GOVERNMENT OF MALTA
MINISTRY FOR AGRICULTURE,
FISHERIES AND ANIMAL RIGHTS

EU funds
for Malta
2014-2020

TABLE TOMATOES PRODUCTION INTEGRATED PEST MANAGEMENT GUIDELINES

Agriculture Directorate

AgriConnect

Agriculture Research & Innovation Hub

CIHEAM

July 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 impacts negatively both tomatoes and potatoes as it devastates harvests, with a high probability of total crop loss if unmanaged.

The pathogen affects all aboveground parts of susceptible plants at any stage of plant development including leaves, stems and fruit. Infections occur with a long duration of wetting conditions, followed by relative humidity of over 90% and temperature 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 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 other plants by wind.

Control and Management

Agronomic Interventions

- Make use of certified-healthy seeds or seedlings.
- Avoid instances of water-logged soil and maintain irrigation to a minimum.
- Ensure a well-balanced fertilization regime.
- Plant debris should be limited during the growing period of the crop. At the end of the cultivation period plant debris should be destroyed (when possible by burning the debris).
- 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 present in previous crops.
- For greenhouse tomatoes, it is important to prune frequently and provide support to the plant.

- Use of mulching between the soil and the plant.
- In hydroponics/soil-less cultures it is important to disinfect the irrigation system and the substrate needs to be changed every year, especially if the previous crops were infected by this fungus.

Chemical Interventions

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

In prevalent high humidity conditions that are 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 Products (1)
- Cymoxanil (2)
- Propamocarb (4)
- Azoxystrobin (5)
- Cyazofamid (8)
- Amisulbrom (8)
- Fosethyl Aluminium
- Metalaxil-M (2)
- Fluazinam (7)
- Dimethomorph (3)
- Mandipropamid (3)
- Metiram (2)
- Ametoctradin (2)
- Oxathiopiprolin (2)
- Zoxamide (6)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

General Conditions

(1) When mixing fungicides do not combine more than two different active substances in the same mixture, for any adversity whatsoever. Products which are excluded from this limitation include cupric products, Fosethyl Aluminium and all organic products.

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

Specific Limitations

(1) Copper application should not exceed the limit of 28 kg/ha in 7 years. It is advisable not to exceed the average of 4 kg/ha of Copper per year over the duration of crop production.
(2) Apply not more than three times per cultivation season.
(3) Maximum of four interventions per growing season. Limit applies for all carboxylic acid-type compounds.
(4) Apply compound via drip irrigation.
(5) At most, apply not more than twice per growing season. Between Fenamidone, Tryfloxistrobin and Azoxystrobin, the combined limit is of not more than three times per cultivation season.
(6) Limit of four applications per cultivation period.
(7) Limit of two applications per cultivation period.
(8) Apply a maximum of three interventions per growing season between cyazofamid and amisulbrom.

Underside of leaf showing sporulation [1]

Tomato late blight stem lesion [2]

Damage to the fruit [3]

Alternaria

Alternaria spp.

Alternaria, or 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 the 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/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 genus, such as aubergines, pepper, potatoes, black nightshade and others.

The infection occurs due to conidia dispersed through rain or irrigation when temperatures are between 6°C to 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 even after spraying of water. It can also spread through seeds and by workers.

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

Control and Management

Agronomic Interventions

- Make use of certified-healthy seeds or seedlings.
- Practice extensively crop rotation of 3 to 4 years with crops such as cereals, sweetcorn etc. It is also important to eliminate host weeds during the crop rotation.
- Avoid instances of water-logged soil and maintain irrigation to a minimum.
- Ensure a well-balanced fertilization regime.
- Plant debris should be limited during the growing period of the crop. At the end of the cultivation period plant debris should be destroyed (when possible by burning the debris).
- Before the planting of the new crop, soil solarization or soil disinfection is recommended, especially if this pathogen was detected in previous crop cycles.
- For greenhouse tomatoes, it is important to prune frequently.
- Apply mulching 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 also active against this adversity.
- When severe episodes of infestations are detected and especially within agricultural areas prone to humid conditions, 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 daytime to minimize the risk of re-infection arising from damp and humid conditions.

PLANT PROTECTION SUBSTANCES

- Copper-based products (5)
- *Bacillus amyloliquefaciens*
- *Bacillus subtilis*
- Azoxystrobin (1)
- Cyflufenamid (2)
- Difenoconazole (3)
- Fluxapyroxad + Difenoconazole (3)
- Zoxamide (4)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

General Limitations

(1) When mixing fungicides do not combine more than two different active substances in the same mixture, for any adversity whatsoever. Products which are excluded from this limitation include 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 with regardless.

Specific Limitations

(1) Apply not more than twice per cultivation period. Do not exceed combined limit of three applications per cultivation period from active substances containing Tryfloxistrobin and Azoxystrobin.

(2) Not more than two applications per cultivation period.

(3) Do not exceed two combined applications from all azole-type compounds

(4) Not more than four applications per cultivation period.

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

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 occur on petioles, stems and calyxes. Small, water-soaked spots of around 2–6 mm start developing on older, 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 15–28°C and the 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 seeds.
- Practice crop rotation extensively.
- Avoid instances of water-logged soil and maintain irrigation to a minimum.
- Irrigation must be carried out during daytime to facilitate excess water evaporation.
- Use plastic mulch to form a barrier between the soil and the plant.
- Minimise field operations when the surface vegetation is wet
- Weeds, such as black nightshade (Solanum nigrum), carolina horse-nettle (Solanum carolinense), Physalis subglabrata and Jimsonweed (Datura stramonium), that may harbor and promote fungal spread should be removed from the field.
- Infected plant debris should be disposed of instantly, preferably ignited.

Chemical Interventions

- In the majority of cases, the application of specific active substances against this disease is not necessary in view that anti-peronospora contact-type products are also active against this adversity.
- Following severe episodes of infestations and especially within agricultural areas prone to high humdity, 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 products (1)
- Azoxystrobin (2)
- Metiram (3)
- Difenoconazole (4)
- Zoxamide (5)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

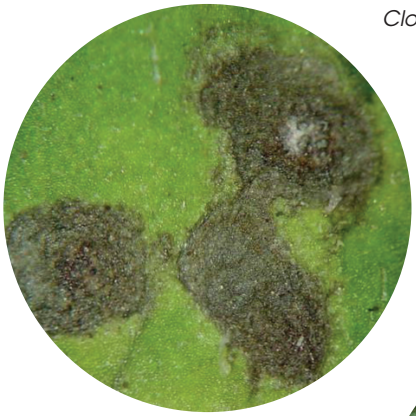
General Conditions

(1) When mixing fungicides do not combine more than two different active substances in the same mixture, for any adversity whatsoever. Products which are excluded from this limitation include 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 with regardless.

Specific Limitations:

(1) Higher permitted limit of 28 kg/ha in 7 years. It is advisable not to exceed the average of 4 kg/ha of Copper per year over the duration of crop production
(2) Apply not more than twice per cultivation period.
(3) Do not exceed three applications per cultivation period.
(4) Do not exceed the combined limit of two application per cultivation period from all Sterol Biosynthesis Inhibitors (SBIs) compounds which fall under the mode of action group G1 (Difenoconazole, Tebuconazole, Tetraconazole and Penconazole).
(5) Do not exceed four applications per cultivation period.



