Factsheet 23/10

Protected Edibles

Project No. PC 289

Horticultural Development Company

Stoneleigh Park
Kenilworth
Warwickshire CV8 2TL
T: 0247 669 2051
E: hdc@hdc.org.uk

Tomato spotted wilt virus in protected edible crops

Tim O'Neill and Jude Bennison, ADAS UK Ltd

Several cases of *Tomato spotted wilt virus* (TSWV) occurred in UK sweet pepper crops in 2008 and 2009. Outbreaks have previously occurred in the UK on lettuce and tomato. The virus has been, and is still, more common on ornamental plants. This factsheet summarises information on the biology and control of this potentially serious disease in protected edible crops.

Action points

- Be aware of the symptoms of TSWV in lettuce, tomato and sweet pepper (see photographs in this factsheet).
- Ensure that you know how to recognise the thrips vector, western flower thrips (WFT).
- Pay close attention to management of WFT at crop turn-around.
- Carefully monitor and effectively manage WFT throughout the season. The virus persists in viruliferous WFT adults throughout their life and just one or a few adults can infect many plants.
- Do not use pesticides harmful to thrips biological control agents in IPM programmes.
- If TSWV is suspected, get a sample tested at a diagnostic laboratory and review your WFT control programme.
- If TSWV is confirmed, promptly remove and destroy any plants with symptoms of TSWV as the virus is systemic in most hosts. Growers must remove whole plants.
- Do not interplant or make overlapping plantings in glasshouses where TSWV has been confirmed.
- Control weeds in and around the glasshouse. WFT and TSWV hosts include chickweed, sowthistle and woody and black nightshades.
- Do not grow any ornamental plants in the same or adjacent glasshouse as lettuce, pepper or tomato.

1 Stunted growth in a pepper crop severely affected by TSWV

Background

In Europe, TSWV was first described in England in 1931 when it was quite common in tomato and some ornamental species (eg chrysanthemum and dahlia). TSWV became much more common and affected a wider range of crops following the establishment of WFT in the UK from 1986 onwards. Significant losses occurred in many ornamental crops and in protected lettuce and occasionally in tomato. In 2008 and 2009 the virus caused crop damage valued in excess of £240,000/ha in sweet pepper crops (Figure 1), and severely damaged a few protected chrysanthemum and aster crops. The disease can be introduced to glasshouses either via virus-infected plant material or via viruliferous thrips vectors surviving from previously infected crops or flying from nearby infected crops. In the UK, western flower thrips (WFT) is currently the vector of TSWV and even a very small population, which may go undetected in a glasshouse, can result in widespread infection in a crop.

Recognition of WFT and its direct feeding damage

Microscopic examination by an expert entomologist is needed to confirm thrips species, but certain features such as colour of adults or larvae can help in thrips recognition. See HDC Factsheet 14/09 for descriptions and photographs of various thrips species.

Adults

Like other thrips species, WFT adults are small, slim insects, with narrow wings fringed with hairs. Female WFT (Figure 2) are slightly larger (1.5 - 2 mm long) and darker than the males. The females usually have a yellowish head and front half of the body and a brownish back half. The males are yellowish all over.

Eggs

Eggs cannot be seen because females lay eggs into plant tissue. However small round bumps of callous tissue can be seen on the underside of leaves at sites where eggs have been laid on sweet pepper.

Larvae

WFT larvae hatch from the eggs after a few days, depending on temperature. There are two larval stages, neither of which have wings. First stage larvae are less than 1 mm long and colourless or white (Figure 3, left). They feed for two or three days before developing into the second stage larvae which are about 1 mm long and yellow (Figure 3, right).

Pupae

When fully grown, most of the second stage larvae drop from the plants to pupate in the ground or substrate, where they are difficult to find. Some can also pupate on the plants, in sheltered places such as the undersides of lower leaves. There are two pupal stages; the prepupa and the pupa, neither of which feed. Both these stages are yellowish and about 2 mm long.

2 Adult female WFT

3 First (left) and second (right) stage of WFT larvae

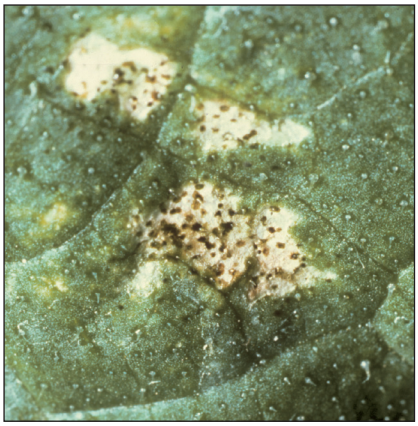
4 WFT pupa

The prepupa has short immature wings and short, forward-pointing antennae. It develops into the pupa which has longer immature wings and longer antennae that fold backwards over the body (Figure 4). When pupation is complete, the adult thrips emerges from the pupal case.

