GOVERNMENT OF MALTA

FONDI.eu

MARROWS INTEGRATED PEST MANAGEMENT GUIDELINES

Agriculture Directorate

AgriConnect

Agriculture Research & Innovation Hub

CIHEAM BARI

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PLANT PROTECTION PRODUCT AUTHORISATION

Plant protection products (PPPs) need to be authorised by the MCCAA to be placed on the Maltese market in accordance with the provisions of Regulation (EC) No 1107/2009 implemented in Malta through Legal Notice 284 of 2011, 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 purchasing or applying any products to ensure their authorisation, even if they are listed in this publication. If assistance is required one can contact AgriConnect for further assistance.

For PPP substances which are listed in this publication and are currently not authorised, the Agricultural Directorate encourages farmers, farmer representatives and commercial entities to contact AgriConnect which will provide 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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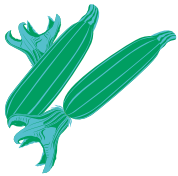

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Grey mould

Botrytis cinerea

Grey mould is a fungal disease that can affect zucchini plants and other members of the cucurbit family. It appears as a white or grey powder on the flowers and leaves of the plant. If left untreated, it can cause the plant to die. High humid weather, free moisture, and temperatures between 18 and 23°C can encourage the growth of this fungus. Temperatures above 32°C inhibit its growth. This form of fungal can thus be expected any time of the year. It is especially something to take care of when plants are grown in greenhouses or under tunnels, where conditions can be humid and overcrowded.

As for symptoms, the young fruits are particularly prone to soft rot attack leading to a greyish appearance of the soft tissues accompanied by collapse and water-soaking of parenchyma tissues, followed by a rapid appearance of grey masses of conidia that can be easily transported to nearby fruit. Infection commonly begins on attached senescent flowers and then, as a soft rot, it spreads to affect the adjacent developing fruit. The life cycle of grey mould is highly complex. *Botrytis cinerea* survives in and around the fields as a saprophyte on crop and weed debris, as pathogen on numerous crop and weed plants, and as sclerotia in the soil. The conidia develop from these sources and become windborne. When the conidia land on the crops, and moisture is available, they will rapidly colonize their food source.

Control and Management

Agronomic Interventions

- Ensure that there is no water stagnation in the soil.
- Avoid damaging the plant that may cause injuries.
- The climatic conditions in a greenhouse must be kept ventilated as much as possible 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 to prevent causing condensation on the plants.

- Aeration should be carried out sparingly and when the temperature outside the greenhouse is below 12°C.
- Plant debris should be removed from the field.
- Provide a balanced fertilization regime.
- Avoid high density planting.
- Avoid plant wetness.

PLANT PROTECTION SUBSTANCES

- *Pythium oligandrum Strain M1*
- *Bacillus subtilis*
- *Bacillus amyloliquefaciens* (1)
- Fenhexamid (2)
- Fenpyrazamine (2)
- Pyrimethanil (3)
- Cyprodinil + Fludioxonil (4)
- Fludioxonil (4)

DIRECTIONS FOR USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

(1) Maximum of 6 interventions per year regardless of disease / pest type.

(2) Maximum of 2 interventions per year when using Fenhexamid and Fenpyrazamine.

(3) Maximum of 2 treatments against this adversity.

(4) When using Fludioxonil, only 1 treatment per cultivation cycle.

Botrytis cinerea on a round marrow and on its flower [1]

Powdery mildew

Sphaerotheca fuliginea, Erysiphe cichoracearum, Podosphaera fuliginea

Powdery mildew is capable of infecting cucumbers, melons, pumpkins, courgettes, watermelons and many other crops. The first visible signs of the pathogen can be found on both sides of the leaves, petioles and stems. Normally the older, lower leaves are the first to show the symptoms. Its action damages the plants causing the deterioration of all vegetation and can quickly lead to a significant limitation of the production potential and (in the case of strong attacks) to a general reduction of the fruit quality. It can be recognized by the typical white specks appearing on the leaves which in favourable conditions can rapidly evolve into a powdery coating spread across the entire leaf surface.

The disease spreads rapidly in the presence of moderate temperatures, absence of precipitation, low light conditions and high levels of relative atmospheric humidity. It causes the appearance of small rounded white spots on the vegetative system of plants which then tend to converge until they cover both leaf blades. Subsequently the leaves turn yellow and, in the most serious cases, dry out resulting in significant damage to production.

All species of powdery mildew overwinter on volunteer or weed host plants, which then serve as a source of initial inoculum. Powdery mildew can also spread by wind as its conidia can be blown by the wind for long distances. The optimum temperature for infection is between 20 and 27°C, and a relative humidity between 40 and 100% is sufficient for the spores to germinate. Low, diffuse light also seems to favour powdery mildew development. The mildew can spread rapidly since the disease cycle can be completed in as little as 72 hours. However, it commonly takes 7-10 days from the time of infection to the development of symptoms and secondary spore production.

Control and Management

Agronomic Interventions

- Where possible the climatic conditions of the greenhouse should be set to reduce humidity and increase air circulation.
- In greenhouses where fungal attacks were present during the previous year/crop, the walls and the structure should be disinfected.
- Unwanted crops and weeds which can harbour the fungus should be removed from the field.
- It is important to follow basic hygienic measures such as;
  (i) limiting the number of visitors in the greenhouse to reduce the risk of dissemination,
  (ii) installing a foot bath at the greenhouse door.
- Plant resistant cultivars.

Chemical Interventions

Intervene when the symptoms occur.

PLANT PROTECTION SUBSTANCES

- *Ampelomyces quisqualis*
- *Pythium oligandrum*
- *Bacillus amyloliquefaciensis* (6)
- *Bacillus pumilus*
- Sulphur
- Potassium bicarbonate
- Cos-oga
- Cerevisane
- Orange oil
- Tebuconazole (3) (4)
- Tebuconazole (3) (4) + Azoxystrobin (1)
- Difenoconazole
- Penconazole (3)
- Tetraconazole (3)
- Fluxapyroxad
- Azoxystrobin (1)
- Trifloxystrobin (2)
- Meptyldinocap (2)
- Bupirimate (2)
- Cyflufenamid (2)
- Cyflufenamid (2) + Difenoconazole (3) (4)
- Fluzapyroxad (5) + Difenoconazole (3) (4)
- Eugenol + Geraniol + Thymol
- Metrafenone

DIRECTIONS FOR USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

A maximum of four interventions per crop cycle against this adversity, with the exception of Potassium Bicarbonate and Sulphur.

