GOVERNMENT OF MALTA

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LETTUCE PRODUCTION INTEGRATED PEST MANAGEMENT GUIDELINES

Agriculture Directorate

AgriConnect

Agriculture Research & Innovation Hub

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March 2025

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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Downy Mildew

Bremia sp., *Bremia lactucae*

Downy Mildew is a disease caused by the parasite *Bremia lactucae* which attacks cultivated lettuce when it is exposed to prolonged periods of humidity (rainfall, fog, dew) and cool temperatures. Lettuce is prone to downy mildew throughout the growing cycle however younger plants are more susceptible to the disease. The parasite attacks the plant tissues which become chlorotic. Infected seedlings become stunted, leading to their death. In older plants, the first symptoms start to appear on the leaves in the crown. Pale green to yellow angular spots form on the upper surface of the leaves while spores develop on the lower side of the leaves. These spots become necrotic and turn brown. As the disease progresses, more spots develop on the crop which may lead to secondary bacterial or fungal diseases such as *Botrytis cinerea*.

Temperatures lower than 20°C and relative humidity close to 100% favour the growth of this fungus. The infection occurs within 2 to 3 hours and the fungus can complete a full cycle in 5 days. As temperature rises, sporulation decreases drastically.

Fungal spores are spread by wind and water splashes during rainfall or irrigation.

Control and Management

Agronomic Interventions

- Practice crop rotation cycles, lasting at least 3 years.
- Destroy any infected crop residues and avoid contact with other crops.
- Promote soil drainage.
- Adequately space the plants to promote air circulation.
- Use resistant and/or tolerant varieties.
- Do not apply excessive fertilizer rates.
- If possible, planting rows should run in the direction of the prevailing wind to encourage ventilation within the crop.

Pale green and yellow angular spots on leaves [1]

Chemical Interventions

- 1-2 applications in seed trays or in the first week of planting, as a preventative measure.
- When the first spots are noticed, fungicide treatment should be carried out immediately.
- Usually, interventions are not required during summer cycles, however there might be exceptions for sensitive cultivars in case of repeated rains.

PLANT PROTECTION SUBSTANCES

- *Bacillus amyloliquefaciens* (2)
- Laminarin
- Copper based products (1)
- Essential Oil of sweet orange (Orange Oil)
- Cerevisane
- Oxathiapiprolin (3)
- Metalaxyl-M (4)
- Metalaxyl (4)
- Fosetyl Aluminum
- Cymoxanil (4)
- Ametoctradin (5)
- Mandipropamid (4)
- Azoxystrobin (5)
- Propamocarb (5)
- Fluopicolide
- Amisulbrom (6)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not exceed the cumulative application of 28kg of copper per hectare over 7 years. It is recommended not to exceed 4kg of copper per hectare per year.
(2) Do not exceed 6 applications per crop cycle.
(3) A maximum of 3 treatments per year and a maximum of 2 treatments per crop cycle.
(4) A maximum of 1 treatment per crop cycle.
(5) A maximum of 2 treatments per crop cycle, regardless of the adversity.
(6) A maximum of 3 treatments per crop cycle, regardless of the adversity.

Spores on the underside of leaves [2]

Powdery Mildew

Erysiphe cichoracearum

Powdery mildew on lettuce is caused by the fungus *Erysiphe cichoracearum*. The first symptoms start to appear on the upper side of the older leaves. Spots of greyish, powdery white mycelium form, which will then gradually cover a substantial part of the infected leaves. Infected plant tissues become chlorotic and brown lesions develop.

The optimal climatic conditions for the development and spread of the fungus are temperatures ranging between 18°C and 25°C and relative humidity of about 95% to 98%. Contrarily to other fungal diseases, the presence of water on the leaves prevents spore germination. The growth of the fungus is also affected by direct sunlight as it prefers diffused light. This is why the symptoms of powdery mildew are generally seen on the lower older leaves of the lettuce. Under favourable climatic conditions, the fungus can complete a full cycle in 4 days.

Fungal spores are spread by wind or water splashes caused by rainfall or irrigation.

Control and Management

Agronomic Interventions

- Practice crop rotation cycles.
- Use varieties that are resistant and/or tolerant.
- A balanced fertiliser regime should be provided.
- Water stagnation in the plot should be avoided.
- In areas where powdery mildew is more constant from one crop to another, sulphur can be used as a preventative treatment.

Chemical Interventions

- Intervene only when symptoms appear.
- Interventions allowed only in protected cultivation.

PLANT PROTECTION SUBSTANCES

- Sulphur
- Eugenol + Geraniol + Thymol
- Essential Oil of sweet orange (1)
- Azoxystrobin (2)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not exceed 6 applications.

(2) Do not exceed 2 applications of this active ingredient. Do not exceed 3 applications with active ingredients from the same mode of action (C3) which include Trifloxystrobin, Azoxystrobin, and Pyraclostrobin.

Greyish, powdery white mycelium form on infected leaves [3]

Alternaria Leaf Spot

Alternaria sp.

Alternaria leaf spot is caused by several fungal species of Alternaria. Symptoms appear on the upper side of the leaves as spores germinate and enter the leaf tissues creating dark brown spots that can be circular or oval in shape. As the disease progresses, multiple spots may coalesce. Younger leaves are more susceptible to the disease.

The fungus can survive on plant debris and also on seeds.Temperatures between 20°C to 25°C accompanied by high humidity climatic periods are ideal for the development of the fungal pathogen.

Fungal spores are spread by wind or water splashes caused by rainfall or irrigation.