Direct feeding damage

It is important to distinguish between direct thrips feeding damage and symptoms of TSWV.

Leaf damage: Thrips adults and larvae feed on leaves, in flowers and on young developing fruit, depending on the host crop. Feeding on leaves of some crops (e.g. cucumber, aubergine and lettuce) causes small white or silvery flecks or patches. Small black specks of thrips droppings are usually visible within the bleached areas, (Figure 5 left). Similar leaf damage can occur on tomato (Figure 5 right). WFT is not a common pest of tomato but cherry tomato varieties are more susceptible. If large numbers of WFT are present, severe leaf damage can occur (e.g. on cucumber), when the bleached areas coalesce and then turn brown and necrotic. On pepper, WFT leaf damage is not so obvious as on cucumber, aubergine and tomato. Damage symptoms by WFT on pepper include silvering and black faecal specks on the leaf underside and interveinal yellowing on the leaf upperside.



5 WFT feeding damage on cucumber leaf (left, note the small bleached areas with black specks) and on tomato leaf (right)

Fruit damage: On flowering and fruiting crops including aubergine, cucumber and sweet pepper, WFT also feed in the flowers and on young developing fruit. The resulting damage can make the fruit unmarketable. Feeding damage on young cucumber fruits can cause scarring and deformed, curled 'pigtail' cucumbers. White or brown scarring on the fruit, particularly underneath the calyx can occur on aubergine and sweet pepper fruits (Figure 6).

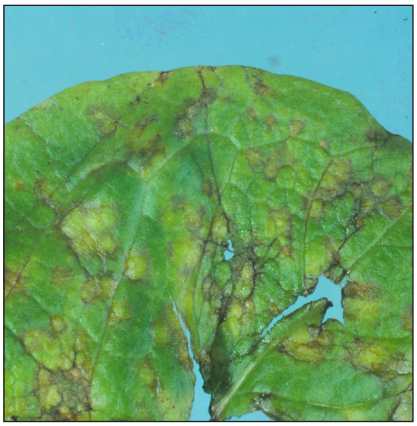
6 WFT feeding damage on pepper fruit results in scarring

Symptoms of TSWV

TSWV causes a tremendous range of symptoms. These can vary according to the host species, age of infected plants (young plants tend to be more susceptible), the level of crop nutrition, and with environmental conditions including temperature. Variations in symptoms also arise due to different strains of the virus. There are indications that symptom severity can vary with different densities of viruliferous thrips. Symptoms have been seen in UK pepper crops from early spring to autumn, even as early as February. Ring spotting is a symptom that occurs in several crop species.

Cucumber

Although infection of cucumber by TSWV has been listed in Japan and the USA, these reports do not describe symptoms of the disease in cucumber. In Japan, TSWV is reported to be a serious disease in cucumber where it is transmitted by *Thrips palmi.* In the UK, cucumbers are often infested by WFT yet TSWV is not a known problem in the crop.



7 Leaf yellowing (left) and ring spots (right) caused by TSWV in lettuce

Lettuce

Although not seen in recent years in the UK, TSWV affected several lettuce crops in the early 1990s, and has devastated lettuce production in some countries. First symptoms are usually seen on the upper part of young inner leaves on one side of the plant. Typical symptoms are slight marginal wilting, necrotic ring spots and leaf blackening (Figures 7 - 8). Sometimes leaves show yellowing and a lateral curvature. Affected plants are unmarketable and frequently collapse and die within two weeks of first symptoms, a response similar to that of basal rot caused by *Botrytis cinerea, Rhizoctonia solani* or *Sclerotinia* spp., except that there are no signs of these fungi present.

8 Leaf blackening on young leaves of round lettuce, a symptom of TSWV infection

Sweet pepper and chilli pepper

TSWV in sweet pepper can totally destroy the crop. The disease is usually first seen on fruit where it causes distorted growth (bumps), uneven ripening, ring spots, line patterns and necrotic patches (Figures 9 -10). Some of these symptoms are easily confused with those caused by *Cucumber mosaic virus*, CMV (Figure 11). TSWV in sweet pepper is also often noticeable in the plant head, as leaf yellowing, stunted growth and sometimes death of the head (Figure 12). Other leaf symptoms include mosaic, chlorotic or necrotic flecks and ring spots (Figure 13). Necrotic streaks appear on stems extending to the terminal shoots. Varieties recently affected in the UK included Fiesta, Ferrari and Prego. Chilli pepper is known to be susceptible to TSWV although no records have yet been confirmed in UK crops.