Close-up of lesions with pycnidia [6]

Leaf spot symptoms [5]

Powdery mildew

Leveillula taurica, Erysiphe spp.

Powdery mildew is caused by fungal pathogens that develop under favorable 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. Infection normally starts at the base and bottom leaves of the plant. With time, this gradually spread up to reach the upper leaves. Powder-like spores (white/grey) may be observed on the plant foliage. Severe infections may result in leaf deformity. As the disease progresses the leaves turn brown, shrivel and die off. The stems and petioles may become infected but not the fruit.

The spores of the fungus can be easily transmitted by the wind and even workers.

The main climatic conditions that are favorable for the development are temperatures around 26°C and relative humidity of about 70 to 80%. Nonetheless, 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 dry days with cool and humid nights. The presence of dew on leaves is also another factor which may contribute to the development of this fungus.

Close-up of diseased leaf [1]

Powdery mildew on leaves [1]

Control and Management

Agronomic Interventions

- In the early phase of plant infection, leaves should be removed and placed in a sealed plastic bag so to avoid/minimize the spread of the spores. These then should be taken away from the crop and destroyed.
- It is important to carry out all field-work activities in consideration of good hygienic practices such as;
  - limiting the number of visitors in the greenhouse to reduce the risk of dissemination,
  - foot bath should be installed at the greenhouse door.
- Green pruning at the base of the plant so to eliminate the attack on the first leaves and at the same time promoting ventilation.
- Where possible the climatic conditions of the greenhouse should be set to reduce humidity and increase air circulation.
- Plant debris, after performing the green pruning, should be removed, and destroyed from the greenhouse during the cultivation period.
- In greenhouses where fungal attacks are present from the previous year/crop, the walls and structure should be disinfected.
- Unwanted crops and weeds which can harbour and promote the spread of fungus should be removed from the field/greenhouse.

Chemical Interventions

With the exclusion of Sulphur-based products, intervene only at the detection of the first signs of infection. Repeat intervention every 8 - 10 days in particular when the climatic conditions favour the emergence of the pathogen concerned.

PLANT PROTECTION SUBSTANCES

- Sulphur
- Potassium bicarbonate (1)
- Cos-Oga (2)
- *Bacillus pumilus*
- *Bacillus amyloliquefaciens* (1)
- Fluxapyroxad (3)
- Tebuconazole (5)
- Tetraconazole (5)
- Difenoconazole (5)
- Penconazole(5)
- Trifloxystrobin (8) + Tebuconazole (5)
- Azoxystrobin (6)
- Bupirimate (7)
- Cyflufenamid (7)
- Metrafenone (7)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

General Conditions

(1) When mixing fungicides do not combine more than two different active substances in the same mixture, for any adversity whatsoever. Products which are excluded from this limitation include 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 with regardless.

Specific Limitations:

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

(2) Do not exceed five applications using COS (chito-oligosaccharides) and OGA (oligo-galaturonides).

(3) The combined limit is of three interventions per growing season from compounds; Fluopyram, Fluxapyroxad and Pentyopirad.

(4) Do not exceed the combined limit of two applications from all azole-type compounds. Also, the combined limit of Tryfloxistrobin and Azoxystrobin is of three applications per cultivation period

(5) 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).

(6) Do not exceed two applications per cultivation period. Not more than three combined applications from compounds containing Tryfloxistrobin and Azoxystrobin.

(7) Do not exceed two applications per cultivation period.

(8) Not more than three combined applications from compounds containing Tryfloxistrobin and Azoxystrobin.

Fusarium wilt

Fusarium oxysporum f.sp. *lycopersici*

Fusarium wilt is caused by a fungal pathogen that commonly occurs during warmer weather, with optimum temperatures of fusarium wilt being 27–30°C. It is able to develop well in sandy, acidic soil and soil which is low in humidity. Shorter days, low light levels and plants which are deficient in nitrogen, phosphorus and calcium encourage this disease. On the other hand excessive use of nitrogen, especially ammonia-based nitrogen, will also encourage this disease.

Symptoms appear on both seedlings and mature plants. Characteristic symptoms for seedling plants at nursery stage may include reduced growth and discoloration of green leaves to yellow. Eventually infected seedlings may wilt completely and the older leaves turn to yellow, curve and wilt. Another common symptom is the browning of the plant vascular organs which can be monitored via dissecting the impacted stem.

Adult plants have similar symptoms as per seedlings. Symptoms 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. With time, browning of the vascular bundle may be revealed as one dissects the stem lengthwise. Browning and necrosis occur also in the root of the plant. Growing within the stem, one can also find adventitious roots. Plant growth is stunted and plant death may occur. In some cases, fusarium can also cause rot on the fruits.

The pathogen is soilborne and can be present in the soil to a depth of up to 80 cm for numerous years. It enters the plants through wounds or through injuries caused to the plant. The disease can also be spread by transplants. Infections occur through the fibrous root system of the plants.

Fusarium wilt yellowing, wilting of leaves[9]

Control and Management

Agronomic Interventions

- Plant crop varieties which are known to be resistant/tolerant against this adversity and use grafted rootstock which is resistant/tolerant.
- Seeds or seedlings used must be certified from diseases.
- Eliminate any plants and vegetative residue which have been infected and destroy them appropriately, if possible by ignition
- If possible avoid planting in an area which was already effected by this adversity.
- Plan crop rotation cycles over extensive periods (every 4 years). On the other hand, limit rotations to non-susceptible crops only (e.g. Graminaceae) following fusarium infection.
- Carry out soil disinfection by soil solarization, steam or chemicals.
- In soilless systems it is important to disinfect all related equipment, the nutrient tanks/reservoirs, and the nutrient solution channels.
- It is important to follow hygienic good practices such as;
- limiting the number of visitors in the greenhouse to reduce the risk of dissemination,
- foot bath should be installed at the greenhouse door.
- Balanced fertilization, containing nitrates instead of the ammonium type of nitrogen. It is important to avoid excessive nitrogen.

PLANT PROTECTION SUBSTANCES

- *Bacillus subtilis* (1)
- *Pseudomonas* sp. Strain DSMZ

LIMITATIONS OF USE AND SPECIAL CONDITIONS

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

Fusarium wilt browning of vascular bundle[4]

Verticillium wilt

Verticillium dahliae, Verticillium albo-atrum

Verticillium wilts are caused by fungal pathogens that cause similar symptoms in tomato plants to those caused by *Fusarium* spp., making both diseases hard to distinguish. Symptoms include slight wilting of the plants, especially during hot parts of the day and reversible during the night. The infected leaves, especially older/lower ones, change to yellow coloration. Early symptoms may also include V-shaped discoloration between the veins and leaf margins. A tan discoloration develops at the base of the plant in the vascular tissue. Affected plants usually survive but undergo considerable vegetative decay, while their fruit remain small and mature early. When dissecting the stem longitudinally or transversely at the lower part or at the branches, it might show a slight brown colour.

