Food and Agriculture
Organization of the
United Nations

Integrated pest management
of major pests and diseases in eastern Europe and the Caucasus

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Foreword

Human society continues to meet challenges in sustainable development – particularly in developing countries. In these countries, agriculture and related activities often form the core of the economy and constitute the sole means of livelihood and survival for the rural population.

Climate change, soil degradation and indiscriminate use of pesticides and fertilizers put sustainable food and agricultural systems at risk. In particular, the overuse of pesticides is known to eliminate important ecosystem services resulting into secondary pest outbreaks which could potentially jeopardize national and regional food security.

Intensive overuse of extremely and highly hazardous chemicals by small-holder farmers are threatening farm activities, public health, nutrition and the overall future of agriculture.

For over 20 years, the FAO Regional Office for Europe and Central Asia, working with governments and nongovernmental organizations, has implemented number of programmes and projects for farmer education and capacity building of extension service to promote and support Integrated Pest Management among the governments and smallholder farmers.

IPM in the region is promoted as an ecological approach to managing pests through understanding the crop ecosystem as a basis of good crop management decisions. Often, low levels of populations of some pests are needed to keep natural enemies in the field and the aim of IPM is to reduce pest populations to avoid damage levels that cause yield loss. The Integrated Pest Management (IPM) is still directly associated with pests and defined as a knowledge-intensive process of decision making that combines various strategies (biological, cultural, physical and chemical, regular field monitoring of the crops etc.) that focuses on reduction of pesticide use to sustainably manage dangerous pests.

IPM strategies are crop and variety specific, country specific, region and location specific, depending on local agricultural practices, available knowledge and crop protection means available for farmers which means that IPM has to be developed and adapted to fit local requirements. Designing and practicing effective IPM programmes is about continues learning and looking for solutions based on changing field circumstances. Therefore, the training approach used by the FAO Regional office is primarily the Farmer Field School (FFS), when farmers meet regularly, facilitated by qualified extension staff, share their problems and discuss solutions. Farmer Filed Schools help to improve the existing knowledge and to build on local ecosystems to ensure sustainable agriculture and food systems.

Education and awareness have a significant impact on farmers' productivity, on environmental protection, health and safety of farm households and sustainable use of natural resources.

Achieving recently agreed Sustainable Development Goals (SDG) is possible through transition to more efficient use of the available resources and right balance between private and public sector initiatives.

This book is intended to guide farmers in the integrated management of pest and diseases, helping them with decision making. It provides a description of the most dangerous pests and diseases, including symptoms, possible location, types of plants, biology as well as ways of monitoring. It also describes the main components of specific Integrated Pest Management.

It is hoped that this publication will serve as a reference and encouragement for farmers and governments for further enhance existing and develop new IPM programmes that it will help farmers to cope with the main pests and plant diseases in the region. This will not only safeguard against adverse effect of pesticides to human health and the environment, but will also promote food security and sustainable crop production intensification in the region for meeting the future challenges.

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- TCP/GEO/3401 "Support for development of Integrated Pest Management (IPM) system for the control of fall webworm (Hyphantria cunea) in Georgia"

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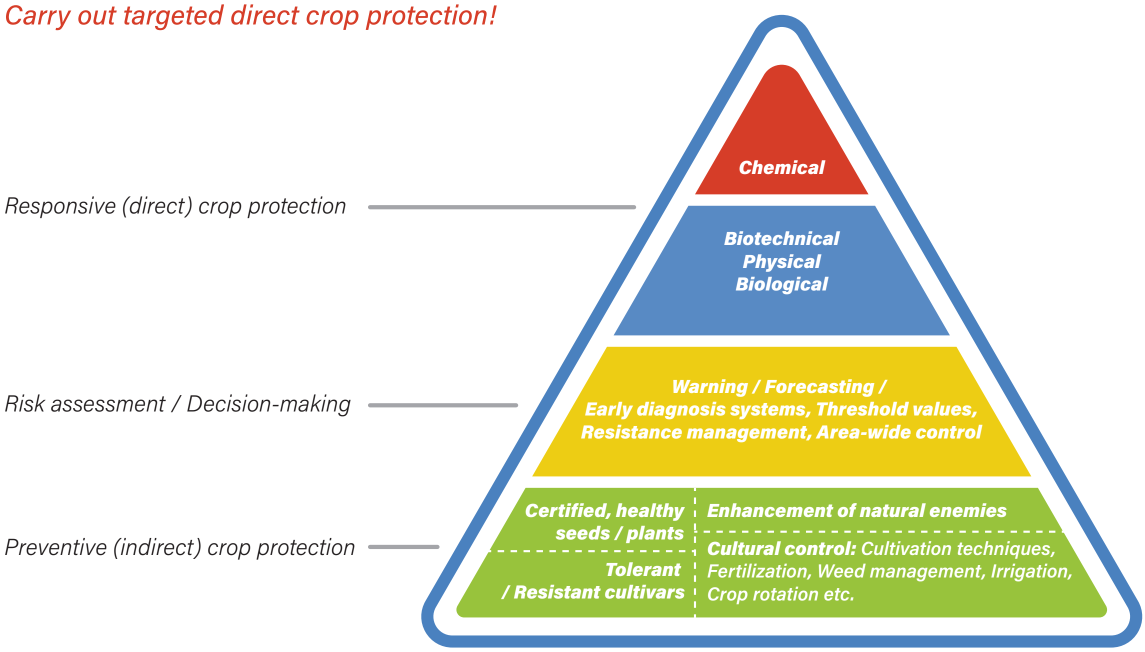
FAO Principles on Integrated Pest Management (IPM)

FAO promotes IPM as the preferred approach to crop protection and regards it as a pillar of both sustainable intensification of crop production and pesticide risk reduction. As such, IPM is being mainstreamed in FAO activities involving crop production and protection.

IPM developed in response to steadily increasing pesticide use that resulted in pest control crises (outbreaks of secondary pests and pest resurgence following development of pesticide resistance) and increasing evidence and awareness of the cost to health and the environment caused by the intensive use of pesticides.

Base your plant protection strategy on prevention and monitoring!
Carry out targeted direct crop protection!



Meissle et al. 2011.Pest Manag. Science,67

Tips		
Always...	*When necessary...*	*Never...*
...search for symptoms according to the phenology of the crop!	...use selective chemicals, but prefer biological methods to protect beneficial organisms!	...spray with the same pesticide successively!
...count with disease problems in rainy periods!	...ask an expert for advice!	...spray without protecting yourself and others!
...buy pesticides with undamaged and original packaging!	...search the internet for information!	...neglect the pre-harvest interval (PHI) after the treatment

Introduction

Integrated Pest Management (IPM) has been known for some decades but is often used and understood in different ways by different people.

The FAO definition of IPM

"Integrated Pest Management (IPM) means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human and animal health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms."

In other words, all available control options (e.g. cultural, physical, biological, chemical) should be considered and applied reasonably by farmers. Nevertheless, IPM is not simply a toolbox and integration of control options. It also involves measures (e.g. prevention, monitoring, forecasting, early diagnosis) which help slow the development of pest populations. An important aspect in IPM is adequate decision-making for any interventions. All decisions should be justified both economically and ecologically. Therefore, management programmes with the regular application of chemicals are not acceptable in IPM. Instead, priority should be given to prevention and alternative control tactics. Principles and more detailed examples in IPM implementations are discussed below:

Putting IPM into context

IPM has been implemented in various regions and countries that are different in terms of their natural and socio-economic conditions as well as their level of agricultural development. However, progression in plant production and protection may be achieved in any existing situations by implementing IPM. The application of IPM is not a simple and strict compliance with rules and regulations, but it rather means actions taken with an environmental approach including principles, strategies and tactics that contribute to the reduced use of chemicals as well as to higher food security for sustainable production. In order to make IPM as effective as possible, it should be adapted to local/regional conditions.

IPM in a spatial scale: thinking of landscapes instead of individual farms

Various types of habitats (e.g. agricultural areas, semi-natural environments) may be identified on a spatial level (i.e. farms, landscapes). They serve as spaces for living, reproduction and overwintering for many living organisms, including pests. Pests can invade newly established crops, spread among different habitats, and build up significant populations therein. The same is true for their natural enemies and antagonists. Thus, the occurrence and distribution of different species, including pests and beneficial organisms, at a given site will be affected by the surrounding habitats and the management practices applied in these habitats.

IPM in a temporal scale: thinking of cropping systems instead of one single season

Cultivated annual and perennial plants host various pests and diseases, and allow the emergence of weeds in the field. In the case of arable crops, the alternation of plant species over time at the same site (crop rotation) may break the life cycle of pests resulting in reduced pest pressure in the subsequent crop. In perennial crops, including orchards, the density of pests in a given year is a major determining factor in the initial infestation level in the subsequent year. Both crop rotation and/or other pest management measures will thus have an impact on the occurrence of pests in any cultivated plants in a temporal scale. In this context, IPM is the rational regulation of pests, present at the same site, not only in one plant species grown in a given year but also in cropping systems over several years. This approach is also valid and applicable for beneficial organisms. Therefore, IPM should be considered in a spatio-temporal context.

General principles for the implementation of IPM

1. Prevention and/or suppression of harmful organisms should be targeted and achieved by combining various options such as:

- Crop rotation and intercropping;
- Use of adequate cultivation techniques (e.g. Seedbed sanitation, sowing/planting time and plant densities, under-sowing, conservation tillage, pruning and direct sowing);
- Where appropriate, the use of resistant/tolerant cultivars and standard/certified seed and planting material;
- Providing balanced nutrient supply and optimal water management;
- Preventing the spread of harmful organisms through field sanitation and hygiene measures (e.g. Removal of infected plants, plant parts and plant debris and regular cleaning of machinery and equipment);
- Protecting and enhancing beneficial organisms (e.g. utilization of "ecological services"inside and outside production sites).

2. Monitoring

- Harmful organisms should be monitored with adequate methods and tools, where available. These should include observations in the field (e.g. occurrence of pests, appearance of symptoms) and, where feasible, scientifically sound warning, forecasting and early diagnosis systems (consisting of traps, weather stations etc.). Regular consultancy with professionally qualified advisors is also recommended. (For further information on monitoring see the next chapter.)

3. Adequate decision-making

- Based on the results of the monitoring and the consideration of local conditions (e.g. cropping system, weather) proper decisions should be made about the need for, timing and methods of pest management. Where feasible, threshold values for harmful organisms should be defined and considered,taking into account the given growing conditions before any treatments.

4. Non-chemical plant protection measures

- Sustainable physical, biological and other non-chemical methods should be preferred to chemical ones especially if they can also provide satisfactory pest control. As chemical pesticides are designed to be toxic to living organisms, are dispersed in the environment and are applied to food crops, their use should only be a last resort; used only if there are no adequate non-chemical alternatives and if it is economically justified. If the application of pesticides is foreseen, a pest management plan needs to be prepared.

5. Specific pesticides

- If after the consideration of available IPM approaches the use of chemical pesticides is deemed to be justified, then careful and informed consideration should be given to the selection of pesticide products. Factors to be taken into account include hazards and risks to users, selectiveness and risks to non-target species, persistence in the environment, efficacy and the likelihood of development or presence of resistance in the target organism. The pesticides to be applied should be as specific to the target agent as possible and should have minimal effects on human health, non-target organisms (e.g. predators, parasitoids, pollinating insects) and the environment (e.g. water, soil). Their use should be kept to a minimum, e.g. by reducing the application frequency or using partial applications. If repeated application of chemicals was justified and required, pesticides with different modes of action (see WHO and EPA toxicity classification schemes) should be applied as part of an anti-resistance strategy to maintain the effectiveness of the available products.

- The products to be applied should be registered in the country of use, or specifically permitted by the relevant national regulatory authority if no registration exists. The use of any pesticides should comply with all the registration requirements including the crop and pest combination for which it is intended.

6. Evaluation

- The efficacy of the applied plant protection measures should be checked and evaluated based on the records on the use of pesticides and on the monitoring of harmful organisms. This will help farmers improve future pest management methods by making use of their knowledge and experience gained.

In addition to the principles above, key factors for the implementation and development of IPM are the knowledge and capacity of farming communities. Without understanding the local agro-ecosystems, mechanisms, biology of pests and their natural enemies etc., IPM cannot be successfully implemented. Farmers should improve their knowledge by participating in training courses and professional consultancy, and they should be involved in the development process. Communication, discussion of problems as well as sharing experiences with each other (community-based learning) are also important, and all contribute to proper decision-making.

