Crop Walkers' Guide

AHDB

Protected Edibles

HORTICULTURE

Protected edibles growers can encounter a wide range of crop problems that can quickly render plants unsaleable unless recognised, diagnosed and dealt with promptly. Often, such problems are linked to pests and diseases, but nutritional and cultural-related disorders may also be involved.

This AHDB Horticulture Crop Walkers' Guide is designed to assist growers, supervisors and nursery staff in the vital task of monitoring crops.

It is designed for use directly on the nursery to help with the accurate identification of many of the economically important pests, diseases and disorders. Weed identification is not covered in this publication.

Pests and diseases

Images of the key stages of each pest or pathogen, along with typical symptoms, have been included, together with bullet-point comments to help identification.

While covering some of the key biological pest control agents used in protected edibles production, this guide does not offer advice on available control measures as these frequently change. Instead, having identified a particular pest or disease, growers should acquaint themselves with the currently available control measures and recommended hygiene protocols.

Diseases, especially viral diseases, are presenting an increasing problem for growers. They can be carried on seed, produce, plant material and the hands and clothing of anyone visiting. As a precaution, ideally all sites should adopt a 'business critical' only visitor policy. Where visitors are essential and need to see the crop, provide adequate coveralls or a complete change of clothing, as well as foot dips, hand-washing and strict disinfection protocols.

It is also important to prevent contamination from imported crops for packing. Ideally keep packing facilities separate from production sites. Transport trays should also be thoroughly cleaned before being moved between the packhouse and production areas.

Nutrient and cultural disorders

Maintaining the correct balance of plant nutrients is essential to producing a healthy crop. Whether this supply of nutrients is from a well-maintained soil or from solution culture through NFT or substrate, it is important for growers and crop managers to be able to identify any nutritional problems at the earliest stages so that corrective action can be taken. The photographs used in this guide were produced by restricting the particular element under scrutiny to produce the desired deficiency, but there are few situations where only one nutrient will be in short supply. You can use the guide to indicate which nutrient is likely to be causing the problem you are presented with and confirm by leaf analysis.

When sampling foliage for nutritional status, you should remove the youngest fully expanded leaves from plants that you are concerned about – but also remove similar leaves from healthy plants for comparison.

As the protected edibles industry produces a diverse range of crops, it is impossible to show every issue associated with each crop. This guide, therefore, presents the most commonly occurring pests, diseases and disorders in protected edible crops. Growers are advised to familiarise themselves with the range of symptoms that can be expressed and be aware of new problems that may occasionally arise.

Nathalie Key
Research and Knowledge Exchange Manager
(Protected Edibles and Mushrooms)
AHDB Horticulture

Pests

SECTION 1

Beneficials
SECTION 2

Diseases
Section 3

BACTERIAL DISEASES

FUNGAL DISEASES

References

SECTION 6

Pests

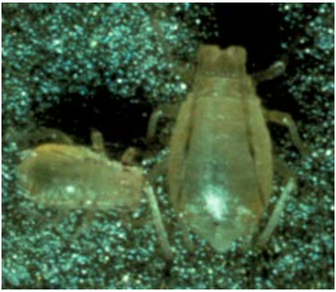
Aphids

Various species

- Several species attack pepper, cucumber, aubergine and tomato.
- Winged adults fly into glasshouses (spring–autumn) and give birth to wingless offspring. First sign may be white cast skins on the upper surface of lower leaves and fruit.
- Feed mainly on underside of leaves, producing copious quantities of honeydew – a growing medium for sooty moulds.
- All species have distinct tubular processes (siphunculi) at the rear, which are useful for identification.

Aphids

Various species




- *Myzus persicae* (top left) – 2 mm long, common on peppers. Usually green but can vary from yellow to red.
- *Aphis gossypii* (top right) – 1–2 mm, forms dense colonies on cucumber leaves. Yellow to dark green, siphunculi black.
- *Aulacorthum solani* (bottom left) – 2–3 mm, yellow-green with distinctive dark patches around siphunculi.
- *Macrosiphum euphorbiae* (bottom right) – largest of these species. Pink to yellow-green with darker stripe down back.

Broad mites

Polyphagotarsonemus latus

- Microscopic mites which can be recognised by the damage caused to peppers and cucumber plants.
- Growing points of peppers become distorted and sometimes blind.
- Foliage of cucumbers is stunted and thickened, similar to hormone herbicide damage.
- Fruits are distorted and may acquire a waxy bloom.

Brown marmorated stink bug

Halyomorpha halys




- Interceptions of this non-native pest are becoming more common in the UK. Populations could become established in heated glasshouses.
- Adults (17 mm) are brown and produce a pungent odour (top left and bottom right).
- Small nymphs change colour as they moult and grow (top right). The oldest nymphs (12 mm) have wing buds (bottom left).
- Adults may be confused with several native bugs, though the latter rarely exceed 12 mm.
- For detailed information, consult the Defra Plant Pest Factsheet 'Brown Marmorated Stink Bug'.

Capsid bugs

Lygus rugulipennis and *Liocoris tripustulatus*




- *Lygus* usually has two generations per year, with adults (top left) invading cucumber crops in April and mid-summer. *Liocoris* adults (top right) and nymphs (bottom left) may be found in peppers and aubergines from March onwards.
- Attack apical parts of plants, causing leaf distortion and loss of growing points.
- Feeding/egg laying in young fruit can lead to distortion.
- Nymphs are fast runners and are most easily caught by tapping foliage over a white tray.

Caterpillars

Laconobia oleracea and *Autographa gamma*

- These are the most common species, but many other moths enter glasshouses and may attack tomato, cucumber, pepper and aubergine plants.
- Tomato moth *(L. oleracea)* larvae (top left) feed on leaves and fruit before pupating under debris or in the glasshouse structure. Usually two distinct generations per year.
- Silver Y moths *(A. gamma)* arrive in the UK during mid-summer. Larvae (bottom left) distinguished from tomato moth by three prolegs (instead of five) and move with a looping action.

French fly

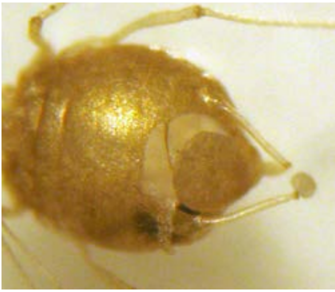
Tyrophagus spp.

- This small mite was widespread when straw bales were used in cucumber production.
- *Tyrophagus* and similar mites are used as prey in *Neoseiulus/ Amblyseius* culture packs. If formulations are suboptimal, the prey mites may breed out of control and emerge onto plants.
- Their feeding produces small holes, which enlarge as the leaves expand.
- Damage to young plants can become quite extensive.

Hyperparasitoids

Various species






- Ten species have been found attacking primary parasitoids of aphids in pepper crops (refer to AHDB Factsheet 27/12).
- Female probes the parasitised aphid to feed and/or lay eggs. Typical holes shown top right.
- Immature hyperparasitoids develop inside the mummified aphid, killing the primary parasitoid.
- First indication is often irregular-shaped emergence holes in mummified aphid (bottom right). By comparison, *Aphidius* emergence holes have neater edges and retain a distinct lid (bottom left).

Leafhoppers

Hauptidia maroccana and other species

- Adults (3 mm) (top left) feed on undersides of cucumber, tomato and pepper leaves. Both adults and nymphs (top right) jump when disturbed.
- As nymphs grow, their cast skins can be confused with those of aphids.
- Symptoms sometimes mistaken for thrips. As feeding continues, areas coalesce and leaves may become totally bleached.
- Pepper fruit can also be damaged.