Control and Management

Agronomic Interventions

- Make use of certified healthy seeds or seedlings.
- Practice crop rotation cycles.
- Remove the residues of infected plants.
- Irrigation by means of sprinklers must be avoided. If irrigation is carried out by sprinklers, it should be done during the daytime so that the crops will be able to dry out rapidly.

Chemical Interventions

- Intervene only when symptoms appear.

Dark brown spots caused by Alternaria sonchi [3]

Dark brown spots caused by Alternaria sonchi [3]

PLANT PROTECTION SUBSTANCES

- Copper-based products (1)
- Metalaxyl-M (2)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

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

(2) Do not exceed two applications.

Lettuce Rust

Puccinia cichorii, Puccinia opizii

Lettuce rust is a disease caused by fungal pathogens that cause several types of rust. These can be grouped under two categories: autoecious rust, whereby the fungus completes its cycle on one single host, and heteroecious rust, whereby the fungus completes its cycle on two different hosts. The initial symptoms of *Puccinia cichorii*, an autoecious rust, are small pale yellow spots. As the disease progresses, these spots develop a rusty colour which eventually turns to dark brown. *Puccinia opizii*, a heteroecious rust, develops yellow to orange circular spots that produce large yellow spores.

Control and Management

Agronomic Interventions

- Practice crop rotation at least every 2 years without growing lettuce.

Chemical Interventions

- Intervene only when symptoms appear.
- Interventions allowed only in protected cultivation.

Lettuce rust caused by the genus Puccinia [5]

PLANT PROTECTION SUBSTANCES

- Copper-based products (1)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

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

White Mould

Sclerotinia sclerotiorum

Sclerotina sclerotiorum, also known as white mould, is a fungal pathogen that may contribute to a significant yield loss. The stem and lower leaves of the lettuce are more affected as these are in contact with the soil. *Sclerotina sclerotiorum* can be present in the soil for 8-10 years through crop residues containing sclerotia or mycelium. Furthermore, *Sclerotina sclerotiorum* can be found on numerous host plants, both on cultivated crops such as tomatoes and peppers, and on wild plants.

The initial symptoms start to appear on the older leaves as the fungus penetrates the plant tissues creating damp, light brown damage. The fungus progresses towards healthier leaves affecting also the crown of the lettuce, causing the leaves to become chlorotic and wilting of the outer leaves. White mycelium may form on infected plant tissues. As the disease spreads, the plant rots and eventually collapses. Sclerotia will form within the surface of the soil, where the plant is in contact with the ground. The Scelerotia are black, elongated, 2 mm to 20 mm long, and 3mm to 7 mm wide. Diseased plants can be easily pulled out from the ground.

The fungus can develop in temperatures between 4°C and 30°C, however, the ideal conditions for the growth of the fungus are temperatures slightly below 20°C. The germination of the ascospores on the lettuce leaves occurs during humid conditions which require the presence of water. Light soils rich in humus are more conducive to the development of this fungus.

Fungal spores are spread by wind or by soil present on ploughing tools.

Control and Management

Agronomic Interventions

- Before the planting of the new crops, soil solarisation is recommended especially if this pathogen was present in previous years. Soil fumigants can also be used.
- Use plastic mulch as a barrier between the soil and the plant, preferably with ridges.
- Avoid instances of waterlogged soil, and maintain irrigation to a minimum.
- Remove and destroy diseased plants and plant debris.
- Use resistant and/or tolerant varieties.
- Apply a balanced fertilization, especially when it includes nitrogen.
- Carry out crop rotations for at least 5 years. Crop rotations should include cereal crops but not crops belonging to the Solanaceae and Cucurbitaceae families. Besides cereals, onions and spinach are also suggested to be included in the rotation.

Chemical Interventions

- Intervene only when symptoms appear.

PLANT PROTECTION SUBSTANCES

- *Bacillus amyloliquefaciens* (1)
- *Pythium oligandrum Ceppo* M1
- Cerevisane
- *Coniothyrium minitans*
- *Bacillus subtilis* (2)
- *Trichoderma* spp
- Eugenolo + Geraniolo + Thymol
- Azoxystrobin (3) (4)
- Pyraclostrobin (4) + Boscalid (5)
- Penthiopyrad (5)
- Fluxapyroxad (5) (6)
- Difenoconazole (6) + Fluxapyroxad (5)
- Fludioxonil (3)
- Cyprodinil (3) + Fludioxonil (3)
- Pyrimethanil (3)
- Fenhexamid (3)
- Isofetamid (5)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not exceed 6 applications, regardless of the adversity.
(2) Do not exceed 4 applications, regardless of the adversity.
(3) Do not exceed 2 applications, regardless of the adversity.
(4) Do not exceed 3 applications, regardless of the adversity, from the same mode of action group (C3) classified as Quinone Outside Inhibitors (QOI fungicides) that includes Azoxystrobin and Pyraclostrobin.
(5) Do not exceed 3 applications, regardless of the adversity, from the same mode of action group (C2) classified as Succinatede hydrogenase inhibitors (SDHI fungicides) that includes Penthiopyrad, Boscalid, and Isofetamid.
(6) Do not exceed 1 application, regardless of the adversity.