Key benefits of using IPM

- ✓ ***Lower risks to human health and the environment (e.g. water resources, pollinating insects)***
- ✓ ***Delayed development of pesticide resistance***
- ✓ ***Money can be saved on plant protection***
- ✓ ***Improved public image of agricultural production***

Selected sources:

AGP – Integrated Pest Management
http://www.fao.org/agriculture/crops/core-themes/theme/pests/ipm/en/

Dir. 2009/128/EC
http://eur-lex.europa.eu/

ENDURE Network
http://www.endure-network.eu/

Environmental and Social Management Guidelines
http://www.fao.org/3/a-i4413e.pdf) – See Annex 1

Environmental and Social Standards
http://www.fao.org/environmental-social-standards/en/

The International Code of Conduct on Pesticide Management
www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Code/CODE_2014Sep_ENG.pdf

Monitoring in IPM

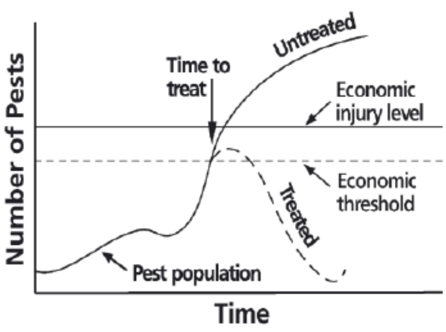
Any decisions about pest management tactics to apply should be preceded by the proper identification of the organisms and conditions occurring in the field. Moreover, careful consideration is required to classify the organisms, and determine any of them as a pest.

The FAO definition of a pest

*"**Pest** means any species, strain or biotype of plant, animal or pathogenic agent injurious to plants and plant products, materials or environments and includes vectors of parasites or pathogens of human and animal disease and animals causing public health nuisance" [Revised 2014: Code of Conduct on Pesticide Management].*

Complete control of all pests is neither necessary in most cases nor appropriate for IPM. Almost all crops can tolerate a certain amount of damage without appreciable effects on vigour and yield. In light of this, it is necessary to make estimations on the pest densities that can be tolerated. A number of economic concepts are helpful in determining the point at which it pays to apply certain control methods:

- **Economic Damage (ED)**: begins at the point at which the cost of crop damage equals the cost of control
- **Economic Injury Level (EIL)**: the lowest pest population density that will cause ED
- **Economic Threshold (ET)** or Action Threshold (AT): the population density at which control action should be determined (initiated) to prevent an increasing pest population (injury) from reaching the EIL. To make a control practice profitable, or at least break even, it is necessary to set ET below EIL.



To make a control practice profitable, or at least break even, it is necessary to set the economic threshold (ET) below the economic injury level (EIL). Graphic: *National Pesticide Applicator Certification Core Manual*, NASDARF

A pest can be non-economic (consistently remaining below economic levels), occasional (normally remaining below EIL but sporadically exceeding the threshold levels), and severe (occurring at high levels regularly and causing major damage without control). Most actual thresholds used in IPM today are more complicated and dynamic than a simple fixed level. Action thresholds can be expressed as the number of pest stages in the crop, damage, or a relative measure of pest activity by trapping or other indirect sampling methods.

Monitoring

Once precautions have been taken to prevent infestations, it is important to regularly check the occurrence of species identified properly and considered to be pests or beneficial organisms, the damage caused by the pests,the crop characteristics, and the environmental factors. This monitoring procedure is a key element of IPM programmes. It helps early detection, ranking of the severity of infestations and estimation of future populations. Therefore,it provides a better chance to avoid economic losses. In addition, regular monitoring works well for evaluating the results of a control strategy used. However, the methods of monitoring vary depending on the pest and the situation. These methods, developed for several species should thus be adapted to local conditions. If monitoring has been carried out carefully, decision-making about any pest control tactics to (or not to) apply and/or evaluation of pest management actions taken formerly may become adequate.

Upon entering any fields there are certain general procedures that must always be followed:

- ✓ ***Identify the field on the scouting report form properly indicating all available data***
- ✓ ***Record date and time of the day***
- ✓ ***Record weather conditions***
- ✓ ***Record crop growth stage***
- ✓ ***Record general soil and crop conditions***
- ✓ ***Sample the field using the method and pattern recommended for the particular pest(s), and,if necessary, collect samples of (potential) pests and/or damaged (parts of) cultivated plants for later identification***
- ✓ ***Record the scouting results using the recording units for the particular pest(s)***

Nowadays, there are many tools and techniques – from rather simple to more complex ones –available for the scout that carries out monitoring in the field. It is very important to be aware that the equipment and the method to be used basically depends on the situation. Therefore, specific knowledge and the choice of adequate devices are required to monitor effectively and reliably.

In practice, for example, traps (light, coloured, pheromone etc.) are widely used to help monitor certain pests. If they are applied properly, they will be suitable tools for checking population activity and getting information for setting the action threshold.

This brochure frequently mentions **pheromone traps** as being recommended trap types in monitoring. In light of this, the most important instructions in connection with their use are summarized as follows:

- ✓ ***Carefully choose the target species that should be trapped in your field***
- ✓ ***Search for information (literature, local data etc.) about the time of emergence of the species, and set the traps in the field 1-2 weeks prior to the expected start of emergence***
- ✓ ***Use original traps and lures (and keep the lures in a deep freezer before use)***
- ✓ ***Assemble the traps on the spot***
- ✓ ***Read the specific instructions for setting the given pheromone trap (e.g. crop height)***
- ✓ ***Consider the size of the area when determining the number of traps to be set (at least two traps for the same species located at min. 10-15 m apart are recommended to operate in a given crop)***
- ✓ ***Check and record the catches at regular intervals and as frequently as possible (at least once a week)***
- ✓ ***Change traps and/or its components (e.g. sticky insert, lure) according to the special instructions, and do not reuse them later***
- ✓ ***Remove all traps from the field when the period of observation (trapping) is finished***

Examples of trap designs:

Funnel trap (with a pheromone lure)

Coloured (yellow) sticky "cloak" trap

Delta trap (with a pheromone lure and a sticky insert)

Selected sources and additional information:

FAO Glossary of phytosanitary terms
http://www.fao.org/docrep/w3587e/w3587e01.htm

University of Idaho - College of Agricultural and Life Sciences Concepts of Integrated Pest Management:
http://www.cals.uidaho.edu/potatoes/PotatoProductionSystems/Topics/IntegratedPestManagement.pdf

CSALOMON®-Commercial website for pheromones
http://www.csalomontraps.com/

Universityof Minnesota - Private PesticideApplication Training Manual
http://www.extension.umn.edu/agriculture/pesticide-safety/ppat_manual/Chapter%201.pdf

University of Maryland – Integrated Pest Management Overview
http://www.udel.edu/IPM/cca/ipmoverview.html

International Plant Protection Convention (IPPC) – Adopted Standards (ISPMs)
https://www.ippc.int/en/core-activities/standards-setting/ispms/

Jenser, G. (Ed.) (2003): Integrált növényvédelem a kártevők ellen. Mezőgazda Kiadó, Budapest.

The Pesticide Environmental Stewardship (PES) Website
http://pesticidestewardship.org/ipm/Pages/Monitoring.aspx

Radcliffe's IPM World Textbook
http://ipmworld.umn.edu/chapters/pedigo.htm

Integrated pest management of major pests and diseases in eastern Europe and the Caucasus

PESTS

Baluchistan melon fly

(Myiopardalis pardalina)

	What do they look like?	Where can they be found?
Adult	5-7 mm, head and thorax orange-yellow, black spots on the thorax, wings with transverse yellow-grey bands	on leaves
Egg	1 mm, white, shiny, oval	under the skin of the young fruit
Larva	11 mm (when full-grown), white, legless	inside the fruit
Pupa	6 mm, light to dark brown, barrel-shaped	either in the fruit or the soil

Host plants

Melon and other species of Cucurbitaceae

Biology

Following overwintering as a pupa in the soil(at a depth of 5-15 cm), the flies emerge at the time of fruit set. Fertilized females lay their eggs under the skin of small, young fruits. A female can lay several dozen eggs during its lifetime. Upon hatching (2-3 days after oviposition), the larvae feed inside the fruit for 8-18 days. The damaged fruits are generally affected by secondary rot, hence they become unfit for consumption and unmarketable. Severe losses in melon crops have been reported in several countries (e.g. Iran), however, in many cases,*M. pardalina* remains a minor or occasional pest. The full-grown larva can pupate either inside the fruit or in the soil. In the latter case, it leaves the fruit through an exit hole before pupation. The exit holes can be observed on the surface of the damaged fruit. The pupal stage lasts 13-20 days. During summer, there may be 2-3 overlapping generations (even four in southern and eastern Iran), each lasting about a month. The adult flies are very susceptible to periods of low humidity.

Monitoring

The manufacturer Russell IPM offers complete monitoring systems for *M. pardalina*. They suggest using the Flycatcher trap design for capturing adults. Checking rotting fruit and searching for tiny exit holes in the surface of the fruits is also recommended.

Control in the open field

Prevention and non-chemical control

- ✓ Crop rotation (and keeping adequate isolation distances from infested crops)
- ✓ Early planting of early maturing varieties
- ✓ Use of plastic mulch
- ✓ Bagging of young fruits soon after pollination (when melons are approx. almond-sized)
- ✓ Removal of all plant residues after harvest
- ✓ Burying of infested fruits in the ground at a depth of at least 75 cm
- ✓ Weed management

Chemical control

- ✓ Adult flies should be targeted by adequate insecticides (e.g. pyrethroids) before egg laying.

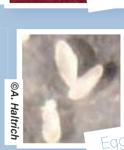
ⓘ **Always follow the label instructions for the dosage, application and safety!**

Bean weevil

(Acanthoscelides obtectus)

	What do they look like?	Where can they be found?
Adult	2-5 mm, compact and oval; short elytra (fore wings) not reaching the end of the abdomen and covered with light grey, brown and yellow-green golden hairs, giving the adult a mottled pattern	in storehouses throughout the year, and on the host plants in the field in summer
Egg	white, about 0.6-0.7 mm in length and oblong in shape	on the seed, or inside or on the ripening pod
Larva	3-3.5 mm (when full- grown), white, cylindrical, C-shaped	inside the seed
Pupa	white, about 4 mm in length	inside the seed

Adult



Egg

Larva

Host plants

Beans and other species of Fabaceae

Biology

The pest damages beans both in the field (during summer) and in storehouses, but major damage is caused mostly in storehouses under temperate climate conditions. Female beetles lay their eggs on the pods or inside them, in the latter case on the inner side of the pod or directly on the seeds. A female can lay several dozen eggs, which may develop from a few days to many weeks, depending on the temperature. After hatching, the larva penetrates the seed, and continues its development inside it while destroying its content. Generally, several larvae can be found feeding in the same seed. Yield decrease may reach 50-60 percent. When full-grown (approx. three weeks), the larva pupates, and the adult leaves the seed through a round "window"(exit hole) of approx. 2 mm in diameter. If beans are stored in a warm place, 3-4 generations of the pest can develop in a year. In addition, its whole life cycle may take place also under adequate field conditions, but it usually overwinters in storehouses. Adults start migrating to the field once the temperature reaches 20°C. The species is very sensitive to temperatures below zero, and prefers high humidity.

Monitoring

Stored beans should be checked regularly to make sure they are not infested.

Control in the storehouse and in the open field

Prevention and non-chemical control

- ✓ Selection and storing of healthy beans only
- ✓ Proper hygiene during storage, elimination of infested beans
- ✓ Heating up of infested stored beans to approx. 60°C for an hour(for consumption or foraging but not for seeding)
- ✓ Keeping storehouse temperatures below zero hinders development of the species

Chemical control

- ✓ Fumigation in the storehouses

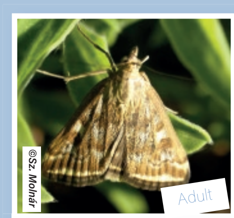
ⓘ **Always follow the label instructions for the dosage, application and safety!**

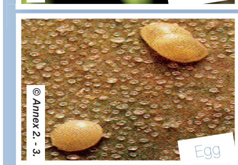
Beet webworm

Beet webworm

(Loxostege sticticalis)

	What do they look like?	Where can they be found?
Adult	brownish, mottled; adults show sexual dimorphism: males are smaller in size than females: wingspan of males is 18-20 mm, and that of females is 20-26 mm; antennae of males are serrate while those of the female are filiform	on the leaves of different plants
Egg	0.8-1 mm in height, 0.4-0.5 mm in diameter, white	on the underside of the leaves or on dried plant parts on the soil, usually in batches
Larva	25-35 mm (full-grown),greenish, greenish grey to black, marked by a black stripe down the middle of the back and with a row of dark circles on each side, head is black with light pattern	on the leaves
Pupa	yellowish to dark brown, in a cocoon of 20-70 mm in length	in the soil





Host plants

Polyphagous (e.g. sugar beet, hemp, legumes, sunflower, mustard, cotton, maize, tobacco, melon, watermelon, Artemisia spp.)