Leaf miners

Liriomyza bryoniae

- Important on tomato, less so on cucumber and pepper.
- Adults (2–2.5 mm) feed on upper leaf surface, causing small bleached spots.
- Larvae produce meandering linear mines within the leaf, followed by red-brown pupae on the underside.
- Populations develop from the start of the season and breeding is continuous.
- Two non-indigenous Liriomyza species have similar appearance but produce different-shaped mines. They are notifiable in the UK. If in doubt, consult Defra PHSI.

Macrolophus bugs

Macrolophus pygmaeus

- Predatory insects (see page 2.11) which also damage plants.
- Feed on veins of tomato leaves, causing downturning, and on trusses, causing premature flower/fruit drop.
- Adults (6 mm) are bright green with large membranous wings. Nymphs are of similar shape but smaller and wingless.
- Numbers increase quickly when there is adequate insect prey. Plant damage usually occurs after other pests have been killed.

Mealybug

Pseudococcus viburni

- On tomatoes, infestations develop on lower stems and later thrive among the horizontal stem bundles.
- On peppers, females hide under the calyx of fruit, leading to rejection by customers.
- Females (3–4 mm) are covered in white waxy filaments for protection. They lay eggs in batches of 100–500 in waxy sacs.
- Immature mealybugs are similar in appearance to females but smaller.

Nesidiocoris bugs

Nesidiocoris tenuis

- Like *Macrolophus, Nesidiocoris* is predatory but also feeds on plants.
- Adults have a dark-coloured band behind eyes and black 'knees', which distinguish them from *Macrolophus.*
- First signs of damage are brown rings on stems and petioles (bottom left).
- Damaged flower stalks swell prior to premature flower/fruit drop.
- Rare in the UK but becoming more common. Refer to AHDB Factsheet 03/17.

Pepper weevil

Anthonomus eugenii

- Specific to peppers.
- Adults (3 mm) are brown, sparsely covered with yellow hairs and have a typical weevil 'snout'. Eggs are laid in flower buds and fruit.
- Larvae and pupae develop inside the fruit, with adult emergence holes being the first obvious external sign of damage.
- Common in Central America and Southern USA but rare in Europe. A notifiable pest in the UK.

South American tomato moth

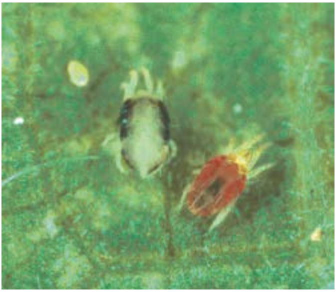
Tuta absoluta

- Adults (6 mm) are nocturnal but may be seen during the day when numerous.
- Eggs (1 mm) are laid on the surface of leaves and stems.
- Larvae produce ‘blotch’ mines, with an accumulation of dark-coloured frass in one part of the mine.
- Larvae may also tunnel in fruit, leaving a very obvious exit hole.
- Refer to AHDB Factsheet 03/10.

Southern green shieldbug

Nezara viridula

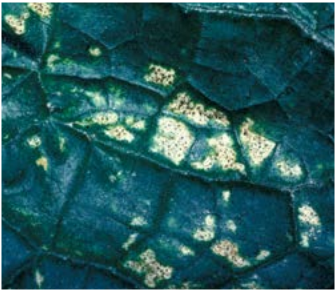
- A recent introduction to SE England and a particular pest of aubergines and peppers.
- Damage is seen as swelling on stems and stunting/wilting of plant heads.
- The larvae change colour at each moult – starting black, then going through various spotty stages until they mature as green adult shieldbugs (15 mm).
- The adults can be mistaken for the native shieldbug, Palomena prasina, but have slightly different markings. Refer to AHDB Factsheet 36/12.



- Two-spotted spider mite *(T. urticae)* is most common. Adults (0.5 mm) turn red in autumn and hibernate off plant.
- Carmine spider mite *(T. cinnabarinus)* is a similar size but dark red and remains on the plant year-round.
- Feed under leaves – speckling shows on upper surfaces of cucumber/tomato leaves, but less so on peppers. Dense webbing is produced as populations increase.
- Sometimes, damage is more severe (hyper-necrotic) to tomatoes (bottom right).

Thrips

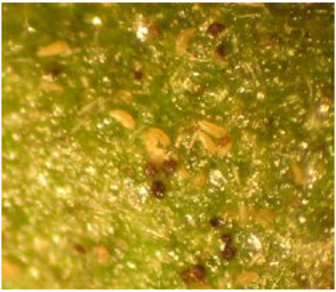
Frankliniella occidentalis and *Thrips tabaci*



- Damages cucumber, aubergine and pepper foliage and fruit.
- Adults (1–2 mm) found on underside of leaves and in flowers.
- If attacked when young, fruit may become seriously distorted, e.g. ‘pigtail’ damage to cucumbers.
- Breeding is continuous throughout the year.
- Western flower thrips *(F. occidentalis)* and onion thrips *(T. tabaci)* can only be distinguished by microscopic examination.

Tomato russet mites

Aculops lycopersici



- Microscopic (0.2 mm) eriophyoid mites (top right) cause bronzing and roughening of stems and 'graze' off trichomes (hairs). Top-left image compares healthy and infested stems.
- Early damage most evident on lower stems but can affect foliage and trusses. Infested leaves have localised necrotic lesions (often confused with potato blight).
- Advanced infestations lead to brown, rough and cracked fruit. Refer to AHDB Factsheet 21/10.

Whitefly (Glasshouse)

Trialeurodes vaporariorum

- Adults (1 mm) found on underside of upper leaves of tomato and cucumber plants.
- Oval eggs are white at first but turn black after 2–3 days.
- Immature stage is a flattened scale (up to 1 mm) attached to the underside of leaves.
- Pupal scales have raised side walls.
- Excrete copious quantities of honeydew, providing a growth medium for sooty moulds.

Whitefly (Tobacco)

Bemisia tabaci

- Adults similar to glasshouse whitefly but tend to hold their wings slightly apart, exposing the pale yellow body.
- Scales appear translucent pale green and pupae have slightly indented sides.
- Capable of transmitting over 25 different viruses, including tomato yellow leaf curl virus (TYLCV). Refer to page 3.32.
- As a non-indigenous pest, it is notifiable to Defra PHSI.

Woodlice

Porcellio scaber and *Armadillidium nasatum*

- Live in the surface of soil/compost and are very common in organic cropping systems.
- Climb plants after dark to graze on leaves and stems. This can seriously deplete the foliage of young plants.
- In early season, stems may be girdled, particularly around grafting scars.
- Later, stems may be penetrated at weak points, such as deleafing scars, allowing entry of secondary disease.

Beneficials

Aphid parasitoids

Several species

- Most are specific to one type of aphid but act in the same way: an egg is laid within the aphid, the immature wasp develops internally and the aphid becomes 'mummified'.
- Often released to supplement natural UK populations.
- Each parasitoid produces a characteristic mummy, e.g. *Aphidius* spp. (top right) in *Myzus* or *Macrosiphum*, *Aphelinus* spp. (bottom left) in *Aulacorthum*, and *Praon* spp. (bottom right) in *Myzus*.