9 Distorted growth of fruit is an early symptom of TSWV in sweet pepper

10 Ring spots on pepper fuit caused by TSWV

11 A similar symptom can result from CMV infection

12 Chlorotic leaf flecking and leaf distortion are typically found in the head of infected pepper plants

Tomato

Leaves show a variety of symptoms from a yellow mottle to black rings, part rings, line patterns and necrotic spots. Young leaves tend to curl slightly downwards and inwards, and may be distorted. Brown spotting or bronzing of young leaves occurs mainly on the upper surface, which led to the alternative common name 'tomato bronzing virus' (Figure 14). Stems and petioles may show necrotic spots. Fruit set is poor and those which do form develop orange or yellow spots. Fruit that is already set at infection may develop very distinct brown spots and ring spots (Figure 15). Young plants appear to lose stem strength and the stems curve. Affected plants are usually stunted (Figure 16) and, if infected as young seedlings, are killed. The virus causes a large reduction in yield.

13 Mosaic and chlorosis of TSWV infected pepper leaves

14 Small brown leaf spots or leaf bronzing led to the alternative common name tomato bronzing virus

Minor edible crops

Several minor protected edible crops are reported as hosts of TSWV including aubergine, basil, celery and mint. Infection has not yet been recorded on any of these crops in the UK.

Aubergine: symptoms include necrotic leaf lesions; severe crop damage has been reported in southern Europe.

Basil: symptoms include ring spots, leaf distortion and severe mosaic.

Mint: symptoms include stunting and

15 Fruit set on infected plants is poor and fruit already formed develop distinct brown spots

16 Tomato plants affected by TSWV are usually stunted

general decline. Newly mature dark green leaves develop bright yellow irregular mottling. Older leaves become bronze then often turn completely yellow and develop irregular, brownish-grey, sunken lesions.

Host range of TSWV

TSWV has a very extensive host range, being reported on at least 900 plant species in both dicotyledon and monocotyledon families. Plants in the Asteraceae, Fabaceae and Solanaceae are particularly affected. Major global crops that have been severely affected include lettuce, peanut, pepper, tobacco, tomato and various ornamental crops. In the UK, ornamental hosts have included aster, chrysanthemum, cyclamen, cineraria (*Senecio cruentus*), dahlia, impatiens, petunia and primula. Weeds are hosts as well as cultivated plants, including groundsel (*Senecio vulgaris*), nightshade (*Solanum nigrum*), sowthistle (*Sonchus* spp.), chickweed (*Stellaria media*) and dandelion (*Taraxacum officinale*).

The tospovirus group

TSWV is a member of the tospoviruses, a virus group of growing worldwide importance. Tospoviruses are all transmitted by and multiply in certain species of thrips. The number of known tospoviruses has increased greatly in recent years and at least 22 are now recognised. Other viruses in the group include *Impatiens necrotic spot virus* (INSV), *Iris yellow spot virus* (IYSV), *Chrysanthemum stem necrosis virus* (CSNV), *Watermelon silver mottle virus* (WSMV) and *Capsicum chlorosis virus* (CaCV). The latter virus was first detected in Australia in 1999 and has since caused serious epidemics in sweet pepper; the virus can also infect tomato. CaCV has so far only been confirmed to be transmitted by *T. palmi* and *Frankliniella schultzei*, both of which are not native to the UK. The virus has not yet been recorded in Britain. INSV, which occurs in the UK, is much more frequently found in ornamentals than on vegetable crops, though chicory, cucumber, lettuce and sweet pepper are all reported as vegetable hosts. IYSV has been recorded once in the UK, on lisianthus; globally it has caused significant damage to onion crops (see HDC Factsheet 19/08 for further details).