(1) A maximum of one intervention per year between Azoxystrobin, Pyraclostrobin and Trifloxystrobin, regardless of the adversity.

(2) A maximum of two interventions per year.

(3) A maximum of two interventions per year with Sterol Biosynthesis Inhibitors (IBE) plant protection substances. These IBE consist of three groups (FRAC groups G1 to G3) and are Demethylation Inhibitors (DMIs), the amines (previously called morpholines), and the Keto-Reductase Inhibitors (KRIs). These substances which are in these groups and are mentioned in these guidelines are: fenhexamid, fenpyrazamine, tebuconazole, difenoconazole, penconazole and tetraconazole.

(4) Between Tebuconazole and Difenoconazole, a maximum of one intervention per year.

(5) A maximum of two interventions per year between Fluxapyroxad, Isopyrazam and Fluopyram, regardless of the adversity.

(6) A maximum of six interventions per year, regardless of the adversity.

Powdery mildew on the surface of a zucchini plant leaf [1]

Powdery mildew on the back of a zucchini plant leaf [1]

Downy mildew

Pseudoperonospora cubensis

The Downy mildew (*Pseudoperonospora cubensis*) is a very typical pathogen for melon, courgette and cucumber. The first symptoms can be first noticed on the surface of the leaves. These symptoms consist of small, pale green to greasy-looking, angular or rectangular spots that are delimited by leaf veins. Then these patches turn chlorotic to bright yellow. Often these early symptoms will create a mosaic or mottled appearance on the leaf. By time the leaf tissue turns brown and necrotic, expanding and causing shrivelling and death of a large area of the leaf surface. With favourable climatic conditions, under the leaf surface, light grey to dark purple sporulation will start to form. The progression of downy mildew can cause stunning or also death to the plant. It can also affect the production of the fruit, the taste and the sugar content.

This pathogen is able to overwinter on volunteer or weedy cucurbit plants which can serve as a source of initial inoculum. If the humidity is at 100% for at least 6 hours and the temperature is 15 to 20°C, sporangia can be produced. Then the spores can be wind-blown or splashed on the host tissue and germination starts if free moisture is present on the leaf for at least 2 hours and the temperature is about 20 to 25°C. The pathogen penetrates through the stomata and, after an incubation period which in optimal conditions can last 3 to 12 days, translucent leaf spots (called oil spots) with an angular outline appear on the upper surface of the leaves inside the veins.

Severe symptoms of downy mildew [2]

Sporulation caused by downy mildew under the leaf surface [3]

Control and Management

Agronomic Interventions

- It is important to follow basic hygienic measures such as;
  (i) limiting the number of visitors in the greenhouse to reduce the risk of dissemination,
  (ii) installing a foot bath at the greenhouse door.
- Where possible the climatic conditions of the greenhouse should be set to reduce humidity and increase air circulation.
- In greenhouses where fungal attacks were present during the previous year/crop, the walls and the structure should be disinfected.
- Unwanted crops and weeds which can harbour the fungus should be removed from the field.
- Grow vining cultivars in trellis mode.
- If possible increase plant spacing.

Chemical Interventions

Intervene when the symptoms occur.

PLANT PROTECTION SUBSTANCES

- Copper (4)
- Cymoxanil (1)
- Azoxystrobin (3)
- Mandipropamid (1)
- Ametoctradin (1)
- Zoxamide (2)
- Cyazofamid (1)
- Propamocarb

DIRECTIONS FOR USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

With the exception of copper products, a maximum of three interventions per crop cycle against this adversity.

(1) A maximum of two interventions per year.
(2) A maximum of three interventions per year.
(3) A maximum of one intervention per year
(4) Not to exceed the cumulative application of 28 kg of copper per hectare over 7 years, and it is recommended not to exceed the average amount of 4 kg of copper per hectare per year.

Symptoms of downy mildew on the surface of the leaf [2]

White mould

Sclerotinia sclerotiorum

The first symptoms of white mould (*Sclerotinia sclerotiorum*) normally appear on dead tendrils or when old leaves or spent flowers rest on the fruit. It may also appear on damaged stems or leaves. Dark green water-soaked lesions develop on the vine or on the fruit. If ideal conditions are present, the lesions enlarge rapidly and will form an injury to the stem, leading to yellowing of the leaves and, if severe, death to the plant. As a result, the stem might split revealing a dense white, cottony fungal growth. The white and cottony mould is accompanied by small black circles on the infected part of the plant. It will eventually rot and break down.

Sclerotinia sclerotiorum can survive in the soil as sclerotia for a few months up to 10 years, depending on different factors, such as soil conditions, soil moisture and depth of burial. Burial depth can lower the germination rate and, if kept dry, it will be able to survive longer. This disease develops when the soil is too rich in nitrogen and the atmosphere is warm and humid (with a temperature between 20 and 25°C). They germinate and may infect the bases of plants directly. Those of *S. sclerotiorum* can also produce small creamy-brown saucer-shaped bodies, called apothecia, on the soil surface that promote infections of subsequent crop cultivations. Spores can be carried in air currents and wind until they land on plant tissue where they germinate and infect under humid and moist conditions following germination after a wet period.

Control and Management

Agronomic Interventions

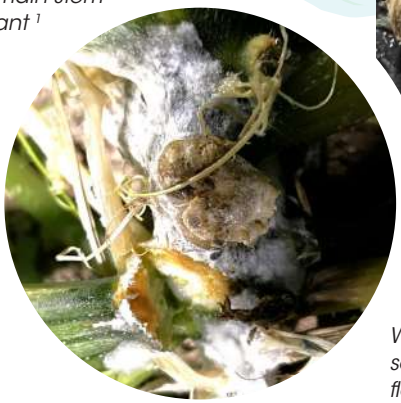
- Transplants should be disease-free.
- Promote air circulation in greenhouses to maintain a low level of humidity.
- Reduce or eliminate the presence of water on the plants by maintaining good ventilation, where possible heating the greenhouses and carrying out irrigation in the morning or early afternoon and not during the night.
- Adequate fertilization should be applied. Nitrogen fertilizer should be regulated and provided at doses which are not too high or too low.