Aphid predators

Several species

- The predatory midge, *Aphidoletes aphidimyza* (top left), is a specific predator of aphids and is available commercially.
- Many other species may be found in crops that are free from chemical pesticides. Some, such as syrphids (top right), are specific to aphids.
- Anthocorid bugs (bottom left) and lacewings (bottom right) are generalist predators and may attack a wider range of pests.

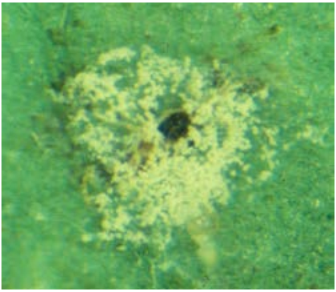
Caterpillar bacterial control

Bacillus thuringiensis

- *Bacillus thuringiensis* (Bt) is the most widely used pathogen for the control of caterpillars.
- The products, which contain a toxin produced by the Bt bacteria during fermentation, are sprayed onto the leaf and kill the caterpillar following ingestion.
- Before use, the caterpillars should be correctly identified as this may influence the choice of product. If in doubt, consult your supplier.

Entomopathogenic fungi

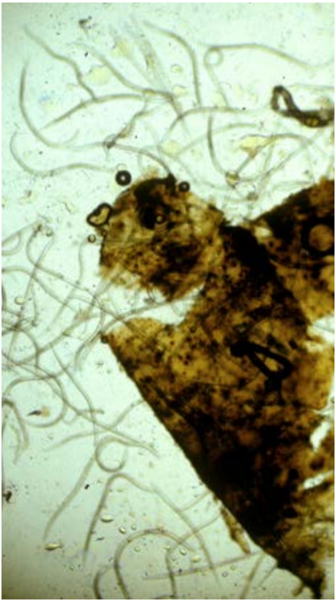
Various species

- Colonies of aphids or whiteflies may become naturally infected with fungal pathogens, causing populations to crash.
- For most species, a mass of fungal mycelium grows on the dead host.
- Several Entomophthorales (bottom left) are specialist parasitoids of specific pests, causing discolouration without white mycelium.
- Commercial formulations of *Lecanicillium* spp., *Metarhizium anisopliae* and *Beauveria bassiana* are available against various insects/mites. If in doubt, consult your supplier.

Entomopathogenic nematodes

Various species



- Microscopic worm-like animals which penetrate the insect's body and release lethal bacteria.
- Traditionally used as a drench against larvae of soilborne pests.
- Under favourable conditions, foliar sprays of *Steinernema feltiae* have given up to 60% mortality of *Tuta absoluta* larvae (Image left) and 50% mortality of *Liriomyza* leaf miner larvae (image right) within mines.

Generalist predator

Macrolophus pygmaeus

- Adults (6 mm) are bright green with large membranous wings.
- Nymphs are of similar shape but smaller and wingless.
- Both are voracious predators, feeding on a wide range of insects/mites.
- Can become a pest when insect/mite prey is limiting (see page 1.10).
- When numerous, *Macrolophus* can be collected and redistributed to areas of need (refer to AHDB Factsheet 02/10).

Amblyseius/Neoseiulus species

- Various species released against thrips, broad mites, whiteflies and spider mites.
- Small mites, just visible to the naked eye, usually found on the underside of leaves, often close to veins, or in flowers.
- Most species vary from semi-translucent to pale straw-coloured, but *A. degenerans* are shiny black.
- Several species are available in culture packs, in which the predators continue to breed and gradually emerge onto plants.

Glasshouse and tobacco whitefly parasitoid

Eretmocerus eremicus

- The yellow female wasp (0.7 mm) lays an egg under the whitefly scale. After hatching, the larva penetrates the host.
- The parasitised scale eventually turns translucent yellow.
- The adult parasitoid can be seen within the scale during the latter stage of its development.
- *Eretmocerus* is usually a more effective parasitoid of tobacco whitefly than *Encarsia*, particularly at higher temperatures.

Glasshouse whitefly parasitoid

Encarsia formosa

- This small (0.6 mm) parasitic wasp is specific to glasshouse whiteflies.
- Eggs are laid in whitefly scales on the underside of leaves. The immature wasp develops inside.
- After a few days, the scale turns black (top right) and eventually one adult emerges, leaving a characteristic round emergence hole (bottom left).
- Supplied as black scales, either loose or attached to cards.

Liriomyza leaf miner parasitoid

Diglyphus isaea

- Adults (1–2 mm) are black wasps with short antennae.
- Females sting (top left) and immobilise *Liriomyza* larvae (top right).
- Eggs are laid within the mine. The immature wasp latches onto the miner (bottom left) and completes its development in that position.
- When fully grown, the immature wasp builds several ‘pit props’ and then forms a turquoise pupa (bottom right).

Liriomyza leaf miner parasitoid

Dacnusa sibirica

- Adults are larger (2–3 mm) than *Diglyphus* and have long antennae.
- Eggs are laid through the leaf and into the *Liriomyza* larvae where the immature wasps develop.
- Unlike *Diglyphus*, the leaf miner continues to feed and eventually emerges from the leaf to pupate.
- Confirm parasitism by dissecting *Liriomyza* larvae or waiting for adult wasps to emerge from *Liriomyza* pupae.

Orius bugs

Various species

- Several species are reared primarily for thrips control but also attack other pests, such as aphids and caterpillars. All species have similar appearance.
- Adults (2–3 mm) are strong flyers. Nymphs are similar in appearance to adults but without wings.
- Found wherever their prey are living on the plant.
- Breed particularly well on peppers, using pollen to supplement their diet.

Various species

- Species of spider mite predators include *Phytoseiulus persimilis, Neoseiulus californicus* and *Feltiella*.
- Adult *P. persimilis* (top left) are slightly larger than spider mites and distinctly pear-shaped. Eggs (top right) are pale pink, oval and twice as big as spider mite eggs.
- The larva of the predatory midge, *F. acarisuga* (bottom left), has no legs or discernible head.
- Fully grown *F. acarisuga* larvae pupate in cocoons (bottom right) on the underside of leaves.
- Typical *Neoseiulus* spp. predators are shown on page 2.1.

Diseases

BACTERIAL

FUNGAL

OOMYCETE

VIRAL

Bacterial canker

Clavibacter michiganensis ssp. *michiganensis*

- Bacterial canker can produce a range of symptoms depending on the type of infection. Systemic symptoms are more common these days.
- Systemic symptoms – a general wilting of the plant; leaves produce necrotic 'windows' as the disease develops. The interior of the fruit can also develop brown staining.
- External symptoms – spotting similar to 'ghost spot' but raised above the fruit surface and rough to the touch. Similar spots may appear on the leaves and stems.

Bacterial stem rots

Pectobacterium spp.




- Uncommon but can occur on cucumber.
- This bacterial problem is expected to increase in the UK with increases in temperature due to climate change.
- Only normally seen in mid-summer (when it is warm), but rapidly goes from first infection to plant destruction.
- Bottom-right image shows the complete disintegration of the stem tissue only a few days after the disease was first seen.

Crown gall

Rhizobium radiobacter

- Uncommon but can occur on cucumber, tomato and pepper.
- Can be seen on cucumber plants with or without root mat disorder – but producing a typical gall on the roots.

- On tomato and pepper can cause stem galls and is also seen on tomato trusses.
- Infected cucumber plants usually show severe magnesium deficiency (interveinal yellowing).

