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MINISTRY FOR AGRICULTURE,
FISHERIES AND ANIMAL RIGHTS

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TOMATOES PRODUCTION FOR PROCESSING INTEGRATED PEST MANAGEMENT GUIDELINES

Agriculture Directorate

AgriConnect

Agriculture Research & Innovation Hub

March 2023

PLANT PROTECTION PRODUCT AUTHORISATION

Plant protection products (PPPs) need to be authorised by the MCCAA before they are placed on the Maltese market in accordance with the provisions of Regulation (EC) No. 1107/2009 implemented in Malta through Subsidiary Legislation S.L. 430.07, Plant Protection Products (Implementation) Regulations, issued under the Pesticides Control Act (Cap. 430).

A list of authorised PPPs can be found on the MCCAA website: https://mccaa.org.mt/Section/Content?contentId=1158

It is the legal obligation of all farmers and professionals making use of PPPs to consult the list prior to the purchase or application of any products to ensure their authorisation, even if they are listed in this publication. One can contact AgriConnect for further assistance.

For PPPs listed in this publication but currently not yet authorised, the Agriculture Directorate encourages farmers, farmer representatives and commercial entities to contact AgriConnect for information and assistance in the authorisation process of products containing such substances.

Colour code for substances listed in this guideline:

- Authorised for use in the Maltese Islands.
- Can be authorised for use.
- Organic
- Beneficial insect

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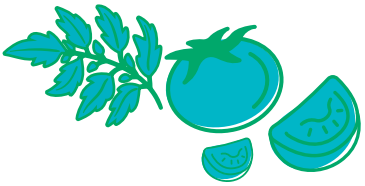


Late Blight

Phytophthora infestans

Late blight, also known as downy mildew, is an infection caused by a water mould (also known as oomycete), which is a fungal-like microorganism. Late blight negatively impacts both tomatoes and potatoes, and devastates harvests, with a high probability of total crop loss if unmanaged.

The pathogen affects all above-ground parts of the susceptible plants at any stage of plant development, including the leaves, the stems and the fruit. Infections occur with a long duration of wetting conditions, followed by relative humidity of over 90% and temperatures between 10°-28°C.

Symptoms include chlorotic spots and lesions on the underside of leaves (2-10mm) that turn brown and become necrotic. Stems and branches also exhibit dark necrotic spots, affecting the phloem and the xylem, which lead to foliar drying and vegetative death. White sporulation may be visible in humid weather. On tomato fruit, symptoms include dark brown, firm lesions, often followed by soft rot. The pathogen survives mainly as mycelium on crop residue. The spores of the fungus can spread to neighbouring plants by wind.

Control and Management

Agronomic Interventions

- Make use of certified-healthy seeds or seedlings.
- Avoid instances of waterlogged soil and maintain irrigation to a minimum.
- Ensure a well-balanced fertilisation regime.
- Diseased plants and/or debris should be removed from the field and destroyed.
- Before the planting of the new crop, soil solarization or soil disinfection is suggested, especially if this pathogen was detected in preceding crops.
- Apply mulching between the soil and the plant.

Chemical Interventions

- Apply preventive contact fungicides to prevent the development of fungal infections, particularly during meteorological conditions which promote the development of such infections.

In prevalent high humidity conditions coupled with the first signs of fungal infection (within maximum 3 days), apply products with preventive, antisporulant and curative action or products with curative activity and prolonged persistence.

PLANT PROTECTION SUBSTANCES

- Copper-based products (1)
- Cymoxanil (2)
- Cyazofamid (4)
- Metalaxyl-M (6)
- Oxathiapiprolin (6)
- Ametoctradin (9)
- Metiram (6)
- Propamocarb
- Azoxystrobin (3)
- Amisulbrom (4)
- Fosethyl Aluminium (5)
- Fluazinam (7)
- Dimethomorph (8)
- Zoxamide (10)
- Mandipropamid (8)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

General Conditions

(1) No more than two different active substances can be used in mixtures of fungicides simultaneously for each adversity. Products which are excluded from this limitation are Copper-based products, Fosethyl Aluminium, and all other organic products.

(2) For each active substance, only one commercial formulation can be used. The use of different formulations with the same active substance is only permitted for the consumption of old stocks or in the case where procurement of compounds is limited.

(3) In the latter scenario, the global limit and maximum quantity of the active substance must be abided by regardless.

Specific limitations

(1) Higher permitted limit of 28kg/ha in 7 years. It is advisable to not exceed the average of 4kg/ha of Copper per year over the duration of crop production.

(2) It is recommended to apply this mixed with other active ingredients. Apply a maximum of three interventions per cultivation period from the same chemical group (Fosethyl Aluminium and Cymoxanil).

(3) At most, apply not more than twice per growing season.

(4) Apply a maximum of three interventions per growing season between cyazofamid and amisulbrom.

(5) Apply the product until the flowering of the second cluster.

(6) Apply not more than three times per cultivation season.

(7) Maximum of two interventions during the cultivation season.

(8) Maximum of four interventions per growing season, from substances (Dimethomorph and Mandipropamid) from the same mode of action group (H5).

(9) If applied on its own, a maximum of three interventions are allowed per cultivation period.

(10) Do not exceed four interventions per cultivation period.

Underside of leaf showing sporulation [1]

Tomato late blight stem lesion [2]

Damage to the fruit [3]

Alternaria

Alternaria spp.

Alternaria, also known as early blight, is caused by a fungal pathogen that can affect leaves, stems and fruit, reducing the overall yield and quality. Symptoms appear on leaves as dark brown/black lesions that can be circular or irregular on the older (lower lying) leaves.The lesions have a 'target spot' appearance due to the alternating concentric rings ranging from light tan to dark brown tissue. As the disease progresses, multiple lesions may coalesce and, once infection becomes severe, leaves drop prematurely. Symptoms on stems are similar to those on the leaves exhibiting lesions that turn brown, sunken and dry. Fruits are also affected at any stage of maturity, exhibiting brown or black, leathery and depressed lesions.

The fungus can survive in the soil, on crop residue and seeds. It can also survive from one season to another on plants belonging to the Solanaceous family, such as aubergines, pepper, potatoes, black nightshade and others.

The infection occurs due to conidia dispersed via rain or irrigation when temperatures are between 6°C and 34°C. The fungus can enter through the plant surface from the cuticle or stomata, and can also enter from damage or wounds on the plant. Once it enters, it can invade the tissue and symptoms (lesions) may start to appear from two to three days after the initial infection. Then it can be spread by wind, rain and after spray watering. It can also spread through seeds and by workers.

Ideal conditions for this fungal pathogen to develop include a relative humidity of 90% or higher, and temperatures between 18°C and 30°C. Other factors which aid the development are dew, low ongoing rainfall (5mm), sprinkler irrigation, stressed plants, poor fertilisation, or plants which are laden with fruits.

Control and Management

Agronomic Interventions

- Make use of certified-healthy seeds or seedlings.
- Practice extensively crop rotation for 3 to 4 years with crops such as cereals, sweet corn, etc. It is also important to eliminate host weeds during the crop rotation.
- Avoid instances of waterlogged soil, and maintain irrigation to a minimum.
- Ensure a well balanced fertilisation regime.
- Before the planting of the new crop, soil solarisation or soil disinfection is suggested, especially if this pathogen was present in previous crops.
- Apply mulching as barrier between the soil and the plant.

Chemical Interventions

- Normally, the application of specific active substances against this disease is not necessary in view that anti-peronospora contact-type products are active against this adversity.
- When severe episodes of infestations are detected and especially within zones which are humid, it is advisable to intervene chemically at the onset of the first symptoms. Repeat the procedure, if necessary, every 8-10 days or after heavy rainfall.
- Plant protection products should be applied during the day in order to allow the plants to dry and not moisten for a long period.

PLANT PROTECTION SUBSTANCES

- Copper-based Products (1)
- Azoxystrobin (2)
- Fluxapyroxad + Difenoconazole
- Cyflufenamid
- Zoxamide (3)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

General Limitations

(1) No more than two different active substances can be used in mixtures of fungicides simultaneously for each adversity. Products which are excluded from this limitation are Copper-based products, Fosethyl Aluminium and all other organic products

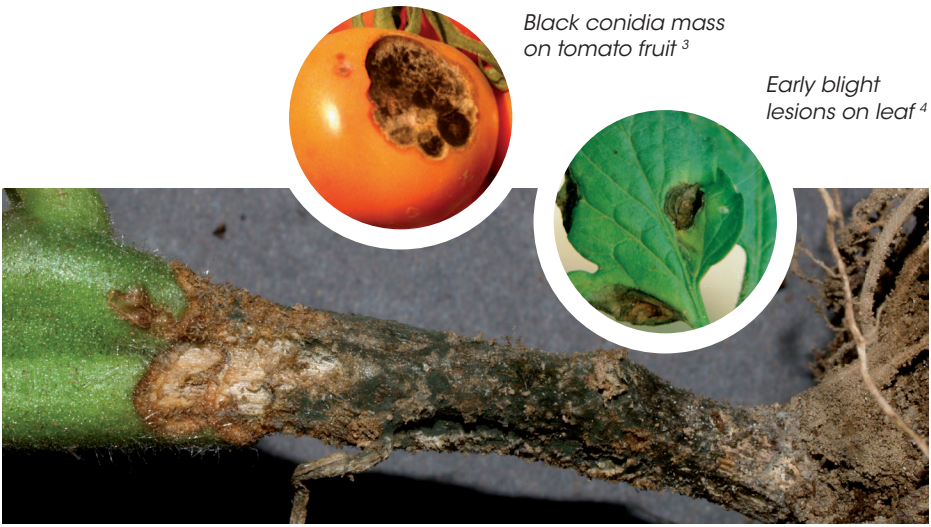
(2) For each active substance, only one commercial formulation can be used. The use of different formulations with the same active substance is only permitted for the consumption of old stocks or in the case where procurement of compounds is limited. In the latter scenario, the global limit and maximum quantity of the active substance must be abided by regardless.