Wilting of external leaves [7]

Large sclerotia at the base of rotted lettuce plant [7]

Large sclerotia at the base of rotted lettuce plant

White mould formation on a rotten stem [6]

Damp, light brown damage on the crown and lower leaves [8]

Grey Mould

Botrytis cinerea

Botrytis cinerea, or grey mould, is a fungal pathogen affecting lettuce that may reduce the overall yield. The lower leaves and the crown of the lettuce are more affected as these are in contact with the soil. *Botrytis cinerea* can survive in the soil for several years on crop residues in the form of mycelium, sclerotia, or conidia. Lettuce plants that have almost reached full maturity are more likely to get infected because the older leaves spread out and come in contact with the soil to give space for the new leaves to develop. Infected leaves develop damp reddish-brown lesions. As the fungal infection progresses it becomes more difficult to control. The fungus attacks the healthy tissue of the plant, and this causes rotting and wilting of the crop. Grey to brown mould forms on the infected areas particularly on basal leaves and the crown.

Botrytis cinerea thrives in damp environmental conditions. The ideal temperatures for the fungus' growth and spread are between 17°C and 23°C and a relative humidity of around 95%. Fungal spores are spread by wind and water splashes during rainfall or irrigation.

Control and Management

Agronomic Interventions

- Before the planting of the new crops, soil solarisation is recommended especially if this pathogen was present in previous years.
- Apply plastic mulch, preferably with ridges.
- Limit irrigation and avoid waterlogging.
- Remove diseased plants and plant debris. Preferably these should not be buried or incorporated in the soil.
- Use less susceptible varieties.
- If possible, rows should be set in the same direction as the prevailing wind.

Damp reddish-brown lesions on the outer leaves [9]

Chemical Interventions

- Intervene only when symptoms appear.
- The organic plant protection products listed below should be used to prevent this disease.

PLANT PROTECTION SUBSTANCES

- *Bacillus amyloliquefaciens* (1)
- Cerevisane
- *Pythium oligandrum*
- *Bacillus subtilis* (2)
- *Trichoderma* spp
- Eugenolo + Geraniolo + Timolo
- Pyrimethanil (3)
- Boscalid (5) + Pyraclostrobin (6)
- Penthiopyrad (4) (5)
- Fludioxonil (3)
- Cyprodinil (3) + Fludioxonil (3)
- Fenhexamid (3)
- Isofetamid (5)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not exceed 6 applications, regardless of the adversity.

(2) Do not exceed 4 applications, regardless of the adversity.

(3) Do not exceed 2 applications, regardless of the adversity.

(4) Do not exceed 1 application, regardless of the adversity.

(5) Do not exceed 3 applications, regardless of the adversity, from the same mode of action group (C2) classified as Succinatede hydrogenase inhibitors (SDHI fungicides) that includes Penthiopyrad, Boscalid, and Isofetamid.

(6) Do not exceed 3 application, regardless of the adversity, from the same mode of action group (C3) classified as Quinone Outside Inhibitors (QOI fungicides) that includes Azoxystrobin and Pyraclostrobin.

Grey mould covering the rotting stem [10]

Lettuce Bottom Rot

Rhizoctonia solani

Rhizoctonia solani is a fungal disease that causes damping off and bottom rot on lettuce. The first symptoms appear on the lower leaves in contact with the soil, which is common as harvest time approaches. Reddish to brown lesions with a dry consistency develop on the petioles, the principal vein, and the lamina. The outer leaves may turn yellow and wilt. The infected areas spread rapidly throughout the plant, causing bottom rot of the lettuce.

R. solani thrives in damp environmental conditions. The soil-borne fungus can develop in temperatures between 5°C and 36°C, however, the ideal conditions for the growth of this fungus are temperatures ranging from 23°C to 27°C. This may vary, depending on the type of strain. *R. solani* can survive in the soil on crop residues and, even in the absence of host plants, through sclerotia or mycelium. The spores of the fungus are dispersed by wind and water splashes during rainfall or irrigation. The fungus is inhibited if the soil is too dry or too wet.

Damage caused by *R. solani* may lead to secondary bacterial or fungal infections, such as Grey Mould (*Botrytis cinerea*.)

Control and Management

Agronomic Interventions

- Practice crop rotation cycles. The recommended crops are cereals, sweet corn, fodder crops, and onions.
- In greenhouses try to avoid excessive humidity and temperature while maintaining a well-ventilated greenhouse.
- Use of certified healthy seeds or seedlings.
- Provide a balanced fertilization regime and avoid excessive use of nitrogen.
- Adequate soil drainage.
- Avoid instances of waterlogged soil and maintain irrigation to a minimum.
- Make use of mulch.

Chemical Interventions

- Intervene during sowing or planting.

PLANT PROTECTION SUBSTANCES

- *Bacillus subtilis*
- *Trichoderma* spp
- *Pythium oligandrum*
- *Pseudomonas* sp. Ceppo DSMZ
- Azoxystrobin (1)(2)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not exceed 2 applications, regardless of the adversity.

(2) Do not exceed 3 applications, regardless of the adversity, from the same mode of action group (C3) classified as Quinone Outside Inhibitors (QOI fungicides) that includes Azoxystrobin and Pyraclostrobin.

Damping off and bottom rot caused by R. solani [11]

Reddish-brown and fairly dry damage areas [12]

Fungal rots

Pythium sp., *Fusarium* sp.

The fungal pathogens *Pythium* sp. and *Fusarium* sp. cause wilt and root rot on the lettuce.

Pythium sp.