Root mat disorder (Crazy root)

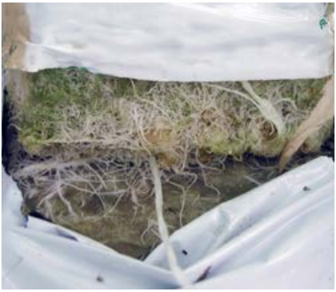
Rhizobium rhizogenes

- Affects cucumber and tomato. Is caused by the bacteria *Rhizobium rhizogenes.*
- Initial infection spreads quite slowly in infected water and may be seen as roots growing vertically out of the propagation cube.
- Root growth increases and masses of unbranched roots are produced, which may restrict water flow into the growing media.
- Foliage growth may also increase.

Thick root disorder

Rhizobium sp.






- Occurs in cucumber only.
- Most usual symptom is thickened roots at the cube base, at or shortly after planting. These often have an 'S' shape and may discolour.
- Close examination shows older roots to be swollen and younger roots to be 'fatter' than normal, possibly flattened.
- It is assumed that the disease is caused by *Rhizobium* sp. and introduced into the crop by planting infected plants.

Botrytis (Grey mould)

Botrytis cinerea

- Infects a wide range of crops, causing plant collapse where stem infection occurs. Grey or grey-brown spores usually seen quite rapidly after infection.
- On tomato, check inside damaged stems and trusses for fungal growth if not seen externally.
- Produces ‘ghost spot’ (bottom right) on the surface of tomato fruit where spores germinate then die off.
- Usually infects via a wound, e.g. leaf scorch or poor crop work, badly pulled or dying leaves or trusses.
- Surface wetness, warm temperatures and high humidities favour the disease.

Black root rot

Phomopsis sclerotioides

- Only occurs on cucumber – *Phomopsis* infection is normally first seen as a small lesion at the base of the stem but is not normally noticed until plants start to wilt.
- The wilting plant problem is often blamed on *Pythium*, but close examination of the roots shows the characteristic small black spots.
- Larger black lesions develop on the roots – these can cover large areas of root tissue.
- Infection comes from resting spores in the soil, especially at row ends where soil is easily exposed.

Cladosporium leaf mould (syn. Fulvia Leaf Mould)

Cladosporium fulvum

- Many modern varieties are resistant to this disease – some are not!
- An increasing problem that was very common on older varieties. Present again because of the use of 'heritage' varieties that have no resistance, but also because some new varieties do not have any resistance at all to the strains of *Cladosporium* present in the crop.
- First seen as slightly paler or discoloured spots on the lower leaves – when you turn the leaf over, you can clearly see the 'mildew-like' spore growth.
- If left untreated, the foliage will become necrotic (bottom right).

Fusarium wilt

Fusarium spp.

- Different *Fusarium* species affect cucumber, tomato and pepper (probably via seed).
- On cucumber and tomato, initial infection is seen at the stem base as a pink/orange fungal mat.
- Further infection sites can be anywhere on that plant or surrounding plants.
- Basal lesions on tomato are usually associated with adventitious root growth from the stem.
- On pepper, *Fusarium* can develop inside the fruit and is difficult to detect until opened. Dark brown lesions occur on pepper stems.

Mycosphaerella

Didymella bryoniae

- Only affects cucurbits.
- Initial infection produces a purple lesion that quickly dries to a papery/straw colour with black dots – these are the spore-bearing bodies that spread infection throughout the crop.
- Lesions often develop on the stem base where condensation occurs in the early morning or evening.
- Spores can also enter via dying flowers and surface damage, causing internal browning and rapid decay.

Penicillium stem rot

Penicillium oxalicum

- Only affects cucurbits.
- Not common on cucumber but seen occasionally. Kills the plant quickly when it occurs.
- Dense blue/grey fungal growth seen at the site of infection – usually low down on the stem at a node.
- Can spread rapidly in humid conditions.
- Dead tissue often rapidly colonised by *Botrytis*, thus masking the initial infection and making diagnosis harder.

Powdery mildew – cucumbers

Sphaerotheca fuliginea and *Golovinomyces orontii*

- Powdery mildew can develop at any time of year.
- Initial infection is usually on the upper leaf surface, but it can develop on the underside of the leaf, the stem and even the fruit.
- First signs are very small patches on the upper surface of the leaf.
- Initial infection is usually slower on mildew-tolerant varieties, but once infection has established, spread can be quite rapid.
- Where inoculum levels are high, the underside of the leaf is also quickly colonised.

Powdery mildew – peppers and tomatoes

Leveillula taurica, Oidium lycopersici and *Oidium neolycopersici*




- In peppers, the first signs of infection are the appearance of pale patches on the upper leaf surface, with spore development on the underside of the leaf. Infected leaves curl and prematurely fall from the plant.
- In tomatoes, initial infection is usually on the upper surface, but it can develop on the underside of the leaf, truss and stem.
- Initial infection is usually slower on mildew-tolerant varieties, but once infection has occurred, spread can be quite rapid.

Sclerotinia (White rot)

Sclerotinia sclerotiorum

- Able to attack any part of many plants – usually during warm conditions.
- Premature plant death is often the first sign of damage. Infection in tomato and pepper can show no external fungal growth. Black resting bodies (sclerotia) are found when the stem is opened.
- White fungal growth rapidly develops on cucumber and aubergine. sclerotia develop within the white fungal growth. The sclerotia survive in soil to reinfect subsequent crops.
- Initial infection may come from field crops such as OSR.

Verticillium wilt

Verticillium spp.

- Occurs on cucumber, tomato and pepper.
- First sign is usually a darkening of the plant head, but this is common to a range of diseases.
- Affected plants wilt, often only on one side of the plant, and the plant may recover overnight before wilting again the next day.
- Cutting into the stem shows brown vascular tissue.
- Roots are unaffected by this disease.
- If a plant wilts and has poor roots, then *Pythium*, *Phytophthora* or some other physiological condition may be the cause. Wilting plants and white roots indicate *Verticillium* as the cause.

Downy mildew

Pseudoperonospora cubensis

- A disease of the summer and early autumn on cucurbits only – spores blow in from outside crops.
- Small pale patches develop on the foliage that become clearly defined by the leaf veins.
- Spread within the crop is very rapid, especially if foliage is wet for any reason.
- Following the initial infection, there are few spores produced, but quite rapidly patches of dark brown spores develop on the underside of the leaf within the pale patches.
- Spores can only come from infected cucurbits but can move many miles. Effective crop disposal is important in preventing spread.

Phytophthora root rots

Phytophthora cryptogea

- Occur on tomato, cucumber and pepper. Affected plants have a purple or red foliage tinge, wilt quickly in bright conditions and grow slowly. Without lab diagnosis, impossible to distinguish from *Pythium* infection.
- Can be introduced on infected plants or picked up from infected soil.
- Can occur shortly after planting – check roots at the base of the rockwool cube at planting. In NFT systems, browning of the roots rapidly spreads down the channel. Also more noticeable at times of stress, such as truss eight setting on tomato (heavy load on a small root system).

Potato blight

Phytophthora infestans

- Becoming more of an issue with the production of resting spores – infections were normally later in the summer, but there is an increase in the disease at the start of the crop.
- Traditional autumn infection through the foliage (top left), but more recent stem base (rootstock and cultivar) infection (top right).
- Leaves, petioles and stems have dark necrotic patches and a pale downy fungal growth may be seen, which can spread rapidly in humid conditions.
- Bottom left shows stem infection from early foliar infection.
- Brown leathery lesions develop on the upper surface of green fruit.
- Fungal growth will also form on stems, foliage, fruits and calyx.