- In case of greenhouses, carry out hygienic good practice measures, such as cleaning the greenhouse structure and the 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 to bury sclerotia so that the soil-borne micro-organisms can destroy this fungus.
- If possible, the row should be done in line with the prevailing wind to provide better air ventilation for the stem.
- Avoid damaging the plant to reduce any injuries.
- Use plastic or biodegradable plastic mulch to avoid contact of the crop with the soil.
- Avoid the planting of crops in high densities especially in areas prone to this fungus.

PLANT PROTECTION SUBSTANCES

- *Trichoderma asperellum and Trichoderma gamsii*
- *Pythium oligandrum* strain M1

Sclerotinia sclerotiorum forming on the main stem of a zucchini plant [1]



White mycelium and small black sclerotia forming on a rotten zucchini flower by Sclerotinia sclerotiorum [1]

Damping-off

Phytophthora spp.

Phytophthora capsici and other *Phytophthora* spp. can lead to several symptoms in cucurbits especially courgettes. These symptoms normally are: die-off of young seedlings, collar and root rot, leaf spot, leaf desiccation and pre/post-harvest fruit rot in mature plants. Symptoms of Phytophthora collar rot and root rot often appear rapidly and the plant dies within days of onset. Affected plants often show sudden and permanent wilting. The stems can collapse, while the foliage of withered plants remains green. Waterlogged soil patches cause extensive damage to the roots, collar and lower part of the stem, close to soil level. As a result, the tissues become soft, turning from white to dark beige-brown. In advanced stages of the disease, the lateral roots break off and eventually the entire root system is destroyed.

Phytophthora spp. manage to survive from one season to the next in the tissues of infected cucurbits or in those of another host (e.g., eggplant, pepper, and tomato). It is also able to survive in the soil. This organism is able to disperse as zoospores released from sporangia in surface and irrigation water, or as sporangia released into the air. Excessive irrigation, heavy rainfall and poor drainage favour the development of this disease. High mid- and late-season temperatures further stress already weakened plants, and the disease can spread rapidly. Its incidence is greater in valley areas, where the soil remains saturated for long periods. Increasing the frequency and/or duration of irrigation increases the incidence of this disease. Favourable conditions for this pathogen include soil temperatures above 18°C and prolonged wet periods with air temperatures of 24–29°C.

A zucchini squash plant showing symptoms of Phytophthora wilt caused by Phytophthora capsici in the field [4]

Phytophthora on zucchini fruit [6]

Close-up of crown of summer squash rotted by Phytophthora [2]

Control and Management

Agronomic Interventions

- Make use of certified-healthy seeds or seedlings.
- 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 to have a balanced fertilisation regime to reduce plant stress.
- Any diseased plants and debris should be disposed of accordingly after the crop cycle and during the cultivation period. Plant roots also should be eliminated where this pathogen is present.
- Make sure that the water source is not contaminated with this pathogen. If there is the risk that the water is contaminated, the water used should be disinfected. This can be done by using methods such as UV filtration and biofiltration.
- If the pathogen was already detected in the preceding crops, the practice of soil solarisation or fumigation is suggested.
- Use plastic mulch on ridges so to avoid water retention.
- If possible try to avoid planting in soils with poor drainage and that are heavy textured.

PLANT PROTECTION SUBSTANCES

- Propamocarb (1)
- Fosetyl-Aluminium + Propamocarb (1)
- Fosetyl-Aluminium
- *Trichoderma gamsii*
- *Bacillus amyloliquefaciens*
- *Pythium oligandrum* strain M1
- *Trichoderma asperellum* and *Trichoderma gamsii*

DIRECTIONS FOR USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

(1) Not more than two treatments per cultivation cycle.

Phytophthora spp infection of ripe zucchini fruit [5]

Root and crown of summer squash rotted by Phytophthora [2]

Root rot

Pythium sp

The disease, known as '*Pythium rot*', mainly affects courgettes in contact with wet soil. It is favoured by humidity surrounding the fruit as well as by a hot-humid climate. It is especially a risk to juvenile plants. The seeds may also be infested with this pathogen. It causes damping-off, root and basal rot. This can be caused before the seedling emerges or after it emerges. Affected seedlings exhibit dark stems with shrivelling at the soil line, 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 pathogens that are responsible for pythium root rot can be present in cultivated soils and attack plant roots under wet conditions. The optimum temperature for Pythium varies for different species of this pathogen. Some species prefer cold soils with temperatures around 15 to 20°C; others have higher thermal optima, such as temperatures of 26 to 30°C.

Control and Management

Agronomic Interventions

- Make use of certified-healthy seeds or seedlings.
- 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 to have a balanced fertilisation regime to reduce plant stress.
- Any diseased plants and debris should be disposed of accordingly after the crop cycle and during the cultivation period. Plant roots also should be eliminated in cases when this pathogen is present.

- Make sure that the water source is not contaminated with this pathogen. If there is the risk that the water is contaminated, the water used should be disinfected. This can be done by using methods such as UV filtration and biofiltration.
- If the pathogen was already detected in the preceding crops, the practice of soil solarisation or fumigation is suggested.
- Use plastic mulch on ridges so to avoid water retention.

PLANT PROTECTION SUBSTANCES

- Propamocarb (1)
- Fosetyl-Aluminium + Propamocarb (1)
- *Trichoderma gamsii*
- *Pythium oligandrum* strain M1
- *Trichoderma asperellum* and *Trichoderma gamsii*
- *Bacillus amyloliquefaciens*
- Fosetyl-Aluminium

DIRECTIONS FOR USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

(1) Not more than two treatments per cultivation cycle.

Seedling with a Pythium spp. damping-off lesion at the soil line [2]

Marrow seedling showing damping-off caused by Pythium spp.[2]

Marrow seedlings showing damping off symptoms caused by Pythium spp.[4]

Tray of marrow seedlings showing damping-off caused by Pythium spp.[2]

Angular leaf spot

Pseudomonas syringae pv. *lachrimans*

The angular leaf spot is also known as the bacterial spot of cucurbits. The first symptoms will appear on the leaves as small irregularly-shaped, water-soaked, grey-coloured lesions. As these lesions expand, they will become angular in shape as the lesion edges become delimited by the leaf veins. In some cases, these lesions can also be surrounded by a chlorotic border. By time these will then become tan to grey and dry. This dry tissue will normally tear down and fall, creating a hole in the leaf. Apart from leaf lesions, ooze can also develop on petioles and stems.