Symptoms of *Pythium* sp. are characterised by broad damp foliar damage with a dark brown colour. A severe fungal infection causes extensive damage to the plant particularly to the outer leaves in contact with the soil. The rotting leaves appear as if the plant tissues have melted. The rotting progresses, reaching the heart of the head. Other symptoms associated with *Pythium sp.* include yellowing, wilting and drying of leaves, greyish deformed taproot with a rough texture, and few secondary roots. *Pythium sp.* reduces the growth rate of infected lettuce, and in the early stages of the crop, the plant may remain stunted.

The fungus can develop in temperatures between 5°C and 43°C, however the ideal temperatures for its growth range from 20°C to 24°C. Humid environmental conditions and high soil moisture favour the development of the pathogen.

Pythium sp. can survive in the soil on organic matter and other host plants such as artichokes and peas. It can be spread by areal dispersion, water splashes during rainfall or irrigation, and contaminated soil particles present on ploughing tools.

Fusarium sp.

Damage caused by *Fusarium* sp. is often seen at the roots, taproot, and stem level, whereby the infected vessels take a rusty brown colour. Other symptoms associated with this soil-borne fungus include yellowing of leaves, brown veins, necrosis of the external part of the leaves, and partial wilting and dying of the leaves, usually a V-shape. *Fusarium sp.* affects the development of the lettuce as these might remain dwarfed or the head does not form.

The fungus thrives during warm weather in temperatures of around 28°C. It can survive in the soil and on plant debris. The spores can be spread by areal dispersion, water splashes during rainfall or irrigation, and contaminated soil particles present on ploughing tools.

Control and Management

Agronomic Interventions

- Use certified healthy seeds or seedlings.
- Compost/substrate used for seedlings should be based on new peat and disinfected.
- If there is any indication of the presence of this fungus or that previous crops were affected by it, the soil should be treated by steam sterilization (to a 10 cm depth for 15 min) if possible. Alternatively, the soil can be fumigated.
- Maintain a balanced fertilization.
- If the crop is grown in the greenhouse try to avoid excessive humidity.
- Carry out crop rotations and include cereals or other fodder crops.
- In cases of soilless cultures/hydroponics, ensure that they are not contaminated, especially if they collect from channels or streams that might be contaminated. In such cases, it is recommended to use a filter to clear organic contaminates from the water, and an additional UV filter should also be used.

PLANT PROTECTION SUBSTANCES

For *Pythium* sp.

- *Trichoderma* spp
- Cerevisane
- Metalaxil-M (1)
- Fosetyl-Aluminium (2)
- Propamocarb (2)
- Propamocarb + Fosetyl-Aluminium (2)

For *Fusarium* sp.

- *Trichoderma* spp. (Organic)

Pythium root rot on hydroponic lettuce [36]

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not exceed 1 application, regardless of the adversity, in the open field, and a maximum of 2 applications in greenhouses.

(2) Use only during the seeding phase.

Symptoms of Fusarium spp. on a young lettuce seedling [38]

Necrosis of the vascular system caused by Fusarium oxysporum f.sp. lactucae [38]

Symptoms of Fusarium on a lettuce crop [37]

Bacteria

Pseudomonas cichorii

Pseudomonas cichorii is a bacterium that affects the leaves and the head of the lettuce. The symptoms usually appear as harvest time approaches. Damp brown spots that vary in size appear on the internal leaves. Other symptoms such as damp elongated lesions of brown to black colour may develop on the main vein and secondary veins. The bacterium infects the plant through the stomata or damaged tissues.

The bacteria can develop in temperatures between 5°C and 35°C, however the ideal temperatures for its growth range from 20°C to 25°C. Humid environmental conditions with prolonged rainfall periods favour the growth of *P.cichorii.*

P. cichorii can survive in the soil, on infected organic matter and seeds, and even in contaminated dirty water.

Damp brown to black lesions on inner leaves [13]

Symptoms of Pseudomonas cichorii at the base of the lettuce plant. [13]

Control and Management

Agronomic Interventions

- Use balanced nitrogenous and potassium fertilization.
- Destroy any infected plants and vegetative residue and avoid contact with other crops.These should be destroyed and not buried in the soil.
- It is not advisable to irrigate with water from canals or collection basins that are not periodically cleaned and contain sediment.
- Sprinkler irrigation is not recommended.
- If the crop is grown in the greenhouse try to avoid excessive humidity and provide good ventilation.
- Make use of mulching.
- Practice crop rotations for at least 4 years.
- Avoid operations that can cause plant injuries.

Chemical Interventions

- Intervene only when symptoms appear or/and in favourable conditions.

PLANT PROTECTION SUBSTANCES

- Copper-based products

LIMITATIONS OF USE AND SPECIAL CONDITIONS

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

Viruses

CMV, LMV

The Cucumber Mosaic Virus (CMV) and the Lettuce Mosaic Virus (LMV) are viral diseases that may influence the overall quality of lettuce.

CMV can reside on several hosts such as cucurbitaceae, tomatoes, and peppers. The damage caused to lettuce by this virus is minimal and diminishes as the crop matures. Symptoms of infection include slight mottling or unobstructed mosaic and leaf necrosis of younger plants. Symptoms may vary depending on the lettuce variety, climatic conditions, and stage of infection.

Symptoms of plants infected by LMV at an early stage may vary, however, these can develop yellowing of veins creating a mosaic pattern, necrotic spots, and stunted plants that impede the head formation. Infections at a later stage exhibit symptoms of light green to yellow mottling, deformation, and twisting of outer leaves. The older the plant is, the less likely it is to develop symptoms as these become more visible during the active growing stage of the lettuce. Symptoms may vary depending on the lettuce variety.