Some of the host plants include Solanaceae (pepper, potatoes and eggplants), cucurbits, artichokes, lettuce, cabbage, strawberry, rose, aster, chrysanthemum and weeds such as Black nightshade and Pigweed. These host plants can act and help in the pathogen multiplication and survival. The optimum temperature of the disease is 20–32°C. The crop may be more sensitive to this pathogen in shorter days and low light. The latter can be more severe if the soil pH is neutral to alkaline. Pathogens are soilborne and can be present in the soil for numerous years. The disease can also be spread via transplantion. This can take place via direct penetration from the root system or from different root injuries, and from wounds which might be caused by nematodes. Infections occur through the fibrous root system of the plants.

Control and Management

Agronomic Interventions

- Plant crop varieties which are known to be resistant against this adversity and use grafted rootstock which is resistant/tolerant.
- Seeds or seedlings used should be free from diseases.
- Eliminate any plants and vegetative residue which are infected and destroy them appropriately, if possible by burning.
- Plan crop rotation cycles over extensive periods (every 4 years). Limit rotations to non-susceptible crops only (e.g. Graminaceae, peas, beans and cabbages) following fusarium infection.

- Plant tomato cultivars which are tolerant or resistant to this adversity.
- Carry out soil disinfection by soil solarization, steam or chemicals. Following the disinfection stage and in preparation of the soil for planting, it is important not to cultivate deeply into the soil so as to avoid bringing up the microsclerotia from the deep and into the treated layer of soil.
- In soilless systems it is important to disinfect all related equipment, the nutrient tanks/reservoirs, and the nutrient solution channels.
- It is important to follow hygienic good practices such as;
  - limiting the number of visitors in the greenhouse to reduce the risk of dissemination,
  - foot bath should be installed at the greenhouse door.
  - tools or equipment used on an area or contaminated crops should be cleaned and disinfected.
- Apply a balanced fertilization regime.

PLANT PROTECTION SUBSTANCES

- *Streptomyces* Strain K61
- *Trichoderma gamsii* (1)
- *Trichoderma atroviride* (1)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) This product is active against *Verticillium dahliae* only.

Verticillium wilt v-shaped necrosis and chlorosis [1]

Verticillium wilt damage on fruit [1]

White mould

Sclerotinia sclerotiorum

White mould or also known as watery soft rot is caused by a fungal pathogen that affects a broad range of hosts. The disease starts at the base of the stem and generally spreads upwards to affect the rest of the plant. Light lesions that are moist appear on the stem and eventually encircle it entirely. White, cottony fungal mycelium appears on infected tissue. Large, irregularly shaped, black sclerotia can form on plant surfaces but are even more abundant inside infected stems. Stems eventually dry and have a bleached appearance and wilting of the plant occurs. Flowers and fruit can also be infected, with fruit turning grey and rotting. Favourable conditions for fungal spread are cool days with a temperature of around 4 – 30°C and high relative humidity, rainfall or heavy dew. Infections can occur from sclerotia in soil or airborne ascospores. This fungus is able to survive in soil for 8 to 10 years on plant debris left in the soil and it can also survive on different plant hosts. The plant hosts for this pathogen are widespread. It is reported that white mould can infect over 400 different plant species. These include crops such as: tomatoes, lettuce, beans, cabbage, peppers, eggplant, cucurbits, celery, peas, carrots, rutabaga, potatoes, sunflower and weeds.

Control and Management

Agronomic Interventions

- Promote air circulation in greenhouses to maintain a low level of humidity.
- Reduce or eliminate the presence of water on the plants by maintaining good ventilation, where possible heating the greenhouses and carry out irrigation in the morning or early afternoon and not during the night.
- Always remove plant debris, such as pruning debris, during the cultivation of the crop.
- Adequate fertilization should be applied. Nitrogen fertilizer should be regulated to be provided at doses which are neither too high nor too low.
- In case of greenhouses, carry out hygienic good practice measures such as cleaning the greenhouse structure and equipment involved and installing foot baths at the entrance.
- Practice crop rotations for at least 5 years with crops such as cereals, broccoli, onions, and spinach.

- In areas where this fungus was present in the previous crops, practice soil disinfection by solarization or soil fumigants.
- The ground should be well worked and drained before planting new seedlings.
- Practice deep ploughing so as to burry sclerotia and then the soil-borne micro-organisms can destroy this fungus.
- If possible, the row should be done in line with the prevailing wind so as to provide better air ventilation for the stem.
- Use plastic or biodegradable plastic mulch so as to minimize and avoid contact of the crop with the soil.
- Avoid the planting of crops in high densities especially in areas prone to this fungus.

Chemical Interventions

Chemical interventions should only take place in the presence of the pathogen in previous years and on the first symptoms. The active substances used should be altered from different mode of action groups.

PLANT PROTECTION SUBSTANCES

- *Coiniothryrium minitans*
- *Trichoderma* spp.
- *Trichoderma gamsii*
- *Trichoderma asperellum*

Stem infected with Sclerotinia sclerotiorum having a bleached appearance. White fungal growth and black rock-like sclerotia present [14]

Tomato leaf mould

Cladosporium fulvum syn. *Passalora fulva*

Tomato leaf mould is caused by a fungal, host-specific pathogen that mainly affect tomato plants grown in greenhouses. The use of excessive nitrogen tends to promote the spread of such pathogen. Infections occur within 24 to 48 hours when temperatures are between 10 to 27°C and high relative humidity at or above 85%. 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 the 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, soil and also on the greenhouse walls. The conidia are very resistant to drying and can survive up to a year even in the absence of a host.

Control and Management

Agronomic Interventions

- Promote air circulation in greenhouses to maintain a low level of humidity.
- Avoid instances where there is the presence of free water on the leaves.
- Carry out green pruning of foliage regularly. The lower leaves should be removed so as to increase ventilation at the lower part of the plant.
- Plant debris should be removed promptly from the greenhouse.
- When removing the crop, the plants should be uprooted and destroyed.
- Provide a balanced fertilization regime and avoid access of nitrogen.
- Avoid high planting density.
- Use varieties which are resistant, these are indicated with 'C5' in seed catalogues.
- The greenhouse structure should be disinfected before planting, especially when the pathogen was already present in the previous crop cycle.

Chemical Interventions

Apply treatments at the first signs of this pathogen. In areas where they are at higher risk, treatment should be carried out at intervals of 10 days.

PLANT PROTECTION SUBSTANCES

- Azoxystrobin (1)
- Difenoconazole (2)
- Tetraconazole (2)
- Metiram (3)
- Cyflufenamid (4)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) At most, apply not more than twice per growing season. Between compounds from the same mode of action group (C3);Tryfloxistrobin and Azoxystrobin apply not more than three times 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) Do not exceed three interventions per cultivation period.

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

Velvety mould on underside of leaves [9]

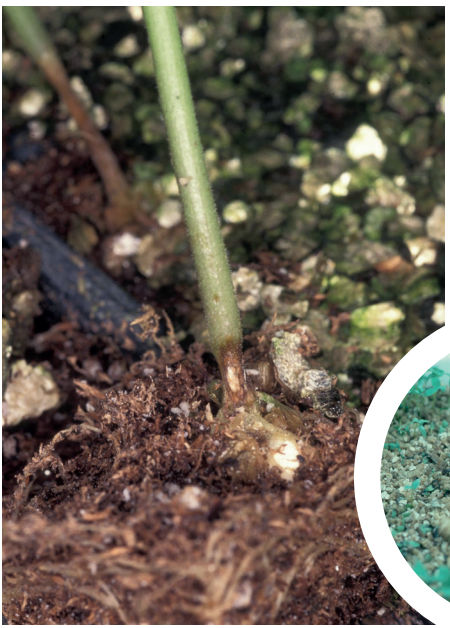
Yellow leaf spots [7]

Damping-off and root rot

Pythium spp.