Biology

The first adults of the species may appear in May and June. Females need vitamin E before oviposition, so they are able to fly large distances searching for flowering plants. Eggs are laid on the underside of the leaves of young plants or on dried plant parts on the soil, either in batches (2-3 and more, sometimes to 20 eggs) or singly. Development of eggs lasts 2-15 days. Larvae (caterpillars) develop for 10-30 days, depending on the temperature. Young larvae spin webs, remain in the webs, and feed on leaves. Older larvae disperse and creep around to feed, and they can skeletonize plant leaves leaving only the veins. The full-grown caterpillar pupates in a cocoon in the soil or on the leaf. The number of generations varies depending on the climatic zone (e.g. it may have 3-4 in the North Caucasus). Overwintering takes place as a larva inside a cocoon in the soil.

Monitoring

Monitoring can be carried out by visual counts (the economic threshold may be about 10 larvae per 1 m^2), but this is very time-consuming. The use of near-ultraviolet (black light) or ultraviolet light traps are suitable for trapping the adults. However, light traps can also capture large numbers of other insects, including moths, which may make selection of *L. sticticalis* specimens difficult.

Control in the open field

Prevention and non-chemical control

- ✓ Deep ploughing in autumn
- ✓ Harrowing in spring
- ✓ Elimination of weeds
- ✓ Early sowing/planting
- ✓ Release of *Trichogramma* spp. (egg parasitoids of the pest)
- ✓ Use of *Bacillus thuringiensis* serovar. *kurstaki* against the young larvae

Chemical control

- ✓ Larvae of the pest can be controlled by chemical insecticides.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Box tree moth

(Cydalima perspectalis)

	What do they look like?	Where can they be found?
Adult	wingspan can reach 40 mm; white, slightly iridescent wings with a dark brown band at the outer margin and a characteristic white spot on the forewing (the wings may be entirely brown, but still show a white forewing spot)	on the leaves of the host or on surrounding plants
Egg	1 mm in diameter, yellowish, and the black head capsule of the larva can be seen just before hatching; flat in shape	on leaves (often on the underside), laid in a mass, and overlapping
Larva	newly hatched larvae are greenish yellow, with black heads; mature larvae have a green ground colour and a striking pattern of thick black and thin white stripes along the length of the body, with large black dots outlined in white on the dorsal side; they can reach 40 mm in length in the last larval stage	on the shoots
Pupa	15-20 mm in length; initially green with dark stripes on the dorsal surface, turning brown with a dark pattern corresponding to the brown wing borders of the adult towards the end of pupation; concealed in a cocoon of white webbing	among the leaves (and twigs)

Adult

Adult

Egg

Larva

Pupa

Host plants

Box tree (*Buxus* spp.)

Biology

The pest, native to East Asia and recently introduced to Europe and West Asia, over winters as an immature larva, protected in a cocoon spun between *Buxu*s leaves. Cold winters, in general,do not play a major limiting role in the survival of the resting caterpillars. Development is continued the following spring, when larvae feed actively on leaves of the host plant, and may be observed as early as March. Pupation takes place in a cocoon, which is hidden among the leaves and twigs of the damaged box tree. Adults appear in May-June. They are attracted to light. After mating, females lay their eggs in batches of 5-20, often on the underside of leaves. Typical symptoms of damage are as follows: younger larvae feed by eating the surface of the leaves only ("windowing"), whereas older larvae feed inside webbing and skeletonize the leaves, leaving only the midribs, and occasionally the outer margins, intact. Frass (excrement) and moulted black head capsules are also apparent. The species can have several (2-3) generations a year, and repeated attacks, as well as heavy infestations, may lead to total defoliation of Buxus plants. Furthermore, as not only the leaves but also the bark of box trees may be damaged, in the case of subsequent attacks the affected plants may dry out and die. Severe infestations have already been observed in historical, formal and private gardens and cemeteries. However, the most serious threat from the pest is likely to be on the natural Buxus populations occurring in the Balkan Peninsula or the Caucasus, for example. Although the adult moths are good fliers, it is widely accepted that the main pathway of introduction of the pest in a new region is the international trade of Buxus plants, as eggs, young larvae or pupae of the species and/or initial symptoms of damage may remain unnoticed on transported planting materials.

Monitoring

Early recognition of the pest is crucial so that control tactics can be applied as soon as possible. As plants for planting may be a primary source of infestation, imported box trees as well as *Buxus* plants grown in domestic nurseries should be carefully inspected prior to sale and/or further distribution. Although older larval instars and symptoms of the damage they cause are very characteristic (webbing, skeletonization of leaves and frass are conspicuous) and easily identifiable, this is not the case with other stages of the species: small clusters of eggs are often found on the underside of leaves, and occur scattered on plants, while overwintering young larvae as well as pupae are often well-hidden among leaves and twigs. The appearance of small black dots (heads of the larvae) in the egg cluster indicates that the larvae are close to hatching, which is an important period to initiate certain control tactics.

Adults of *C. perspectalis* are easy to identify once they turn up in a region not affected previously.

Figure: A - Cydalima perspectalis adults attracted to light in a home garden; B – Eggs of the pest laid on the underside of a leaf and being close to hatching (note the black heads in the egg cluster); C – Young larvae "windowing"; D – Pupa hidden amongst damaged leaves

They are attracted to light, so can be captured by light traps, but pheromone traps are also available for the detection and monitoring of the species.

Control in the open field

Prevention and non-chemical control

- ✓ Use of healthy planting material (note: public awareness should be raised by communicating the risks of moving infested box trees)
- ✓ Proper pruning, and removal and destruction of infested plant parts
- ✓ Manual removal of larvae/pupae from infested plants, repeated every 2-3 days, can be an effective control measure, although it may be laborious and time-consuming
- ✓ Showering the trees with a strong water jet or sucking the larvae off the plants with a vacuum cleaner has proven very effective
- ✓ Use of *Bacillus thuringiensis* serovar. *kurstaki* against the young larvae

Chemical control

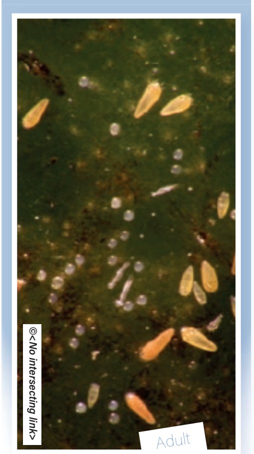
- ✓ Chemical treatments should focus on the young larvae when they become active in spring, and/or the caterpillars hatching from eggs laid by emerging females later in the season. Timing, based on monitoring, is very important. Dense webs formed by and protecting the growing larvae reduce the chance of effective control.
- ✓ Good coverage of the foliage (by reaching the inner parts of dense bushes when spraying) is crucial for adequate pest control (e.g. by using an electric backpack sprayer and adding a spreader sticker to the tank mix).
- ✓ Several insecticides belonging to different chemical groups have been shown to give good control results, although the use of broad spectrum insecticides (e.g. organo phosphates, pyrethroids) must be avoided in natural *Buxus* stands.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Citrus rust mite

(*Phyllocoptruta oleivora*)

	What do they look like?	Where can they be found?
Adult	body about three times longer (0.15 mm) than wide, elongated, wedge-shaped, straw to yellow in colour	on the leaves, green twigs and fruits
Egg	transparent, spherical	
Larva/nymph	similar to the adult	



Host plants

Citruses

Biology

The female lays one or two eggs a day during her lifetime (14-20 days). Eggs hatch in about three days at 27°C. The length of the life cycle from egg to adult is six days at the above temperature so the species goes through numerous generations in a year. Optimal conditions for development are temperatures around 25°C and high relative humidity. Before fruits are about 1.5 cm in diameter, the mites mostly occur on the underside of young leaves. Later they colonize the fruits; initially feeding on the protected parts, and then on the entire surface. Green twigs may also be affected. Damage is caused by piercing and sucking of the epidermal cells, which results in rust-like blemishes on oranges and silvery ("sharkskin-like") blemishes on lemons. Heavily infested fruits are smaller, reduced in quality, and may drop. Symptoms of leaf injury may be observed on both surfaces and may include the loss of gloss (bronzing), appearance of yellow patches and necrotic spots. The species can be spread by infested plants and also by wind.

Monitoring

The pest should be monitored from early spring through summer. Regular examination of plants may reveal increasing mite populations in time before they can cause significant damage. A magnifying glass of at least10× magnification is necessary to find the minute mites on young leaves and fruits. They usually feed in protected places, such as the stylar end of the fruit. The mites leave damaged plant surfaces for fresh leaves and fruits. Once one or more infested fruits are found and if *P. oleivora* was a problem the previous year, the orchard should be checked closely. Threshold levels depend on last year's rust mite problems and current market conditions. Many scientific methods of sampling or scouting for rust mite populations and determining action thresholds have been described and can be applied once adapted to the local conditions.

Control in the open field

Prevention and non-chemical control

- ✓ Use of healthy planting material

Chemical control

- ✓ The use of broad spectrum pesticides should be avoided to save naturally occurring predatory mites which help control the populations of the pest.
- ✓ In some cases, the infestation is localized and a spot treatment may be sufficient for control.
- ✓ The need for and the number of treatments are affected by the selling purposes: the application of chemicals may be reduced if the fruit is for processing and some cosmetic damage can be tolerated.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Codling moth

(*Cydia pomonella*)

	What do they look like?	Where can they be found?
Adult	wingspan is 14-21 mm (resting moths hold their wings roof-like); the fore wings are dark grey with transversal sinuate lines and with coppery-tinged spot at the tip	on the trunk, branches, leaves or fruits
Egg	1 mm in diameter, whitish, flattened, disc-shaped, almost transparent	on the fruit or on the leaves near fruits
Larva	a/newly hatched: 2 mm,yellowish-white with a black head b/full-grown: 12-18 mm, white with a pinkish tinge and brown head	in the fruit,under loose bark or in crevices of the trunk, in plant debris, in the soil or on wooden materials
Pupa	9-12 mm, brown, yellowish-brown, in a cocoon	under loose bark or in crevices of the trunk, in plant debris, in the soil or on wooden materials

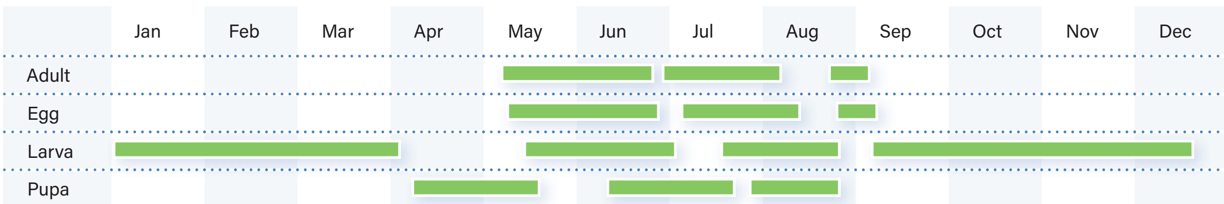
Host plants

Pome fruits and other fruits(e.g. walnut)

Biology

In spring, the moths emerge at about the time that apple trees are in full bloom or soon after flowering. Adults are most active after sunset and usually above 15°C. Females lay their eggs singly on fruits and leaves, on their upper side mainly, avoiding pubescent surfaces. Eggs develop for 5-14 days, depending mostly on temperature. The newly hatched larva finds the fruit, and penetrates it. (Sometimes the larva only makes a shallow bore and then either dies or moves to another location to feed, leaving a little shallow hole on the surface called a sting.) After a few days feeding under the skin, and following the first moult, the larva tunnels towards the core, where it continues its development. While feeding, the caterpillar pushes excrement out of the apple through the entry hole, which is gradually enlarged and often serves as an exit hole. The larva is able to finish its development in a single fruit, but often more than one apple is needed by the larva to become full-grown (approx. 3-5 weeks). In the latter case, neighbouring fruits in the same cluster may be attacked. Damaged fruits often drop prematurely, they are not marketable, and may cause problems also during storage by becoming sources of fungal infestations. The larva regularly leaves the fruit for pupation, which takes place after preparing a cocoon under bark scales, in crevices, in plant debris, in the soil or on different wooden materials (e.g. crates). There are usually 2-3 generations a year in Armenia and Moldova. The species overwinters as a larva inside a dense cocoon.