Specific Limitations

(1) Highest permitted limit of 28kg/ha in 7 years. It is advisable to not exceed the average of 4kg/ha of Copper per year over the duration of the crop production

(2) At most, apply not more than twice per cultivation period.

(3) Apply a maximum of four applications per cultivation period.



Black conidia mass on tomato fruit [3]

Early blight lesions on leaf [4]

Canker at the base of plant, blackish growth of Alternaria conidia [5]

Septoria leaf spot

Septoria lycopersici

Septoria leaf spot is caused by a fungus pathogen that can affect the plant at any stage of development. Symptoms commonly develop on leaves but can also occur on the petioles, stems and calyxes. Small, water-soaked spots of around 2mm-6mm start developing on older and lower leaves. The lesions gradually become grey or tan in colour with brown margins. Since there are many of these spots, as they enlarge they sometimes coalesce. Numerous, dark brown, pimple-like pycnidia (the asexual fruiting body of the fungus) are sometimes visible in the centre of the lesions. As the disease progresses, affected leaves turn yellow, shrivel and drop prematurely.

Infections develop in temperatures between 15°C and 28°C. Pathogen favours wet and humid conditions. Infections occur by conidia that mainly spread through rain, irrigation, wind or handling of plants.

Control and Management

Agronomic Interventions

- Always ascertain the use of certified-healthy seed.
- Practice crop rotation.
- Avoid instances of waterlogged soil and maintain irrigation to minimum.
- Carry out irrigation during the day to allow time for the soil to dry quicker.
- Use plastic mulch as barrier between the soil and the plant.
- Try to avoid carrying out work when the vegetation is wet.
- Weeds, such as black nightshade (*Solanum nigrum*), carolina horse- nettle (*Solanum carolinense*), longleaf groundcherry (*Physalis subglabrata)*, and Jimsonweed (*Datura stramonium*) that may harbour the fungus should be removed from the field.
- Infected plant debris should be disposed of, preferably burned.

Chemical Interventions

- Normally, the application of specific active substances against this disease is not necessary in view of the fact that anti-Peronospora contact-type products are active against this adversity.
- When severe episodes of infestations are detected, and especially within zones which are prone to humid conditions, it is advisable to intervene chemically at the onset of the first symptoms. If necessary repeat the procedure every 8-10 days.

PLANT PROTECTION SUBSTANCES

- Copper-based Products (1)
- Azoxystrobin (2)
- Difenoconazole (2)
- Metiram

LIMITATIONS OF USE AND SPECIAL CONDITIONS

General Limitations

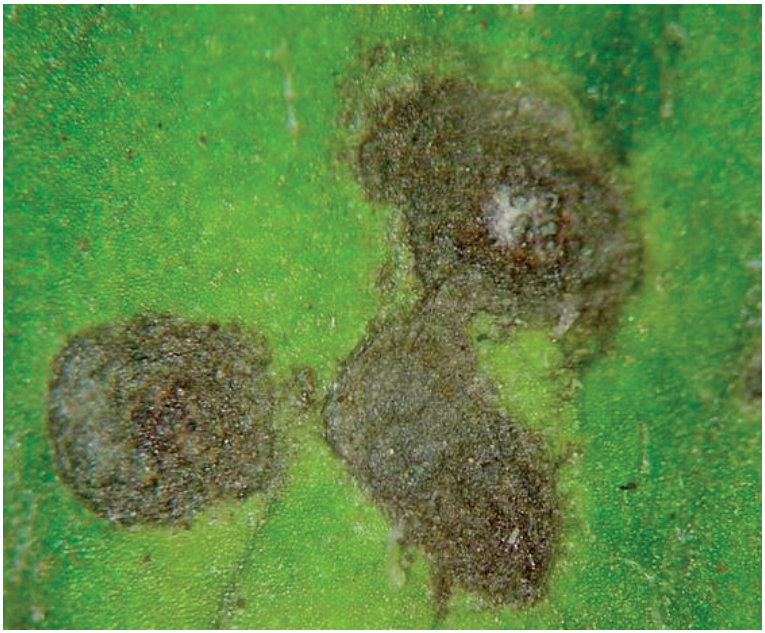
(1) No more than two different active substances can be used in mixtures of fungicides simultaneously for each adversity. Products which are excluded from this limitation are Copper-based products, Fosethyl Aluminium and all other organic products.

(2) For each active substance, only one commercial formulation can be used. The use of different formulations with the same active substance is only permitted for the consumption of old stocks or in the case where procurement of compounds is limited. In the latter scenario, the global limit and maximum quantity of the active substance must be abided by regardless.

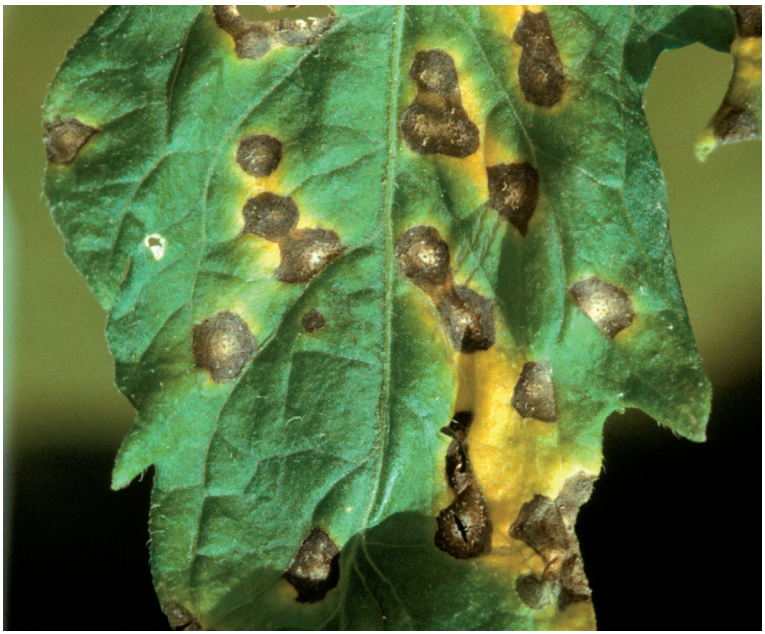
Specific Limitations

(1) Highest permitted limit of 28kg/ha in 7 years. It is advisable to not exceed the average of 4kg/ha of Copper per year over the duration of crop production.

(2) At most, apply not more than twice per growing season.



Leaf spot symptoms [5]



Close-up of lesions with pycnidia

Powdery mildew

Leveillula taurica, Erysiphe spp.

Powdery mildew is caused by fungal pathogens that develop under favourable conditions of high humidity on dry plant tissue. In the early stages of infection, pale green spots appear on the upper side of the lower leaves. The lower leaves are often infected first, with symptoms moving up the plant to the upper leaves. White/grey sporulation that looks like powder on foliage may be observed. Severe infections may result in leaf deformity. As the disease progresses, the leaves turn brown, shrivel and die off. The stems and the petioles may become infected, but not the fruit.

The spores of the fungus can be easily transmitted through wind and by agricultural operators.

The main climatic conditions that are favourable for the development are temperatures around 26°C and relative humidity of about 70% to 80%, although infections have been also recorded in temperatures of 10°C to 33°C. Another factor which may lead to the development of this fungus is a combination of warm and dry days with cool and humid nights. The presence of dew on leaves is also another factor which may promote development of this fungus.

Close-up of diseased leaf[1]

Powdery mildew on leaves[1]

Control and Management

Agronomic Interventions

- Once symptoms are noted, immediately remove first leaves and place them directly in a plastic bag to avoid or minimise the dissemination of the spores. These, then, should be sealed and destroyed.
- It is important to follow basic hygienic measures, such as limiting the number of visitors to minimize risk of fungus dissemination.
- Unwanted crops and weeds which can harbour the fungus should be removed from the field or greenhouse.