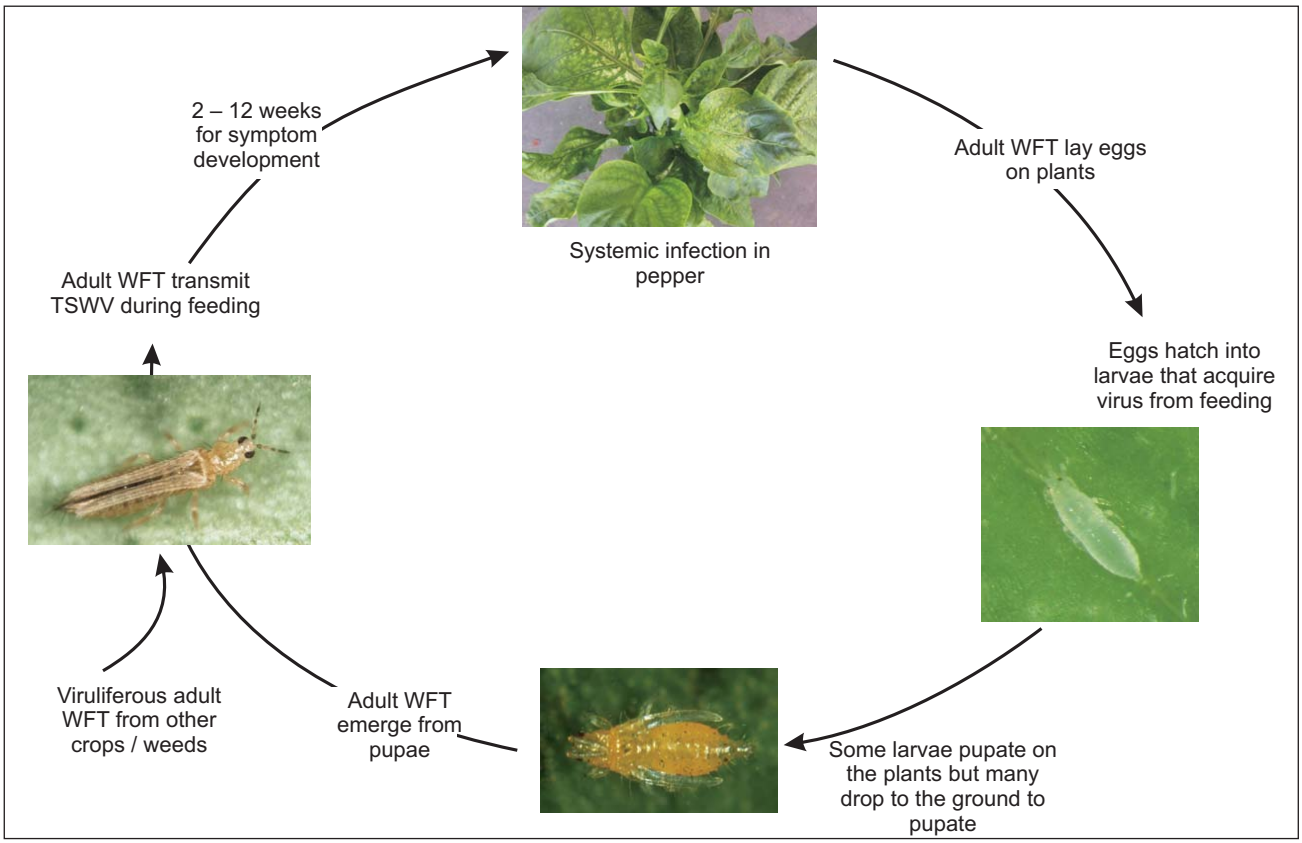
Spread of TSWV

Infected plant material

TSWV could potentially be introduced to the nursery in infected plant material e.g. young plants (such as aubergine, tomato or pepper) or cuttings (such as some ornamental species). The virus could then be acquired and spread by resident WFT on the nursery, or by WFT coming in with the plants. If TSWV is confirmed on the nursery, any infected plants will be a source of the virus. In addition, weeds will be a potential source as infected WFT could spread the virus from the crop to weeds in or around the glasshouse and subsequent WFT generations could spread the virus back to the crop(s).

Thrips

Worldwide, TSWV can be spread by several species of thrips including the onion thrips (*Thrips tabaci*), WFT (*Frankliniella occidentalis*), tobacco thrips (*F. fusca*), blossom or tomato thrips (*F. schultzei*) and chilli thrips (*Scirtothrips dorsalis*). Of these species, only onion thrips and WFT are native or established in the UK. In the 1930's TSWV in the UK was spread by onion thrips. At that time the virus was not uncommon in tomato crops and was thought to be transmitted from ornamental plants like chrysanthemum. Currently, WFT is the vector of TSWV in the UK. It is possible that UK populations of onion thrips do not transmit contemporary strains of TSWV. WFT is a very efficient vector of the virus and just a few viruliferous adults can spread TSWV to many plants in the glasshouse.



17 Diagrammatic life-cycle of WFT showing its transmission of TSWV

Not all WFT populations carry TSWV. The virus can only be acquired by the first stage WFT larvae, when feeding on infected plants. When these larvae develop into the adult stage, the viruliferous adults spread TSWV by flying to healthy plants and transmitting the virus during feeding (see Figure 17). Second stage larvae occasionally transmit the virus but as they are wingless and do not tend to move between plants, the winged adults are by far the most important stage for virus spread. TSWV persists in the salivary glands of adult WFT so there is a risk of virus transmission each time the insect feeds on plants. The adults do not transmit the virus to their offspring.

In seed

TSWV is not seed transmitted.