The fungal pathogens Pythium 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 of wet soils especially if water soakes through and cool temperatures. Affected seedlings exhibit dark stems with shrivelling at the soil line and becoming yellow before dying off. In soilless crop production on substrates, the fungus can also affect the plant throughout the whole production cycle 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. The rot can be sometimes seen at the crown as it turns brown or black in colour. Eventually, the foliage may start yellowing and wilting of the plant occurs. Plant infections lead to necrosis of fruit and yield losses.

The optimum temperature for Pythium varies from different species of this pathogen. Some species prefer cold soils with temperature around 15 to 20°C others have higher thermal optima, such as temperatures 26 to 30°C.



Lesion on the lower stem [1]

Damping-off symptoms showing area of seedlings not emerging [10]

Control and Management

Agronomic Interventions

- Always ascertain the use of certified-healthy seeds.
- Practice crop rotation extensively.
- Avoid instances of waterlogged soil and maintain irrigation to minimum. If required apply organic matter to alleviate the soil.
- Provide balanced fertilization regime so as to avoid stress to the plants.
- Any diseased plants and debris should be disposed accordingly after the crop cycle and during the cultivation period. Plant roots also should be eliminated in cases when this pathogen is present.
- Plant tomatoes on ridges and use plastic/biodegradable plastic mulch to minimize water retention around the crop.
- Use drip-type irrigation when possible.
- If the pathogen was already detected in the preceding crops, the practice of soil solarization or fumigation is suggested.
- In soilless cultures before planting a new crop disinfect all parts involved such as the irrigation system and drainage system.The substrate should be replaced.
- Make sure that the water source is not contaminated with this pathogen. If there is the risk that the water might be contaminated, the water use should be disinfected. This can be done by using methods such as UV filtration and biofiltration.

Chemical Interventions

Intervene at the presence of the first symptoms.

PLANT PROTECTION SUBSTANCES

- *Trichoderma asperellum*
- *Trichoderma* spp
- *Trichoderma gamsii*
- Propamocarb (1) + Fosethyl Aluminium

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Employ twice per cultivation period. Apply compound via drip irrigation or localized application.

Brown root rot

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/tolerant against this adversity and use grafted plants with resistant rootstock.
- Practice crop rotation extensively.
- Eliminate any diseased plants, including the roots, from the field and destroy appropriately.
- Fields which have been susceptible to infection by this pathogen or associated with past infestation cases, should be disinfected before planting of the new crop. This can be done by soil fumigants or soil solarization or pasteurization. Alternatively, one can grow the crop in a soilless culture.
- The material used for soilless culture should be changed if this pathogen was detected in the previous crop cycle.

Symptoms of brown root rot [11]

Botrytis grey mould

Botrytis cinerea

Botrytis rot, also known as grey mould, is a fungal pathogen that infects a variety of plant species and can cause significant damage during cultivation and post-harvesting. The disease favours high relative humidity about 95% and free water caused by rains, overhead irrigation, or heavy dew and is especially common in greenhouses in periods with prolonged high ambient humidity. The pathogen favours mild temperatures of 17 to 23°C. Under favourable 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. Infected fruit, the green non ripe ones, will show thin whitish rings of diameter of about 2 to 10 mm which encircles a small central necrotic lesion, these are known as 'ghost spots'. On ripe fruit these spots will be yellowish. The fruit 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 and can be carried through wind, air currents and water droplets. These apply both in outdoor cultivation and greenhouses. Workers can also be a means of dissemination of this pathogen.

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 were the plant can be able to evaporate, especially for greenhouse crops.
- The climatic conditions in a greenhouse must be kept ventilated as much as possible so as to reduce the ambient humidity and to avoid the presence of water on the plants.
  - Try to maintain the temperature inside the greenhouse about 17°C at sunrise so as to prevent causing condensation on the plants.
  - Aeration should be carried out sparingly and when the temperature outside the greenhouse is below 12°C.
- When carrying out green pruning, care shout be given to keep the cut within the stem as smooth as possible and to avoid large wounds.
  - Preferably pruning should be carried out in the morning since the wound will have more time to dry.
  - Pruning should not be done when the weather is overcast or with high humidity.
- Provide a balanced fertilization regime.
- Plant debris should be removed from the field.
- Avoid high density planting.

Chemical Interventions

- Use active substances with different mode of actions so as to avoid the development of resistant strains.
- In conditions known for promoting infection, apply preventive treatments especially when green pruning is carried out.

PLANT PROTECTION SUBSTANCES AND DEVICES

- *Bacillus subtilis* (1)
- *Phthium oligandrum* strain *M1*
- *Aurebasidium pullulans* (2)
- *Trichoderma atroviride*
- *Bacillus amyloliquefacien* (3)
- *Saccharomyces cerevisiae*
- Cerevisane
- Fenexamid (4)
- Penthiopyrad (5)
- Pyrimenthanil (4)
- Fludioxonil (6) + Cyprodinil (6)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

General Limitations

(1) When mixing fungicides do not combine more than two different active substances in the same mixture, for any adversity whatsoever. Products which are excluded from this limitation include 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 with regardless.

Specific Limitations

(1) Do not exceed four applications per cultivation period.

(2) Do not exceed five applications per cultivation period.

(3) Do not exceed six applications per cultivation period.

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

(5) Apply a maximum of one application per cultivation period. Not more than 3 interventions per cultivation period from compounds from the same mode of action group (C2); Fluxapyroxad and Penthiopyrad compounds regardless of crop or disease.

(6) Do not exceed one application per cultivation period.

Ghost spots on fruit [1]

Diseased stem showing grey sporulation[1]

Tomato viruses

CMV, PVY, ToMV, TSWV

Various viral pathogens can affect tomato plants and these include the cucumber mosaic virus (CMV), potato virus Y (PVY), 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 the leaves. Fruits ripen unevenly, may remain small, exhibit discoloured spots and depressions and sometimes browning of necrotic lesions, and there is an overall reduction in yield. Transmission of virtual pathogens occurs through pests vectors such as aphids, thrips and other insects, mechanically, or through plant debris or seeds and insects.

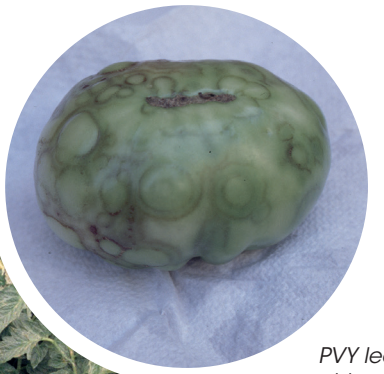
Control and Management

Agronomic Interventions

- Sow only plants that have been certified free of viruses.
- Sow plants that are known to be tolerant to virus infection.
- Monitor for virus vectors (aphids and thrips) in high-risk areas.
- Control the weeds to avoid potential spread of viruses.
- Install foot baths at all the greenhouse entrances with a viricide.
- Once detection of 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 [7]

ToMV symptoms on leaves [12]



PVY leaf chlorosis [5]

TSWV plant wilting [7]

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 canker develops under conditions of temperature between 25 to 30°C and high humidity. This leads to the yellowing of the leaves' edges following by the leaves turning brown, wilting, with entire plant death. If dissected, the stems exhibit internal discolouration with brown streaks in the vascular system. The stems can split and yellow sticky bacterial ooze may emerge from cut stems. Fruit can exhibit white creamy spots with brown centres.