Chemical Interventions

With the exclusion of Sulphur products, intervene only at the detection of the first signs of infection. It is important to ensure full coverage of the lower leaves and also of the underside of the leaves. Repeat intervention every 8 to 10 days, particularly when the climatic conditions promote the emergence of the pathogen concerned.

PLANT PROTECTION SUBSTANCES

- Sulphur
- *Bacillus amyloliquefaciens* (1)
- Tebuconazole (2)
- Tebuconazole (2) + Azoxystrobin (3)
- Difenoconazole (2)
- Tetraconazole (2)
- Penconazole (2)
- Azoxystrobin (3)
- Bupirimate (4)
- *Ampelomyces quisqualis*
- Cos-Oga
- *Bacillus pumilus*
- Cyflufenamid (5)
- Metrafenone (5)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

General Limitations

(1) No more than two different active substances can be used in mixtures of fungicides simultaneously for each adversity. Products which are excluded from this limitation are Copper-based products, Fosethyl Aluminium, and all other organic products.

(2) For each active substance, only one commercial formulation can be used. The use of different formulations with the same active substance is only permitted for the consumption of old stocks or in the case where procurement of compounds is limited. In the latter scenario, the global limit and maximum quantity of the active substance must be abided by regardless.

Specific Limitations

(1) Do not exceed six interventions per cultivation period.

(2) A maximum of two interventions per cultivation period from active substances that are from the same mode of action group; G1 (Tebuconazole, Difenoconazole, Tetraconazole and Penconazole).

(3) At most, apply not more than twice per growing season. Between Tryfloxistrobin and Azoxystrobin apply not more than three times per cultivation period.

(4) Do not exceed two interventions per cultivation period.

(5) Do not exceed two applications per cultivation period from active substances that are from the same mode of action group; U (Cyflufenamid and Metrafenone).

Damping-off and root rot

Pythium spp., *Phytophthora* spp.

The fungal pathogens *Pythium* spp. and *Phytophthora* spp. cause damping-off, root and basal rot in tomato plants. Damping-off is a term that refers to the death of seedlings before or after emergence generally under favourable conditions – wet soils, especially if water-soaked, and cool temperatures. Damage can also be caused throughout the production cycle of the plant. Affected seedlings exhibit dark stems with shrivelling at the soil line and seedlings yellowing and dying off. Pathogens may have a negative impact on the root system of the plant, as less nutrients and water are available for absorption. The pathogens can also affect the plant at a later stage in development in the form of root rot. Symptoms include the formation of brown lesions on young roots that spread, affecting the whole root system, leading to necrosis of the roots.

Sometimes, the rot can be seen at the crown once it turns a brown or black colour. Eventually, the foliage may start senescence, and wilting of the plant occurs. Symptoms can occur on the fruit, such as blossom-end rot and, in some situations, also reduction in the fruit size.

Lesion on the lower stem [1]

Damping-off symptoms showing area of seedlings not emerging [7]

Control and Management

Agronomic interventions

- Always ascertain the use of certified-healthy seed.
- Practice crop rotation extensively and, if possible, include cereals and forage crops.
- Avoid instances of waterlogged soil and maintain irrigation to minimum.
- In case of clay-rich soils, maximise input of soil organic matter.
- Ensure a balanced fertilisation regime to reduce plant stress.
- If the pathogen was already detected in the preceding crops, the practice of soil solarisation or fumigation is suggested.
- Plant tomatoes with plastic mulch on ridges to avoid water retention.
- Use drip-type irrigation when possible.

PLANT PROTECTION SUBSTANCES

- Propamocarb
- *Trichoderma asperellum* (1)
- *Pythium oligandrum* Strain M1 (2)
- *Trichoderma gamsii* (1)
- *Trichoderma atroviride* (3)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Allowed only when used for foliar treatments in open field.

(2) Allowed only against *Pythium*.

(3) Do not exceed five interventions per cultivation period.

Brown root rot/corky root

Pyrenochaeta lycopersici

Brown root rot, or corky root rot, is caused by the fungal pathogen *Pyrenochaeta lycopersici*. The disease occurs mainly in protected cultivation, since in open fields it is hindered by crop rotation. The roots of infected plants are distinctly corky, with extensive brown lesions appearing as bands around the roots that progressively become dry and may crack.

Above ground, the affected plants show stunted growth and slow development, while older plants exhibit withering and dieback of leaves. The pathogen has an optimum development with soil temperatures around 15°-20°C. The fungus survives in the soil or plant tissue as microsclerotia.

Control and Management

Agronomic interventions

- Plant varieties which are known to be resistant against this adversity.
- Practice crop rotation extensively.
- Eliminate any diseased plants, including the roots, from the field and destroy as appropriate.
- Parcels which have impacted heavily from past infestations should be disinfected before planting the new crop. This can be done by soil fumigation or soil solarization or pasteurization.

Symptoms of brown root rot [8]

Fusarium and Verticillium wilt

Fusarium oxysporum f.sp. *lycopersici*, *Verticillium dahliae*, *Verticillium albo-atrum*

Fusarium and Verticillium wilt are caused by fungal pathogens that yield similar symptoms in tomato plants. Both wilts occur more commonly during warmer weather, with optimum temperatures of Fusarium wilt being 27°-30°C, while that of Verticillium wilt is slightly lower at 23°-25°C. Symptoms of both diseases include slight wilting of the plants, especially during hot parts of the day. Fusarium wilt also results in yellowing, wilting, and dying of the lower leaves, commonly on one side of the plant.

Fusarium wilt also causes a cancer to develop at the base of the stem. This cancer is initially dark brown, as the infected tissue becomes recessed. Usually, the cancer develops longitudinally on the side of the stem, in the form of a flame that sometimes can reach up to 30cm within the stem from the base. Normally the central part of the cancer is salmon-pink colour.

As the disease progresses, browning of the vascular bundle may be observed by dissecting the stem lengthwise. Browning and necrosis occur also in the root of the plant. Plant growth is stunted and plant death may occur. Verticillium wilt exhibits similar symptoms, but yellowing is uniform. Early symptoms may also include V-shaped discolouration between the veins and the leaf margins. Affected plants usually survive, but undergo considerable vegetative decay, while their berries remain small and mature early. Verticillium wilt will not lead to the death of the plant. On the contrary, Fusarium may lead to the death of the plant. Although Verticillium may not cause the death of the plant it will lead to crop losses and, eventually, reduced yields.

Both pathogens are soil-borne and can be present in the soil for numerous years through crop residues containing the mycelium, micro and macro conidia, and chlamydospores of these pathogens. They can also spread from different host plants, both cultivated plants as well as weeds. Some of the host plants include Solanaceae (pepper, potatoes and eggplants) and weeds, such as Black nightshade and Pigweed. The disease can also be spread through transplants.

Control and Management

Agronomic interventions

- Plant varieties which are known to be resistant and tolerant against this adversity.
- Destroy any plants and vegetative residue which has been infected, and avoid contact with other crops. These should be destroyed not buried in the soil. If the plant cannot be burned, because it is still not dry enough, it should be placed in a plastic bag or covered well to form a mechanical barrier.
- Tools such as boxes, tractors, implements and hoes should be disinfected if used in areas where these pathogens are present.
- Practice soil disinfection by solarisation or chemicals.
- Plan crop rotation cycles over extensive periods (every 4 years). The crop rotation should not include crops which are host and sensitive to these pathogens. Thus, it should not include crops from the Solanaceae family, cucurbits and strawberries. The crops used in the rotation should be non-susceptible crops only (e.g. Graminaceae, peas, beans, lettuce and cabbage).
- Avoid over-watering and injuries to the plants.
- Disinfect water used for irrigation by means of biofiltration, UV filters and other disinfection devices.

PLANT PROTECTION SUBSTANCES

- *Trichoderma asperellum* (1)
- *Trichoderma* spp (2)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) This must be used against Verticillium only.

(2) This product must be used against Fusarium only.

Fusarium wilt yellowing, wilting of leaves[9]

Verticillium wilt v-shaped necrosis and chlorosis[1]

Fusarium wilt browning of vascular bundle[4]

Verticillium wilt damage on fruit[1]

Cladosporium leaf mould

Mycovellosiella fulva, (syn. Cladosporium fulvum, Passalora fulva)

Tomato leaf mould is caused by a fungal, host-specific pathogen that mainly affects tomato plants grown in greenhouses. In the open field it is normally found in shaded areas where it stays wet for a long period. The use of excessive nitrogen tends to promote this pathogen. Infections occur within 24-48 hours when temperatures are between 10°- 27°C and at a high relative humidity of 85% or above. The oldest leaves are infected first. Symptoms include the formation of light green to pale yellow spots with undefined margins, which form on the upper sides of leaves, while olive/dark green, velvety mould can be observed on the underside. As leaf spots grow, they turn brown/dark red and the entire leaf starts to wither and die. This pathogen may also affect the stem. . Infected blossoms turn black and fall off. Fruit infections are rare. The pathogen survives as mycelium or as conidia on infected crop residues and soil. The conidia are very resistant to drying, and can survive up to a year even in the absence of a host.