Both LMV and CMV are transmitted by aphids in a non-persistent way. The viruses are transmitted from infected plants to healthy plants by vector aphids through punctures on the plant tissue. LMV can also be transmitted by seeds.

Control and Management

Agronomic Interventions

- Use certified healthy seeds or seedlings.
- Use resistant varieties, where possible.
- Monitor for virus vectors (aphids and thrips) in high-risk areas and control accordingly.
- Once you detect the first plants with virus symptoms:
  (1) remove the plant from the field and place it in a plastic bag;
  (2) avoid contact with other crops;
  (3) burn the infected plants;
  (4) mark the area where the infect plant was located for further monitoring.

Aphids

Nasonovia ribisnigri, Myzus persicae, Uroleucon sonchi, Acyrthosiphon lactucae

The most common aphids that attack lettuce are *Nasonovia ribisnigri, Myzus persicae, Uroleucon sonchi*, and *Acyrthosiphon lactucae*. Aphids are small insects, around 1.5 mm to 2.5mm long, with low mobility. Their colour (yellow, green, brown, and black) differs according to the species.

These parasitic insects feed on the stems and underside of the leaves creating sugar honeydew from the excess sugar from the sap. This affects the photosynthesis process of the lettuce, influencing the growth and overall quality of the plant. The honeydew causes sooty mould which could be the source of the growth of several types of mould such as *Alternaria spp*. Aphids are also vectors of numerous viruses, including CMV and LMV. The viruses are transmitted from infected plants to healthy plants by the vector aphid through punctures on the plant tissue.

The aphid population is more abundant during spring and autumn.

Control and Management

Agronomic Interventions

- Infestations can be contained through naturally occurring beneficial insects.

Chemical Interventions

- Intervene at the appearance of the first colonies.

PLANT PROTECTION SUBSTANCES

- Potassium salts of Fatty Acids
- *Beauveria bassiana*
- Maltodextrin
- Azadirachtin
- Pyrethrin pure
- Deltamethrin (1) (2)
- Flupyradifurone (3)
- Lambda-Cyhalothrin (2) (3)
- Tau-Fluvalinate (2)
- Acetamiprid (4)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not apply more than 3 applications, regardless of the adversity.

(2) Do not apply more than 3 applications of pesticides from the same mode of action group (IRAC 3A).

(3) Do not apply more than 1 application, regardless of the adversity.

(4) Apply a maximum of 1 application per crop cycle and not more than 2 applications per year.

Nasonovia ribisnigri infestation [14]

Acyrthosiphon lactucae aphids [15]

Myzus persicae aphid [16]

Whitefly

Trialeurodes vaporariorum, Bemisia Tabaci

The greenhouse whitefly, *Trialeurodes vaporariorum*, and the silverleaf whitefly, *Bemisia Tabaci* are polyphagous pests that attack lettuce. Whitefly infestation is commonly seen on the underside of the leaves during warm climatic conditions.

The whitefly's life cycle can be divided into three stages: eggs, four larvae stages, and adult. Tiny white eggs 0.25 mm in diameter are laid on the underside of the leaves. These oval-shaped eggs darken as they reach the hatching phase of the larvae after 7 to 10 days. The larvae are oval, flat, and 0.3 mm long with developed legs and antennae. As the larva progresses to the next stage, it becomes flattened, transparent, and 0.37 mm long. The last two stages of the larva differ only in length as it goes from 0.51 mm to 0.73 mm long. Adult whiteflies can be 0.9 mm to 1.1 mm long, depending on the sex of the insect, with the females being larger. These are yellow in colour, and have white wings that are covered by a waxy coating. The life cycle of the whitefly changes under different climatic conditions. In temperatures of around 27°C, an entire cycle can be completed within 20 days. This makes it possible for multiple generations to be present in one season.

Similar to aphids, the whitefly feeds on plant tissue, creating sugar honeydew from excess sugar from the sap. This affects the photosynthesis process of the lettuce, influencing the growth and overall quality of the plant. The honeydew causes sooty mould which could be the source for the growth of several types of mould such as *Alternaria spp*. Whiteflies can also be vectors of numerous viruses that are transmitted from one plant to another.

Control and Management

Agronomic Interventions

- Use suitable nets to screen all greenhouse openings in order to prevent the entry of adult whiteflies.
- Place yellow stick traps for pest monitoring.
- Maintain the area free of weeds.

Chemical Interventions

- Intervene at the initial signs of infestation.
- In low-risk areas, intervene when 10 nymphs per leaf are detected.

PLANT PROTECTION SUBSTANCES

- Maltodextrin
- Essential Oil of sweet orange (Orange Oil) (1)
- Pyrethrin pure
- Azadirachtin
- *Beuveria bassiana*
- *Lecanicillium muscarium* (2)
- Terpenoid blend QRD 460

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not apply more than 6 applications, regardless of the adversity.

(2) Do not apply more than 8 applications, regardless of the adversity.

Bemisia tabaci adult [18]

Trialeurodes vaporariorium infestation [17]

Leafworms

Spodoptera littoralis, Helicoverpa armigera

Spodoptera littoralis and *Helicoverpa armigera* are polyphagous pests that feed on a variety of economically important crops including lettuce.