General development of C. pomonella in Moldova



Monitoring

The pheromone trap of *C. pomonella* can be used to monitor the flight activity of the pest and can help time the application of insecticides. Pheromone traps are available from many manufacturers; here we give an example for the use of the Csalomon® (Plant Protection Institute, Centre for Agricultural Research, HAS, Hungary) codling moth trap: the sticky delta trap with the codling moth pheromone lure should be hung in the tree at about the end of April in Hungary (no later than the blooming period). The traps should be placed at a height of approx. 2-2.5 m or higher in the upper part of the canopy, making sure the entrances are not blocked. Weekly checks are necessary. The lures should be replaced every 4-6 weeks, and the sticky inserts should be changed when the stickiness diminishes and/or their surface is covered with many moths (at intervals of approx.7-10 days). For reliable detection and monitoring, one pair of traps should be used per 1-5 ha.

Orchards of less than 1 ha or with mixed fruits or irregular borders are difficult to monitor with pheromone traps. The key to the successful application of any insecticides against *C. pomonella* is timing, which should be based on the proper use of pheromone traps and temperature-based models adapted to the local conditions.

Control in the orchard

Prevention and non-chemical control

- ✓ Proper design of orchards, pruning of trees and thinning of fruits greatly improve spray application efficiency
- ✓ Removal of any alternate non-commercial host plants of the pest
- ✓ Clearing trunks and branches of old bark, removal of any pieces of flaking bark, broken branches and litter from the crotch of the trees
- ✓ In autumn, corrugated cardboard bands can be placed around trunks to trap caterpillars, which are looking for sheltered places for overwintering. Inspect the bands every two weeks, and destroy all caterpillars (in cocoons)
- ✓ Inspection of fruits every 10 days, and removal and destruction of any fruits found with small holes or any other symptoms of damage by *C. pomonella*
- ✓ Collecting and removal of any fruits dropped prematurely
- ✓ Light traps can be used not only in monitoring but also for population control to some extent as they can attract adults
- ✓ Paying attention to the use of anything made of wood and introduced in the orchard, especially wooden crates and props
- ✓ Release of *Trichogramma* wasps (egg parasitoids of the pest)
- ✓ Use of *Bacillus thuringiensis* serovar. *kurstaki* against the young larvae
- ✓ Use of *Cydia pomonell*a granulosis virus (CpGV) against the larvae
- ✓ Mating disruption (MD) (preferably in orchards large and isolated enough)

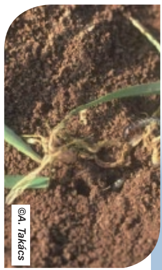
Chemical control

- ✓ Treatment with insecticides during hatching of caterpillars before they penetrate the fruit.
- ✓ For spraying, selective insecticides (e.g. insect growth regulators) should be preferred to broad spectrum insecticides (e.g. organophosphates, pyrethroids) to reduce the risk posed to human health and the environment (e.g. natural enemies of *C. pomonella* and other beneficial arthropods, including bees).

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Corn ground beetle

(Zabrus tenebrioides)



	What do they look like?	Where can they be found?
Adult	14-16 mm in length, black with weak metallic sheen, elytra with 9-9 strips	on the ground surface, in the soil
Egg	2-5 mm, white, brilliant, oval	in the soil, laid in batches
Larva	5-10 mm when newly hatched, 25-28 mm when full-grown, off-white, head and three thoracic segments dark brown, abdominal segments with light brown dorsal spots, body flattened	in the soil, living in burrows close to its host plant
Pupa	14-17 mm, yellowish, later light brown, with visible legs and wings	in the soil

Adult

Larva

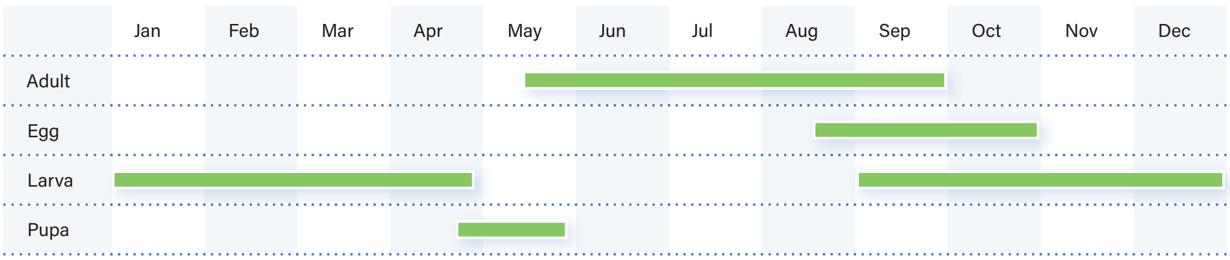
Host plants

Cereals and other species of Poaceae

Biology

The beetles start emerging in May-June. They feed on the developing ears of grain. During warm and dry summers, the adults bury themselves in the ground, becoming active again usually from the second half of August or the beginning of September when temperatures decrease and the weather becomes rainy. They then lay eggs at a depth of 5-15 cm in the soil. Low humidity hinders egg development. Larvae live in the upper layer of the soil (at a depth of approx. 10-20 cm), within burrows adjacent to their host plants. At night, they leave the burrows and eat the leaves. For diurnal feeding, larvae drag leaves inside their burrows. Leaves of the affected plants are shredded and reduced finally to a fine, fibrous mat on the soil surface. Feeding activity decreases during the cold periods from late autumn, and the larvae overwinter in the soil. They are sensitive to low ground temperatures. Larval activity increases in spring; they continue damaging the leaves until pupation, which takes place at the end of April to second half of May. The pupal stage lasts 15-20 days.

General development of Z. tenebrioides



Monitoring

Scouting should be carried out in late summer and autumn. Thresholds can be determined based on catches of beetles captured with pitfall traps and/or the average number of larvae per square meter in the field. The amount of precipitation in the mentioned period has been found to affect considerably pest populations and the expected level of damage in autumn and next spring. Any methods developed for monitoring *Z. tenebrioides* should be adapted to the local conditions.

Control in the open field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Prevention and non-chemical control

- ✓ Appropriate crop rotation
- ✓ Early harvest of grain crops
- ✓ Exclusion of grain losses
- ✓ Immediate and careful removal of straw from the field
- ✓ Elimination of volunteer plants from summer to early autumn
- ✓ Stubble shelling with subsequent ploughing to a depth of 20-22 cm

Chemical control

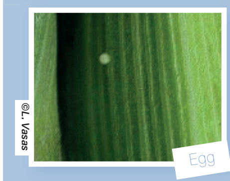
- ✓ Seed treatment (seeds dressed with appropriate insecticides)
- ✓ Spraying the crop using insecticides to control young larvae (application should be carried out at sunset)
- ✓ Application of adequate insecticides to the soil (not preferred)

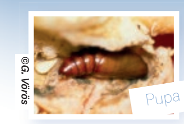
ⓘ **Always follow the label instructions for the dosage, application and safety!**

Cotton bollworm

(Helicoverpa armigera)

	What do they look like?	Where can they be found?
Adult	body length is 12-20 mm, wingspan is 30-40 mm; variable in colour, but fore wings are usually orange-brown in females and lighter, greenish-grey in males, with a black or dark brown kidney-shaped marking near the centre; hind wings are creamy white with a dark brown or dark grey band on the outer margin; identification of adult H. armigera requires dissection of genitalia	on the plants
Egg	0.4-0.6 mm in diameter, white, glistering at first,later greenish, changing to dark brown before hatching, spherical in shape, with a costate surface	distributed on various parts of the plant (e.g. on the leaves and reproductive organs)
Larva	35-42 mm (full-grown caterpillar), highly variable in colour (greenish to red-brown), with three dark stripes along the dorsal side, and one light stripe under spiracles on the lateral side	on the plants, in the reproductive organs
Pupa	14-22 mm in length, dark brown to red-brown	most frequently in the soil





Host plants

Polyphagous (e.g. cotton, tomato, maize, legumes, tobacco, sorghum)

Biology

Several hundred eggs can be laid one by one or in small batches of 2-3 by a single female on different parts of the plant (e.g. leaves, flower buds, fruits). Larvae hatch in three days at 23-25°C, while egg development may take more than a week during colder periods (spring and autumn). Once hatched, the larva usually eat some or all of the empty egg-shell before moving some distance and starting to feed on the plant, usually in a secluded place such as a flower, flower bud, or the underside of a leaf. Larger larvae prefer to feed on immature fruits, which therefore often become hollowed out, but feeding on leaves also occurs in the absence of reproductive organs. Larvae often move about between feeding sites on or between adjacent plants. They become full-grown in approx. 2-3 weeks, but may develop for more than a month. The time of development is affected by the temperature, precipitation as well as the food source. When fully fed, the larva enters the soil to pupate, at a depth which depends on the hardness of the soil. Pupa are generally formed at a depth of 2-18 cm, but occasionally may be found in the litter or at the last feeding site on the plant (e.g. cotton boll, maize ear). Emerging females must feed on flowers before oviposition, and they can migrate over large distances. The moths are active at twilight and night. Depending on the climatic conditions, the species may have many generations a year. It overwinters as a pupa in the soil.

Monitoring

Adults can be captured by light traps; however, pheromone traps should be preferred for monitoring, as they are much more species-specific. Pheromone traps are available from many manufacturers. Here we give an example for the use by the Csalomon® (Plant Protection Institute, Centre for Agricultural Research, HAS, Hungary) cotton bollworm traps: both sticky delta and funnel traps may be suitable for catching males of *H. armigera*. The former may be recommended primarily for detection and monitoring

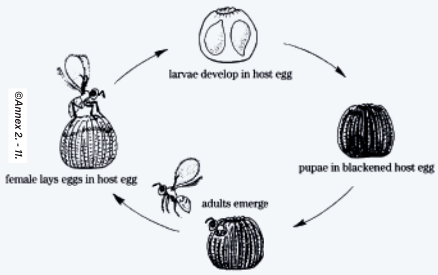
flight dynamics. Its sticky insert may become covered with moths within a very short period and should thus be changed rather frequently. For catching large numbers of moths and/or for some quantitative monitoring the latter trap design should be used. Traps should be placed at the height of the top of the crop. Trapping should be started generally in mid-May in Hungary, but the emergence of adults may start as early as April or only in June, depending on the climatic conditions. During the vegetation period, local population densities may be affected also by immigrant moths.

Plants may be inspected visually for eggs and/or larvae to monitor and assess population sizes of *H. armigera*. Special methods have been developed for different crops, which may be used once adapted to the local conditions. Larvae can be seen on the surface of plants but they are often hidden within plant organs (flowers, fruits etc.). Holes bored and heaps of frass (excreta) may be visible, but otherwise it is necessary to cut open the plant organs to detect the pest.

Control in the open field

ⓘ **Important note: Helicoverpa armigera is currently on the A2 quarantine list of EPPO!**

Prevention and non-chemical control



- ✓ Removal of crop residues from the field
- ✓ Deep ploughing in autumn
- ✓ Trap cropping
- ✓ Growing resistant cultivars or varieties less susceptible to the pest
- ✓ Adequate spacing (renders the crop more accessible to insecticides)
- ✓ Weeding
- ✓ Hand picking of larvae
- ✓ Release of *Trichogramma* spp. (egg parasitoids of the pest)
- ✓ Use of *Bacillus thuringiensis* serovar. *kurstaki* against the young larvae
- ✓ Use of *Helicoverpa armigera* nuclear polyhedrosis virus (HaNPV) against the young larvae

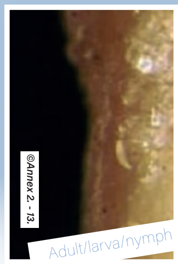
Chemical control

- ✓ Most insecticide applications are targeted against the larval stages, but as these may be effective enough when larvae are small, scouting for eggs and spraying soon afterwards is very important.
- ✓ Consideration has to be taken to the facts that the young larvae are difficult to find while the older larvae soon burrow into the reproductive organs where they become less accessible to chemicals.
- ✓ Anti-resistance strategies should be applied to maintain the effectiveness of available insecticides.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Dry bulb mite

(*Aceria tulipae*)



Adult/larva/nymph

What do they look like?	Where can they be found?
Adult/larva/nymph: tiny, elongated, wedge-shaped	between the layers of bulbs in storage, also on leaves in the open field

Host plants

Allium spp.(e.g. onion, garlic, leek), tulips

Biology

The pest can be found between the layers of the bulbs in storage. Maximum egg hatch occurs at close to 100 percent relative humidity, and the species can complete its life cycle in 8-10 days at 24-27°C. Feeding injury can be seen as sunken brown spots on garlic cloves. Feeding damage on garlic may lead to wilting and drying of cloves. Cool temperatures would prevent population growth during the winter although eggs, nymphs and adults are able to survive in the bulbs for extended periods either in storage or in bulbs left in the soil during winter. The use of infested cloves is the most frequent reason of infection in the field. Feeding on the foliage causes stunting, twisting, curling and discoloration. If infested bulbs are planted out, the mite may be dispersed by wind (to some extent).The species can transmit viruses.