Velvety mould on underside of leaves[9]

Yellow leaf spots[10]

Control and Management

Agronomic interventions

- Provide a balanced fertilization regime and avoid access of nitrogen.
- Avoid high planting densities.
- Use varieties which are resistant and tolerant.These are normally indicated with 'C5' in seed catalogues.

Chemical Interventions

- Apply treatments at the first signs of this pathogen. In areas prone to high risk, treatment should be carried out at intervals of 10 days.

PLANT PROTECTION SUBSTANCES

- Copper-based products (1)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Highest permitted limit of 28kg/ha in 7 years. It is advisable to not exceed the average of 4kg/ha of Copper per year over the duration of crop production.

Botrytis grey mould

Botrytis cinerea

Botrytis rot, also known as grey mould, is a fungal pathogen that infects a variety of plant species. The disease proliferates under high humidity of about 95% and excess water caused by rains, overhead irrigation or heavy dew, as well as mild temperatures of 17° to 23°C. Under such conditions, the duration of the cycle is about 4 days. The pathogen can infect all above-ground parts of the plant and produces a dense, velvety, grey/brown mould on infected tissue. Infections may occur on leaves and stems, with the disease often starting at sites where tissue is damaged through scars, cracks or pruning wounds. When stem infections occur, lesions can expand, affecting the whole stem and leading to plant wilting above the site of infection. Botrytis also affects the flowers and can infect the pedicle (the part connecting the flower to the cluster) and developing fruit. Infected flowers may dry and wilt, and in humid conditions are covered with grey mould. Green-coloured infected fruit will exhibit thin whitish rings of diameter about 2mm-10mm which encircles a small central necrotic lesion. Such lesions are known as 'ghost spots'. On ripe fruit these spots will be yellowish. Fruit will then exhibit lesions with a soft rot covered in a grey-brown or whitish mould. Fruits can also get mummified.

The pathogen is widespread in the environment. It can survive in the soil on plant debris for several years. It can be spread to other crops by wind and air currents and also through water droplets. Spread can also occur as operators work the field.

Control and Management

Agronomic interventions

- Avoid instances of waterlogged soil and maintain irrigation to a minimum.
- Use drip-type irrigation, and carry out irrigation in periods when the plant can be able to evaporate, especially for greenhouse crops.
- Provide a balanced fertilization regime.
- Avoid high density planting.

Chemical Interventions

- Use active substances with different modes of action to avoid the development of resistant strains.
- Under conditions which promote fungal spread, apply preventive treatments especially when green pruning was carried out.

PLANT PROTECTION SUBSTANCES

- *Bacillus amyloliquefaciens*
- Penthiopyrad (1)
- *Bacillus subtilis*
- *Pythium oligandrum* strain M1

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Apply a maximum of one application per cultivation period.

Ghost spots on fruit[1]

Diseased stem showing grey sporulation[1]

Bacterial diseases

Pseudomonas syringae pv. *tomato, Xanthomonas campestris* pv. *vesicatoria, Pseudomonas corrugata*

Bacterial diseases affecting tomatoes include: bacterial speck, caused by *Pseudomonas syringae* pv. tomato; bacterial spot, caused by *Xanthomonas campestris* pv. *vesicatoria;* and pith necrosis, caused by *Pseudomonas corrugata.*

The bacterial disease affects all the above-ground parts of the plant.

Bacterial speck appears as numerous small, dark brown/black lesions on leaves, fruit, and stems. The spots exhibit a necrotic centre and a chlorotic halo. Spots can merge and cause extensive marginal necrosis. Lesions also appear on fruit as tiny dark spots, black with a hydropic halo on immature fruit and as black spots on mature ones.

Bacterial spot occurs under favourable conditions of high temperatures and relative humidity. On leaves, water-soaked spots with a diameter of 2mm-3mm form. These are initially yellow-green and, with progressive necrosis, become brown surrounded with a yellowish halo. On the fruit, spots with a dark green halo form, growing to a diameter of 3mm-8mm and turning into a scabby brown lesion.

When pith necrosis symptoms first appear on maturing fruit, the leaves will turn yellow and start to wilt. Dark brown to black necrotic lesions start to form on the stem. Severely infected plant stems crack and collapse, and stems will exhibit pits that appear emptied, with blackened inner canals. Common and easy-to-identify symptoms are the numerous adventitious roots that start to emerge out of stems that are affected by the disease.

The pathogens are preserved in the soil, on infected crop residues, or on contaminated seeds at the time of extraction from infected berries. Infections can infect the plants through the stomata or wounds.

Bacterial canker split, discoloured stem[11]

Bacterial canker fruit spots[11]

Bacterial speck on leaf [1]

Bacterial speck on fruit[12]

Bacterial spot on leaf [4]

Bacterial spot, scabby lesions on fruit[13]

Adventitious roots caused by pith necrosis[1]

Pith necrosis: cross-section through stem[1]

Control and Management

Chemical Interventions

- Intervene after signs of first signs of infection with repeated interventions every 7-10 days after flowering.

Agronomic interventions

- Plant only seeds and plantlets which are visibly healthy and tolerate varieties. Use seeds and seedlings which are certified healthy.
- Avoid water-logging events and surface type irrigation.
- Provide a balanced fertilisation regime.
- Practice crop rotations with rotation periods every 2-3 years. If possible, include cereals.
- Destroy weeds and unwanted vegetation from field. Burn and destroy plant residue after harvest.

PLANT PROTECTION SUBSTANCES

- Copper-based products (1)
- Acibenzolar-S-methyl (2)
- *Bacillus subtilis*

LIMITATIONS OF USE AND SPECIAL CONDITIONS

General Limitations

(1) No more than two different active substances can be used in mixtures of fungicides simultaneously for each adversity. Products which are excluded from this limitation are Copper-based products, Fosethyl Aluminium, and all other organic products.

(2) For each active substance, only one commercial formulation can be used. The use of different formulations with the same active substance is only permitted for the consumption of old stocks or in the case where procurement of compounds is limited. In the latter scenario, the global limit and maximum quantity of the active substance must be abided by regardless.

(3) Highest permitted limit of 28kg/ha in 7 years. It is advisable to not exceed the average of 4kg/ha of Copper per year over the duration of crop production.

(4) Do not exceed four interventions per cultivation period, regardless of crop and disease.

Stolbur

Candidatus Phytoplasma solani

Candidatus *Phytoplasma solani* is also known as 'stolbur', 'big bud', 'yellows' and 'proliferation'. Stolbur is caused by phytoplasma bacteria. Infected plants have a bushy appearance due to decreased leaf size and shorter internodes, and the plant is overall stunted. Leaves start to curl and take on a purplish hue. The flowers become hypertrophic, have swollen peduncles and sepals, and flower abnormalities can result in aborted reproductive organs. An infected plant produces little fruit formation that reaches maturity, and those which do are highly malformed. The disease generally affects a small number of plants, and these would commonly be found at the edge of fields since it is transmitted by vectors (such as leafhoppers) from other plants.

Control and Management

Agronomic interventions

- Plan crop rotation cycles over extensive growing periods.
- Destroy diseased vegetation.
- Counteract the emergence of pathogen by controlling the vectors of such disease, e.g. leafhoppers.
- Control and destroy unwanted weeds and vegetation from field.

Extensive development of lateral shoots giving infected plant a bushy appearance[14]

Candidatus Phytoplasma solani. Modification of flower development [36]

Tomato viruses

CMV, PVY, ToMV, TSWV

Various viral pathogens can affect tomato plants. These include the cucumber mosaic virus (CMV), the potato virus Y (PVY), the tomato mosaic virus (ToMV), and the tomato spotted wilt virus (TSWV).

Symptoms of the viruses vary, especially since a plant may be infected with multiple viral pathogens and strains, and it is also hard to visually distinguish if the plant is infected with one viral pathogen or another. The general symptoms of the viral disease include a yellow appearance of the plant and stunted growth if the plant has been infected early, leaf chlorosis, mottling, malformation, blistering, curling and reduction in the size of leaves. Dark necrotic spots may appear on leaves. Fruits ripen unevenly, may remain small, exhibit discoloured spots, depressions, and sometimes browning of necrotic lesions, and there is an overall reduction in yield. Transmission of virtual pathogens occurs through pest vectors such as aphids, thrips and other insects, mechanically, or through plant debris or seeds and insects.

Control and Management

Agronomic interventions

- Sow only plants that have been certified free of viruses.
- Sow plants that are known to be tolerant to viruses.
- Monitor for virus vectors (aphids and thrips) in high risk areas.
- Control and destroy unwanted weeds and vegetation from field.
- Once you detect the first plants with virus symptoms:
    (1) remove the plant from the field and place it in a plastic bag;
    (2) avoid contact with other plants;
    (3) burn the infected plants;
    (4) mark the area where the infected plant was removed for further monitoring.