The female *Spodoptera littoralis* moth lays thousands of eggs in groups of around 20 to 350 eggs on the underside of the leaves. The eggs are small, measuring about 0.45 mm by 0.35 mm, round, and covered with hairy scales deriving from the moth's abdomen. The eggs have a whitish-yellow colour which darkens as the hatching stage approaches. The larva grows to around 4 cm long and its colour varies from brown to green. As the larva matures, dark patches with yellow and white spots form. The pupa is brown and around 15 mm to 20 mm in length. Under favourable climatic conditions, in temperatures between 22°C and 27°C, the life cycle takes around 5 weeks to complete, making it possible to have multiple generations in one season. This pest is mostly common at the end of summer and during autumn.

The female *Helicoverpa armigera* moth lays around 1,000 eggs during its lifespan. The eggs are small, round, and white in colour, turning brown to black as they progress to the hatching phase. The larva grows to about 3 cm to 4 cm long. Its colour varies from white to yellow or green, with a darker head. Dark markings develop on the larva's body. Mature larvae dig a small tunnel in the ground to pupate. A complete life cycle in ideal warm temperatures takes around 6 weeks.

Heavy infestations by leafworms can do extensive damage to the crops as the larvae feed on the leaves. Large holes and yellow-green to dark-green larval excrement are visible on the foliage. The damaged leaves affect the photosynthesis of the plant and may cause fungal or bacterial infections.

Spodoptera littoralis larva [20]

Control and Management

Agronomic Interventions

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

Chemical Interventions

- Intervene at the initial signs of infestation.
- For varieties like Trocadero, Iceberg, etc., intervene before the leaves close.

PLANT PROTECTION SUBSTANCES

- *Bacillus thuringiensis*
- Azadirachtin
- Deltamethrin (3) (4)
- Etofenprox (4) (5)
- Spinosad (1) (2)
- Chlorantraniliprole (5)
- Tebufenozide (1) (6) (7)
- Methoxyfenozide (6)
- Emamectin Benzoate (1) (5)
- Spodoptera littoralis Nucleopolyhedrovirus (SpliNPV) (8)

Adult Helicoverpa armigera [21]

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Should only be used in open field.
(2) Do not apply more than 5 applications, regardless of the adversity.
(3) Do not apply more than 3 applications, regardless of the adversity.
(4) Do not apply more than 3 applications of pesticides from the same mode of action group (IRAC 3A).
(5) Do not apply more than 2 applications, regardless of the adversity.
(6) Do not apply more than 1 application of pesticides from the same mode of action group (IRAC 18).
(7) Should only be used to control Spodoptera spp.
(8) Avoid using water with a pH lower than 5 and above 8, otherwise use a buffer product.

Adult Spodoptera littoralis [19]

Helicoverpa armigera larva [22]

Cutworms

Agrotis spp.

There are several species of cutworm belonging to the genus *Agrotis*. The female cutworm moth lays hundreds of white eggs on the leaves and stems close to the soil. The hatching larvae feed on the leaves. As they mature, they go hiding in the soil during the day and emerge and feed on lettuce during the night. Cutworms are polyphagous pests that mainly grow in moist soils. The caterpillar is around 4 cm long, usually of greyish-brown or greyish-green colour, depending on the species, with dark spots on its body. The life cycle of cutworms takes around 60 days, however, this may vary according to the species and climatic conditions. This makes it possible to have multiple generations in one season.

During the transplanting and early stages of lettuce, cutworms may cause serious damage as these sever the main stem at the soil line. On mature crops, the cutworm may bore into the lettuce crown. Serrated leaves can be seen.

Control and Management

Chemical Interventions

- Intervene at the initial signs of infestation.

PLANT PROTECTION SUBSTANCES

- Deltamethrin (1) (2)
- Azadirachtin

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not apply more than 3 applications, regardless of the adversity.

(2) Do not apply more than 3 applications of pesticides from the same mode of action group (IRAC 3A).

Agrotis ipsilon larva [23]

Agrotis segetum moth [39]

Wireworms

Agriotes spp.

Wireworms are soil pests belonging to the genus of beetles *Agriotes*. Adult female beetles lay hundreds of eggs just underneath the soil surface, around 10 cm in depth, usually in grassy areas, to prevent the desiccation of the eggs. The eggs are round, 0.5 mm in diameter, translucent, and are laid in clusters or individually. Young larvae are white and turn golden-brown as they mature. These can grow up to 3 cm long with a tough and shiny skin.

Wireworms feed on seeds and roots of the plant, causing wilting or death of lettuce, especially in younger crops.

Control and Management

Agronomic Interventions

- Avoid re-sowing successive lettuce crops in the event of persistent infestations.
- Avoid mowing ditches and meadows adjacent to the crop cultivation areas during July and August.

Chemical Interventions

- Intervene on the first detection of the pest.

PLANT PROTECTION SUBSTANCES

- Lambda-Cyhalothrin

Agriotes spp. larva [24]

Lygus Bug

Lygus rugulipennis

Lygus rugulipennis is a polyphagous pest that feeds on various economically important crops, including lettuce. Adult females, through their ovipositors, lay eggs inside the plant tissue. Nymphs, the young insects after hatching, are green, wingless, and resemble the shape of the adults. As these grow into adults, the colour changes to yellow-brown, with a distinctive triangular pattern on the back. The insect is flat and can grow up to 6 mm long. Adult lygus have wings and two long antennae. The insects are more abundant during warm weather. The adults can overwinter in plant debris on the ground or in other suitable shelters.

Damage symptoms made by lygus bugs include tiny holes that may develop into lesions caused by feeding punctures and during oviposition. The insect's saliva damages the plant tissues as it contains degrading enzymes.

Control and Management

Agronomic Interventions

- Avoid mowing ditches and meadows adjacent to the crop cultivation areas during July and August.

