and then sucking up the juices. Early symptoms of mite damage can be seen as a silvery white flecking or speckling where the mites are feeding, usually along the midrib progressing outward to the leaf edges as the population increases. Growth in affected plants is also reduced with distortion of flower and leaf buds. High mite numbers can remove nearly all the chlorophyll and leaves will turn yellow and dry up.

They prefer dry hot conditions quickly getting out of control in summer months when conditions are suitable.

Host plants and hygiene practices
TSM have a very wide host range with most broadleaf weeds as hosts. It is an important pest of glasshouses as it attacks both ornamental and most vegetable crops. It can also be a pest of outdoor crops, including strawberries, grapevines and most deciduous fruit trees.

There are some simple things that can be done to avoid high mite numbers:
- Control weeds that harbour the pest
- Avoid introducing infested seedlings or other plant material into the crop
- Remove old plants that may be a source of mites for new plantings
- Increase humidity to reduce breeding
- Identify infestations early as the mites are easily moved around the greenhouse by workers

Crop monitoring

MAKE INSPECTIONS ROUTINE AND KEEP GOOD RECORDS !

TSM are unable to fly so they will not be observed on sticky cards, plant inspection is the only way to monitor for mites. Looking for mite damage will indicate which plants to inspect more closely. A hand lens, normally 10-15X is required for monitoring for TSM. TSM will be found on all plant parts including old and new leaves, main and secondary stems, but rarely on the fruit. To be sure about TSM numbers in a crop all these habitats need to be monitored. TSM however do prefer the youngest and most tender growth. Eggs can also be found in these areas.

- Get into the habit of walking right through your crops in a set pattern (a M or Z)
- Check about (about 1%) of your plants very carefully
- Look at leaf and plant surfaces for patches of small feeding spots
- Check underside of leaves for feeding mites
- Keep good records of pest levels and treatments used

Note:

- ***If you can spot isolated hot spots early you may only need to spray a small area!***
- ***Plan to introduce biological control agents as soon as thrips are found***

Chemical control

In the early days of TSM problems organophosphates (OP's) were used to kill mites and serious resistance problems arose when these chemicals were used continuously. Chemical control of TSM has not usually been difficult but problems are encountered if they become established and 2-3 applications must be timed correctly to fit their life cycle. Recently there is anecdotal evidence of widespread TSM resistance to avermectin based insecticides. This is likely due to near total reliance on this chemical to control mites in many crops instead of rotating chemical groups, and the increasing use of this chemical to control thrips.

Many alternatives are not systemic so may appear ineffective if good coverage is not achieved. All foliage must be well covered with the spray, especially the underside of the leaf especially if the chemical works by contact with no systemic activity.

Application must be made before damaging numbers develop i.e. before webbing can be seen. Small droplet size is much more effective and will make better contact with the pest. Depending on the chemical used repeated application may need to be made, most registered chemicals do not kill the egg stage or have enough residual to kill hatching larvae. Two applications should be used at about 5-7 days apart to kill all stages. If possible try to spot treat infestations instead of treating the whole greenhouse since TSM develops resistance to chemicals very quickly when the same chemical is used. Use chemicals that have different modes of action (i.e. are in a different chemical class and work differently) in rotation to prevent resistance developing.

Botanical oil concentrates have been developed to provide an effective "soft" alternative.

Include a resistance management strategy into your spray program to reduce the chance of resistance. If monitoring indicates the need to spray earlier, then insecticide resistance, inappropriate spray application or inadequate farm hygiene should be suspected and expert advice sought.

Relevant beneficial insects

There are many natural enemies such as predatory mites, lacewings, ladybirds, thrips and pathogenic fungi. These have been investigated and biological control programs using predatory mites have been used. Predatory mites are now available for use in greenhouses and other environments. Predatory mites that can control this pest are now available in Australia at Biological Services at Loxton; http://biologicalservices.com.au/ and Goodbugs; http://www.goodbugs.org.au/. The suppliers on this page will help you develop an IPM program suitable for your crop and situation. Many also provide IPM monitoring services.

You can also boost the numbers of wild beneficial insects in your crop naturally by holding back on broad spectrum insecticides, providing safe plant species as habitat near the crop and maintaining higher levels of organic soil carbon.

5) Aphids
Green Peach Aphid, Cotton Aphid, Potato Aphid
Family Aphididae, HEMIPTERA

Author unknown

Description and life cycle
Aphids are small (2-3mm) soft bodied insects, pear shaped, ranging in colour from a light olive green and pinkish to dark green and black.

Aphids have unusual lifecycles. Some aphids have primary and secondary hosts, others will produce eggs for a winter diapause in cold climates. In more temperate climates and especially in protected environments where the autumn temperatures are not extreme and suitable hosts are available, continuous reproduction by females alone is possible. Females give birth to live female young at the rate of 4-6 per day.

There are usually 4 nymphal stages all a smaller version of the adult but sometimes lighter in colour. Some colonies can have aphids of two colour forms. There are also winged and wingless adult forms which occur in the same colony. Several environmental factors trigger the production of winged forms that can fly off to start new colonies. Aphids often enter a crop in large numbers in flights, which then reproduce large numbers of wingless colonies.

A female will give birth to more than 100 live young over her life of one to four weeks. These young can mature into adults in 4-7 days in summer and immediately begin producing live offspring. A colony can produce many generations in a very short period of time. The ideal temperature for aphids is about 22oC with most activity occurring during the warmer months. No development generally occurs below ~5oC or above ~33oC.