Monitoring

Garlic cloves should be examined under a microscope to find the pest. No special monitoring methods have been developed for the species.

Control in the open field and during storage

Prevention and non-chemical control

- ✓ Crop rotation
- ✓ Use of healthy bulbs for planting
- ✓ Planting in peaty soils instead of sandy and loamy soils Plants with symptoms that have been caused by the pest and also plant debris should be removed from the field
- ✓ Flood irrigation or heavy winter rains can reduce mite populations
- ✓ Light or moderate infestations can be controlled with the normal drying process prior to storage
- ✓ Water treatments of bulbs at 55°C for 10, 15 and 20 minutes prior to planting can reduce mite populations but can also reduce sprouting of cloves

Chemical control

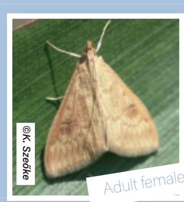
- ✓ Soaking affected cloves for 24 h in 2 percent soap (not detergent) and 2 percent mineral oil has been reported to provide good control.
- ✓ Sulphur dusting of plants in the field has been recommended, and dipping bulbs in pesticides just prior to planting may also be effective.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

European cornborer

(Ostrinia nubilalis)

	What do they look like?	Where can they be found?
Adult	body length is 13-15 mm, wingspan is 23-32 mm, coloration varies from pale yellow to light brown (males are smaller in size and coloured darker than females), wavy bands across the wings	on the plants
Egg	0.5 mm in diameter, white at first but later turning to yellow, and the black head capsule of the larva can be seen just before hatching; flat in shape	usually on the underside of the leaves, laid in a mass, and overlapping like tiles on a roof
Larva	when full-grown: 20-28 mm, grey to light brown or pink, dorsally in each segment there is a series of four anterior spots followed by two small posterior spots, and each spot has a seta; the ventral side of the body is cream-coloured and unmarked	inside the stem
Pupa	13-20 mm in length, brown or yellow, in a thin and loose cocoon	inside the stem



Adult female

Adult

Egg

Larva

Pupa

Host plants

Polyphagous (e.g. maize, hop, millet, hemp, sorghum, pepper)

Biology

The minimum threshold temperature for flight activity of the species is 13-15°C. Adults are active at twilight and night, they can fly over large distances, and females need water to begin oviposition. They lay their eggs in batches of about 20-40, usually on the underside of leaves. Eggs (as well as early instar larvae) are sensitive to and can be desiccated by warm and dry winds. The black head capsule of the larva is visible within the egg shortly before hatching, which takes place in 3-9 days. The newly hatched larvae disperse and can drop from the leaves on silk threads. Feeding begins in the whorl of maize. When the leaf expands, the holes made by the larvae appear in a typical transverse line. Boring into the stem takes place soon in case of dry weather (low relative humidity). Larval feeding inside the maize stem destroys the vascular tissue. As a result, heavily attacked plants are smaller and produce fewer kernels per ear. Frass and holes are easily visible on stems and/or on the apical part of maize ears. Damaged (tunnelled) stems can be easily broken by wind (often near the tassel). Larvae develop for 3-7 weeks. Pupation takes place in a loose cocoon in a chamber prepared inside the stem, and lasts 10-25 days, depending on temperature. The species may have one to several generations per year (e.g. two in Moldova as well as in the North Caucasus), and it overwinters in the larval stage inside the stem. Overwintering larvae can stand heavy frosts.

Monitoring

Moths can be captured with light and pheromone traps; however, when sex pheromone traps are used for monitoring, it is crucial that the pheromone blend applied as a bait represents the blend being used by the local population of the species. Catches of adults in traps should initiate intensive scouting for egg masses and also for the signs of early larvae damage (the "shot holes" on leaves of the whorl of maize) during the first generation of the species. Further symptoms caused by and the different developmental stages of *O. nubilalis* described above may be searched for during the season.

Control in the open field

Prevention and non-chemical control

- ✓ Use of maize hybrids resistant or less susceptible to the pest
- ✓ Adjusting sowing date (in areas characterized by more than one generation of *O. nubilalis*, early sown sweetcorn may escape appreciable damage to the ears)
- ✓ Cutting of stems close to the soil during harvest, stalk shredding (the overwintering site of larvae) and ploughing to a depth of 20 cm
- ✓ Release of *Trichogramma* spp. (egg parasitoids of the pest)
- ✓ Use of *Bacillus thuringiensis* serovar. *kurstaki* against the first stage larvae

Chemical control

- ✓ Chemical treatments should aim the young larvae when they hatch and wander on the plant before boring into the stem.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

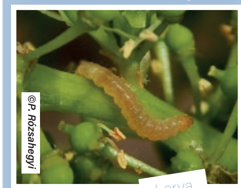
European grapevine moth

(*Lobesia botrana*)

	What do they look like?	Where can they be found?
Adult	Body length is 6-8 mm, wingspan is 10-15 mm,fore wings with a mosaic-shaped pattern with black, brown, cream, red and blue	on the leaves
Egg	0.6-0.8 mm in diameter, pale cream, later becoming light grey and translucent with iridescent glints;flat, elliptical	on leaves, stems, flower buds and berries and/or other smooth surfaces
Larva	a/newly hatched: 1 mm, with deep brown, nearly black head, and light yellow body b/full-grown: 10-15 mm, with lighter head, and a body variable from light green to light brown in coloration	in webs in flower clusters, among and inside berries
Pupa	4-9 mm in length, brown, in a whitish cocoon	in rolled leaves, in bunches, under the bark, in stake crevices or other hidden places

Adult

Egg



Larva

Pupa

Host plants

Grapevines and many other plant species (e.g. gooseberry, currant, Clematis vitalba, Cornus sanguinea, Ligustrum vulgare, Hedera helix)

Biology

The European grapevine moth usually has several generations a year. The number of generations is determined by the photo period and temperature of the given geographical area. For example, it has three generations in Armenia, Moldova and Hungary. Different altitudes as well as microclimatic conditions within an area may modify the development of the species. Moths are mostly active at dusk, but some activity may also occur at dawn or at any time on cloudy days. Females can lay their eggs, usually one by one, on different parts of grapevine (e.g. leaves, stems, flower buds, berries). Larvae hatch in 4-10 days, depending on the temperature, and they start to reach the reproductive organs of the plant. Those of the first generation feed on inflorescences. The larva first penetrates single flower buds, but later agglomerates several flower buds with silk threads forming glomerules visible to the naked eye, and continues feeding while protected inside. Frass may also be observed as adhered to the glomerules. Caterpillars of the second generation feed on unripe berries while those of the third one damage ripening/ripe fruits. Larvae feed externally and when berries become a little desiccated, they bore into them. Damaged berries are secured to surrounding ones by silk threads. Many berries may be affected by a single larva, several larvae may damage a single bunch, and damaged fruits may also be invaded by pathogenic organisms (e.g. *Botrytis cinerea*). Larvae develop for 3-4 weeks and then they pupate in cocoons on leaves, in bunches, under the bark of grapevine, in stake crevices or other sheltered places in the vicinity of the plant. During the vegetation period the pupal stage lasts about two weeks. The European grapevine moth overwinters in the pupal stage, mainly on tree trunks.

Monitoring

Moths can be captured with both light and pheromone traps. The latter is recommended as they are species-specific. A major problem when using sex pheromone traps of *L. botrana*(as with many other pests) is the lack of a clear relationship between the number of males trapped and the damage caused by the offspring, given the high number of uncontrolled ecological factors involved. At present, only a negative prediction can be made reliably enough: minimal (or even no) damage can be expected only when male catches in traps are sporadic (or nil); but if catches are moderate or high, the damage caused by the offspring is practically unpredictable. Nevertheless, according to experience in Hungary, it is usually not necessary to spray if the weekly catch does not exceed 25-30 moths per trap. Temperature-based models have been developed for the species, and they may be useful for prognosis in IPM,once adapted to the local conditions. Inspection of inflorescences, berries and other plant parts for the developmental stages (eggs, larvae, pupae) of and the damage caused by the pest may be recommended, although it may be time-consuming.

Control in the vineyard

Prevention and non-chemical control

- ✓ Use of cultivars less susceptible to the pest (e.g. characterized by less dense bunches)
- ✓ Proper pruning of grapevine and thinning of shoots(to increase air circulation and to render the crop more accessible to insecticides)
- ✓ Weeding (in both rows and inter-rows)
- ✓ Adjusting the date of harvest (to reduce damage caused by larvae of the third generation)
- ✓ Removal of damaged inflorescences and fruits
- ✓ Use of Bacillus thuringiensis serovar. kurstaki against the young larvae
- ✓ Mating disruption

Chemical control

- ✓ Treatment with insecticides during hatching of caterpillars before they become protected by webbing and/or before they penetrate into the fruit.
- ✓ For spraying, selective insecticides (e.g. insect growth regulators) should be preferred to broad spectrum insecticides (e.g. organophosphates, pyrethroids) to reduce risk posed to human health and the environment (e.g. natural enemies of L. botrana).
- ✓ Well-timed treatment(s) against the first (and second) generation(s) may make further sprayings unnecessary.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

European wheat stem sawfly

(Cephus pygmeus)

	What do they look like?	Where can they be found?
Adult	5-11 mm in length, black with yellow transversal sections on the abdomen	on the flowers of different plants, on the host plants
Egg	1 mm in length, white, kidney-shaped	in the stem
Larva	10-15 mm, yellowish white with hazel head, S-shaped body with highly reduced legs	in the stem
Pupa	10-12 mm, white when first formed but soon darkens to black spotted with yellow	in the stem (base part)

Adult

Host plants

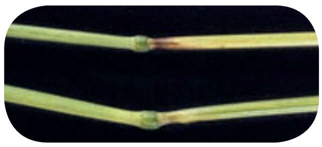
Wheat, rye, barley and other species of Poaceae (e.g. oat, millet, brome, timothy)

Biology

The wheat stem sawfly has one generation per year. Adults start flying between April and June, depending on latitude. In the North Caucasus, flight usually coincides with the beginning of flowering of black locust (*Robinia pseudoacacia*), and the peak of emergence occurs during ear formation by winter wheat. Adults can be found on flowers of crucifers (Brassicaceae) and composites (Asteraceae). For laying the egg, the female saws through the wall of the culm with her ovipositor. The egg develops for about a week. The larva lives inside the stem, feeds on the tissues around fibrous vascular bundles, and usually complete its development before the grain begins to ripen. Larval feeding causes loss of weight of grains and reduced grain quality because of the damage to conducting vascular fibres. The damaged stems easily break hence yield losses may increase by harvest. (*Note: photos above show damage by a closely related sawfly species.*) Overwintering takes place in a thin, semi-translucent, waterproof cocoon in a chamber prepared in the base part of the stem. Pupation occurs in spring.

Monitoring

The adult wasps are weak fliers, and therefore the use of entomological sweep nets is effective for collecting the insects. Plants should be assessed for the presence of the pest and the severity of symptoms. Stems should be examined for signs of internal feeding and discoloration of plant parts (e.g. darkened areas on the stem) and for signs of stem breakage resulting from the presence of the larva. Stems should be cut open to reveal the egg (difficult to see) or the larva. Infested stems contain frass.



© Gary Hein, Susan Harvey, and Jeff Bradshaw from the University of Nebraska – Lincoln (UNL)

Control in the open field

Prevention and non-chemical control

- ✓ Appropriate crop rotation
- ✓ Stubble shelling and deep autumn ploughing
- ✓ Use of cultivars less susceptible to the pest (e.g. wheat varieties with solid lower stem segments)
- ✓ Early harvest, and cutting close to the soil surface

Chemical control

- ✓ The available non-chemical methods are generally sufficient to control the pest. Natural enemies of the species can also regulate *C. pygmaeus* populations. Moreover, chemical control would be difficult and probably not be cost-effective.