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 black spots 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 2-3 mm form. These are initially yellow-green but with progressive necrosis they become brown surrounded by a yellowish halo. Spots with a dark green halo form on the fruit. Such spots grow to a diameter of 3–8mm and turn into a scabby brown lesion.

Pith necrosis symptoms first appear on maturing fruit, with the leaves turning yellow and later start to wilt. Dark brown to black necrotic lesions start to form on the stem. Severely infected plant stems crack and collapse and stems exhibit pits that appear emptied with blackened inner canals. A common, easy to identify symptom is 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.

Control and Management

Agronomic Interventions

- Plant only seeds and plantlets which are visibly healthy and tolerate varieties. Use seeds and seedlings which are certified free from diseases.
  - Avoid water logging events and surface type irrigation.
- Keep a well-ventilated greenhouse.
- Practice crop rotations with rotation periods every 2-3 years.
- Destroy weeds and any unwanted vegetation. If these are infected, these should be destroyed by igniting vegetation and always avoid burying practices.
- In fields where there were previous cases of this pathogen disinfect the greenhouse walls before planting.
- Practice sanitary measures.
  - Install foot bath at greenhouse entrances.

Chemical Interventions

Intervene after the first indications of infection with repeated application of compounds every 7-10 days following the flowering phase.

PLANT PROTECTION SUBSTANCES AND DEVICES

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

LIMITATIONS OF USE AND SPECIAL CONDITIONS

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

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

Bacterial canker split, discoloured stem[13]

Bacterial canker fruit spots[13]

Bacterial speck on leaf [1]

Bacterial speck on fruit [14]

Bacterial spot on leaf [4]

Bacterial spot, scabby lesions on fruit [14]

Pith necrosis: cross-section through stem [1]

Adventitious roots caused by pith necrosis [1]

Aphids

Myzus persicae, Macrosiphum euphorbiae

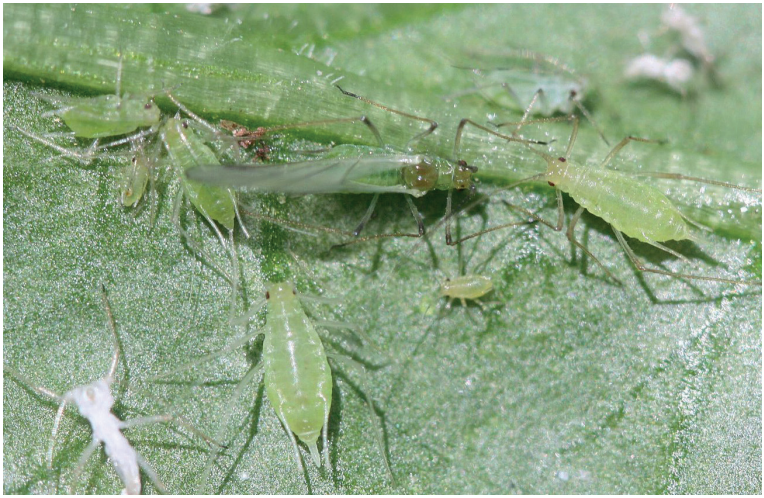
The two most common aphids on tomatoes are the green peach aphid (*Myzus persicae*) and the potato aphid (*Macrosiphum euphorbiae*). Aphids are sap-sucking insects and can also cause damage by being vectors for disease, spreading viral pathogens. Favourable conditions for these insects are mild temperatures.

The green peach aphid adult is oval-bodied, around 1.2–2.1mm 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 1.7–3.6mm long.

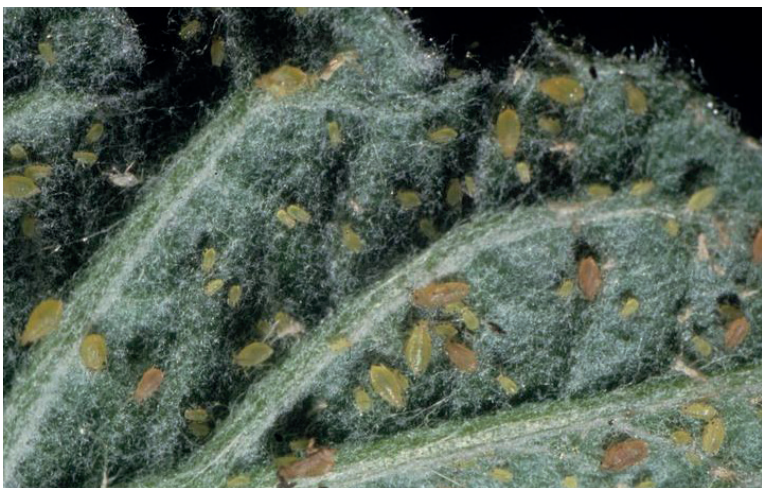
One often finds aphids at different life stages on one plant. In greenhouses, infestations can occur early in the season due to parthenogenetic females surviving in the environment in unfavourable periods (absence of crops, lower temperatures). Aphids can attain high density and severe infestations may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

The larva and adults are normally found on the underside of the leaves, 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 within the colonies of aphids one can also find white caste skins and the presence of honeydew. On this honeydew, consequently, one can find also sooty mould growing. Aphids are vectors of numerous viruses including CMV.



Macrosiphum euphorbiae aphids [16]



Myzus persicae infestation [17]

Control and Management

Agronomic Interventions

- Infestations can be limited via the application of beneficial insects that occur naturally in the field or other beneficial insects.
- Protect all greenhouse apertures and entrances using an insect net.

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 AND DEVICES

- Pure Pyrethrin (1)
- Sufloxaflor (2)
- Acetamiprid (3)
- Maltodextrin
- Flupyradifurone (4)
- Flonicamid (5)
- Spirotetramat (6)
- Potassium salts of Fatty Acids
- Azadirachtin

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not exceed more than two applications.
(2) Limit to one application per cultivation period.
(3) Combined limit of one application from all neonicotinoid pesticides.
(4) One application per cultivation period. If grown in protected environment, two applications are allowed.
(5) Maximum of two interventions; Allowed only on *Myzus persicae* and *Aphis gossypii.*
(6) Maximum two interventions per cultivation period. Do not exceed cumulative limit of four applications per cultivation period from Spirotetramat and Spiromesifen active substances.

Leaf miner

Liriomyza spp.

Liriomyza is a genus of leaf miner flies that include 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 1–2 mm in body length black and yellow coloured flies.

Females lay eggs, generally on the upper side of the leaves, with an ovipositor. Eggs are small (~0.2mm in 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 and change colour to a yellow-orange in later instars and grow to around 3 mm in length.