Pythium root and stem rot

Pythium spp.

- Affects cucumber, tomato and pepper. Infected plants can rapidly wilt and orange/brown root rot can be seen on all affected crops. Main symptoms are for cucumber plants.
- There may be visible fungal growth or stem lesions of *P. aphanidermatum* on the stem base of cucumber plants at delivery – check plants before delivery.
- Frequently introduced on new plants or from a localised infection in the old crop when inter-planting or replanting.
- Rapidly spread from plant to plant in hydroponic growing systems, especially at temperatures above 24°C.

Alfalfa mosaic virus (AMV)

Alfamovirus

- Occurs on tomato. Not very common, but can occur where aphids bring it into the crop or spread it in an infected crop.
- Necrotic patches seen in plant head, which spread through the plant and the whole head dies.
- Fruits develop blisters giving them a ‘boiled’ appearance, which can be a different colour to the rest of the fruit.

Beet pseudo-yellows virus (BPYV)

Crinivirus group

- Occurs on cucumber, causing leaf yellowing very similar to magnesium deficiency. There are no fruit symptoms. Also affects lettuce, producing similar leaf yellowing.
- Infection often occurs quite low down in the plant where infected whiteflies feed shortly after planting and transfer the virus to the crop.
- Can devastate affected crops when infection is severe.
- Introduced into the crop via infected glasshouse whitefly on imported plants and spread within the crop by whitefly.

Columnea latent viroid (CLVd)

Pospiviroid

- Occurs on tomato only, probably from seed infection. First sign is a reduction in growth, some leaf distortion and the heads turn pale. Leaf bronzing and reddening is also frequently seen.
- Leaf mosaic appears as they mature, with some necrotic patches. Plants rapidly run out of vigour. Affected plants may exhibit a thinning of stems.
- Symptom severity can vary within an affected crop as disease expression is affected by light intensity and temperature.

Cucumber mosaic virus (CMV)

Cucumovirus

- Occurs on many species, including cucumber, tomato, pepper and weeds such as chickweed and groundsel.
- Introduced and spread from plant to plant by aphids.
- Symptoms vary with the strain of virus – symptoms include distinct spots on leaves and fruit, mosaic leaf pattern or a netting pattern along leaf veins.

Cucumber green mottle mosaic virus (CGMMV)

Tobamovirus group

- Affects cucumber only. Plants infected in the first few days after planting often wilt.
- Produces dark green blisters on the youngest leaves, older leaves are usually symptomless. There are no fruit symptoms.
- Spread rapidly by hand and sap transfer between plants and through roots, affecting all plants in a growing module.
- Initial infection via infected seed or from existing on-site infection that has been overlooked.

Melon necrotic spot virus (MNSV)

Necrovirus group

- Affects cucumbers only, producing small necrotic patches anywhere on the leaf. There are no fruit symptoms.
- Necrotic patches can increase in size and number, affecting large areas of individual leaves.
- Weakened plants may succumb to other diseases such as *Pythium*.
- Infected water is the most common source of entry. Spread by *Olpidium* – a soil fungus that can infect inert growing media as well as soil.

Pepino mosaic virus (PepMV)

Potexvirus

- Can infect tomato and aubergine. However, only tomato exhibits symptoms.
- Symptoms are very variable and range from symptomless in some varieties, through small yellow spots to true yellow mosaic. Infected plants may have a 'nettle head' appearance.
- Fruit marbling is quite common, but some types, especially cherry types, show little or no fruit symptoms other than failure to fully ripen. Yield losses result through reduced vigour and poor fruit quality.
- Introduced in infected seed or by handling infected fruit/plants.
- Spread is very rapid by root contact or handling.

Potato spindle tuber viroid (PSTVd)

Pospiviroid

- Occurs on tomato and pepper. Mild strains may produce no obvious symptoms; severe strains produce variable symptoms depending on variety and environment.
- Symptoms appear to be more severe at temperatures above 25°C and when the 24-hour average is above 20°C.
- Leaves at the head of the plant turn yellow, curl and often have a purplish tinge. Main veins remain green. Leaves are smaller than normal and the plant becomes thin and stunted, producing ‘bunchy tops’.

Southern tomato virus (STV)

Amalgaviridae

- It is suspected that this virus is common in tomato crops but is undiagnosed because of the lack of foliar symptoms. It has been diagnosed on UK crops.
- As mentioned, there are, confusingly, no distinct foliar symptoms.
- Fruit symptoms are very similar to PepMV and ToBRFV – so any suspect plants must be checked out, if only to eliminate this from the possible cause.
- It does not spread within the crop.

Tomato brown rugose fruit virus (ToBRFV)

Tobamovirus

- This virus is a new major threat to the global tomato crop and is already widespread in Europe and elsewhere. It has been diagnosed in UK crops.
- Ensure any new arrivals of plants are thoroughly inspected, and where possible quarantined.
- Symptom expression varies with variety and increases with increasing temperature.
- Severe fruit symptoms are not always present but can include brown rugose patches and chlorosis.
- Leaves can develop mosaic patterning, become mottled and narrow and develop necrotic patches. Necrotic streaks can develop on stems.
- Symptoms are very similar to those of other viruses - if in doubt, test.

Tobacco necrosis virus (TNV)

Necrovirus group

- Affects cucumber only, producing small necrotic patches along the veins. There are no fruit symptoms.
- Necrotic patches increase in size and can affect large areas of individual leaves when large leaf veins are damaged. Stems, petioles and even tendrils are affected.
- Infected water is the most common source of entry. Spread by *Olpidium* – a soil fungus that can infect inert growing media as well as soil.

Tomato spotted wilt virus (TSWV)

Tospovirus

- Pepper fruit becomes distorted, with uneven ripening, ring spots, line patterns and necrotic patches. Leaf symptoms include mosaic, chlorotic or necrotic flecks and ring spots. Necrotic streaks appear on stems, extending to terminal shoots.
- Affects tomato, pepper and aubergine. Spread by Western flower thrips.
- Tomato leaves may have a yellow mottle, black rings, line patterns and necrotic spots. Young leaves curl slightly downwards and inwards and may be distorted. Brown spotting or bronzing of young leaves occurs mainly on the upper surface.

Tomato yellow leaf curl virus (TYLCV)

Begomovirus

- Tomato and pepper can be affected.
- Infected tomato plants are severely stunted, producing very small, yellow leaves and small fruit.
- Leaves often bend downwards, are stiff and have a leathery texture. There is an upward cupping and chlorosis of leaf margins on less severely affected plants.
- Introduced and spread by tobacco whitefly.

Nutrient disorders

CUCUMBER

PEPPER

TOMATO

Boron

B

- Foliage becomes very brittle and lower leaf tips become yellow – this develops into a broad cream margin as leaves age.
- The growing point may produce very small leaves or die out completely if the deficiency is severe.
- Fruit marking similar to 'Cold stripe' may also develop.
- Normal range: 30–80 µg/g.
- Deficiency: <20 µg/g.

Boron toxicity

B

- A narrow yellow leaf margin develops and rapidly becomes scorched – young leaves may become cupped.
- As the toxicity becomes severe, the veins near the leaf margin become pale yellow.
- The growing point may become white and die if the toxicity is severe.
- Normal range: 30–80 µg/g.
- Toxicity: >150 µg/g.

Calcium

Ca

- The margins of the youngest leaves become scorched and expanding leaves are cupped.
- This problem can be induced by restricted translocation.
- Normal range: 2–10% Ca.