This bacterium can also infect the fruit. The early symptoms on the fruit are normally oval to circular lesions that are small, around 1 to 5 mm in diameter, and water-soaked. These will, by time, turn into a brown discoloration and exudates may also form. These fruit lesions will develop into internal rots and a secondary decay will form. This will make the fruit unmarketable.

This disease proliferates when temperatures are between 24 and 30°C, in humid conditions even due to excess irrigation. Contaminated tools can also be a source of infection or / and spread of disease. The penetration of the bacterium can occur through micro wounds although the stomata are the elective route of entry of the pathogen into plant tissues where it can only occasionally move systemically. The pathogen can also be seed-borne and, as a result, it can infect the cotyledons upon germination. The bacteria can be spread from plant to plant by splashing water from greenhouse dew, rain and irrigation. Other ways of spreading this pathogen can be insects and during harvesting. The pathogen is able to survive in the soil on infested plant residues for at least two years.

Control and Management

Agronomic Interventions

- Plant only seeds and plantlets which are visibly healthy and tolerate varieties. Use seeds and seedlings which are certified healthy and free form pathogens.
- Avoid water logging events and surface type irrigation.

Leaf lesions of angular leaf spot on cucumber leaf [2]

Leaf lesions of angular leaf spot on cucumber leaf [2]

- Provide a balanced fertilisation regime.
- Practice crop rotations with rotation periods every 4 years. If possible include cereals.
- Keep the greenhouse well ventilated.
- Destroy weeds and infected vegetation. Infected vegetation should be destroyed by igniting. Always avoid burying practices.
- In fields where there were previous cases of this pathogen disinfect the greenhouse walls before planting.
- Try to carry out harvesting and any other work when the foliage is dry.
- Practice sanitary measures;
  - (i) Install a foot bath at greenhouse entrances.
  - (ii) Avoid water sources which might be contaminated with this bacterium, e.g. from surface run-offs or other water sources that contain organic matter.

Chemical Interventions

- Intervene after cultivation work in the field is completed, especially if injuries might have been caused to the plant.
- Once detected, at the early stages of disease, apply copper.

PLANT PROTECTION SUBSTANCES

- Copper (1)

DIRECTIONS FOR USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

(1) Maximum limit of 28 kg in 7 years (4 kg per year/hectare).

Scab of cucurbits

Cladosporium cucumerinum

The initial symptoms of scab are pale green lesions that are irregularly shaped. As the disease progresses the lesions enlarge and turn grey to brown. Then the inner tissue of the lesions breaks and falls out, creating irregular holes in the leaf. The border of these lesions may also have a chlorotic colour. In the case of new leaves, these may twist and become deformed. These lesions may also be found on the stem and petioles. If there are humid conditions the lesions on the leaves, the petioles and the stem can be covered with a powdery, dark green, fungal growth.

This fungus can also affect the fruits by causing greasy-looking, sunken specks on the fruit surface. These can then grow in size becoming circular to oval and grey. Dark green sporulation may appear on the lesions. Normally these fruits will ooze a sticky exudate. These conditions may cause secondary organisms to colonise the fruit and cause fruit rot.

This disease can survive on old crop residues or other organic matter in the soil. In some cases, this disease can survive for up to three years. Under ideal conditions, the conidia can be dispersed through the air and land on susceptible tissues, later germinating and infecting the host. The ideal conditions for this pathogen to infect the plant are 100% relative humidity or free moisture, and temperatures between 17 to 27°C. Growth of this fungus can also happen in temperatures of 5 to 30°C. This pathogen can also be seedborne.

Symptoms of scab on the stem [40]

Symptoms of scab on the leaf [41]

Control and Management

Agronomic Interventions

- Promote air circulation in greenhouses to maintain a low level of humidity.
- Avoid the presence of free water on the leaves.
- Provide a balanced fertilization regime and avoid excess nitrogen.
- Avoid high planting densities.
- Remove all the diseased plants and all residues of previous diseased plants.
- Utilize crop varieties that are resistant, where possible.
- Utilize treated seeds and seeds certified free from diseases.
- Give at least two years before planting another crop from the cucurbitaceae family in the same location.
- Try to avoid growing courgettes in low-laying, shaded areas that can be prone to heavy fogs and/or dews.

Chemical Interventions

Intervene when symptoms occur.

PLANT PROTECTION SUBSTANCES

- Cupric products (1)

DIRECTIONS FOR USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

(1) Do not to exceed a cumulative application of 28 kg of copper per hectare over 7 years. It is also recommended not to exceed the average amount of 4 kg of copper per hectare per year.

Fusarium wilt

Fusarium oxysporum f. sp. cucurbitae

Cucurbits are susceptible to several vascular wilt diseases such as fusarium wilt. Symptoms can be visible throughout the whole lifecycle of the crop. Symptoms such as damping off from the lower stem can show even at seedlings stage.

The initial symptoms are a dull green to grey-green foliage, the older leaves becomeing yellow, and temporary wilting of shoot tips and young leaves during the warmer time of the day. By time, as the disease develops, wilting can be noticed on all the leaves and the shoots. Advanced symptoms can include a stunted appearance, poor growth, reduced fruit set, and leaves becoming necrotic brown and dying off. The fruit can then become sunburned, and the plant will collapse and die. These symptoms may be observed when the plant is stressed or when the fruit set is being formed or when development is taking place.

One way to identify this disease is by cutting through the stem, although in some cultivars this might not be evident. If this disease is present, generally, one will notice a light-to-dark brown to a red-brown discoloration in the xylem tissue in the taproot, the crown, and the lower stem.

The pathogen is soil-borne and is able to persist in the soil for a long time as saprobes.This pathogen can also be seed-borne. Fusarium infects the crop via the roots, then it colonizes the xylem and becomes systemically distributed. Normally, fusarium wilt can be more sever if the crop is grown in sandy porous soils which are high in nitrogen and with a pH value of 5 to 6. The optimum soil temperatures are between 20 and 27°C.