Mechanical

TSWV and other tospoviruses are physically and chemically very unstable. Longevity *in vitro* at room temperature is 2 - 5 hours. They are inactivated in plant sap at a temperature of 40 - 50°C for 10 minutes. Spread from plant sap or debris is considered unlikely to be of practical significance with normal handling of plants.

Crop monitoring

Monitoring for WFT and TSWV symptoms

Regular crop monitoring for WFT and for symptoms of both WFT damage and virus infection is a key measure to aid effective control. Monitoring can be done by a dedicated staff member but in addition, staff working in the crop on a day to day basis should be trained in recognition of thrips and symptoms of thrips damage and TSWV. Potential problems can then be spotted early and reported to the nursery manager so that prompt action can be taken.

Crop inspection

Check plants at least every week throughout the production period. Pay particular attention to young plants when brought onto the nursery and during the first few weeks of production. Check leaves and fruit for symptoms of thrips damage and TSWV infection. During pest monitoring, pay particular attention to flowers if they are present e.g. on aubergine, cucumber and pepper, as this is where WFT prefer to feed. Tapping flowers onto a white plastic tray or white paper on a clipboard or notebook is a useful detection method if thrips are not easily seen in the flowers. Any dislodged thrips can be seen on the tray or paper. If there are no flowers present or no thrips found in them, check leaves for thrips or damage symptoms. Thrips can be present on upper or lower sides of the leaves but are more commonly found on the undersides.

18 Check sticky traps weekly for adult thrips

Sticky traps

Use of sticky traps for thrips monitoring should always be done in addition to regular plant monitoring, not as a substitute. Adult thrips are attracted to both yellow and blue sticky traps. Blue traps can be more effective than yellow at detecting low densities of WFT. However, yellow traps are also useful for monitoring for other pests in some crops e.g. leaf miners and whiteflies. Traps can be particularly useful during the first few weeks of production to check for WFT when numbers are still low and they may not be detected on the plants. Traps are best placed about a foot above the tops of the plants before the plants are fully grown, to reduce the numbers of flying biological control agents caught. Only use as many traps as can practically be checked every week (e.g. one trap every 500m^2). More traps (e.g. one per 100m^2) can be used in smaller glasshouses or in high risk situations. Check traps weekly and record presence and numbers of thrips. Trap counts can be used to indicate thrips 'hotspots' or increase in numbers. Only adults will be caught (Figure 18) as larvae do not fly.

Thrips lures

Two lures are available, designed to increase sticky trap catches of thrips, to aid early detection and help indicate population increases. A sex aggregation pheromone specific to WFT (Thripline ams) is available from Syngenta Bioline. The pheromone attracts both male and female WFT and is supplied as small rubber lures which are stuck onto the lower section of sticky traps. A thrips attractant, Lurem-tr, is available from Koppert. This attracts various thrips species, thus it will not help to distinguish thrips species on traps. The attractant is supplied in small slow-release dispensers that are stuck onto sticky traps.

Indicator plants for TSWV

Petunia can be used as an indicator plant to monitor for thrips carrying TSWV in a glasshouse. Young plants are introduced into a glasshouse for 7 - 14 days. Petunia plants develop local virus lesions (pale spots which turn brown) on leaves within a week of feeding by WFT adults carrying TSWV (Figure 19). The thrips attraction and virus transmission to petunia may be enhanced by using blue or yellow traps without glue placed at plant height.

Petunia is attractive to WFT, shows TSWV symptoms quickly and does not become systemically infected during the monitoring period and thus is not a significant source of virus. It is important to use thrips-free petunia to avoid them being a source of WFT.

19 Petunia indicator plants showing local TSWV lesions (pale and dark brown spots) on lower right leaf

Testing crop plants for TSWV

When testing suspect plants for TSWV, select the tissue with the most obvious symptoms and test several plants. Virus distribution within plants is very variable, although generally the highest concentration is found associated with severe symptoms and possibly in younger leaves just above those with symptoms in plants in which the virus is systemic. Tissues can be tested on-site using a lateral flow device specific for the virus. Test kits are available from Forsite Diagnostics (www.forsite-diagnostics.com). Alternatively, send a sample to a plant clinic or seek advice.

Control measures

Legislative control

TSWV is an EU listed quarantine pathogen. In the UK a suspected outbreak should be reported to Fera PHSI where it occurs in plants for planting (i.e. during propagation) or in potato. It is not a statutory requirement to report outbreaks in other crops, nor is it a requirement to report infestations of WFT, as WFT is no longer a quarantine pest in the UK.