Copper

Cu

- Leaf size is greatly reduced and older leaves develop interveinal yellowing. Mature leaves produce yellowing around the minor veins, producing a mottled appearance.
- The main veins, leaf margin and isolated interveinal areas remain green.
- Flowering is restricted and young fruit have small sunken brown areas over a pale skin.
- Normal range: 7–17 µg/g.
- Deficiency: <4 µg/g.

Iron

Fe

- The youngest leaves are completely yellow and reduced in size and may become almost white if not corrected.
- Fe deficiency is frequently induced during periods of stress or poor root growth (during rapid lateral development) or by root disease.
- Fe deficiency is very difficult to diagnose by leaf analysis – results are not conclusive.
- Deficiency: <80 µg/g.
- Severe deficiency: <40 µg/g.

Magnesium

Mg

- Interveinal yellowing develops on the middle and lower leaves and gradually progresses up the plant – symptoms may be confused with beet pseudo-yellows virus.
- The yellowing spreads across the leaf until only the main veins remain green.
- Normal range: 0.4–0.8% Mg.
- Deficiency: <0.3% Mg.

Manganese

Mn

- The margin and interveinal parts of the leaf become pale green then yellow.
- The finest veinal network remains green, compared with iron deficiency where it all goes pale.
- Mn deficiency can be induced during periods of stress, poor root growth or high pH in the growing media.
- Normal range: 100–300 µg/g.
- Deficiency: <20 µg/g.

Manganese toxicity

Mn

- Excess manganese produces reddish-black deposits in the veins of lower leaves.
- This deposit is also accumulated at the base of hairs (trichomes) on petioles and leaf lamina.
- Yellowing develops around the veins and spreads interveinally, leading to premature death of the leaf.
- Normal range: 100–300 µg/g.
- Toxicity: >900 µg/g.

Molybdenum

Mo

- Growth is restricted and leaves become pale green.
- Small pale yellow or white areas develop near the leaf margin.
- Lower leaves may wilt and die prematurely.
- Unlike other nutrients, molybdenum deficiency occurs at low pH rather than high pH.
- As Mo levels are very low normally, it is difficult to indicate deficiencies from leaf analysis.

Nitrogen

N

- Growth is restricted and fewer fruits develop.
- The leaves of deficient plants (left) are reduced in size and are pale green/yellow, compared with normal (right).
- Leaf analysis shows 2% N in deficient leaf and 5% N in normal leaf (leaf lamina only).
- Normal range: 3.5–5.5% N.
- Deficiency: <2.5% N.

Phosphorus

P

- Growth is severely restricted and random necrotic patches develop on maturing leaves.
- Leaf analysis examples shows 0.2% P (left) and 0.1% (right).
- Normal range: 0.35–0.8% P.
- Deficiency: <0.2% P.

Potassium

K

- Plant growth may not be severely affected but yield may be greatly reduced.
- Yellow margins develop on the expanding leaves and spread interveinally; these leaves tend to curl downwards.
- Fruit from potassium-deficient plants tend to be poorly developed at the proximal (stem) end.
- Normal range: 3–5% K (laminae); 12–16% K (petioles).
- Deficiency: <2% K (laminae); <10% K (petioles).

Zinc

Zn

- Growth can be severely restricted – leaves and internodes are reduced in the head.
- Petiole and tendril development is also restricted.
- Leaves become yellow/green, almost grey, except for the main veins which stay green.
- Normal range: 40–100 µg/g.
- Deficiency: <25 µg/g.

Zinc toxicity

Zn

- Interveinal areas become yellow/green.
- The entire veinal network becomes dark green, eventually becoming blackened – this helps distinguish this disorder from Mn deficiency.
- Normal range: 40–100 µg/g.
- Toxicity: >950 µg/g.

Boron

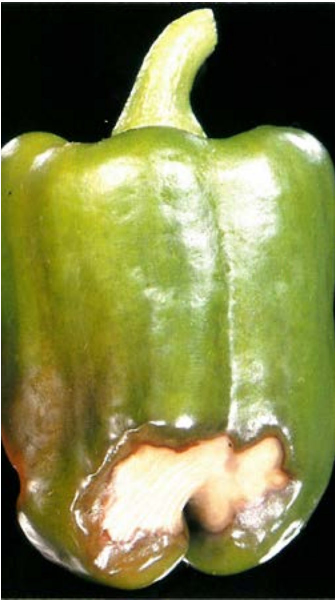
B

- New leaves of young plants become distorted.
- The most common symptom is the yellowing of tips on mature leaves, with red/brown deposits in the veins that are clearly visible when viewed with transmitted light.

- Normal range: 30–80 μg/g.
- Deficiency: <20 μg/g.

Calcium

Ca



- The margins of the youngest leaves become yellow.
- Fruit damage – blossom end rot appears, but this may also be physiological.
- High conductivity (EC) in the root zone and excessive levels of ammonium both increase the risk of blossom end rot.
- Normal range: 1.5%–3.5% Ca (leaf); 0.1%–0.2% Ca (fruit).
- Deficiency: <1.0% Ca (leaf); <0.08% Ca (fruit).

Copper

Cu

- Growth is restricted and leaf size is reduced, but leaves remain dark green.
- Leaf margins tend to curl upwards.
- Normal range: 6–20 µg/g Cu.
- Deficiency: <4 µg/g Cu.

Iron

Fe

- The youngest leaves are yellow/white and the leaf tips remain green at first as yellowing spreads from the leaf base.
- Iron deficiency is difficult to diagnose by leaf analysis.

- Normal range: 80–200 µg/g.
- Deficiency: <66 µg/g.

Magnesium

Mg

- Interveinal yellow/green chlorosis on mature leaves, although vein margins may remain darker green.
- Normal range: 0.35–0.8% Mg.
- Deficiency: <0.3% Mg.

Manganese

Mn

- The youngest leaves are bright yellow/green and small dark brown interveinal areas develop beginning near the tip.
- In severe cases, leaves will wither and drop.
- Normal range: 100–300 µg/g.
- Deficiency: <20 µg/g.

Manganese toxicity

Mn

- Excess Mn produces yellow/green areas on lower leaves and these gradually spread over the whole leaf, which will die prematurely.
- Normal range: 100–300 µg/g.
- Toxicity: >1,000 µg/g.

Molybdenum

Mo

- Leaves of seedlings in acid media become yellow and growth is restricted.
- Not common in substrate cropping.
- As Mo levels are normally very low, it is difficult to indicate deficiencies with leaf analysis.
- Unlike other nutrients, molybdenum deficiency occurs at low pH rather than high pH.

Nitrogen (Pepper)

N

- Growth is severely restricted and leaves are yellow/green.
- Lower leaves become yellow and die prematurely.
- Normal range: 3.5–5.5% N.
- Deficiency: <2.0% N.

Phosphorus

P

- Growth is severely restricted, but in contrast to N deficiency, the foliage remains green.
- Leaf margins tend to curl up and lower leaves die prematurely.
- Normal range: 0.3–0.8% P.
- Deficiency: <0.2% P.

Potassium

K

- Growth is restricted and small red/brown spots develop from the leaf tips.
- Interveinal and marginal yellowing may also develop on older leaves.

- Normal range: 3.0–6.0% K.
- Deficiency: <2.0% K.

Sulphur

S

- This deficiency is rare.
- Can be confused with N deficiency.
- Leaves become pale yellow/green and new leaves may be narrow and pointed.
- Normal level: 0.13% S.
- Deficiency: <0.04% S.