CMV symptoms on leaves [9]

ToMV symptoms on leaves [15]

PVY leaf chlorosis [7]

TSWV plant wilting [9]

Wireworms

Agriotes spp.

Wireworm is the common name given to the larval stage of different species of beetles from the *Agriotes* genus. Mature female beetles lay their eggs in the soil. When the larvae hatch they are white and, as they mature, they generally become yellow-brown. They remain present in the soil, develop a tough skin, and can grow up to 3cm in length. In the larval stage, the pest causes damage to the tomato plant due to feeding on the roots.

The larvae also devour seeds in the soil, preventing seedling germination.

Control and Management

Agronomic interventions

- Avoid re-sowing successive tomato crops in the event of persistent infestations.
- Works that impact the soil surface modify the hydrological conditions of the soil and thus promote the introduction of larvae into the soil column.
- Avoid successive cultivation of fodder plants for at least 2 years.

PLANT PROTECTION SUBSTANCES

- Lambda-Cyhalothrin (1)
- Tefluthrin (1)
- *Beauveria bassiana*

Agrotis sp. larva [16]

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Products are to be applied into the ground at pre-sowing or pre-transplanting stage, or when surface tillage close to the crop is being carried out, or when installing mulching. The limit for Pyrethroids applied in the ground shall not be combined with the limit for any Pyrethroids applied at field surface level. Apply a maximum of 3 applications per cultivation.

Aphids

Myzus persicae, Macrosiphum euphorbiae

The two most common aphids on tomatoes are the green peach aphid (*Myzus persicae*) and the potato aphid (*Macrosiphum euphorbiae*). Aphids are sap-sucking insects and can also cause damage by being vectors for disease, spreading viral pathogens. Favourable conditions for these insects are a mild temperature and greenhouse summer conditions.

The green peach aphid adult is oval-bodied, around 1.2mm to 2.1mm in length, and yellow green to grey green. The potato aphid is relatively large in size and has an elongated pear-shaped body. The colour varies from yellow green to pinkish red. Adult females can be wingless or winged, and their body size is around 1.7mm to 3.6mm long.

One often finds aphids at different life stages on one plant. In greenhouses, infestations can occur early in the season due to parthenogenetic females surviving in the environment in unfavourable periods (absence of crops, lower temperatures). Aphids can attain high density, and severe infestations may lead to weakened plants caused by abundant feeding.

The larvae and adults are normally found on the underside of the leaves during feeding. Then the excess sugar from the sap is released in the form of honeydew. The damages caused on the leaves by feeding is the cause of chlorotic dots, and young leaves can become deformed. Sometimes a reduction in plant growth can also be noticed. On the surface of different parts of the crop, in between the colonies of aphids, one can also find white caste skins and the presence of honeydew. On this honeydew, consequently, one can also find sooty mould growing. Aphids are vectors of numerous viruses including CMV.

Control and Management

Agronomic interventions

- Infestations can be contained through insects via naturally occurring insects in field or other beneficial insects.

Chemical Interventions

High-risk areas for viruses:

- Intervene at the appearance of the first colonies.

Low-risk areas for viruses:

- Do not apply chemical compounds before at least 10% crop-surface infection rate.
- When possible, target the application of compounds along the plot boundaries.

PLANT PROTECTION SUBSTANCES

- *Beauveria bassiana*
- Acetamiprid (1)
- Maltodextrin
- Flupyradifurone
- Cypermethrin (2)
- Deltamethrin (2)
- Esfenvalerate (2)
- Lambda-Cyalothrin (2)
- Flonicamid (3)
- Spirotetramat (3)
- Potassium salts of Fatty Acids
- Azadirachtin
- Pirimicarb ()
- Sulfoxaflor (1)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

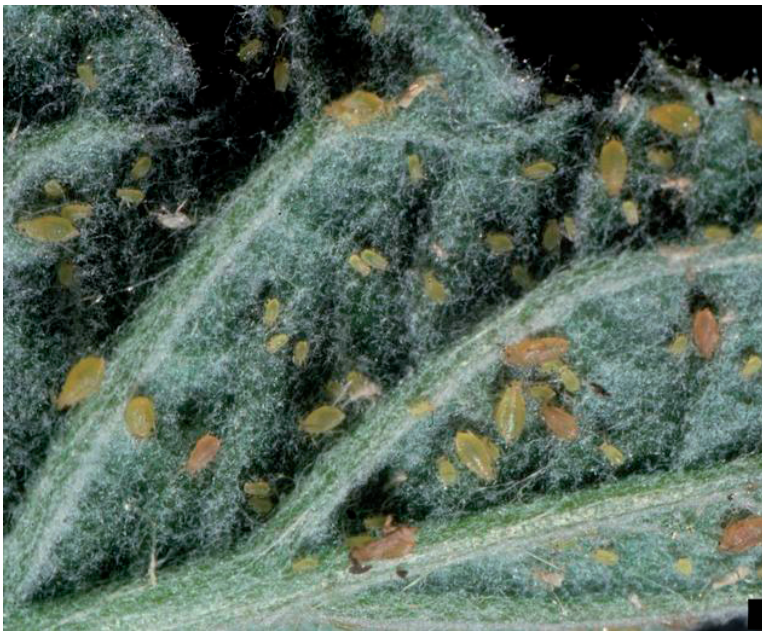
(1) At most, one intervention per cultivation period.

(2) Maximum one intervention per cultivation period. Do not exceed cumulative limit of one application per cultivation period from all Pyrethroid compounds: Cypermethrin, Deltamethrin, Lambda-Cyalothrin and Esfenvalerate (mode of action group 3).

(3) Maximum of two interventions. Allowed only on *Myzus persicae*.

(4) Only one intervention per cultivation period.

Macrosiphum euphorbiae aphids[17]



Myzus persicae infestation[18]

Leaf miner

Liriomyza spp.

Liriomyza is a genus of leaf miner flies that includes the various species of polyphagous leafminers that are present in Malta, such as *Liriomyza bryoniae, Liriomyza trifolii* and *Liriomyza huidobrensis*. Adult leaf miners are around 1mm-2mm long, black- and yellow-coloured flies.

Females lay their eggs generally on the upper side of leaves with an ovipositor. Eggs are small (~0.2mm diameter), oval, off-white and slightly translucent. The eggs hatch in 2-5 days, and the larvae reach maturity in approximately a week. The larvae are legless maggots that are translucent when they hatch, change colour to a yellow orange in later instars, and grow to around 3mm in length.

The first visible signs are chlorotic puncture lesions on the leaves. The larvae feed by digging mines in the mesophyll layer of the leaves. The mines are extensive, irregular and increase in width as the larvae mature, and look white with dried brown areas.

Before pupation, the larvae generally exit the leaf mine and pupate in the ground or on the leaf. A new adult emerges in 1-2 weeks. Adults cause damage to leaves through feeding, leaving puncture marks that appear as white speckles, as well as through oviposition. Seedlings may be impacted greatly, while in older plants reduced yield can occur due to premature leaf fall. Damage caused to the leaves may also give rise to secondary infections by a fungal or bacterial disease.

The duration of the life cycle of this insect varies from different species. The average lifecycle for all species is of 41 days at a temperature of 15°C and 17 days at a temperature of about 25°C

Control and Management

Agronomic interventions

- Store apart and destroy all crop residues after harvest.

Chemical Interventions

- Intervene only when a diffused type infestation has been detected or when infestation is seriously risking the complete loss of crop.

PLANT PROTECTION SUBSTANCES

- Spinosad (1)
- Acetamiprid (2)
- Azadirachtin

LIMITATIONS OF USE AND SPECIAL CONDITIONS

General Limitations

(1) Carefully evaluate the presence of leaf miner to avoid confusion with *Tuta absoluta*, to avoid carrying out interventions that are not suitable for this adversity.

Specific Limitations

(1) Maximum of three interventions per cultivation period.

(2) Maximum of one intervention per cultivation period.

Adult Liriomyza trifolii [19]

Mines caused by larva feeding [20]

Cutworms

Agrotis ipsilon, Agrotis segetum

The black cutworm, *Agrotis ipsilon*, and the turnip moth, *Agrotis segetum*, are species of the Agrotis genus of moths of the family Noctuidae. The caterpillars (at larval stage) are the cause of the damage to the tomato plant since they feed on the crop. Both species are very polyphagous, and they complete 2-3 generations per year. The most serious infestations occur periodically and derive from autumn and spring oviposition. The adults are partial to humid soils and females lay from a few hundred to over 1,000 eggs. As the caterpillars mature, they become most active at night; during the day they are present in the soil. They are grey-black or brown in colour, reach around 4cm in length and curl up into a crescent shape when disrupted. They reach maturity in around 40-50 days.