The first visible damage is many chlorotic punctures 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 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 the 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 temperature of 15°C and 17 days at temperature of about 25°C.

Control and Management

Agronomic Interventions

- Store apart and destroy all crop residues after harvest.
- Protect all greenhouse apertures and entrances using an insect net.

Chemical Interventions

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

PLANT PROTECTION SUBSTANCES

- Spinosad (1)
- Abamectine (2)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

General Limitations

(1) Carefully evaluate the presence of Leaf miner in order to avoid confusion with Tuta absoluta and carry out interventions that are suitable for this adversity.

Specific Limitations

(1) Maximum of three interventions per cultivation period.
(2) Maximum of six interventions per cultivation period. Combined limit of three interventions from Abamectine and Emamectine.

Adult Liriomyza trifolii [18]

Mines caused by larva feeding [4]

Two-spotted spider mite

Tetranychus urticae

The lifecycle of the two-spotted spider mite, or also known as red spider, includes a total of 5 development stages. These are the eggs, larva protonymph, deutonymph, and adult. The time in which a cycle is complete varies on the temperature. In temperatures of about 30°C it takes about 7 days, while in temperatures of about 15°C it takes 36 days. The adult female is able to diapause in low temperatures or when the food supply diminishes.

An adult female of the two-spotted spider mite is ~0.6 mm in length, 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/orange red. The round small eggs, 0.14mm in diameter, at first translucent and then become yellow 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 mite 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 by walking to other plants or can be transported by workers, equipment/machinery or scattered by moving plant parts/debris.

Control and Management

Agronomic Interventions

- Dispose apart and destroy all crop residues after harvest and pruning material.
- Protect all greenhouse apertures and entrances using an insect net.
- Maintain the area free from unwanted weeds.

Biological Interventions

The beneficial insect *Ambliseius andersoni* and *Phytoseiulus persimilis* can be used to control spider mites. These natural predators should be released preferably before the infestation takes place and also during the progress of infestation to promote the control of mites.

Chemical Interventions

- Intervene when a diffused infestation has been detected.

PLANT PROTECTION SUBSTANCES AND BENEFICIAL INSECTS

- *Phytoseiulus persimilis*
- *Ambliseius andersoni*
- *Beauveria bassiana*
- Terpenoid blend QRD 460 (5)
- Maltodextrin
- Potassium salts of fatty acids
- Cyantraniliprole (1)
- Acibenzolar-S-methyl
- Bifenazate
- Abamectine (2)
- Clofentezine (3)
- Hexythiazox (3)
- Tebufenpyrad (3)
- Fenpiroximate (3)
- Spiromesifen (4)
- Cyflumetofen
- Acequinocyl

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) The combined application limit for Chlorantraniliprole and Cyantraniliprole is of two applications per cultivation period.

(2) For active substances Abamectin and Emamectin do no use more than two applications per cultivation period.

(3) Limit of one application per cultivation period.

(4) A total of four combined applications from Spirotetramat and Spiromesifen.

(5) To be used only in greenhouses.

Two females and an egg [19]

Leaves with stippled appearance [4]

Tomato fruit borer

Helicoverpa armigera

The tomato fruit borer, *Helicoverpa armigera*, is the larval stage of a moth in the family Noctuidae and is a polyphagous pest that feeds on a variety of important crops. The caterpillar larvae causes damage to tomato plants by feeding on foliage as well as flowers and fruit. Female moths can lay hundreds of eggs. Fully grown caterpillar larvae are approximately 4 cm long. The larva is generally green to brown in colour. *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 that feed on leaves and flowers. A second generation follows with larvae that damage both ripe and unripe fruit, leaving circular holes. During a season, there can be around 4 generations, after which the pest overwinters in the soil.

The life cycle of these Lepidoptera species is split into four stages; eggs, larva or caterpillar, pupa or chrysalis and butterfly/moth. The eggs can have different colours such as transparent, white, brown, black or purple. The size of the eggs normally is smaller than one millimeter in diameter. The eggs can be deposited in groups on different parts of the plants. When these eggs hatch, these turn into caterpillars. Then the larva turns into pupae and usually measures about 2 to 2.8 cm and is red-brown in colour. After pupae it then changes to a butterfly. The length of the life cycle depends on the temperature, however, it ranges from 10 days to weeks.

Control and Management

Agronomic Interventions

- Store apart and destroy all crop residues after harvest.
- Protect all greenhouse apertures and entrances using an insect net.
- It is advisable to make use of pheromone traps for an accurate deduction 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

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

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Use not more than once per cultivation period.

(2) Maximum of three interventions per cultivation period. When using spinosad-type compounds, do not exceed more than three applications per growing season.

(3) Maximum of two interventions per cultivation period. When using spinosad-type compounds, do not exceed more than three applications per growing season.

(4) Apply a maximum of two interventions per cultivation period. Do not exceed the combined limit of two applications per cultivation period when using active substances: Chlorantraniliprole and Cyantraniliprole.

(5) Maximum of two interventions per cultivation period between active substances Methoxyphenozide and Tebufenozide.

(6) Limit of three applications per cultivation from compounds containing Abamectin and Emamectin.

(7) Limit of two interventions per cultivation period.

Helicoverpa armigera larva [20]

Helicoverpa armigera larva feeding on fruit [21]

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 larval stage, i.e. the caterpillars, are the cause of damage to the tomato plant since they feed on the crop. Both species are very polyphagous, 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 1000 eggs. As the caterpillars mature, they become most active at night and during the day 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 larva 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

Agronomic Interventions

- Store apart and destroy all crop residues after harvest.
- Protect all greenhouse apertures and entrances using an insect net.

Chemical Interventions

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

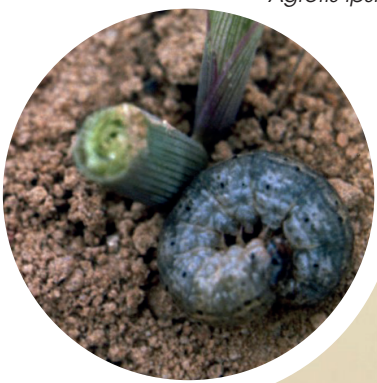
PLANT PROTECTION SUBSTANCES

- Cypermethrin (1)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Maximum three interventions 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 [22]



Agrotis sp. Larva [23]

African cotton leafworm

Spodoptera littoralis

The African cotton leafworm, *Spodoptera littoralis*, is the larval stage of a moth in the family Noctuidae and is a polyphagous pest that feeds on a variety of important crops. The adult moths have a greyish-brown body with a wingspan of 30-40 mm and a life span of 5-10 days. Female moths can lay hundreds of eggs (between 20-1000 eggs) on the lower surface of younger leaves or upper parts of the plant. Fully grown caterpillar larvae are are approximately 45 mm long, blackish-grey or dark green in colour and may become reddish-brown. The pupa is about 15–20 mm, reddish brown and cremaster with two small spines.

The caterpillar larvae cause damage to tomato plants by feeding on foliage as well as flowers and boring fruit making them unmarketable. Boring of the fruit often happens from the stem. Feeding causes extensive damage including the potential for secondary infections and decay. *Spodoptera littoralis* can go through numerous life cycles in a year with around 7–9 generations in greenhouses.