Lygus rugulipennis [25]

PLANT PROTECTION SUBSTANCES

- Etofenprox (1) (2)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not apply more than 3 applications, regardless of the adversity.

(2) Do not apply more than 3 applications of pesticides from the same mode of action group (IRAC 3A).

Slugs and Snails

Deroceras reticulatum, Arion spp

Slugs and snails are pests that feed on lettuce leaves. They are normally active during rainy and humid environmental conditions. Irregular holes or damp orange-brown lesions appear on the leaves. The damage caused by slugs and snails can be confused with that caused by other pests that feed on lettuce foliage, such as caterpillars. Slugs and snails leave a silvery mucous trail. These pests can be devastating, especially during the initial growth stage of the crops following the transplanting in the soil, as the slugs and snails may feed on the new foliage, impacting the development of the plant.

Control and Management

Chemical Interventions

- In the presence of the pest, distribute poisoned baits (follow instructions on the product label).

PLANT PROTECTION SUBSTANCES

- Metaldehyde
- Ferric Phosphate

European brown snail Cornu aspersum [27]

Foliar damage caused by snails [26]

Deroceras reticulatum, Slug [27]

Leaf miner

Liriomyza spp.

Liriomyza is a genus of several polyphagous leaf miner flies that include various species present in Malta, such as *Liriomyza bryoniae, Liriomyza trigolii*, and *Liriomyza huidobrensis*.

Leaf miner flies are black with bright yellow spots, however, the colours may vary slightly, according to the species. Adult females, through their ovipositors, lay eggs on the surface of the leaves. The eggs are very small, measuring about 0.3 mm by 0.1 mm, oval and translucent. As the eggs hatch, the larvae are colourless, later changing to orange-yellow as they mature. The larvae are legless and grow around 3 mm long. The larvae feed on plant tissue forming mines that become wider as the larvae mature.

Once the larvae approach the pupation state, they exit the leaf and pupate on the soil. The pupa is oval, around 2.3 mm long, and has a yellowish colour that turns darker as the pupa develops into an adult fly.

In warm climatic conditions, the life cycle of the leaf miner takes around 21 to 28 days, resulting in multiple generations in one season. This may vary, depending on the species.

Damage to the leaves is caused by the female flies as they puncture the leaf tissue to feed and oviposit. The puncture marks turn white and appear as speckles on the leaves. More damage is caused by the larvae as they feed on plant tissues, creating leaf mines. The damaged leaves affect the plant's photosynthesis and may cause fungal or bacterial infections.

Adult Liriomyza trifolii [28]

Diglyphus isaea, a beneficial insect [29]

Control and Management

Agronomic Interventions

- Use seedlings free from infestation.
- Protect all greenhouse apertures and entrances using an insect net.
- Destroy infected crop residues.

Chemical Interventions

- Use chemical controls only when the presence of Diglyphus isaea (leaf miner parasite) is not visible or scarce and when the symptoms show.

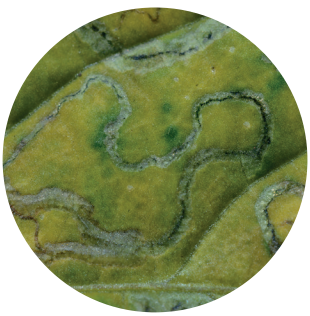
PLANT PROTECTION SUBSTANCES

- *Diglyphus isaea*
- Abamectin (1)
- Spinosad
- Azadirachtin

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not apply more than 1 application, regardless of the adversity.

Larva of Liriomyza spp in its mine [40]



Damage of leaf miner on a leaf [41]

Two-spotted spider mite

Tetranychus urticae

Tetranychus urticae, also known as red spider mite or two-spotted spider mite, is a polyphagous pest that feeds on various economically important crops, including lettuce.

The red spider mite is very small, measuring 0.5 mm to 0.6 mm in length for a female adult, oval and hairy. During the overwintering stage, the females are orange to brick red in colour. Male mites are smaller however these tend to be more active than the females. The colour of the insect varies, ranging from light yellow, green, brown, and bright red with two dark spots on the abdomen.

Female mites can lay around 120 eggs. The eggs are round and translucent and in time change to light yellow, usually 0.13 mm in diameter. Before hatching, the eggs become pale reddish. Fertilised eggs develop into females while unfertilised eggs grow into males. The length of the cycle of the eggs, larvae, nymph, and adult stages varies according to the weather. In temperatures of 25°C it takes around 14 days to complete a full life cycle. During warm climatic conditions, more infestations are present on the field. Oviposition stops as temperatures drop below 12°C and the red spider overwinters.

Tetranychus urticae are visible on the foliage as small dots. Early symptoms can be identified when tiny chlorotic spots appear on the leaves giving a stippled effect. Leaves under serious infestations may turn white or bronze which leads to drying and fall of the leaf.

Female mites overwinter in straws or dead vegetation, in dry soil crevices, in cracks in poles and stacks or in other similar environments.

Control and Management

Agronomic Interventions

- Protect all greenhouse apertures and entrances using an insect net.
- Maintain the area free from unwanted weeds.

Biological Interventions

- The beneficial insect *Phytoseiulus persimilis* can control spider mites if the crop is grown in a protected environment (greenhouses). This particular beneficial insect should be released when 3 to 4 two-spotted spider mites are noticed on one lettuce leave. This should be released at a rate of 2 individuals per plant and at least every 2 weeks.
- In the presence of this mite in the previous crop cycles, proceed with the launch of the beneficial insects within 7-10 days after the transplant.