Zinc

Zn

- Dark green leaves develop small purple areas, randomly scattered interveinally; these areas become brown as they enlarge.
- Normal range: 40–100 µg/g.
- Deficiency: <25 µg/g.

Boron

B

- Yellowing of the tips of terminal leaflets is usually the first symptom. This can be induced by heavy fruit load.
- The yellowing will gradually spread over the whole leaf.
- Purple-brown deposits form in the main vein and can be easily seen with transmitted light.
- When severe, corky areas can develop near the calyx of the fruit.
- Normal range: 30–80 µg/g.
- Deficiency: <25 µg/g.

Boron toxicity

B

- Small brown spots which later enlarge and coalesce develop along the leaf margin and the calyx tips become scorched.
- Lower leaves become yellow and die rapidly as the symptoms spread up the plant.
- Normal range: 30–80 µg/g.
- Toxicity: >150 µg/g.

Calcium

Ca

- The margins of the youngest leaves become scorched and cupped.
- Fruit may develop blossom end rot – but this can also be caused by environmental problems.
- Normal range: 2–4% Ca.
- Deficiency: <1.0% Ca.

Copper

Cu

- The youngest leaves become dark and wilt – this may develop after frequent wilting into scorch.
- The margins of older leaves curl upwards and pale spots develop, firstly near the leaf tips.
- Flower buds fail to develop.
- Symptoms are rare but may resemble salinity damage.
- Normal range: 7–20 μg/g.
- Deficiency: <4 μg/g.

Iron

Fe

- The youngest leaves are completely yellow, reduced in size and may become almost white if not rectified.
- Fe deficiency is frequently induced during periods of poor root growth or disease.
- Fe deficiency is difficult to diagnose by leaf analysis – leaf analysis results are a poor indicator.
- Normal range: 80–200 µg/g.
- Deficiency: <60 µg/g.

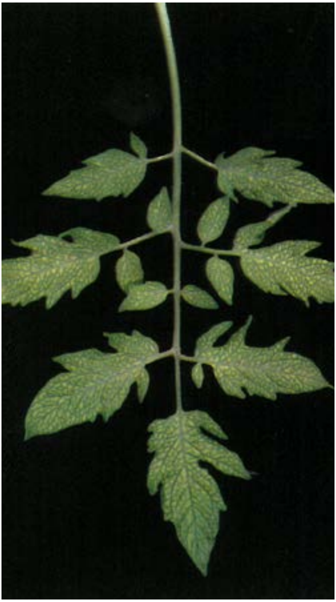
Magnesium

Mg

- Interveinal yellowing develops on the middle and lower leaves and gradually progresses up the plant.
- The yellowing spreads across the leaf until only the main veins and leaf margin remain green.
- Normal range: 0.35–0.8% Mg.
- Deficiency: <0.3% Mg.

Manganese

Mn



- The margin and interveinal parts of the leaf become pale green then yellow.
- The finest veinal network remains green.
- Mn deficiency can be induced during periods of poor root growth, rapid foliage growth or high pH in the growing media.

- Normal range: 100–300 µg/g.
- Deficiency: <25 µg/g.

Manganese toxicity

Mn

- Excess Mn produces reddish-black deposits in the veins of lower leaves.
- Yellowing develops around the veins and spreads interveinally, leading to premature death of the leaf.
- In severe cases of Mn toxicity, spots develop on the stem and petioles and calyx tip scorch also occurs.
- Normal range: 100–300 µg/g.
- Toxicity: >1000 µg/g.

Molybdenum

Mo

- Growth is slightly restricted and leaves become yellow-green.
- The older leaves develop a pale yellow margin which spreads interveinally.
- The margins may become almost white or very pale brown.
- Unlike other nutrients, molybdenum deficiency occurs at low pH rather than high pH.
- Normal range: >0.4 µg/g.
- Deficiency: <0.3 µg/g.

Nitrogen

N

- Growth is restricted and leaves of deficient plants are reduced in size and are pale green/yellow compared with normal.
- Areas of purple pigmentation may also develop before premature death of lower leaves.
- Normal range: 3.5–5.0% N.
- Deficiency: <2.5% N.

Phosphorus

P

- Growth is severely restricted and undersides of leaves become purple and may die prematurely.
- Purpling can also appear when plants are cold or when N deficient.
- Small necrotic areas develop interveinally on older leaves.
- Normal range: 0.35–0.75% P.
- Deficiency: <0.2% P.

Potassium

K

- Fruit ripens unevenly (blotchy ripening), but this symptom can also have other causes.
- Yellow margins develop on the expanding leaves and these areas scorch easily.
- This marginal yellowing can develop interveinally if the deficiency persists.
- Normal range: 3.5–6.3% K.
- Deficiency: <2.5% K.
- Severe deficiency: <1.0% K.

Zinc

Zn

- Leaflets become curled downwards and inwards.
- The main vein remains green, but interveinal areas become yellow.
- Brown areas develop near the midrib and main veins and on the petioles.
- Normal range: 35–100 µg/g.
- Deficiency: <20 µg/g.

Zinc toxicity

Zn

- Growth is restricted and becomes spindly.
- Interveinal yellowing develops on the leaflets, while the petioles and underside of the veins become purple.
- The smallest leaflets may remain partly unfolded.
- Normal range: 35–100 µg/g.
- Toxicity: >250 µg/g.

Cultural disorders

CUCUMBER

PEPPER

TOMATO

Burned heads




- Images show progression of burned ends. Healthy (top left); tightening (top right); going – further tightening (bottom left); gone (bottom right).
- Caused by poor water movement in the early stages of establishment – confusingly, this can be caused by both high and low humidity.
- Note that the pointed tip of the leaf is the first part to be reduced and is a good indicator of damage to come.

Calcium leaf scorch – low levels

- Frequently caused by poor water movement in the plant (transpiration), rather than by actual deficiency of calcium. Improve ventilation and provide sufficient irrigation.

Chimera

- This is caused by a genetic change in the tissues that leave some areas with less green pigment, producing a range of leaf and fruit symptoms.
- Left side shows severe chimera, where much of the tissue containing the chlorophyll has gone. Right side shows the same problem, just less severe 'silvering'.
- Remove affected shoots or whole plants to prevent affected fruits developing.

Cold stripe

- Normally caused when cold, damp stem fruits are rapidly dried by bright sunlight – hence the name. It can also be caused by excessive root pressure.

Fasciation

- The plant appears to produce multiple stems fused together.
- This a genetic abnormality and will not spread within the crop.
- Remove any affected plants.

Guttation

- Too much water applied and too little to do with it – the plant can 'eject' water through hydathodes on the leaf edges, clearly seen here.
- Usually occurs when a dull day follows a bright day – where too much water becomes available the following morning.

Leaf scorch

- Caused by poor water movement in the plant, especially when light levels increase rapidly from dull to very bright in the mornings.
- Shade when needed on young crops and on mature crops when radiation levels are high (>600 W/m^2).

Root pressure




- Caused by excessive root pressure – this is an increasing problem with newer cultivars and is difficult to balance the need for enough water without having excess.
- ‘Snot’ dripping from fruit wounds or directly out of the lower part of the fruit.
- Raised area on the leaf – usually caused when fruit load is low.

Blossom end rot

- Frequently caused by poor water movement in the plant, rather than by actual deficiency of calcium.
- Improve ventilation and provide sufficient irrigation. High conductivity (EC) in the root zone and excessive levels of ammonium both increase the risk of blossom end rot.