Greenhouse whitefly

(Trialeurodes vaporariorum)

	What do they look like?	Where can they be found?
Adult	1.5 mm, resembles a tiny moth; wings held relatively flat while resting and covered with white waxy secretion	on the underside of the leaves
Egg	0.25 mm long, yellowish-white turning to purplish grey after 2 days, conical in shape, on a short pedicel	on the underside of the leaves, often in (partial) circles
Nymph	tiny, usually pale green, oval, flat, scale-like	on the underside of the leaves
Pupa	0.8 mm in length, whitish, oval, marginal fringes and downward curving wax setae around the edge	on the underside of the leaves

Host plants

Polyphagous (e.g. aubergine, tomato, sweet pepper, cucumber, chrysanthemum, *Fuchsia*, *Gerbera*, *Pelargonium*)

Biology

Females usually lay their eggs on the underside of leaves, often in partial or complete circles. The crawlers (first instar nymphs),which emerge from the egg within about a week, are the only mobile juvenile stage, but they usually stay on the same leaf. After a few days of wandering, the crawler settles down,and all further immature, scale-like stages are immobile. Feeding ceases during the last (fourth) instar, often also called pupa or puparium. It takes about a month at 21°C to reach the adult stage. Then the adult emerges through a T-shaped slit. The species has many generations a year. Adults commonly make relatively short flights but can be dispersed by wind for large distances. Whiteflies are sap-sucking insects in both the adult and immature stages. A typical symptom of damage is the presence of excreted honeydew on the surface of leaves and/or fruits. Honeydew may be colonized by sooty mould, which inhibits photosynthesis by leaves and may render the fruits unmarketable. Heavy infestations reduce the overall plant vigour and cause stunted growth and poor yields. The species can transmit viruses. In the temperate zone, the pest usually cannot overwinter outdoors, but can survive under greenhouse conditions and/or in flats in the presence of host plants.

Monitoring

Monitoring can be carried out using various tools, but visual sampling and the use of yellow sticky traps are the most common ones. Leaf samples should be taken and inspected in the laboratory with a microscope to check the occurrence of eggs and/or nymphs. Yellow sticky sheets or tapes may be suitable for early detection, tracking the movement of adults, and may also be used to help suppress pest populations. They should be placed at a height of the top of the crop. However, the number of whiteflies on traps does not give reliable information on the population density and should

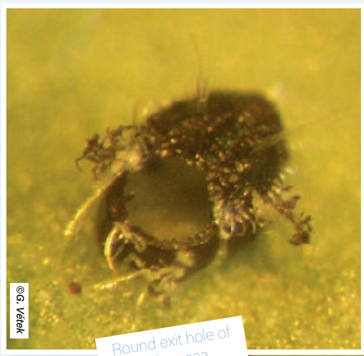
not be used alone to determine the need for treatments. Trapping can be useful for determining when visual sampling should begin. Yellow sticky traps are not species-specific (they can attract also thrips, aphids, flies etc.) and should be cleaned or changed when they are covered with many insects.

Control in the greenhouse

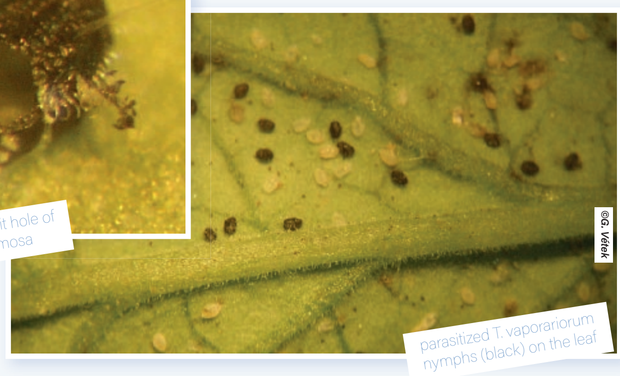
Prevention and non-chemical control

- ✓ Avoidance of introducing infested plants
- ✓ Use of adequate insect exclusion screens
- ✓ Removal of infested plants from and around the greenhouse
- ✓ Application of appropriate numbers of yellow sticky traps
- ✓ Use of biological control agents such as parasitic wasps (Encarsia formosa, Eretmocerus eremicus), predatory bugs (Macrolophus pygmaeus, Nesidiocoris tenuis), predatory beetles (Delphastus catalinae), predatory mites (Amblydromalus limonicus, Amblyseius swirskii) and/or entomopathogenic fungi (Beauveria bassiana, Verticillium lecanii)

E. formosa on a hanging tag



Round exit hole of E. formosa



parasitized T. vaporariorum nymphs (black) on the leaf

Chemical control

- ✓ A single spray of any chemicals will only kill the susceptible stages present at the time of treatment or during the time the chemical remains active. All other stages will survive and continue to develop. Thus repeated treatments at intervals of a few days may become necessary during the cropping period.
- ✓ There are many insecticides available on the market for greenhouse whitefly control, but strains of the species resistant to one or other of them have become established. Therefore, anti-resistance strategies should be applied to maintain the effectiveness of insecticides.
- ✓ It is important to choose insecticides and methods of application that are not harmful to biological control agents.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Onion fly

Onion fly

(Delia antiqua)

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	What do they look like?	Where can they be found?
Adult	5-7 mm long, ash-grey, with or without a longitudinal abdominal stripe in males and females, respectively; adults are more or less similar to houseflies, and identification of the males requires dissection of genitalia	on the plants
Egg	1 mm, white, elongated, longitudinally striped	laid in batches on the leaves, on the neck of the plant, on the soil
Nymph	8-10 mm (full-grown), creamy white, cylindrical, with dark,hooked mouth parts on the tapered end	in the bulb, on the roots
Pupa	7 mm, chestnut brown, barrel-shaped	in the soil

©Annex 2. - 17.

Adult

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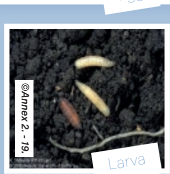
Egg



©Annex 2. - 19.

Larva

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Pupa

Host plants

Onion, garlic, leek and other bulbous plants

Biology

In spring, the flight of adults occurs in April-May, coinciding with the flowering of cherry and dandelion, but may extend to late June. Following some feeding on flowers, females start laying their eggs in batches of 5-20on the soil close to the host plant or on onion leaves and other parts of the plant. Larvae hatch within a few days and go into the bulb from the root side or through the base of leaves. They may also be found feeding on the roots. Feeding in the bulb by several maggots causes cavities. Leaves of damaged young plants turn yellow and wilt, bulbs rot quickly, especially in humid weather, and the whole plant may die. Damage to older plants does not regularly lead to the death of the plant, but yellowing of leaves and distortion of bulbs may be observed. Moreover, damaged bulbs if infected by pathogens may become sources of further infestations, also after harvest during storage. Larvae feed for 15-25 days, and their development may take place in only one or several bulbs. In the latter case, they penetrate the adjacent bulb from the root side. When full-grown, larvae leave the plant and pupate in the surrounding soil at a depth of 5-20 cm. The pupal stage lasts about 2-3 weeks. The number of generations depends on the climatic conditions of the region (e.g. two generations may occur in Hungary while even three in more southern regions). The species overwinters in the pupal stage in the soil. Adults are usually more active during mid-day in spring, and on cloudy, cool summer days while early in the morning and late afternoon during hot temperatures in summer.

Monitoring

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There are various methods of assessing onion fly activity. An inverted-screen cone trap baited with damaged onions can be used to trap adults. It is most effective early in the season for detecting flight activity when onion plants are small. Yellow sticky traps placed around field edges just above the growing foliage can also be used to monitor fly activity. Checking these traps once a week aids in determining relative seasonal activity. Temperature-based calculations may also be useful for prognosis in IPM if adapted to the local conditions. Plants (leaves, bulbs) should be inspected regularly for the presence of eggs and larvae. By using information resulted from monitoring, one can assess the need for and the adequate time of any sprayings to reduce the number of flies capable of laying eggs.

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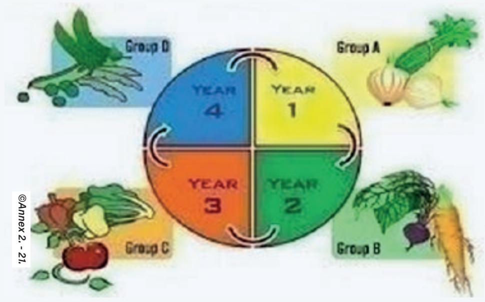
Control in the open field

Prevention and non-chemical control

- ✓ Appropriate crop rotation and isolation (approx. > 1.5 km) from previous and other onion fields
- ✓ Both the choice of the aim of growing and the adjustment of the time of sowing and/or planting to try to avoid periods of peak emergence of the pest as much as possible when the plants are relatively young may help reduce damage by maggots
- ✓ Autumn ploughing
- ✓ Weed management
- ✓ Minimizing any damage to onions during any field works
- ✓ Regular removal of infested plants
- ✓ Appropriate harvest (no onions should remain in the field)



Chemical control

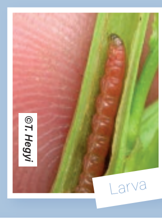
- ✓ Timing of spraying is very important if chemical control is applied against the pest (mainly against the adult flies before oviposition), but it is not that easy.
- ✓ The regular use of chemicals, especially if they are of the same mode of action, may lead to the development of resistance by the pest hence must be avoided.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Oriental fruit moth

(Grapholita molesta)

	What do they look like?	Where can they be found?
Adult	5.5-7 mm in length, wingspan is 9-16 mm (resting moths hold their wings roof-like); fore wings are dark grey-brown, hind wings are lighter; for exact identification, investigation of the genitalia is necessary	on the leaves
Egg	approx. 0.7mm in diameter, translucent-white when laid, later becoming yellow; flat, round or slightly oval	on leaves near the tip of young shoots, on buds, on fruits
Nymph	9-14 mm, yellowish white, partly pinkish with a brownish head (full-grown); a black anal fork (anal comb), above the anal opening, is present	in young shoots, in fruits
Pupa	5-7 mm, yellowish brown at first, turning to reddish brown later, in a cocoon	in the axils of twigs, under pieces of the bark, on or in the fruits, in the litter or soil



Host plants

Peach, nectarine, apricot and other stone fruits, also pome fruits

Biology

The moth begins flying in the middle of spring, usually coinciding with the end of blooming. Moths are active above 15°C, and mating occurs in the evening hours. Females can lay their eggs singly on leaves near the tip of young shoots, on buds, and later on fruits with glabrous surfaces. Eggs develop for a few days or 1-2 weeks, depending on the temperature. In spring, the caterpillars penetrate into young shoots of different fruit trees (e.g. peach, almond) often through the top bud, and bore inside causing the shoots to wilt and crook. The pest can also damage fruits. In this case, caterpillars can feed on the surface or can enter them from the side or at the stalk,and they prepare cavities inside the fruits. The surface indications of the presence of the caterpillar in the fruit are frequently not that evident and occasionally lacking, and only a small part of such injured fruit can be detected during grading. Fruits damaged by ***G. molesta*** can be infected by fungal pathogens (*Monilinia* spp.) that cause brown rot. A single larva can damage several shoots and/or fruits during its development. The larval development may last about 1-3 weeks, varying with temperature, humidity and feeding conditions. Pupae in cocoon may be found in the axils of twigs, under pieces of bark, on or in the fruits as well as in the litter or soil. The complete life cycle of the pest is about a month. The number of generations of the species is variable, depending on the climatic conditions (e.g. it can have 3-4 generations in Hungary while 4-5 in Armenia). Overwintering takes place in the larval stage in a dense cocoon in crevices, under flakes of the bark or in other sheltered places on or close to the tree.

Monitoring

Pheromone traps can be used to monitor adult moths. It is important to note, however, that in the case of *G. molesta* the sex pheromone traps may also attract males of the plum moth (*G. funebrana*), and specimens of the two species can be distinguished only by dissecting the genitalia. Although laborious, it is possible to achieve complete selectivity by putting the sticky inserts in the delta traps only from noon until evening. In this period, oriental fruit moths will be captured exclusively, as the plum moth responds to the pheromone only at the end of the night and very early morning. Temperature-based calculations may also be useful for prognosis in IPM if adapted to the local conditions.

Bait traps containing terpinyl acetate added to fermenting brown sugar solution can also attract *G. molesta* males and, most importantly, fertilized females.

Young, growing shoot tips and later also fruits showing the symptoms described above should be examined to reveal larvae and assess the rate of damage caused.