When an infected plant dies, the fungus produces chlamydospores that will be deposited into the soil, and thus increasing the pathogen presence. This pathogen can be distributed via equipment, shoes, vehicles, and water.

Control and Management

Agronomic Interventions

- Practice crop rotation for at least three year.
- Eliminate plants that are infected and also remove previous crop residues.
- Ensure that there is no water stagnation in the soil.
- Utilize crop varieties that are resistant.
- Favour transplanting over sowing methods.
- Use seeds that are treated, and certified free from diseases.
- Do not acquire seeds from other infected fields.
- Solarize the soil by utilizing a transparent P.E. film with a thickness of 0.05 mm. It is recommended to carry out solarisation in the months of July - August for at least 50 days.

PLANT PROTECTION SUBSTANCES

- *Pseudomonas* sp. strain DSMZ 13134
- *Pythium oligandrum*

Seedling infected by Fusarium [42]

Viruses

CMV; SqMV; ZYMV; WMV-2

There are many types of virus diseases in the courgette family. Among the most common are the zucchini yellow mosaic virus (ZYMV), which is also noticeable on the fruits, which become curved and lumpy and with cracks, and the cucumber common mosaic virus (CMV), which despite its name manifests itself more on courgettes and pumpkins, producing small, deformed and mosaic-like fruits. Virus diseases in courgettes are infections normally transmitted by aphids, very common parasites that infest cucurbits. In recent years there has been a virus strain coming from New Delhi which transmits the virus from plant to plant via a vector insect, the *Bemisia tabaci*, also known as the white fly. Worldwide, this virus is considered very dangerous and causes farmers to worry since little control solutions to it exist.

Courgette viruses manifest themselves both in late spring and summer, but little in winter.

Control and Management

Agronomic Interventions

- Sow/plant only plants that have been certified free of viruses.
- Sow/plant plants that are known to be tolerant to viruses.
- Monitor for virus vectors (aphids, whiteflies and thrips), prevent them and control them.
- Control and destroy unwanted weeds and vegetation from field.
- Following 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.

- Protect all greenhouse apertures and entrances using an insect net, so to limit or avoid the introduction of virus vectors inside the greenhouse.
- In the case of open field crops pay special attention to virus vectors, normally during the summer months, and cover the crop with a protective net to act as a barrier from insects vectoring the viruses.
- Practice sanitary measures;
  (1) Install foot baths at greenhouse entrances.
  (2) Disinfect the tools used.

Zucchini Yellow Mosaic Virus symptoms on a courgette plant leaf [2]

A zucchini squash leaf showing symptoms of the squash virus infection [4]

Tomato leaf curl New Delhi virus on zucchini plant [7]

Yellow squash showing symptoms of infection with mosaic virus, which is transmitted by aphids [8]

Aphids

Aphis gossypii

Aphids are very common parasites that attack mainly cucurbits, i.e. plants such as cucumber, melon, pumpkin, courgette and watermelon. Aphids multiply continuously and populations reach their maximum density in late spring and during summer. Aphid infestations only rarely occur in late autumn or winter because in this period few individuals survive on the plants that host them. This depends very much on the season weather patterns. Indeed, due to climate change, populations of aphids are remaining active in early autumn and appear also in early spring with high intensity. The distinct colour can be used for aphid identification, even though the colour can vary to green, dark grey and yellowish. The age of the aphid can determine its colour. While their length as adults is approximately 2 millimeters, they are easily visible to the naked eye, as an aggregation of aphids usually forms on the plant.

Aphids damage courgettes both directly, by removing sap from leaf tissues, and indirectly: aphids act as vectors of various diseases by transmitting viruses to plants. This normally leads to a typical yellowing of the leaves. When aphids attack courgettes, they are unlikely to limit themselves to infesting a few plants. Aphids can become a real problem for the entire field, whether grown outside (open field) or in protected cultivation. The affected leaves appear yellowed and rolled. While they feed, these insects produce honeydew, a sticky sugary substance, on which, later, sooty mold develops. Sooty mold is caused by fungi and can cover more or less large areas of the leaves of your plants. Furthermore, courgette aphids do not only attack the leaves, but they also manage to infest the flowers which, if affected, will also wither.

Control and Management

Agronomic Interventions

- Infestations can be contained through insects via naturally occurring insects in field or other beneficial insects.
- Protect all greenhouse apertures and entrances using an insect net.
- Do not exceed the use of any nitrogenous fertilisers.
- When any infestation is observed remove all the attacked plants.
- Use white reflective plastic mulch to keep the aphids away from the crop.
- Maintain a buffer strip at the edges of the parcel to ensure the development of antagonists (predators and parasitoids).

Chemical Interventions

- Intervene with the chemical application in the presence of the pests, in order to limit virus infections (CMV).
- On observation of localized infestation treat only attacked plants.

PLANT PROTECTION SUBSTANCES AND BENEFICIAL INSECTS

- *Chrysoperla carnea*
- *Beauveria bassiana*
- Maltodextrin
- Potassium Fatty acid salts
- Cyantraniliprole + Acibenzolar-S-methyl (4) (5)
- Cyantraniliprole
- Acetamiprid (2)
- Sulfoxaflor (6)
- Flupyradifurone (5)
- Tau-fluvalinate (3)
- Lambda-Cyhalothrin (3)
- Deltamethrin (3) (4)
- Flonicamid (5)
- *Aphidoletes aphidimiza*
- Mineral oil (1)
- Pyrethrins

DIRECTIONS OF USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

(1) It is recommended to add mineral oil to the active substance mentioned in order to limit the spread of viruses. This is to be done before and until flowering.

(2) A maximum of one intervention per crop cycle, regardless of the adversity, and not more than twice per year.

(3) With pyrethroids, a maximum of one intervention per crop cycle, regardless of the adversity.

(4) A maximum of three interventions per year, regardless of the adversity.

(5) A maximum of two interventions per year, regardless of the adversity.

(6) A maximum of two interventions per year between Chlorantraniliprole and Cyantraniliprole, regardless of the adversity.

Aphis gossypii nymph [10]

Aphid infestation on courgette flower [9]

Aphid infestation on courgette leaf [9]

Two-spotted spider mite

Tetranychus urticae

The lifecycle of the two-spotted spider mite, also known as the red spider, includes a total of 5 development stages. These are the egg, 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, and 36 days in temperatures of about 15°C. The adult female mate is able to diapause in low temperatures or when the food supply diminishes.