Chimera

- This is caused by a genetic change in the tissues that leave some areas with less green cells, producing a range of leaf and fruit symptoms.
- Remove affected leaves or plants.

Excess vigour

- This is not common but can be seen on some cultivars when excess vigour allows continued development of fruit tissue inside the maturing fruit.

Fruit – gold speckle

- Caused by an imbalance of calcium in the fruit.
- Crystals of calcium oxalate puncture the cells near the surface of the fruit, producing the light flecking.

Blossom end rot

- Frequently caused by poor water movement in the plant, rather than by actual deficiency of calcium.
- Improved environment will stimulate transpiration and move calcium to the distal end (base) of the fruit.
- High conductivity (EC) in the root zone and excessive levels of ammonium both increase the risk of blossom end rot.

Calcium leaf scorch

- Frequently caused by poor water movement in the plant, rather than by actual deficiency of calcium. Improve ventilation and provide sufficient irrigation for good water movement in the plant.

Cat face (Corky stylar scar)




- A problem where the stylar (flower) end of the fruit is damaged at, or soon after, pollination.
- It is more often seen on larger fruiting cultivars with numerous locules (all the illustrations are of beefsteak types).
- Low temperatures and vigorous growth seem to play a part, as the problem tends to be more of an issue with unheated crops.

Chimera (Silvering)




- This is caused by a genetic change in the actual tissues that leave some areas with less green cells, producing a range of leaf and fruit symptoms.
- Symptoms can be very similar to virus symptoms – be very sure before you dismiss this.
- Remove affected leaves or plants.

Foliage – CO_2 toxicity

- Excess CO_2 results in leaf bleaching; this image shows damage caused by a malfunction in the control system, resulting in CO_2 levels being very high.

Foliage – herbicide damage

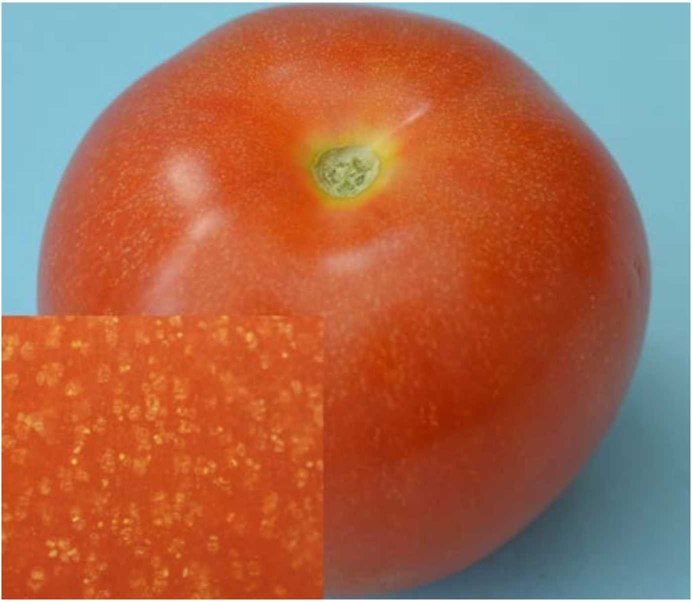
- Symptoms vary with the type of herbicide involved.

- Damage from hormone or translocated weedkillers is quite common because only very low levels are needed to produce severe symptoms in tomato.

Fruit disorders

- Red/Greens (top left) – fruits that are ripening out of sequence because of issues with flower development/pollination.
- Ring cracking (top right) – irrigation problems, resulting in outer skin maturing but the internal tissue continues to grow.
- 3. Chimera (bottom left).
- 4. 'Extra bits' (bottom right).
- All caused by environmental or genetic issues.

Fruit – gold speckle



- Caused by an excess of calcium in the fruit – the excess calcium reacts with natural oxalic acids in the fruit.
- Crystals of calcium oxalate form inside the cells and puncture the cell walls near the surface of the fruit, allowing air to enter, producing the light flecking.

Stem – vigour

- Some cultivars produce stem damage – bifurcation (splitting) and lesions below leaves, especially where there is excessive vigour.
- This is especially a problem with grafted plants during the establishment phase of the crop.

References

Acknowledgements

AHDB Horticulture is very grateful to Dr Rob Jacobson and Derek Hargreaves for writing this Protected Edibles Crop Walkers' Guide.

Our gratitude also goes to Phil Morley (APS Group Director of Agronomy), for technically reviewing this publication, and to the following people: Adrian Fox (Senior Virologist, Fera), Joe Ostaja-Starzewski (Entomology Diagnostics Team Leader, Fera), Dr Paul Beales (Mycologist, APHA), and Andy Aspin (Senior Plant Bacteriologist, Fera), for technically editing previous versions of this publication.

Photographic credits

Section 1 – Pests

All images are copyright of Dr Rob Jacobson, except the below, which are copyright to the following:

1.1 (top left and top right) © University of Warwick
1.2 (all images) © University of Warwick
1.3 (bottom right) © University of Warwick
1.4 (top left) © David R Lance, USDA APHIS PPQ, Bugwood.org; All other images © Gary Bernon, USDA APHIS, Bugwood.org
1.6 (bottom left and right) © University of Warwick
1.7 (all images) © Derek Hargreaves
1.9 (top left and top right) © University of Warwick
1.10 (top left, top right and bottom left) © University of Warwick
1.11 (top left and right) © Syngenta Bioline
1.14 (all images) © University of Florida
1.15 (top left) © Dupont
1.16 (all images) © Derek Hargreaves
1.18 (top left and top right) © University of Warwick
1.19 (bottom left) © Derek Hargreaves
1.20 (top left, bottom left and bottom right) © University of Warwick
1.21 (all images) © BCP Certis

Section 2 – Beneficials

All images are copyright of Dr Rob Jacobson, except the below, which are copyright to the following:

2.1 (all images) © University of Warwick b4
2.2 (top right and bottom right) © University of Warwick
2.4 (top left and bottom right) © University of Warwick
2.5 (all images) © Koppert UK Ltd
2.6 (all images) © University of Warwick
2.7 (top left) © University of Warwick; (bottom left) © Dr Ricard Greatrex
2.8 (all images) © University of Warwick
2.9 (top left and bottom left) © University of Warwick; (bottom right) © Koppert UK Ltd

2.10 (bottom left) © University of Warwick;
(bottom right) © Koppert UK Ltd

2.11 (top) © University of Warwick

2.12 (all images) © University of Warwick

2.13 (all images) © University of Warwick

Section 3 – Diseases

All images are copyright of Derek Hargreaves, except the below, which are copyright to the following:

3.11 (bottom right) © Tim O'Neill (ADAS)

3.17 (all images) © Martin McPherson

3.27 (top right and bottom right) © Central Science Laboratory

3.30 (top right and bottom right) © Aviv Dombrovsky

3.31 (top left, bottom left and bottom right) © Tim O'Neill (ADAS)

3.32 (left and bottom right) © Central Science Laboratory;
(top right) © Gerry Hayman

Section 4

All images are copyright MAFF/AFRC (1987) – Diagnosis of Mineral Disorders, Vol 3 Glasshouse Crops, TSO

Section 5

All images are copyright of Derek Hargreaves

Produced for you by:

AHDB Horticulture
Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

T 024 7669 2051
E comms@ahdb.org.uk
W ahdb.org.uk
@AHDB_Hort

If you no longer wish to receive this information, please email us on **comms@ahdb.org.uk**

30016 1122