Chemical Interventions

- Intervene in the presence of outbreaks.

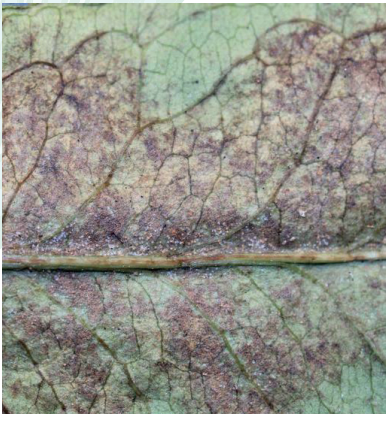
PLANT PROTECTION SUBSTANCES AND BENEFICIAL ORGANISMS

- *Phytoseiulus persimilis*
- Abamectin (1)
- Terpenoid blend QRD 460

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not apply more than 1 application, regardless of the adversity.

Two-spotted spider mite infestation [30]



Damage caused to the underside of the infested leaf [31]

Thrips

Frankliniella occidentalis, Thrips spp.

Frankliniella occidentalis, also known as Western Flower Thrip, and other Thrips spp. are polyphagous pests that feed on various economically important crops, including lettuce.

Adult thrips have an elongated narrow body less than 2 mm long, with fringed hairy wings. Their colour may vary from yellow, orange, brown, and black. Their life cycle consists of 6 stages: eggs phase, 2 larva stages, prepupa, pupa, and adults. Under favourable environmental conditions, a full life cycle takes around 11 days in temperatures around 27°C.

Thrips damage the crops as they puncture the leaf tissue to feed on the plant sap and during oviposition. The damaged tissue becomes silver turning to brown. Thrips can be destructive for other host plants such as tomato plants as these can be vectors of the tomato spotted wilt virus (TSWV).

Control and Management

Agronomic Interventions

- Maintain the area free from weeds.
- Protect all greenhouse apertures and entrances using an insect net.
- Place blue stick traps for monitoring.

Chemical Interventions

- Intervene at the initial signs of infestation.

PLANT PROTECTION SUBSTANCES

- Potassium salts of Fatty Acids
- Terpenoid blend QRD 460
- Spinosad (Organic)(1) (2)
- Etofenprox (3)(4)
- Deltamethrin (3) (1)
- Abamectin (5)
- Acetamiprid (5)

LIMITATIONS OF USE AND SPECIAL CONDITIONS

(1) Do not apply more than 3 applications, regardless of the adversity.
(2) Should only be used in open field cultivation.
(3) Do not apply more than 3 applications of pesticides from the same mode of action group (IRAC 3A).
(4) Do not apply more than 2 applications, regardless of the adversity.
(5) Do not apply more than 1 application, regardless of the adversity.

Foliar damage caused by Frankliniella occidentalis [32]

Frankliniella occidentalis; second instar nymph [34]

Adult Frankliniella occidentalis [33]

Root-knot nematodes

Meloidogyne spp.

Meloidogyne is a genus of several parasitic, polyphagous nematodes that feed and infect the roots of lettuce plants. Nematodes are microscopic organisms that live in the soil.

A female nematode can lay hundreds of eggs typically on the host plant roots. As the nematode progresses to the second juvenile stage, it becomes mobile and penetrates the roots, moving into the vascular system. As the nematode feeds on the roots, it causes swelling and the formation of knots, white to brown galls. Other symptoms visible above ground are slow plant growth, yellowing leaves, and wilting. The symptoms may vary according to the species. Under favourable environmental conditions, a full life cycle of *Meloidogyne spp.* can be completed in 19 days.

Nematodes, including their eggs, can be dispersed by the wind through dust particles, water runoff during rainfall or irrigation, or soil present on ploughing tools.

Control and Management

Agronomic Interventions

- Practice crop rotation cycles.
- Eliminate and destroy the residues of the previous and affected crops, including the roots.
- Disinfect agricultural tools/machinery used in contaminated areas.
- Solarize the ground with a polyethylene transparent plastic 0.035 mm to 0.050 mm thick during June-August for at least 50 days. Do this after the harvest since many nematodes will still be present in the top layer of the soil.

Chemical Interventions

- Carry out chemical applications when the presence of root-knot nematodes is observed or if damage occurred in the previous year.
- Intervene once in the pre-transplantation stage using the adequate product in a granular or liquid formulation, then 20-30 days after planting.

PLANT PROTECTION SUBSTANCES

- Garlic extract
- *Paecilomyces lilacinus*
- Azadirachtin

Root knots caused by Meloidogyne spp [35]

PHOTO REFERENCES

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Forstwirtschaft, Bugwood.org, licensed under CC BY-NC 3.0 US DEED

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35 DAFF Archive , Bugwood.org, licensed under CC BY-NC 3.0 US DEED

36 Penn State Department of Plant Pathology & Environmental Microbiology Archives, Penn State University, Bugwood.org, licensed under CC BY-NC 3.0 US DEED

37 Dr Andrea Minuto, CERSAA, Albenga (IT), EPPO (2024) EPPO Global Database. https://gd.eppo.int [accessed date: 10th December 2024]

38 Servizio Fitosanitario Regione Emilia-Romagna (IT), EPPO (2024) EPPO Global Database. https://gd.eppo.int [accessed date: 10th December 2024]

39 Amanhuy Duque and Andrea Castro, https://www.inaturalist.org/, licensed under CC BY-NC 4.0

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