The 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. At first, the round small eggs, 0.14mm in diameter, are translucent. Later, when close to hatching, they become yellow. They 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 and 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 this will give the leaves a stippled appearance. Severe infestations may lead to leaf bronzing.

Under greenhouse conditions the development of the spider mite is especially favourable, carrying an elevated risk of total crop destruction. The conditions that favour the development of this phytophagous are mainly three: i) climates with high temperatures and low humidity where the lack of rain or wetting allows the spider to reproduce quickly, favouring the presence of cobwebs that facilitate the movement of the mite; ii) excessive nitrogenous fertilizations that make the sprouts more appetizing, and iii) the use of insecticides with a broad spectrum of action that weaken the populations of the natural predators of the spider mite.

Generally, attacks develop in a very heterogeneous manner with the infection centred around hotspots of the phytophagous flanked by uninjured plants. This way of starting the infestation makes careful and constant monitoring of the crop absolutely essential if one wants to be able to spot the very first signs of the outbreak.

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

- In the presence of this mite, disinfect all equipment/machinery used so to avoid dissemination to uninfected crops and fields.
- Limit the use of nitrogen fertilizer and other practices that promote more foliage and increased vegetation.
- 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

- Introduce the spider mite predator, *Amblyseius californicus*, at a rate of 4 individuals per square meter in one or more releases.
- In the presence of the spider mite, introduce, in one or more releases, *Phytoseiulius persimilis* at a rate of 4-12 individuals per metre squared, or *Amblyseius californicus* at a rate of 20 individuals per metre squared.
- If synthetic insecticides were used, delay the release of these beneficial insects by 20 days.
- If the naturally occurring beneficial insect *Phytoseiulus persimilis* is present in the field at a ratio of 1 (*Phytoseiulus persimilis*) to 10 (*Tetranychus urticae*), this should be sufficient to control an infestation. Other indigenous predators, such as *Orius* spp. and *Stethorus punctillum,* can also be sufficient to stop infestations.

Chemical Interventions

- Intervene at the appearance of any leaf discolorations and in the case of insufficient presence of predators, as described above.

PLANT PROTECTION SUBSTANCES AND BENEFICIAL INSECTS

- *Beauveria bassiana* (3)
- *Phytoseiulus persimilis*
- Potassium salts of fatty acids
- Terpenoid blend QRD 460
- Maltodextrine
- Spiromesifen (1)
- Pyridaben (2)
- *Amblyseius californicus*
- *Amblyseius andersoni*

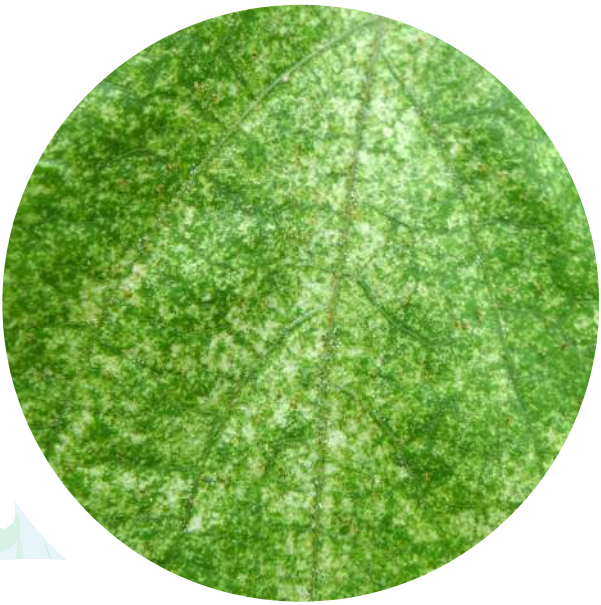
DIRECTIONS FOR USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

Each active substance should be used at most one intervention per crop cycle against this adversity. When carrying out the application of these active substances, mixtures between active ingredients mentioned are permitted, regardless of the limitation of treatment against adversity.

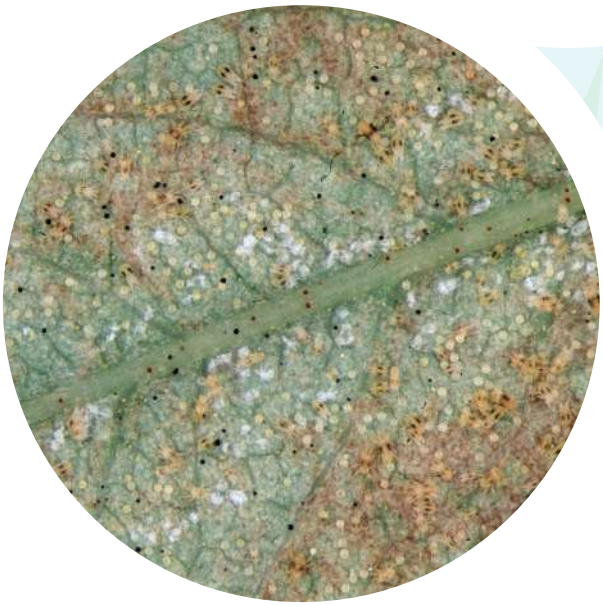
(1) A maximum of two interventions per year, regardless of the adversity.

(2) A maximum of one intervention per year.

Two female Tetranychus urticae and an egg [2]



Symptoms of spider mite infestation on the surface of the leaf [20]



Infestation of Tetranychus urticae [19]

Whitefly

Trialeurodes vaporariorum, Bemisia tabaci

The silverleaf whitefly, *Bemisia tabaci,* and the greenhouse whitefly, *Trialeurodes vaporariorum,* are polyphagous pests that affect the cucurbit plants, among others. This insect's lifecycle goes through different stages: egg, four larva stages, and 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 and oval-shaped, with a diameter of 0.25 mm. By time, the eggs change to a darker colour and hatch into larva in 7 to 10 days. The larvae are oval, flat and 0.3 mm long and have an antenna and developed legs. At the second larval stage they become flattened, transparent and measure 0.37 mm. At the third and fourth larval stage they are similar however the lengths are different: 0.51 and 0.73 mm. Whitefly 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.