Early in the season, the larvae can feed on the stem of the tomato plant, and, in the case of seedlings and recent transplants, the cutworm severs the main stem at the soil line. In later generations, the larvae cause damage by feeding on the fruit, creating irregular holes on the surface of the fruit. Injuries are more common with fruit that are touching the ground. The feeding only affects a small number of fruit, therefore not causing serious economic damage.

Control and Management

Chemical Interventions

Intervene when one larva per five meters per crop row is observed. Take four sample points along every five metres of crop row in a diagonal manner. Samples are to be taken at the initial stages of the crop development.

PLANT PROTECTION SUBSTANCES

- Cypermethrin (1)
- Deltamethrin (1)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Maximum one intervention per cultivation period. When considering applications of Pyrethroids compounds take note that granular-type pyrethroids applied to the soil are not to be considered within the application limits for foliar treatments for this group of chemical substances.

Agrotis ipsilon next to severed stem [21]

Agrotis sp. larva [22]

Foliar moths

Helicoverpa armigera, *Autographa gamma* (Syn. *Plusia gamma*), *Spodoptera* spp.

The corn earworm, also called the tomato fruit borer, *Helicoverpa armigera*, the beet worm, *Autographa gamma*, and armyworms, *Spodoptera* spp., are the larval stage of specific moths in the family Noctuidae, and are common polyphagous pests that feed on a variety of important crops. The caterpillar larvae cause damage to tomato plants by feeding on foliage as well as flowers and fruit. Severe infestations can cause the larvae to devour entire leaves, leaving skeletonised structures. Female moths can lay hundreds of eggs. Fully grown caterpillar larvae are approximately 4cm long. The larvae can have different colour forms, depending on the species and the different growth stages. Commonly, the species of larva caterpillars are whitish-yellow, green, brown to mottled reddish-brown.

Helicoverpa armigera can cause devastating damage to all the above- ground parts of a tomato plant. The adults appear in April, and females lay numerous eggs from which the first generation of larvae hatch, feeding on leaves and flowers. A second generation follows with larvae that damage both ripe and unripe fruit. During a season, there can be around 4 generations, after which the pest overwinters in the soil.

Autographa gamma adults, Silver Y moths, are characterised by migratory flights that begin in April and then continue until October. The females lay in isolation and on the underside of the leaves up to 500 eggs. The larvae live on the underside of the leaves, on which they crystallise when ripe under a white silky texture.

For the Lepidoptera species, the life cycle is categorised into four stages; egg, larva or caterpillar, pupa or chrysalis, and butterfly/moth. The eggs can have different colouration, such as transparent, white, brown, black or purple. The size of the eggs normally is smaller than one millimetre in diameter. The eggs can be deposited in groups on different parts of the plants. When these eggs hatch, they turn into caterpillars about 20mm to 50mm long, depending on the species. This is the stage where most damage is done to multiple parts and organs of the plant. Then the larvae turn into pupae, usually measuring about 2cm to 2.8cm and red-brown coloured. After the pupa stage, it then transforms to butterfly stage. The length of the life cycle depends on the temperature, however it ranges from 10 days to weeks.

Control and Management

Agronomic interventions

- It is advisable to make use of pheromone traps and stick traps for an accurate monitoring of the number of adults and the development of new larvae.

Chemical Interventions

- Intervene only at the appearance of the first larvae.

PLANT PROTECTION SUBSTANCES AND DEVICES

- *Bacillus thuringiensis*
- Cypermethrin (1)
- Deltamethrin (1)
- Etofenprox (1)
- Lambda-Cyalothrin (1)
- Spinosad (2)
- Spinetoram (3)
- Chlorantraniliprole (4)
- Methoxyphenozide (5)
- Emamectin benzoate (6)
- *Spodoptera littoralis* nucleopoliedrovirus (SpliNPV)
- Virus Hear NPV (Nuclear Polyhedrosis Virus)
- Metaflumizone (7)
- Azadirachtin

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Maximum one intervention per cultivation period. Do not exceed cumulative limit of one application per cultivation period from all Pyrethroid compounds: Cypermethrin, Deltamethrin, Lambda-Cyalothrin and Esfenvalerate (mode of action group 3).

(2) Maximum of three interventions per cultivation period. When using Spinosad-type compounds (Spinosad and spinetoram, mode of action group 5) do not exceed more than three innervations per growing season.

(3) Maximum of two interventions per cultivation period. When using Spinosad-type compounds (Spinosad and spinetoram, mode of action group 5) do not exceed more than three innervations per growing season.

(4) Apply a maximum of one intervention per cultivation period, regardless of crop or disease.

(5) Maximum of 1 intervention. Not allowed for the control of Plusa.

(6) Limit of two applications per cultivation period if *Tuta absoluta* is present.

(7) Limit of two interventions per cultivation period, regardless of crop or disease.

Helicoverpa armigera larva [23]

Helicoverpa armigera larva feeding on fruit [16]

Autographa gamma larva [24]

Spodoptera sp. larva feeding on fruit [20]

Southern green shield bug

Nezara viridula

The southern green stink bug is a polyphagous pest. Adults can be recognised from their distinct shield-like shape and solid green colour. Adults are around 12mm to 16mm in length and 8mm wide. The immature stages of the insect have a different colour. Nymphs start black and progressively turn green, having a distinctive pattern of spots on the abdominal segments which eventually disappear once they turn into adults.

The shield bug overwinters in the adult state in sheltered areas and completes two generations a year with a life cycle of around 70 days. It can infest tomato crops, especially those near uncultivated areas. Feeding by nymphs and adults on fruit results in toxic saliva being released into the cells, leading to cell death. Symptoms include the appearance of small yellow spots on the fruit, which enlarge and can cover a large proportion of the surface. The necrotic spots lead to a colour change of the infected part of the fruit, reducing fruit quality and yielding fruit with a bad flavour. This bug could be a vector of bacteria and yeast, which can in turn adversely impact the crop.

This bug has several developmental stages, starting with the egg, five larval stages and then the adult. The span of one life cycle varies according to the ambient temperature. At temperatures of about 30°C, a life cycle takes about three weeks, and at temperatures of about 20°C it takes about two months. The eggs are off-white in colour and shaped like a small keg grouped in a honeycomb. These are usually found on the underside of the leaves. When the larva hatches from the egg, it is usually dark red to black and with white spots. Then the life cycle is followed by five instars, the first larvae being 1mm long and the fifth one being 1cm long. This is the last stage before it changes to an adult.

Control and Management

Agronomic interventions

- In cases with high infestation, use crop insect covers to protect the crop.
- Keep the area weed-free.

Chemical Interventions

- Limit interventions to areas where a diffused type infestation has been detected.

PLANT PROTECTION SUBSTANCES AND DEVICES

- Acetamiprid (1)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Apply a maximum of one intervention per cultivation period, regardless of crop or disease.

Nezara viridula adult [25]

Nymphs at different stages of maturity [26]

Brown marmorated stink bug

Halyomorpha halys

Halyomorpha halys has been observed in Malta for the first time very recently, in 2018. This species is remarkably polyphagous; it can live on many plants, including tomatoes. The pest is a stink bug in the Pentatomidae family. The adults are between 12mm and 17mm in length, are brownish to grey with marbled or mottled dorsal colouration, and have a shield-like body shape. Females lay whitish eggs in clusters of around 20 to 30, generally deposited on the undersides of leaves.

The first instar is black with reddish-orange colours, and the nymphs remain close to the hatched egg at this stage until they moult into the second instar stage. The stink bugs feed by inserting their needle-like mouthparts into the cells of the plant, and in the process they inject toxic saliva that causes tissue damage. Infestations on tomatoes occur in the summer period, with juvenile and adult forms feeding on the fruit. The damage is similar to that of the Southern green shield bug, with fruit exhibiting discoloured spots. The bug completes two generations a year and overwinters as an adult in a sheltered area.

Control and Management

Agronomic interventions

- In cases with high infestation, use crop insect covers to protect the crop.
- Keep the area weed-free.

PLANT PROTECTION SUBSTANCES AND DEVICES

- Deltamethrin (1)
- Lambda-Cyalothrin (1)

Halyomorpha halys adult[50]

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Apply a maximum of two interventions per growing season from substances from the same mode of action group (3): Deltamethrin and Lambda-Cyalothrin.

Two-spotted spider mite

Tetranychus urticae

The life cycle for the two-spotted spider mite, also known as red spider, consists of a total of 5 developmental stages. These are the egg, larva, protonymph, deutonymph, and adult. The life span for each cycle varies with temperature. In temperatures of about 30°C it takes about 7 days, and 36 days in temperatures of about 15°C. The adult female is able to diapause in low temperature or when the food supply diminishes.

An adult female of the two-spotted spider mite is ~0.6mm long, usually of a pale greenish-yellow colour with two dark patches on its body. The body is oval, with long dorsal hairs. Overwintering adults can turn brown-red or orange-red. The small round eggs, 0.14mm in diameter, at first translucent and then yellow when close to hatching, are laid by the female on the underside of the leaves. The process of development from egg to larva and nymph stages to adult may take between 5 to 19 days.