Spodoptera littoralis larva [25]

Spodoptera littoralis adult moth [24]

Eggs of Spodoptera littoralis 34

Spodoptera spp. Larva feeding on fruit [4]

Control and Management

Agronomic Interventions

- Use pheromone traps to monitor the presence of this pest and place electro-fluorescent traps for mass capture of adults.
- Protect all greenhouse apertures and entrances using an insect net.

Chemical Interventions

- Intervene only at the appearance of the first larvae.

PLANT PROTECTION SUBSTANCES AND DEVICES

- Spinetoram (1)
- *Spodoptera littoralis nucleopoliedrovirus*
- Tebufenozide (2)
- Methoxyphenozide (2)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Maximum of two interventions per cultivation period. When using spinosad-type compounds per do not exceed three applications per growing season.

(2) Maximum of two applications per cultivation period from active substances of the same mode of action group (Tebufenozide and Methoxyphenozide).

Thrips

Frankliniella occidentalis

Thrip species found on a tomato plant include the western flower thrips, *Frankliniella occidentalis.* Adult thrips are generally less than 1.5 mm 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, with as little as 13 days when the temperature is around 30°C. The lifecycle of thrips consist of six stages; eggs, 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 8 cm 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 on leaves which appear as silver lesions, irregular in shape and size and then these become necrotic and take on a beige shade. These also dotted with tiny black spots, as a result of the faeces left by thrips. Thrips may also damage the flowers and fruit, including scarring or discoloration. Thrips can be a vector of 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 day.

Control and Management

Agronomic Interventions

- Place yellow stick traps.
- Maintain the area/inside and outside of the greenhouse weed free.
- Protect all greenhouse apertures and entrances using an insect net.

Chemical Interventions

Intervene at the initial signs of infestation.

PLANT PROTECTION SUBSTANCES

- *Beauveria bassiana*
- Essential Oil of sweet orange
- *Paecilomyces fumosoroseus*
- Potassium salts of fatty acids
- Terpenoid blend QRD 460 (5)
- Acibenzolar-S-methyl (benzothiadiazole)
- Spinetoram (1)
- Abamectin (4)
- Formentate (2)
- Chlorantraniliprole (3)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not exceed two applications per cultivation period. Also consider cumulative limit of not more than three applications when using spinosine-type compounds in one cultivation period.

(2) Only one application per cultivation period.

(3) Maximum of two combined applications per cultivation period from Chlorantraniliprole and Cyantraniliprole.

(4) Maximum three applications per cultivation period from compounds Abamectin and Emamectin.

(5) To be used only in greenhouses.

Frankliniella occidentalis adult [26]

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 thee lifecycle stages; egg, four larva stages and then the adult. This Lifecyle is carried out on the underside of the crop leaf. The eggs are able to survive in temperatures which are below 0°C for several days. The eggs are white, oval shaped and their diameter is of 0.25mm. By time, the eggs change to a darker colour and hatch into larva in 7 to 10 days. The larvae are oval, flat and 0.3mm long and have an antenna and developed legs. At the second larvae stage they become flattened, transparent and measure 0.37mm. During the third and fourth larvae stage they are similar however the lengths are different; 0.51 and 0.73 mm respectively. Whiteflies adults are 1 to 1.5 mm long, yellow in colour and have white wings that are covered with a waxy coating.The lifecycle of whiteflies at optimal temperatures around 28°C takes around 20 days and multiple generations can be present in a season.

The adult and nymphs feed on leaf sap with their piercing, sucking mouthpart that in severe infestations, can result in 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/inside and outside of the greenhouse weed free.
- Protect all greenhouse apertures and entrances using an insect net.

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.

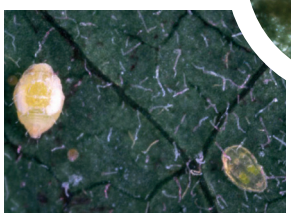
PLANT PROTECTION SUBSTANCES AND DEVICES

- *Beauveria bassiana*
- *Ambliseius swirskii*
- Potassium salts of fatty acids
- *Paecilomyces fumosoroseus*
- Essential oil of sweet orange
- Terpenoid blend QRD 460 (4)
- Azadirachtin
- Maltodextrin
- Pyrethrin (1)
- Acetamiprid (3)
- Flupyradifurone (1)
- Cyantraniliprole (5)
- Acibenzolar-S-methyl
- Flonicamid (6)
- Sulfoxaflor (2)
- Piriproxifen (2)
- Spirotetramat (7)
- Spiromesifen (8)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Maximum of two applications per cultivation period.
(2) Limit of one application per cultivation period.
(3) Limit of one application combined from all neonicotinoids compounds.
(4) To be used only in greenhouses.
(5) Limit of two applications from Chlorantraniliprole and Cyantraniliprole.
(6) Limit of two applications per cultivation period when used with drip irrigation. A maximum of 3 applications per cultivation period, if applied by spraying.
(7) Maximum of two applications per cultivation period. Apply up to four applications between active substances from the same mode of action group 23 (Spirotetramat and Spiromesifen).
(8) Apply up to four applications between active substances from the same mode of action group 23 (Spirotetramat and Spiromesifen).

Bemisia tabaci adult [27]



Bemisia tabaci larvae [36]

Bemisia tabaci eggs [35]

Trialeurodes vaporariorum infestation

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 1 cm in lenght 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 a minimum and maximum thresholds at 14 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 during 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 causing 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 and place electro-fluorescent traps for mass capture of adults.
- Install sexual confusion devices at the start of the crop cycle.
- Protect all greenhouse apertures and entrances using an insect net.

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 puncture 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 chemical resistance by insects.

PLANT PROTECTION SUBSTANCES AND DEVICES

- Sexual confusion devices (8)
- *Bacillus thuringiensis*
- Azadiracthin
- Emamectin benzoate (1)
- Abamectin (1)
- Spinetoram (2)
- Spinosad (3)
- Metaflumizone (4)
- Etofenprox (6)
- Tebufenozide (7)
- Cyantraniliprole (5)
- Chlorantraniliprole (5)
- Acibenzolar-S-methyl

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Maximum of three applications per cultivation season from active substances from the same mode of action group 6 (Abamectin and Emamectin benzoate).

(2) Two permitted applications per cultivation period. Do not exceed the combined limit of three applications from all Spinosad-type compounds in one cultivation season.

(3) Three permitted applications per cultivation period. Do not exceed the combined limit of three applications from all Spinosad-type compounds in one cultivation season.

(4) Two application per cultivation period.

(5) Limit of two applications from Chlorantraniliprole and Cyantraniliprole per cultivation season.

(6) Limit of one application from all pyrethroid compounds in one cultivation period.

(7) From Tebuzenozide and Metossifenozide, only two applications in one cultivation period.

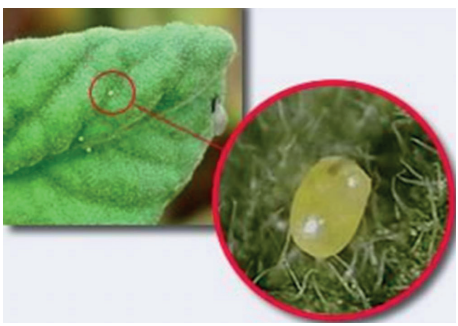
(8) Install these devices at the beginning of the crop cycle, at planting stage.