Adults and nymphs feed on leaf sap with their piercing, sucking mouthpart. In severe infestations this feeding can result in yellowing of leaves and weakening of plants. They produce honeydew that may lead to black sooty mould, which contaminates also the fruit. *B. tabaci* can be responsible for irregular maturity and colour spots on the fruits. Whiteflies, like aphids, can also be vectors of plant viruses.

Trialeurodes vaporariorum adult [21]

Trialeurodes vaporariorum at puparium stage [21]

Control and Management

Agronomic Interventions

- Place yellow stick traps.
- Protect all greenhouse apertures and entrances using an insect net.

Biological Interventions

If the crop is cultivated inside a protective environment, such as a greenhouse, the beneficial insects below can be used.

- Before the presence of whiteflies, as a preventative measure, introduce in one or more releases the following beneficial insects:
  (1) *Eretmocerus eremicus* at a rate of 1-2 wasps per m^2 or
  (2) *Amblyseius swirskii* at a rate of 30-50 mites per m^2.
- In instances of infestation outbreaks, increase the rate to 20 wasps per m^2 for *Eretmocerus eremicus* and 80 to 120 mites per m^2 for *Amblyseius swirskii*.

Chemical Interventions

- Apply when an infestation is visible and when there is an insufficient presence of predators (mirids) and parasitoids (*Encarsia* spp., *Eretmocerus* spp.).

Multiple life stages of Trialeurodes vaporariorum [19]

Heavy infestation of Trialeurodes vaporariorum on leaf of greenhouse-grown zucchini [21]

PLANT PROTECTION SUBSTANCES AND BENEFICIAL INSECTS

- *Encarsia formosa*
- *Beauveria bassiana*
- *Amblyseius swirskii*
- *Eretmocerus eremicus*
- *Paecilomyces fumosoroseus*
- Essential of sweet orange
- Azadirachtin
- Potassium salts of fatty acids
- Cyantraniliprole + Acibenzolar-S-Methyl (4)
- Cyantraniliprole (4)
- Terpenoid blend QRD 460
- Pyriproxyfen (1)
- Flonicamid (2)
- Acetamiprid (1)(2)
- Sulfoxaflor (2)
- Pyrethrin
- Lambda-Cyhalothrin (3)
- Flupyradifurone (2)

DIRECTIONS FOR USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

(1) A maximum of one intervention per crop cycle, regardless of the adversity.

(2) A maximum of two interventions per year, regardless of the adversity.

(3) With Pyrethroids, a maximum of one intervention per crop cycle, regardless of the adversity.

(4) A maximum of two interventions per year between Chlorantraniliprole and Cyantraniliprole, regardless of the adversity.

Bemisia tabaci eggs [24]

Adult Bemisia tabaci [22]

Puparium of Bemisia tabaci [23]

Thrips

Frankliniella occidentalis

Together with mites, thrips (Thysanoptera) are among the smallest plant parasites. They can be beige, brown, dark brown or reddish in colour and have a slim body with typical narrow, fringed wings. The most common species are the onion thrip (*Thrips tabaci*), which infests different fruit and vegetables, and the western flower thrip (*Frankliniella occidentalis*). A study done recently (*Degabriele, G., Cavalleri, A., Goldarazena, A., & Mifsud, D. (2023). The Terebrantia (Insecta: Thysanoptera) of the Maltese Islands. Diversity, 15(4), 514. https://doi.org/10.3390/d15040514*) found other species of thrips present in the Maltese Islands. Few of these species which can affect courgettes are the poinsettia thrips (*Echinothrips americanus*), cotton bud/tomatoes thrips (*Frankliniella schultzei*), banded glasshouse thrips (*Hercinothrips femoralis*), black glasshouse thrips (*Heliothrips haemorrhoidalis*) and grain thrips (*Limothrips cerealium*).

Thrips are occasional parasites but cause significant damage, for example to cucurbit crops. A thrips infestation manifests itself as silvery-white spots on the upper surface of the leaves. On the underside, puncture wounds and accumulations of blackish excrement can be seen in correspondence with the spots. Thrips prefer very hot, dry weather in which they multiply exponentially. During storms they willingly let the wind carry them to other crops.

Their presence can be verified on the underside of the leaves and they are also very common inside the flower. They are about 1 mm long and have a colour ranging from brown to yellowish, almost black. These insects feed on the leaves or flower of the courgette, which will be perforated and surrounded by a typical silvering. Thrips can also cause poor fruit development and damage to the flower by feeding on it.

Control and Management

Agronomic Interventions

- Protect all greenhouse apertures and entrances using an insect net.
- It is advisable to place chrome-blue traps to identify the presence of the phytophagous at an early stage.
- Avoid leaving weeds and dry stubble of weeds near the crop.

Biological Interventions

- In open field at the beginning of flowering stage, introduce *Orius laevigatus* (1-2 individuals/m^2) in one or more releases.
- In greenhouses apply interventions at the beginning of flowering stage in one or more releases, *Amblyseius cucumeris* (200-400 /m^2), *Amblyseius swirskii* (30-50 /m^2) or *Orius laevigatus* (1-2 /m^2).

Chemical Interventions

- Intervene with the chemical application as soon as the first pests are visible on the crop.

PLANT PROTECTION SUBSTANCES AND BENEFICIAL INSECTS

- *Orius laevigatus*
- *Ambliseius cucumeris*
- *Amblyseius swirskii*
- *Paecilomyces fumosoroseus*
- Cyantraniliprole + Acibenzolar-S-Methyl (1)
- Cyantraniliprole (1)
- Terpenoid blend QRD 460
- Azadirachtin (Margosa extract)
- Abamectin

DIRECTIONS FOR USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

(1) A maximum of two interventions per year between Chlorantraniliprole and Cyantraniliprole, regardless of the adversity.

Thrips on courgette flower [1]

Thrips tabaci (larva) [25]

A number of thrips on courgette flowers [1]

Adult Frankliniella occidentalis [26]

Moths and Worms

Autographa gamma; Mamestra brassicae; Heliothis harmigera; Udea ferrugalis; Spodoptera esigua

Generally brown, night-flying moths in their adult stage, they have a larval stage in their lifecycle that causes damage to the plants. Generally, the moths are medium-sized, stout bodied, proboscis well developed, tympanal organs located in the metathorax. Most of the species have a drab appearance but some are brightly coloured. A typical pattern found on the forewing has transverse lines and about three distinct markings. These are: a kidney-shaped mark (the reniform stigma); a small circle (the orbicular stigma); and a dart-like mark (the claviform stigma).