Control in the orchard

Prevention and non-chemical control

- ✓ Choice of early cultivars
- ✓ Proper pruning of trees and thinning of fruits improves the efficiency of spray application
- ✓ Removal of any alternate non-commercial host plants of the pest
- ✓ Clearing trunks and branches of old bark, removal of any pieces of flaking bark, broken branches and litter from the crotch of the trees
- ✓ In autumn, corrugated cardboard bands can be placed around trunks to trap caterpillars, which are looking for sheltered places to overwinter. Inspect the bands every two weeks, and destroy all caterpillars (in cocoons).
- ✓ Regular removal and destruction of infested shoots and fruits
- ✓ Collecting and removal of any fruits dropped prematurely
- ✓ Use of *Bacillus thuringiensis* serovar. *kurstaki* against the young larvae
- ✓ Mating disruption (MD) (preferably in orchards large and isolated enough,or applied area-wide)with hand-applied dispensers or sprayable microencapsulated (MEC) pheromone formulations

Chemical control

- ✓ The key to the successful application of any insecticides against *G. molesta* is timing, which should be based on the proper use of traps and temperature-based models adapted to the local conditions.
- ✓ For spraying, selective insecticides (e.g. insect growth regulators) should be preferred to broad spectrum insecticides (e.g. organophosphates, pyrethroids) to reduce the risk posed to human health and the environment.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Potato tuber moth

(Phthorimaea operculella)

	What do they look like?	Where can they be found?
Adult	body length is 10 mm, wingspan is 12-17 mm;fore wings are greyish brown with dark spots (a characteristic "X" pattern on females and 2-3 dots on males) and both pairs of wings have fringed edges; slender appearance at rest	on the plant
Egg	0.5 mm, oval, pearly white, later yellowish	underside of leaves, on leaf stalks, stems, potato tubers (often at buds), soil or on bags (in stored potatoes)
Larva	older larvae are 10-15 mm in length, pink or yellowish green, with a pale longitudinal stripe along the median of its back	in the leaf mines, petioles, stems, tubers (in potato) or fruits (e.g. in tomato)
Pupa	5.5-6.5 mm, brown, in a cocoon	in the soil, tubers or stems

Host plants

Potato and other species of Solanaceae (e.g. tomato, aubergine, pepper, tobacco, Datura stramonium)

Biology

The pest is able to cause damage in the field, in storehouses and in greenhouses. Under field conditions, emergence of moths begins at the end of April. They are active after sunset and at dawn, and are attracted to light. Females lay their eggs singly or in batches of 2-3 on the underside of leaves, sometimes on leaf stalks, stems, exposed potato tubers or lumps of soil. Caterpillars hatch in 3-15 days, and they penetrate into the leaves, where they make blotches while mining,or bore into the petioles or stems. If they bore into the tubers (usually at eye buds), they make long, irregular galleries inside. Tunnels gradually get filled with excrement. Silk and excrement on tubers indicating infestation by the pest can be observed at the eye buds. Pathogenic organisms can develop inside the tunnels made by the larvae, which causes the tubers to rot and emit an unpleasant smell. Larval development may last several weeks. Pupation takes place in a cocoon,normally in the soil. Development of all stages and consequently the number of generations are highly influenced by temperature. Optimum temperature and air humidity for development are 22-26°C and 70-80%, respectively. Lethal temperatures for all stages of the pest are below -4°C and above +36°C. In storehouses, eggs are laid directly on the tubers or on bags, and the larvae damage the tubers. Pupation may occur in various sheltered places. The species can reproduce continuously in storehouses as well as in greenhouses under suitable climatic conditions and in the presence of food. Host plants grown in the open field may become infested by sowing infested tubers as well as by moths migrating from the storehouse (or greenhouse in the case of tomato) to the fields.

Figure 5: Establishment Index of *Phthorimaea operculella* in Armenia

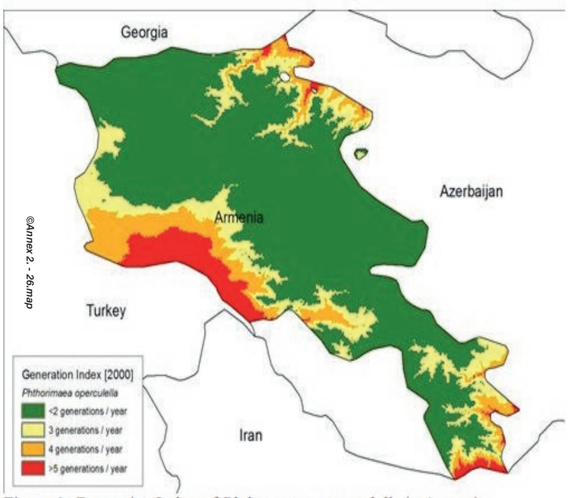
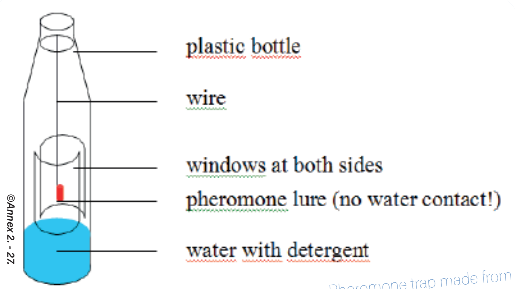


Figure 6: Generation Index of *Phthorimaea operculella* in Armenia

Monitoring

Pheromone traps are suitable for detecting potato tuber moth activity and helping to time insecticide applications. One option is to use pan traps filled with soapy water (the soap helps break the surface tension of the water) and fixed with a protective lid from which the lure is suspended. The traps should be placed on the top of the bed, and they should be checked and serviced at least once a week. Homemade bottle traps may also be applied similarly to pan traps. A further option is to place the lure in a sticky trap. The advantage of the sticky traps is that they do not dry out like pan traps, but they can become dusty, rendering them ineffective. Catches from traps may help determine action thresholds. Light traps may also be used in monitoring. Temperature-based calculations may also be useful for prognosis in IPM if adapted to the local conditions.

Regular checks for leaf mines and tunnels in leaf stalks, stems and tubers are also recommended.



Pheromone trap made from a bottle

Control in the open field and in the storehouse/greenhouse

Prevention and non-chemical control

- ✓ Crop rotation
- ✓ Use of healthy seed tubers
- ✓ Choice of cultivars less susceptible to the pest
- ✓ Use of potato cultivars that set tubers deep
- ✓ Deep planting and good coverage of potato seed tubers with soil (more than 5 cm) during hilling(s)
- ✓ Taking action to prevent cracks from developing more than 5 cm in the soil (e.g. by sprinkle irrigation instead of furrow irrigation)
- ✓ Removal of any alternate non-commercial host plants (weeds belonging to the family Solanaceae)
- ✓ Appropriate and rapid harvest of tubers as soon as the skin sets, without leaving the tubers in the field even for the night
- ✓ Removal of all plant residues after harvest
- ✓ Selecting and destroying damaged tubers before storage
- ✓ Keeping low storage temperature (below 11°C)
- ✓ Installation of exclusion screens added to ventilation openings and entry points of storehouses and greenhouses, and the disciplined use of entry doors
- ✓ Proper sanitation in storehouses as well as in greenhouses
- ✓ Mass trapping by using pheromone traps of appropriate design and in adequate numbers in either storehouses or greenhouses
- ✓ Mating disruption (MD)
- ✓ Use of Bacillus thuringiensis serovar. kurstaki against the young larvae both under field conditions or during storage
- ✓ Use of Phthorimaea operculella granulosis virus (PhopGV) against the larvae

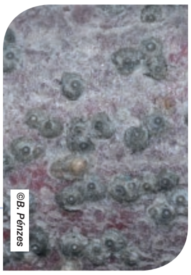
Chemical control

- ✓ In order to save beneficial arthropods, which may be able to control populations of the pest in the field, the use of broad spectrum insecticides (e.g. organophosphates, carbamates, pyrethroids) should be avoided and selective ones should be preferred for application.
- ✓ Treatment of tubers may be possible to protect tubers during storage, but the use of the active ingredient that can be applied is basically determined by the purpose the tubers are stored for (i.e. for human consumption or seeds).
- ✓ Use of the attract-and-kill strategy against *P. operculella.*

ⓘ **Always follow the label instructions for the dosage, application and safety!**

San José scale

(Diaspidiotus perniciosus)



	What do they look like?	Where can they be found?
Adult	**a/female:** scale is 1.5-2 mm, usually dark grey, rounded, with concentric rings; the body of the adult under the scale is yellow, rounded and flat **b/male:** scale is 1 mm in length, elongate-oval; body is orange with one pair of wings and a dark band across the back	on the bark, on shoots, fruits
Crawler	0.2-0.3 mm, yellow, oval, distinctly segmented	on the bark, on shoots, fruits

Larva

Adult male

Larva

Crawler

Host plants

Polyphagous (e.g. apple, pear, peach, plum, currants, blackthorn)

Biology

The number of generations of the species varies depending on the region (e.g. it usually has two generations in Hungary). Adults appear in spring (in Central Europe in April), and fertilized females give birth to nymphs (crawlers), which settle down within a few hours and start to form a covering made of secreted waxy filaments. Some (8-12) days later, the second instar nymph appears, and following a second moult under the scale soon afterwards, the species reaches the adult stage in the case of females. In males, the second nymphal stage is followed by the so-called pre-pupal and pupal stages, which are non-feeding stages similarly to the adult male. The males are winged, and following their emergence from under the scale they start to look for females to mate with. Damage may by caused to the bark, leaves and fruits when nymphs and adult females pierce the plant tissue with their long thread-like mouth parts and suck out plant fluids. The greenish host tissue around the scale often turns red. A high population may cause the wilting of leaves, appearance of cracks on the woody plant parts, twig and branch dieback, and without any control the entire plant may die. The pest overwinters as a young nymph under a black scale on woody parts of the plants, and continues its development the next spring. Specimens of the species may spread both actively (crawlers and winged males) and passively (crawlers on the wind, insects or birds and different developmental stages with infested planting material).

Monitoring

Monitoring of San José scale during the dormant season may be carried out by collecting spurs (the short shoots containing the flower buds) and examining them (preferably with a stereo microscope) for live specimens as well as for tiny emergence holes on scales, which indicate the activity of parasitoids. (A parasitized scale can be recognized by a small hole in the top of the scale covering.) If a large number of scales have been parasitized, the use of insecticides during the growing season should be minimized, and those that are not harmful to the natural enemies are recommended for use so that naturally occurring parasitic populations will be saved. The dormant sampling can also help determine if any treatments are needed to control the pest. If monitoring indicates that pest densities may require treatment and dormant controls were not or cannot be applied for some reason,pheromone traps should be used to detect male (as well as parasitoid) emergence in spring. Information obtained from catches from the traps can help schedule control actions and should be used in conjunction with degree-day calculations (temperature-based models) adapted to the local conditions. Sticky tape can be used to directly monitor the crawlers when they hatch.

Control in the open field

ⓘ **Important note: *Diaspidiotus perniciosus* is currently on the A2 quarantine list of EPPO!**

Prevention and non-chemical control

- ✓ Use of healthy planting material
- ✓ Proper pruning (renders the canopy more accessible to insecticides)
- ✓ Removal of infested plant parts
- ✓ Use of the parasitoid *Encarsia perniciosi* in classical biological control

Chemical control

- ✓ A properly applied dormant oil sprayed with good coverage may be effective enough, and may eliminate spring flight and suppress infestation throughout the growing season.
- ✓ Based on regular monitoring and prediction, application of insecticides in the growing season should be timed to control emerging males and/or crawlers as soon as they appear.
- ✓ In order to save beneficial arthropods that may be able to control populations of the pest, the use of broad spectrum insecticides (e.g. organophosphates, carbamates, pyrethroids) should be avoided and selective ones (e.g. insect growth regulators) should be preferred.
- ✓ In some cases, the infestation is localized and spot treatment may be sufficient for control.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Sunn pest

(Eurygaster integriceps)

	What do they look like?	Where can they be found?
Adult	12 mm, varying in coloration but usually light brown, wide-oval body, with a big scutellum covering the wings and the whole abdomen	on stems, leaves and ears (during the vegetation period), often in the litter of forests (in winter)
Egg	1 mm, green, shiny, spherical or barrel-shaped	on the underside of leaves, on stems, weeds, ground lumps, laid in rows next to each other, each normally containing seven eggs
Nymph	similar to the adult in appearance when full-grown, but with only the rudiments of wings	on leaves, stems and ears

Adult

Egg

Nymph

Host plants

Wheat and other cereals

Biology

The sunn pest has one generation per year. Overwintered adults start flying at an average daily temperature of 12-14°C in spring. They migrate from their overwintering sites (litter in woods mostly) to cereal fields. Fertilized females lay their eggs in a few (generally 2-3) rows, normally containing seven eggs per row,on the underside of leaves, on stems, weeds or sometimes ground lumps. Both the abiotic conditions and the phase of development of the host plant have an effect on fertility. Oviposition lasts several weeks, and eggs may develop from about a week to a month. Nymphs (the pest has five nymphal stages) cause damage by feeding (piercing and sucking) on different parts of the plant. Feeding may be especially harmful if it occurs on the young grains (injection of saliva reduces baking quality).Severe attacks on young plants, in which the pest feeds on the leaves and stems, can cause the plants to yellow and wither through the destruction of the growing point of the central leaf. Later in the season, ripening grain is damaged. If the ear is attacked at the budding stage, it is usually aborted causing "white ears". Grain damage can range from complete destruction if the kernel is attacked in the "milky" stage, to slightly shrivelled if attacked in late maturity. The presence of a central black pinpoint on the grain surrounded by a pale or discoloured halo may also indicate an attack by this pest. If the insect cannot finish its development before harvest, then the larvae and young adults continue feeding under windrows or on fallen ears and grain. Fully developed adults migrate to overwintering sites.