Malte adult [22]

Borrowing of larva in fruit [21]

Feeding of larva on leaf [21]

Larva of Tuta absoluta inside a tomato stem [16]



Egg of Tuta absoluta [16]

Tomato russet mite

Aculops lycopersici

The tomato russet mite attacks various cultivated Solanaceae plants including the tomato, potato, aubergine, pepper and tobacco. The mite is small and not visible with 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, hot and dry weather with humidly 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 can be distributed through the field by 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/machinery used so as to avoid dissemination to uninfected crops and fields.
- Maintain the area weed free.
- 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.
- Protect all greenhouse apertures and entrances using an insect net

Biological Interventions

A beneficial insect which can control tomato russet mite is *Ambliseius andersoni.* This can be introduced at infestation stage or before infestation when there is the favourable conditions for this pest.

Chemical Interventions

Intervene once symptoms have been detected.

PLANT PROTECTION SUBSTANCES

- *Spirotetramat (1)*
- *Sulphur*
- *Potassium salts of Fatty acids*

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not exceed two applications per cultivation period. Spirotetramat and Spiromesifen combined limit of four applications per cultivation period.

Tomato russet mite (Aculops lycopersici) damage on tomatoe fruit [37]

Root-knot nematodes

Meloidogyne spp.

Root-knot nematodes are parasitic, polyphagous species that feed and infect the roots of tomato plants, among other Solanaceae plants. Nematodes are present in the soil and are very small, less than 1 mm in length. The life cycle of *Meloidogyne* spp. takes between 3 to 8 weeks, and depends on the 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 0.5 mm 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 were 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. *Meloidogyne* spp. can live on a wide range of plants, over 5500 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 – 200,000 larvae per one kilo of soil.

Eggs and larvae can be moved from a place to another by water runoff, drainage and irrigation water. The larvae itself 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/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 crop and affected crops, including the roots.
- Avoid water stagnation when carrying irrigation.
- Use only tolerant / resistant crop varieties and root stocks.
- Use Brassicaceous seed meals.
- Repeat pre-planting ploughing for several times.
- Agricultural tool/machinery used in contaminated areas should be cleaned.
- Solarize the ground with a polyethylene transparent plastic having thickness of 0.035-0.050 mm 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 lilacinum* strain 251 (former *Paecilomyces lilacinus* strain 251) (1)
- Garlic extract
- Geraniol+thymol
- Azadiractin
- Fluopyram (3)
- Abamectin (nematicide) (2)
- Fosthiazate
- Oxamyl (4)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

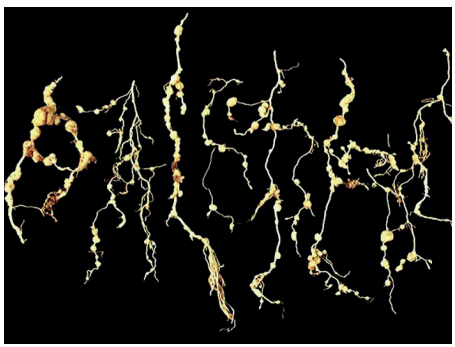
(1) Apply product to the ground, 14 days prior to sowing. Repeat treatment every 6 weeks at a dose of 4Kg/Ha.

(2) Apply three times per cultivation period. Limit applies for both Abamectin and Emamectin in one cultivation period. Apply product via irrigation system using drip.

(3) One application per cultivation period. Two interventions are allowed when grown under protected cultivation. Do not exceed the maximum permitted limit of two applications from compounds Boscalid, Fluopyram, Pentopyrad, Fluxapyroxad and Isopyrazam.

(4) Should be applied only by drip irrigation when the crop is transplanted. To be used only in greenhouses.

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



Meloidogyne sp. forming galls on roots [28]

Sclerotinia, Rhizoctonia, Pythium

Sclerotinia sp., *Rhizoctonia solani, Pythium* spp.

The fungal pathogens *Sclerotinia* sp., *Rhizoctonia solani*, and *Pythium* spp. can cause various rots and mould in tomato plants – *Sclerotinia sclerotiorum* causes stem rot and white mould; *Pythium* spp. cause damping-off, root and basal rot in tomato plants (refer to pg 25 and pg 26 respectively). *Rhizoctonia solani* causes similar symptoms to that of *Pythium* and this soil-borne fungal pathogen is responsible for seedling damping- off and foot rot. Symptoms may include stem lesions and infected plants may wilt, remain stunted or die off. The pathogens can be treated as indicated below.

Control and Management

Agronomic interventions

- Always ascertain the use of certified-healthy seeds.
- Practice crop rotation extensively.
- Avoid instances of waterlogged soil and maintain irrigation to a minimum.
  - Use drip-type irrigation when possible.

Chemical Interventions

Interventions are to be applied at pre-planting phase.

PLANT PROTECTION SUBSTANCES AND DEVICES

- Metam-sodium (1)
- Metam-potassium (1)
- Dazomet (2)
- *Trichoderma asperellum (3)*
- *Trichoderma atroviride (3)*
- *Trichoderma harzianum*
- *Pythium oligandrum* strain M1

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not exceed the limit of once every three years. Maximum allowed application per year is of 1000 litres of formulation compound.

(2) Do not exceed the limit of once every three years. Apply at doses of 40-50g per meter squared.

(3) Maximum of five applications per cultivation period.

Symptoms of root rot caused by Rhizoctonia solani

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 12 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 20–30 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 2nd instar stage. The stink bugs feed by inserting their needle-like mouth parts 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

- Protect all greenhouse apertures and entrances using an insect net.
- Keep the area weed free.

PLANT PROTECTION SUBSTANCES

- Deltamethrin (1)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Apply a maximum of one application taking into consideration all pyrethroid compounds.

Halyomorpha halys Adult

Southern green shield bug

Nezara viridula

The southern green stink bug is a polyphagous pest. Adults can be identified from their distinct shield-like shape and solid green colour. Adults are around 12 to 16 mm in length and 8 mm wide. The immature stages of the insect have a different colour; nymphs start black and progressively turn green while having a distinctive pattern of spots on the abdominal segments, which eventually disappears 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 of 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 grow bigger 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 affect the crop.

This bug has multiple development stages, starting with the eggs, five larval stages and then the adults. The spam of one life cycle varies according to the temperature. At temperatures of about 30°C a life cycle takes about three weeks and at temperature of about 20°C it takes about 2 months. The eggs are off-white in colour, shaped like a small keg, grouped in honeycomb and found usually on the underside of the leave. When the larva hatches from the eggs, the larva, is usually dark red to black and with white spots. Then the life cycle is followed by five instars, the first larvae being 1 mm long and the fifth one being 1 cm long. This is the ultimate stage before it changes into an adult.

Control and Management

Agronomic interventions

- Protect all greenhouse apertures and entrances using an insect net.
- Keep the area weed free.

Chemical Interventions

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

PLANT PROTECTION SUBSTANCES

- Deltamethrin (1)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Apply a maximum of one application taking into consideration all pyrethroid compounds.

Nezara viridula adult [31]

Nezara viridula adult [32]

Nymphs at different stages of maturity [32]

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