Integrated Pest Management (IPM)

Most growers of protected aubergine, cucumber, herbs, pepper and tomato use IPM programmes based on using cultural control methods, resistant varieties where available and biological control agents together with minimal use of compatible pesticides. Pesticides should only be used as a last resort for control of WFT, as not only is the pest resistant to most pesticides, but use of pesticides can disrupt the IPM programme by having adverse effect on biological control agents used against thrips and other pests.

Good management of IPM programmes is critical for success. Choice, combinations, timings and rates of release or application of biological control agents within the programme should be planned, monitored and managed carefully. Any pesticides used for control of pests or diseases on the crop should be carefully selected for minimal impact on biological control agents, otherwise there can be serious and long-lasting disruption of the IPM programme. If in doubt, seek advice from the biocontrol supplier or a specialist IPM consultant.

Cultural control at crop turnaround

If a previous crop has been infested with WFT, and particularly if the crop was infected with TSWV, a thorough clean-up programme should be used to minimise thrips carry-over to the next crop. Crop debris should be promptly removed and disposed of. Leaving crop debris on the nursery will maintain a source of thrips which can reinvade the glasshouse and infest the new crop. WFT can overwinter on plant material, crop debris and in substrates both in glasshouses and outdoors in the UK. Long sticky 'curtain' traps can be useful to trap any thrips adults remaining in empty glasshouses before replanting.

Removal of plants infected with TSWV

Inspect plants carefully on arrival and in the first few weeks after planting for any possible symptoms of TSWV. Test any suspect plants for the virus. If TSWV is confirmed on a propagation nursery, report this immediately to Fera PHSI, who will advise on an eradication programme. There is no pesticide that controls TSWV so infected plants need to be disposed of promptly and carefully. Remove affected plants from the crop as soon as they are detected, place in sealed bags and take in covered skips or trailers to a local authority disposal site. It is necessary to remove the whole plant as the virus is systemic. Control weeds in and around the glasshouse which can act as reservoirs of both TSWV and WFT. Do not interplant or make overlapping plantings in a glasshouse where TSWV has been confirmed on the crop.

TSWV - resistant plant varieties

There is limited host plant resistance to TSWV. Some varieties of lettuce, pepper and tomato have partial resistance to TSWV. However, a variety found to be resistant to TSWV in one area may be susceptible to TSWV in another area where it is exposed to different strains of the virus. In tomato, at least five different TSWV resistance genes

have been identified, each conferring resistance to different strain groups; experiments indicated it was not possible to breed a homozygous tomato cultivar resistant to all known strains of TSWV using these resistance genes. Resistance-breaking TSWV strains have recently been identified in sweet pepper. Intensive effort is being made to obtain genetically resistant varieties as this could be the most effective way of avoiding the disease.

Biological control of thrips

Several biological control agents are available for the control of thrips and the main ones used on protected edible crops are summarised below. The use of *Amblyseius* spp. predatory mites on cucumber and pepper, together with *Orius* predatory bugs on pepper, usually give effective control of WFT on these crops. Use of biological control agents within an IPM programme needs to be planned and managed carefully, if necessary, with the help of a specialist IPM consultant.

Amblyseius cucumeris: This predatory mite feeds only on young thrips larvae and not on the adults or pupae, so successful control depends on preventive introduction from planting. In protected edible crops, the mites are released in sachets which release the predators over a 6 - 8 week period. The mites do not fly so if plants are not touching, a sachet should be introduced to each plant (once plants are touching the predators can walk from plant to plant). On crops with pollen such as peppers, the predators will also feed on pollen and establish on the crop even in the absence of thrips. *A. cucumeris* is not suitable for use on tomato, and although it is used successfully on protected herbs, it is not yet used on commercial lettuce crops.

Amblyseius swirskii: This predatory mite is very similar to *A. cucumeris* but feeds on whitefly eggs and young scales in addition to thrips larvae. *A. swirskii* is not native to the UK and only has a licence for release in fully enclosed glasshouses or tunnels (not in open-sided tunnels or those with doors left open). *A. swirskii* needs warmer temperatures than *A. cucumeris* to develop and establish in the crop; optimum temperatures are 25 - 28°C, when it multiplies more rapidly than *A. cucumeris* and thus can give better control of WFT. As with *A. cucumeris*, *A. swirskii* is not suitable for use on tomato.

Orius laevigatus: *Orius* species are also known as flower bugs. The predator performs best on crops with pollen like peppers. Like *Amblyseius* species, *Orius* can establish on pollen in advance of thrips infestation. *Orius* plays an important role in the IPM programme on peppers where it supplements biological thrips control given by *Amblyseius* species. Both the adults and nymphs of this predatory bug feed on both thrips adults and larvae. The adults are active flyers and can thus move around in the crop looking for thrips prey. *Orius* is particularly sensitive to pesticides, thus great care should be taken when selecting any pesticide for use before or after releasing *Orius* (see chemical control section below).