Their eggs have a hemispherical shape, with a flat base, ribbed vertically, and the surface has a net-like appearance.

The larvae generally have five pairs of abdominal prolegs; the crotches are of one size and arranged in a half circle. The majority of the larvae are relatively glabrous (smooth). The caterpillars can vary in colour depending on the stage of maturity but are generally green, brown or grey. They feed on the foliage. The early instar larvae may feed on the underside of leaves leaving the rest of the tissue of the leaf intact. As the larvae develop, they start consuming whole leaves. Caterpillars can also damage the fruit by borrowing holes that can lead to rotting, although this is not common. Mature larvae can also cut through stems.

Udea ferrugalis adult [33]

Spodoptera esigua adult [34]

Control and Management

Agronomic Interventions

- Protect all greenhouse apertures and entrances using an insect net.
- Pest Monitoring: Use traps that capture pests by attracting them through the means of pheromones. These traps will help signal the onset of an infestation, during the first catches intensify the monitoring on the crop.

Biological Interventions

In the presence of the first larvae, intervene by applying *Bacillus thuringiensi.* Repeat the treatment, if necessary, on a weekly basis.

PLANT PROTECTION SUBSTANCES AND BENEFICIAL INSECTS

- *Bacillus thuringiensis*
- *Helicoverpa armigera nucleopoliedrovirus*
- *Spodoptera littoralis nucleopolyhedrovirus (SpliNPV)*
- Emamectin benzoate (2)
- Chlorantraniliprole (1)

DIRECTIONS FOR USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

(1) A maximum of two interventions per year between Chlorantraniliprole and Cyantraniliprole, regardless of the adversity.

(2) A maximum of two interventions per year.

Spodoptera esigua larva [35]

Late instar, lateral view of larval body of Mamestra brassicae [30]

Autographa gamma larva [27]

Autographa gamma adult [28]

Heliothis armigera adult [31]

Heliothis armigera larva feeding on a seedling [31]

Udea ferrugalis larva [32]

Mamestra brassicae adult [29]

Root-knot nematodes

Meloidogyne spp.

These small nematodes are a problem for numerous crops. In this genus the dimensions ranges from 0.6 to 2 mm and there is a morphological difference between the female and the male. The former is flask-shaped while the latter has an elongated shape. The males are not always present.

These nematodes are preserved as larvae, active or quiescent, and as quiescent eggs for a period of time that can reach up to three years. In the presence of attackable roots the eggs hatch, and the larva that emerges immediately penetrates the roots. The infestations appear in April until they disappear in October-November, with a maximum presence expected between May and September. The best environmental conditions for development are heat and high soil humidity. There can be up to 5-7 generations in a single year. In ideal conditions a female can produce from 300 to 1000 eggs. At a temperature of about 20°C the cycle takes 57 days, and at 27°C it takes 25 - 30 days.

The larvae penetrate the roots causing tissue disorganization. The plant reacts with an abnormal growth of the tissues (due to hypertrophy, i.e. due to the larger size of the cells) with the formation of root galls. These modifications alter the functionality of the roots, especially the smaller ones, compromising absorption. This brings the plants under stress conditions until they die.

Control and Management

Agronomic Interventions

- Crop rotation 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 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 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.
- Allow a period of dry following of the field. during this period practice deep plowing during the warmer months. during this period also make sure that no weeds are kept growing.
- Make use of mycorrhizal fungi by immersing the seedlings in a solution with these beneficial fungi and by integrating them during irrigation.

O Chemical Interventions

- Intervene with chemical applications when sure of the presence of the pest and when the crop has been damaged in the previous year.

PLANT PROTECTION SUBSTANCES

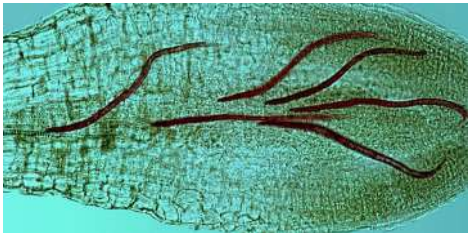
- *Paecilomyces lilacinus* (1)
- Garlic extract
- Fluopyram (2) (3) (4)
- Azadiractine
- Abamectin (4)

DIRECTIONS FOR USE OF SUGGESTED PLANT PROTECTION SUBSTANCES

(1) Apply in the soil 14 days before planting and repeat every week with a dose of 4kg/ha.
(2) A maximum of one application through the crop cycle.
(3) A maximum of two interventions per year between Fluxapyroxad, Isopyrazam and Fluopyram, independently.
(4) Through irrigation system.

Root full of nodules caused by Meloidogyne sp. [2]

Symptoms of nematodes on roots [37]



Second-stage juveniles of root-knot nematode, Meloidogyne sp., penetrating the root-tip [36]

Leaf miner

Liriomyza spp.

Liriomyza is a genus of leaf miner flies that includes the various species of polyphagous leaf miners that are present in Malta, such as *Liriomyza bryoniae, Liriomyza trifolii and Liriomyza huidobrensis*. Adult leaf miners are around 1-2 mm long and yellow-coloured. Females use ovipositors to deposit their eggs, generally on the upper side of the leaves. Eggs are small (up to 0.2 mm 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 the 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 ovipositing. 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 lifecycle 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.

Adult of L. bryoniae [38]

Leaf mine caused by Liriomyza bryoniae [38]

Control and Management

Agronomic Interventions

- Protect all greenhouse apertures and entrances using an insect net.
- Install sticky traps and monitor for presence.
- Once detected or at the presence of leaf mines, release *Diglyphus isaea* at a rate of 0.1 to 0.2 individuals per metre squared, in 1 to 2 releases.

Chemical Interventions

- Use chemical control only when the presence of *Diglyphus isaea* (leaf miner parasite) is not visible or scarce.

PLANT PROTECTION SUBSTANCES AND BENEFICIAL INSECTS

- *Diglyphus isaea*
- Azadirachtin

Adult L. trifolii [39]

Larva of Liriomyza huidobrensis in its mine [38]

Adult of L. huidobrensis [38]

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