Major infestations occur during the summer months with several generations present in a year. Feeding results in pale spots appearing on the leaves since the mite feeds by puncturing leaf cell walls, sucking out the content. The mites also produce webbing to protect them from predators that can cover the surface of the plant. Eventually, the leaves result in a stippled appearance. Severe infestations may lead to leaf bronzing. When the populations of the mites are high, unripe and ripening fruit may also be damaged. The calyx may exhibit depigmentation, while the berries exhibit necrotic streaks and bronze spots. Two-spotted spider mites can spread by plant-to-plant contact. They can also spread via crawling to other plants or through transportation by workers, equipment or machinery, or scattered by moving plant parts or debris.

Control and Management

Agronomic interventions

- The beneficial insect *Phytoseilus persimilis* can be used to control spider mites. These natural predators should be released not less than three times per cultivation every 14-day interval.

Chemical Interventions

- Intervene at the presence of 3-4 mites per leaf.

PLANT PROTECTION SUBSTANCES AND DEVICES

- *Beauveria bassiana*
- Sulphur
- Maltodextrin
- Bifenazate
- Abamectin (1)
- Potassium salts of Fatty Acids
- Clofentezine
- Hexythiazox
- Etoxazole (2)
- Fenpiroximate
- Acequinocyl
- Cyflumetofen

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) For Abamectin, no more than two consecutive interventions, and up to a maximum of three interventions, regardless of the adversity.

(2) Only one intervention per cultivation period, regardless of adversity or crop.

Two females and an egg [28]

Leaves with stippled appearance [17]

Tomato russet mite

Aculops lycopersici

The tomato russet mite attacks various cultivated Solanaceae plants, including tomato, potato, aubergine, pepper and tobacco. The mite is small and not visible to the naked eye. It multiplies almost uninterruptedly during the vegetative cycle of the host plants and survives in winter on the plant or crop residue. At optimal temperatures of 27°C, and hot and dry weather with humidity of around 30%, a lifecycle takes a week to complete, hence multiple generations can be present in a season. The mites feed on the content of cells from leaves, stems and fruit. This mite is not able to fly, however it may spread via wind, workers and tools.

Symptoms include leaves turning to a greasy bronze or russet colour. Similar symptoms can be observed on stems and petioles. In the case of severe infestations, the plant appears scorched and the pest may kill the entire plant. In addition to damaging the leaves, it causes the abortion of the flowers and hinders the development of the fruit, on which it causes the appearance of suberifications and sometimes very deep cracks.

Control and Management

Agronomic interventions

- In the presence of this mite, disinfect all equipment or machinery used in order to avoid dissemination to uninfected crops and fields.
- Maintain the area free of weeds.
- Plants showing the symptoms of this mite should be removed from the field and destroyed before the infestation is able to spread to other plants.

Chemical Interventions

- Intervene once symptoms have been detected.

PLANT PROTECTION SUBSTANCES AND DEVICES

- Abamectin (1)
- Sulphur (2)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) With Abamectin, no more than two consecutive interventions, and up to a maximum of three interventions, regardless of the adversity.

(2) Read the product label and use only those products that report the application of sulphur against this adversity.

Tomato russet mite (Aculops lycopersici) damage on tomatoe fruit [35]

Tomato leaf miner

Tuta absoluta

The tomato leaf miner is a moth which causes severe damage to tomato production with the larval stage responsible for damage on several plant parts. Adult moths are about 1cm in length and silver- grey in colour. The lifecycle lasts an average of 30 days in summer and becomes longer in autumn and winter. The optimum temperature for *T. absoluta* is 30°C, with minimum and maximum thresholds at 14°C and 35°C. Under greenhouse conditions its continuous development results in the presence of all stages of T. absoluta throughout the growing season. Females lay eggs on the apical of leaves and, less frequently, on the stem or sepals, and may lay up to 260 eggs in a lifetime. The larvae, white to green in colour, feed by mining in the leaf, stem or fruit and exit the mine to pupate. Pupation occurs on leaves, in the soil, main stems and fruit. The moths are active during the night and hide between the leaves in the daytime.

The infestation initially affects the leaves, however all the above ground parts of the plant can be affected, including the fruit at any stage of development. The larvae have a preference for leaves and stems but may also be found in or under the crown of the fruit and in the fruit itself; small heaps of excrements are often found near the entrance hole. The most distinctive symptoms of the presence of the species are the blotch- shaped mines in the leaves in which the larvae can be found. In case of a serious infestation, leaves die off completely, while mining damage to the stems causes malformation of the plant. Damage to the fruit may result in secondary fungal and bacterial infections.

Control and Management

Agronomic interventions

- Use pheromone traps to monitor the presence of this pest.

Biological interventions

Safeguard or/and introduce natural predators of this pest such as *Heteroptera* bugs, *Macrolophus caliginosus*, *Nesidiocoris tenuis* and also some *Hymenoptera parasitoids*, e.g. *Trichogramma* spp.

Chemical Interventions

- Intervene at the first signs of entry holes on the crop leaves or fruit.
- The application of chemical products is to be repeated twice every 7-10 day interval per active substance.
- Alternate between different chemical substances to avoid onset of chemical resistance.

PLANT PROTECTION SUBSTANCES AND DEVICES

- *Bacillus thuringiensis*
- Abamectin (1)
- Spinosad (7)
- Spinetoram (2)
- Chlorantraniliprole (3)
- Etofenprox (4)
- Azadiracthin
- Emamectin benzoate (5)
- Metaflumizone (6)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) When using Abamectin, no more than two consecutive interventions. Do not exceed the limit of three applications per cultivation period.

2) Do not exceed more than two applications per cultivation period. In addition, follow maximum limit of three interventions with Spinosine-type compounds.

(3) Maximum one application per cultivation period including pyrethroids.

(4) Maximum of two applications per cultivation period between Emamectin benzoate and abamectin.

(5) Limit of three applications per cultivation period, regardless of crop or disease.

(6) Maximum of two applications per cultivation period, regardless of crop or disease.

(7) Do not exceed more than three applications per cultivation period. In addition, follow maximum limit of three interventions with Spinosine-type compounds.

Malte adult [29]

Feeding of larva on leaf [16]

Borrowing of larva in fruit [16]

Thrips

Frankliniella occidentalis

Thrip species found on a tomato plant include the western flower thrips, *Frankliniella occidentalis,* and Thrips spp., such as the onion thrips, *Thrips tabaci.* Adult thrips are generally less than 1.5mm in length, having a narrow, elongated body, with fringed wings. The females are larger in size than the males. The colour of an adult varies but is generally light yellow to dark brown. The length of the life cycle is dependent on temperature but is generally around 34 days when the temperature is around 15°C, or as little as 13 days when the temperature is around 30°C. The lifecycle of thrips consists of six stages: egg, two larval stages, two pronymphs stages, and adult stage. The larvae and adults can survive on different hosts and can also take refuge when the temperatures are mild. They can take refuge in places such as plant debris and can also be found up to 8cm deep in the soil. Thrips can also hibernate in field crops such as *Allium*. Several generations are present in a year.

Thrips may cause symptoms such as silver lesions on leaves, making them appear irregular in shape and size, later becoming necrotic and taking on a beige shade. The leaves can also be dotted with tiny black spots, which are the faeces left by the thrips. Thrips may also cause damage to the flowers and fruit, including scarring or discolouration. Thrips can be a vector of the tomato spotted wilt virus (TSWV). The virus can only be acquired by nymphs, however the transition of TSWV can continue throughout the life of a thrip, which can last 30 to 45 days.

Control and Management

Agronomic interventions

- Place blue stick traps.
- Maintain the area free of weed.

Chemical Interventions

- Intervene at the initial signs of infestation.

PLANT PROTECTION SUBSTANCES AND DEVICES

- *Orius spp* (beneficial insect)
- *Beauveria bassiana*
- *Metarhizium anisopliae*
- Essential Oil of sweet orange
- Potassium salts of fatty acids
- Azadirachtin
- Etofenprox (1)
- Pyrethrin (1)
- Spinosad (2)
- Spinetoram (3)
- Acetamiprid (4)
- Formetanate (4)

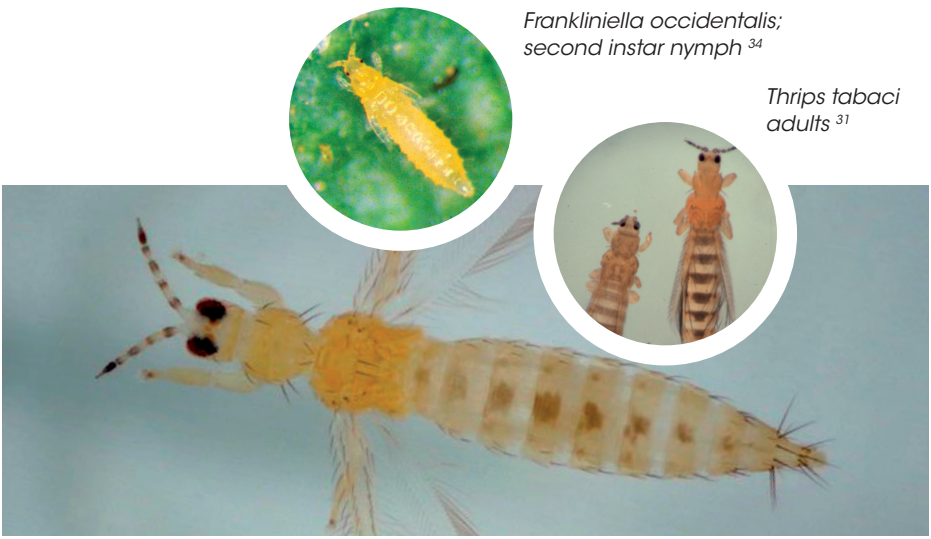
LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Limit of one application per cultivation period between Etofenprox and Pyrethrin.