Hypoaspis miles and ***Hypoaspis aculeifer***: These ground-dwelling predatory mites are regularly used in IPM programmes on protected ornamental crops, although they are also used on protected herbs and occasionally on other edible crops. They are primarily used against sciarid flies, but will also feed on other prey in the growing media or substrate including thrips pupae. Thus they can supplement biological control of thrips life stages on the plants by other biological control agents. A newly available predatory mite, *Macrocheles robustulus* will also feed on ground-dwelling prey including WFT pupae.

Insect-pathogenic fungi: Insect-pathogenic fungi are microbiological control agents and thus subject to the pesticide approval system (unlike predators and parasites). Two fungal products are currently approved in the UK that will give some control of thrips in suitable environmental conditions:

Verticillium lecanii: The whitefly strain of this fungus ('Mycotal') will also infect thrips. Mycotal has approval for use on most protected edible crops (see Table 1) and is supplied as spores in a wettable powder for application as a high volume spray. To be effective, the fungus needs to make contact with the thrips and needs a temperature of at least 18°C and a relative humidity of more than 75% for 10-12 hours after application. It is thus more suitable for application in the evening during warm, humid weather. As *V. lecanii* is a fungus, any fungicides used on the crop for disease control should be selected and timed carefully.

Beauveria bassiana: This fungus ('Naturalis-L') has recently been approved for use on any protected edible or ornamental crop, for control of whitefly with some reduction of thrips. *B. bassiana* works in a similar way to *V. lecanii* but is not quite so dependent on high humidities (minimum 50% relative humidity for infection). As with *V. lecanii*, fungicide choice and timing should be carefully planned to avoid adverse effects on *Beauveria*.

Chemical control of WFT

Thrips are difficult to control with pesticides. Adults and larvae are difficult to target with contact pesticides and the eggs and pupae are in inaccessible places. In addition, WFT has developed severe resistance to most chemical pesticides. Until recently, spinosad (Conserve or Tracer) was the most effective pesticide against WFT, but some UK populations have now developed resistance to spinosad, e.g. on chrysanthemum and strawberry. Such WFT populations with severe resistance to all chemical pesticides can only be controlled with biological control agents, with some possible supplementary control with selected biopesticides or physically acting products.

Table 1 lists pesticides and biopesticides currently approved for use on some protected edible crops that may give some control of thrips, depending on thrips species and resistance status of the thrips population. Pesticides against thrips should only be used as a last resort and all label recommendations and precautions for resistance management should be followed to avoid increasing problems with resistance. If using IPM, pesticides for use against WFT and other pests and diseases should be selected for minimal adverse effect on all biological control agents being used on the crop. Use of pesticides harmful to biological control agents will disrupt IPM programmes. For example, use of thiacloprid (e.g. Calypso) on sweet peppers for leafhopper control has disrupted biological control of WFT in recent years. Only brief information about the compatibility of pesticides against biological control agents is given in Table 1. For further information, consult your IPM consultant or biological control supplier. The following websites are also useful for information on side effects of pesticides on biological control agents:
www.biobest.be
www.koppert.com

Table 1. Currently approved pesticides and biopesticides (July 2010) on specified protected edible crops that may give some control of WFT depending on the resistance status of the WFT population*

Active ingredient (example products)	Insecticide group	Cucumber	Tomato	Sweet pepper	Chilli pepper***	Aubergine	Lettuce	Compatibility with biocontrols**
Abamectin (Clayton Abba, Dynamec)	avermectin	Label approval	Label approval (excluding cherry tomato) SOLA (cherry tomato)	SOLA	SOLA (cayenne pepper)***	SOLA	SOLA	Harmful to most biocontrols for up to 3 weeks
Beauveria bassiana (Naturalis-L)	Insect-pathogenic fungus	Label approval (any protected crop)	Label approval (any protected crop)	Label approval (any protected crop)	Label approval (any protected crop)	Label approval (any protected crop)	Label approval (any protected crop)	Safe to most biocontrols
Fatty acids (Savona)	Soap concentrate	Label approval	Label approval	Label approval	SOLA (cayenne pepper)***	SOLA	Label approval	Safe to most biocontrols once spray deposit dry
Natural plant extracts (Eradicoat)	Physical pesticide	Label approval (any protected crop)	Label approval (any protected crop)	Label approval (any protected crop)	Label approval (any protected crop)	Label approval (any protected crop)	Label approval (any protected crop)	Safe to most biocontrols once spray deposit dry
Pyrethrins (Spruzit)	pyrethrins with naturally derived oil	Label approval (any protected crop)	Label approval (any protected crop)	Label approval (any protected crop)	Label approval (any protected crop)	Label approval (any protected crop)	Label approval (any protected crop)	Harmful to some biocontrols for up to 1 week
Pyrethrins (Pyrethrum 5 EC)	pyrethrins with the synergist PBO	Label approval (any edible crop)	SOLA and label approval (any edible crop)	SOLA and label approval (any edible crop)	SOLA (cayenne pepper, chilli***) and label approval (any edible crop)	Label approval (any edible crop)	Label approval (any ed-ible crop)	Harmful to some biocontrols for up to 1 week
Spinosad (Conserve, Tracer)	spinosyn	Label approval (Conserve)	Label approval (Conserve)	Label approval (Con-serve)		Label approval (Conserve)	SOLA (Tracer)	Safe to many biocontrols but harm-ful to *Orius* and parasitic wasps for up to 2 weeks
Teflubenzuron (Nemolt)	benzoylurea	SOLA	SOLA	SOLA		SOLA		Safe to many biocontrols but harmful to *Orius* nymphs for up to 2 weeks
Thiacloprid (e.g. Calypso)	neonicotinoid	SOLA	SOLA	SOLA		SOLA	SOLA	Harmful to most biocontrols for up to 2 weeks
Verticillium lecanii (Mycotal)	Insect-pathogenic fungus	Label approval	Label approval	Label approval	SOLA (cayenne pepper)***	Label approval	Label approval	Safe to most biocontrols