Crops attacked and problems caused.
Aphids are sup sucking insects, most species of which occur world wide. They feed on a large range of crops including vegetables, tree crops, broad acre crops and ornamentals. Herbaceous weeds are also favoured hosts of aphids. Aphids are usually found on the soft growing points of plants living in colonies. When aphid numbers are very high they will be found on any growth over the whole plant. If a winged aphid is found alone it has usually just arrived.

Aphids can be high risk in any crop if not treated. These sap sucking insects reduce the total plant vigour and the production and fruit quality suffers. Their feeding usually distorts the new growth affecting the leaves, flowers and fruit. In some crops feeding aphids can transmit viruses which can often have more impact on the crop than the actual feeding itself. The sticky honeydew excreted onto the plant by aphids while feeding encourages sooty mould growth which covers the foliage and fruits, retarding growth and reducing the market value of the fruit.

Reducing the threat of invasion and attack
Aphid numbers can be greatly reduced by observing the following practices:

- Control weeds on field edges if scouting indicates aphids are present and control weeds within crops
- Destroy old crops immediately after harvest has finished
- Use a fallow period, if possible, when no crop is grown to clear pest populations
- Do not plant new crops near or close to neighbouring infested weeds or old crops (greenhouse and open field)
- Use seedlings that have been grown away from infested areas, i.e. start with a clean crop.
- Avoid moving aphids around the crop on staff moving from infested to clean areas. Do not work in old crops on windy days, especially when prevailing winds are blowing towards new plantings
- Mesh screening has been shown to effectively exclude aphids in covered/protected crops and use of reflective plastic soil mulch can be beneficial in reducing aphid numbers.
- Rolls of yellow sticky tape may be useful in some greenhouse designs if placed near entry points and hot spots.

Monitor pest populations for early control. Use yellow cards to alert you of new infestations and scout plants by turning leaves to work out were they are. Control is simpler and less expensive when plants are young and spray coverage is not an issue.

Crop monitoring
MAKE INSPECTIONS ROUTINE AND KEEP GOOD RECORDS !

- Get into the habit of walking right through your crops in a set pattern (a M or Z)
- Check about (about 1%) of your plants very carefully
- Hunt for aphids and symptoms of virus disease where this is an issue
- Check underside of new leaves for feeding nymphs and adults
- Keep good records of pest levels and treatments used

Monitoring with sticky traps (only adults with wings are caught on traps)*:*
For insecticide-based control programs economic thresholds need to be worked out from monitoring and spray records using sticky trap and plant leaf checks. Decide on a threshold level for aphids in your crop, above which you must spray and below which you can safely withhold spraying.

- Plan the layout of traps to identify hot spots and estimate overall aphid levels together with plant scouting
- Place traps just above the plant tops
- Do a weekly count of aphids on each trap and look for infected plants. Mark infected plants with tape for removal and replace sticky traps.
- Note any aphid hot spot and check aphid numbers on nearby plants to find the size of hot spots. Check for biological control activity.
- Record trap, scouting details
- If aphid numbers are above the threshold you must spray. Think about using chemicals compatible with bio control
- Check numbers on marked plants 1-2 days after spraying to check results

Note:

- ***If you can spot isolated hot spots early you may only need to spray a small area!***
- ***Plan to introduce biological control agents as soon as thrips are found***

Chemical control
Chemical control of aphids is not as difficult as some of the other pests, though some aphid species are resistant to some chemicals. All stages are susceptible but small droplet size is much more effective and will make better contact. Only spray for aphids when you need to, but don't wait till you've got large numbers, spray early and always look for 'hot spots" in your monitoring.

Because of the aphids habit of colonising the growing points, they can be easy targets, but are more difficult to control when large populations move to the underside of leaves. For this reason the systemic type of insecticides are more effective. When using the contact products you need to make sure you spray the entire plant to achieve control. Remember that only a few females will recolonise a plant in a week in summer.

Include a resistance management strategy into your spray program to reduce the chance of aphids becoming resistant. If monitoring indicates the need to spray earlier, then insecticide resistance, inappropriate spray application or inadequate farm hygiene should be suspected and expert advice sought.

Relevant beneficial insects
Natural enemies have been investigated and biological control programs using a number of naturally occurring insects is possible. There is a parasitic wasp, hoverfly larvae, several ladybird beetles and lacewings that will attack aphids, but they are all very easily killed by insecticides and their residues. Naturally occurring beneficial insects usually lag behind the build up of aphids and some damage can occur before effective control is achieved.

As with WFT you can also boost the numbers of these wild beneficial insects in your crop naturally by holding back on broad spectrum insecticides, providing safe plant species as habitat near the crop and maintaining higher levels of organic soil carbon.

Only a parasitic wasp and the green lacewing are commercially available for aphid control. The brown lacewing and a ladybird beetle are currently under development.

`The female adult wasp is about 0.6mm long and black in colour, with a thin slender body. A female wasps lays its egg into the aphid, the wasp egg then hatches and feeds on the insides of the aphid. The aphid dies and the larvae of the wasp pupates inside the aphid body swelling it and turning it into an "aphid mummy" usually a golden or silvery appearance depending on the aphid species. An adult wasp then emerges from a small circular hole it cuts in the shell. At 25oC a wasp lifecycle takes 10days.

Green lacewings are generalist predators and the larval stage will eat most small insects and eggs it encounters. It particularly likes aphids and can consume 60 aphids in an hour. Adults feed on nectar and pollen.

Commercial suppliers of bio-control agents in Australia can be found listed at the Goodbugs web site. http://www.goodbugs.org.au/ The suppliers on this page will help you develop an IPM program suitable for your crop and situation. Many also provide IPM monitoring services.