(2) Maximum three applications per cultivation period. Also consider cumulative limit of not more than three applications when using Spinosine-type compounds (Spinosad and Spinetoram) in one cultivation period.

(3) Do not exceed two applications per cultivation period. Also consider cumulative limit of not more than three applications when using Spinosine-type compounds (Spinosad and Spinetoram) in one cultivation period.

(4) Maximum one application per cultivation period.



Frankliniella occidentalis; second instar nymph [34]

Thrips tabaci adults [31]

Frankliniella occidentalis adult [34]

Whitefly

Trialeurodes vaporariorum, Bemisia tabaci

The silverleaf whitefly, *Bemisia tabaci,* and the greenhouse whitefly, *Trialeurodes vaporariorum*, are polyphagous pests that affect tomato plants. This insect has three lifecycle stages: egg, four larva stages, and the adult stage. This lifecyle is carried out on the underside of the crop leaf. The eggs are able to survive in temperatures below 0oC for several days. The eggs are white, oval shaped with a diameter of 0.25mm. By time, the eggs change to a darker colour and hatch into larvae in 7 to 10 days. The larvae are oval, flat and 0.3mm long, and have antennae and developed legs. At the second larvae stage they become flattened, transparent and measure 0.37mm. At the third and fourth larvae stages, the larvae are similar however the lengths are different: 0.51mm and 0.73mm. Adult whiteflies are 1mm to 1.5mm long, yellow in colour, and have white wings that are covered with a waxy coating. The lifecycle of whiteflies at temperatures around 28°C takes about 20 days. Multiple generations can be present in a season.

The adult and nymphs feed on leaf sap with their piercing, sucking mouthpart. In severe infestations, their feeding can cause yellowing of leaves and weakening of plants. They produce honeydew that may lead to black sooty mould, which contaminates fruit. *B. tabaci* can be responsible for irregular maturity and colour spots on the fruits. Whiteflies, like aphids, can also be vectors for secondary pathogens causing viral disease.

Control and Management

Agronomic interventions

- Place yellow stick traps.
- Maintain the area free of weed.

Chemical Interventions

- Intervene in high-risk areas for plant viruses.
- Intervene at the initial signs of infestation.
- In low-risk areas, intervene at the detection of 10 nymphs per leaf.

PLANT PROTECTION SUBSTANCES AND DEVICES

- *Beauveria bassiana*
- Maltodextrin
- Potassium salts of fatty acids
- Essential oil of sweet orange
- Pyrethrin pure
- Acetamiprid
- Etofenprox (2)
- Flonicamid (3)
- Sulfoxaflor
- Piriproxifen (1)
- Esfenvalerate (1)
- Azadirachtin (4)

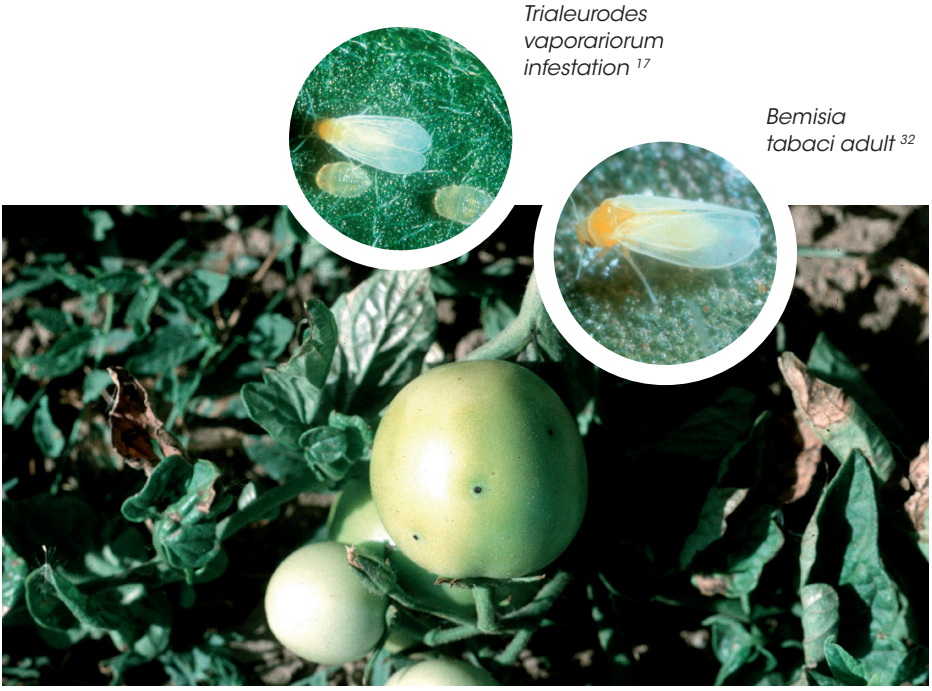
LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Limit of one application per cultivation period.

(2) Follow limit of one intervention with Pyrethroids compounds (mode of action group 3A; Esfenvalerate, Etofenprox and Pyrethrin).

(3) Maximum two applications per cultivation period.

(4) Apply product when the initial infestations are detected.



Trialeurodes vaporariorum infestation [17]

Bemisia tabaci adult [32]

Oviposition injury to tomato fruit [17]

Root-knot nematodes

Meloidogyne spp.

Root-knot nematodes are parasitic, polyphagous species that feed and infect the roots of tomato plants. Nematodes are present in the soil and are very small, less than 1mm in length. The lifecycle of *Meloidogyne* spp. takes 4 to 8 weeks or more, this depends on environmental conditions. Females produce egg masses which may contain over 600 eggs.

Root-knot nematodes start causing damage in their second juvenile stage, at which point they are vermiform and less than 0.5mm in length. They penetrate the vascular cylinder of the roots. This induces hypertrophy and hyperplasia, which eventually lead to the root formation of characteristic knots, white galls gradually turning to brown. Nematodes are generally not evenly distributed in a field, and symptoms may be visible in patches where nematode concentration is high. Field symptoms include stunted growth and yellowing of leaves and wilting of the plant.

Nematodes are able to survive in the soil for about two years even in the absence of the host plants. *Meloidogyne* spp. can live on a wide range of plants, in fact over 5,500 different plants. Most of these plants are crops, such as chrysanthemum, carnation, rose, peach, banana, peppers, eggplant, lettuce, melon, cucumber, artichoke, carrot, celery beans and sweet potato. During one season there could be several generations, and the infestation may reach 100,000 to 200,000 larvae per one kilo of soil.

Eggs and larvae can be transported from one place to another by water runoff, drainage and irrigation water. The larvae themselves can also be able to move a short distance in instances where the soil is wet. Other ways of dissemination are by wind through dust particles, contaminated plants, tools and machinery. Conditions which can encourage the development of these nematodes include moist and warm soils.

Control and Management

Agronomic interventions

- Crop rotate with crops which are not a host to this nematode for at least 4 years. Some of the suggested crops to include in the rotation are: onion, garlic, corn, winter cereals and arugula.

- Eliminate and destroy the residues of the previous and affected crops, including the roots.
- Avoid water stagnation when carrying out irrigation.
- Use only tolerant / resistant crop varieties and rootstocks.
- Use Brassicaceous seed meals.
- Repeat pre-planting ploughing several times.
- Agricultural tools and machinery used in contaminated areas should be cleaned.
- Solarize the ground with polyethylene transparent plastic, having thickness of 0.035mm-0.050mm during the months of June-August for at least 50 days. This is suggested to be done after the harvest of the crops since many nematodes will be present in the top layer of the soil.

PLANT PROTECTION SUBSTANCES

- *Paecilomyces lilacinus*
- Garlic extract
- Geraniol+thymol
- Azadirachtin
- Fluopyram (1)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) One application per cultivation period.

Healthy tomato (left), and infected with Meloidogyne sp. (right) [1]

Meloidogyne sp. forming galls on roots [33]

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