• Pyrethroid insecticides such as cypermethrin and deltamethrin have been excluded from the table as both WFT and onion thrips are likely to be resistant. These pesticides are also not compatible with IPM, having harmful effects on most biological control agents for up to 12 weeks after application. Closely related products containing pyrethrins have been included although WFT and onion thrips are likely to be resistant to the active ingredient. The products are formulated with oil or the synergist PBO which may allow them to have some effect.

• SOLA = Specific Off-label Approval

• Growers must hold a paper or electronic copy of the appropriate SOLA document before using any product under the SOLA arrangements. Any use of a pesticide with a SOLA is at grower's own risk. Relevant SOLAs are available from the HDC; or CRD (Tel. 01904 455775) or on the CRD website www.pesticides.gov.uk or from the LIAISON database www.fera.defra.gov.uk/liaison (subscribers only)

• Always follow label or SOLA recommendations, including rate of use, timing and maximum number of applications. If crop safety information is unavailable, test the product on a small number of plants first before use on a larger scale.

• If in doubt about MRL's on any crop, seek advice from CRD (Tel. 01904 455775).

*Important – Growers must always check the current approval status of products listed in this factsheet before intended use as this could have changed since it was produced.

**Full details of compatibility of pesticides with biological control agents are available from biological control suppliers or IPM consultants.

***Cayenne pepper is *Capsicum annuum*, an annual plant with single fruit that hang down from the plant. Chilli ('bird's eye') pepper is *Capsicum frutescens*, a perennial plant with clusters of fruit that point upwards.

Further information

Other useful publications

• HDC Report PC 289. Sweet pepper: securing knowledge on TSWV and a potyvirus in an infected crop to increase understanding of a potential threat to UK growers.

• HDC poster. Tomato spotted wilt virus (TSWV) in pepper.

• HDC Factsheet 14/09. Thrips control on protected ornamental crops.

• HDC Factsheet 19/08. Iris Yellow Spot Virus: A potential threat to the onion industry.

• HDC Factsheet 10/07. Guidelines on nursery hygiene for outdoor and protected ornamental crops.

Suppliers of biological control agents

Agralan Ltd
(Biobest products)
The Old Brickyard
Ashton Keynes
Swindon
Wilts SN6 6QR
Tel. 01285 860015
www.agralan.co.uk

BCP Certis
Newbury House
Court Lodge Farm
Hinxhill
Ashford
Kent TN25 5NR
Tel. 01233 667080
www.bcpcertis.com

Biowise
Hoyle Depot
Graffham, Petworth
West Sussex GU28 OLR
Tel. 01798 867574
www.biowise-biocontrol.co.uk

Fargro Ltd
(Syngenta Bioline products)
Toddington Lane
Littlehampton
West Sussex BN17 7PP
Tel. 01903 721591
www.fargro.co.uk

Koppert UK Ltd
Green House
Unit 8
53 Hollands Road
Haverhill
Suffolk CB9 8PQ
Tel. 01440 704488
www.koppert.co.uk

Syngenta Bioline
Telstar Nursery
Holland Road
Little Clacton
Clacton
Essex CO16 9QG
Tel. 01255 863215
www.syngenta-bioline.co.uk

Biocontrol agents and sticky traps can also be obtained through most horticultural merchants.

Acknowledgements

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Additional information:

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