Monitoring

Sunn pest populations vary from year to year in response to climatic conditions. Pest populations should be monitored regularly to determine if it is necessary to apply chemical controls. The use of entomological sweep nets is effective for collecting the insects. Plants should be assessed for the presence of the different developmental stages of the pest and the occurrence of symptoms. Sites suitable for overwintering (e.g. litter in forests) should also be inspected, which may help predict the risk of infestation during the next season.

Control in the open field

Prevention and non-chemical control

- ✓ Avoidance of growing wheat on marginal lands in the foothills
- ✓ Fertilizing winter crops with mineral fertilizers in early spring with subsequent harrowing
- ✓ Use of early wheat cultivars
- ✓ Early sowing
- ✓ Early harvest with subsequent shelling and autumn ploughing

Chemical control

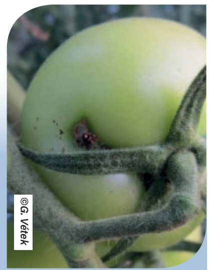
✓ The use of chemical insecticides is not always necessary and the number of applications should be reduced based on the results of insect scouting.

✓ The occurrence of natural enemies and their potential role in pest population control should be observed and considered, and decisions about treatments should be made accordingly.

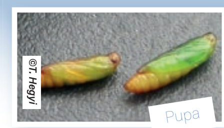
ⓘ **Always follow the label instructions for the dosage, application and safety!**

Tomato leafminer

(Tuta absoluta)



	What do they look like?	Where can they be found?
Adult	body length is about 7 mm, wingspan is 8-12 mm, with filiform antennae, and brown or silver in colour with black spots on fore wings	on the plant
Egg	0.35 mm in length, creamy white to yellow, oval-cylindrical	on leaves (mainly), buds, on the calyx of green fruits and other aerial parts of the plant
Larva	1 mm (first instar) - 8 mm (last instar), cream in colour with a dark head, becoming greenish to light pink (depending on food consumed) in the second to fourth instars	in the leaf mines, stems, flowers or fruits
Pupa	4-5 mm, greenish in colour at first, turning chestnut brown and dark brown near adult emergence	in the soil, on the surface of the plant or in mines



Host plants

Tomato and other species of Solanaceae (e.g. potato, aubergine)

Biology

The species has a high reproductive potential. Larvae do not enter diapause as long as food is available, and there may be as many as 10-12 generations per year. The life cycle can be completed in about a month depending on environmental conditions (It means 24-76 days depending on the environmental conditions). Adults are nocturnal and usually hide among leaves during the day. Females lay their eggs, usually singly, on aerial parts of their host plants (tomato is the main host) and a single female can lay a total of about 260 eggs during its lifetime. After hatching, young larvae penetrate into tomato fruits, leaves or stems on which they feed and develop, thus creating conspicuous mines and galleries. Although the larvae spend most of their life inside mines, second instars can leave the mines, thus exposing them to predation, well-timed application of pesticides and possibly parasitism. Fruits can be attacked as soon as they are formed, and the galleries bored inside them can be invaded by secondary pathogens leading to fruit rot. The larvae can tunnel into the fruit and leave only a surface hole visible, and/or may mine just below the surface, creating a yellow-coloured fruit mine. On leaves, larvae create mines, which are irregular and may later become necrotic. Galleries in stems alter the general development of the plants. Tomato plants can be attacked at any developmental stage, from seedlings to mature plants. Black frass noticed on/in different parts of the plant may also indicate the presence of the pest. There are four larval instars. Pupation may take place in the soil (at a depth of a few centimetres), on the surface of the plant or within mines(in certain cases in a cocoon), depending on the environmental conditions. The pest may develop continuously under adequate conditions (e.g. in greenhouses).In colder areas, if occurring in protected cultivation where the conditions are suitable and remain relatively unchanged throughout the year, indoor infestations may become sources of transient outdoor populations during summer. Therefore, greenhouses may represent reservoirs for regular re-infestation of plants grown outdoors. Up to 100 percent losses have been reported in tomato crops, and even where programmes of control are implemented, losses can still exceed 5 percent.

Monitoring

Pheromone traps of different designs are available to detect tomato leaf miner activity. One option is to use pan traps filled with soapy water (the soap helps break the surface tension of the water) with the lure secured above the water with a wire attached at both ends of the container. The traps should be placed at the base of plants mostly in greenhouse situations. Pan traps with water can capture large numbers of adult males without becoming saturated with insects. Another option is to place the lure in a sticky delta trap. With tomatoes, delta traps should be hung on stakes near plant foliage, about 1 metre off the ground. In general, trap location should not be higher than 30-60 cm above the top of the tomato or other host plants because *T. absoulta* males fly close to the host plants. In heavy infestations, sticky inserts may become saturated with trapped males or moth scales causing them to lose their effectiveness at capturing and retaining additional moths. In these situations, the traps should be serviced more frequently. The level of risk may be estimated based on the number of males trapped within a given period.

Light traps may be used to capture both males and females. However, they are not recommended for use in vented greenhouses that do not have proper screening in the openings. A high effectiveness of trapping may be reached when a combination of pheromone lures and a specific light frequency is used to attract *T. absoluta* adults.

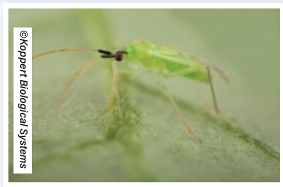
Besides setting different types of traps, regular visual inspection of plants is also very important for adequate decision-making on control actions. This type of inspection helps to reveal the occurrence of different developmental stages of the pest as well as the symptoms of damage as early as possible.

Furthermore, special attention should be paid to variable packing and planting materials originating in locations where the pest is present.

Control in the open field and in the storehouse/greenhouse

ⓘ **Important note: Tuta absoluta is currently on the A2 quarantine list of EPPO!**

Prevention and non-chemical control



- ✓ Crop rotation
- ✓ Use of healthy planting material
- ✓ Removal of any alternate non-commercial host plants (weeds belonging to the family Solanaceae)
- ✓ Proper sanitation in greenhouses
- ✓ Installation of exclusion screens added to ventilation openings and entry points of greenhouses, and the disciplined use of entry doors
- ✓ Removal of infested plant parts (but with paying attention to any beneficial arthropods possibly present on them; e.g. parasitized greenhouse whitefly pupae on the underside of leaves)
- ✓ Removal of all plant residues after harvest
- ✓ Cleaning of packing materials
- ✓ Light traps can be used not only for detection but also for population control as they can attract the adult moths
- ✓ Mass trapping (particularly in protected cultivation)
- ✓ Mating disruption (MD)
- ✓ Use of biological control agents such as predatory bugs (e.g. *Macrolophus pygmaeus*,*Nesidiocoris tenuis*), parasitic wasps (*Trichogramma achaeae*) and/or entomopathogenic bacteria (*Bacillus thuringiensis* serovar. *kurstaki*) or other organisms

Chemical control

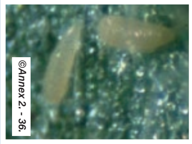
- ✓ As there may be many generations a year and as larvae are mostly internal feeders, it is difficult to achieve effective chemical control.
- ✓ There are many insecticides available on the market for tomato leaf miner control, but strains of the species resistant to one or more of them have become established, meaning that anti-resistance strategies should be applied to maintain the effectiveness of insecticides.
- ✓ It is important to choose insecticides and methods of application that are not harmful to biological control agents.
- ✓ Use of the attract-and-kill strategy against *T. absoluta.*

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Tomato russet mite

(Aculops lycopersici)

What do they look like?	Where can they be found?
Adult/larva/nymph: very small (a 14×magnifying glassis required to observe them), wedge-shaped, generally translucent and yellowish, tan or pink	on all aerial plant parts



Host plants

Tomato, aubergine, potato and other species of Solanaceae

Biology

Under field conditions, airborne adults of A. lycopersici may begin to infest tomatoes from perennial alternate hosts shortly after transplanting. Females begin to oviposit soon after having become established on the host. Eggs are laid on the undersides of leaves, on leaf petioles and on stems on the lower portion of plants. Juvenile stages tend to congregate on the edge of leaves. The species has piercing and sucking mouth parts. Feeding on the underside of lower leaves and on petioles and stems by the pest causes a greasy appearance, which becomes bronzed. Leaves may yellow, curl upwards, dry out and drop. Damage starts at the bottom of plants and moves upward and may be confused with nutritional deficiencies, plant diseases or water stress. The mite feeding on inflorescences and young tomato fruits causes dropping of flowers and russeting of fruits. As the plant begins to die, the mites may aggregate at the highest parts of the plants and be picked up and spread by wind. Under optimal conditions, it may take less than a week for the species to complete its life cycle. Consequently, populations may increase rapidly to very high densities with catastrophic impact on the vitality of the host, especially under dry weather conditions. When the primary host dies, some of the mites are dispersed by the wind to nearby alternative hosts, where they can form overwintering aggregations. In greenhouses, young plants are commonly infested from surviving populations of mites on the remnants of previous crops of infected plants, or mites newly introduced on young plants.

Monitoring

Due to the minute size of the mites, monitoring is usually done by looking for symptoms of potential damage and then confirming mite presence with a magnifying glass or with a microscope.

Control in the open field and in the greenhouse

Prevention and non-chemical control

- ✓ Use of healthy planting material
- ✓ Avoidance of planting new crops near infested crops
- ✓ Removal of any alternate non-commercial host plants of the pest
- ✓ The movement of people or equipment from infested to uninfested areas should be avoided
- ✓ Infested plants and also plant debris should be removed
- ✓ Use of the predatory mite Amblyseius andersoni against the pest

Chemical control

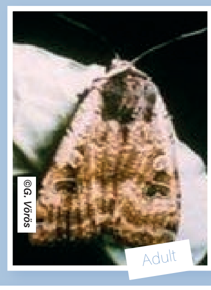
- ✓ Chemical control should be applied only if the presence and identity of the species have been confirmed.
- ✓ Good coverage of all parts of the plant when spraying is necessary for adequate control.
- ✓ The risk of damaging the pest's natural predators may be reduced by well-timed sprayings and/or avoiding the use of broad spectrum chemicals.

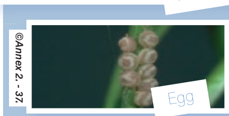
ⓘ **Always follow the label instructions for the dosage, application and safety!**

Turnip moth

(Agrotis segetum)

	What do they look like?	Where can they be found?
Adult	body length is 18-22 mm, wing span is 34-45 mm;variable in colour; fore wings are yellowish grey, brown or almost black in females, while lighter in males; outlines of the round, reniform and cuneiform spots are usually well visible; hind wings are light grey in females and white in males;females with setaceous, males with comb-like antennae	close to the soil level
Egg	0.5-0.6 mm in diameter, white, later with reddish pattern, changing to grey before hatching, spherical in shape, with acostate surface	on plant residues, on the ground, on the underside of leaves adjoining soil surface or aggregating in a rosette
Larva	40-52 mm (full-grown caterpillar); greenish grey, later glossy dark grey with dark stripes extending along dorsal and lateral sides, and with a lighter ventral part	on leaves, on/in root collars and young stems
Pupa	16-20 mm in length, red-brown	in the soil (in a cavity)





Host plants

Polyphagous (e.g. cotton, maize, tomato, tobacco, sunflower, cereals, potato, sugar beet, spruce seedlings)

Biology

The moths are active at twilight and night. Females need nectar for the beginning of oviposition. Several hundred eggs can be laid singly or in small batches of 2-3 by a single female on plant residues, on the ground or on the underside of leaves adjoining the soil surface or aggregating in a rosette. Larvae hatch in three days at around 30°C, while egg development may take more than three weeks during colder periods (10-12°C). The larvae feed externally on plantlets (cotyledon leaves, first true leaves) and can also cause damage to young stems and root collars. The young larvae of *A. segetum* feeding on leaves results in the presence of very tiny, round "windowpanes". Feeding on stems results in small holes in the stems or cut stems. Symptoms of chewing on tubers and roots are a variety of holes, ranging from those that are small and superficial to very large, deep ones. The time of larval development is largely affected by the temperature, precipitation as well as the food source, and may vary between approx. three weeks and three months. When fully fed, the larva pupates in the soil at a depth of 1-6 cm. The pupal stage may last several weeks. Depending on the climatic conditions, the species may have many generations a year (e.g. two generations in Hungary and Moldova, while three in Armenia, Azerbaijan and Georgia). It overwinters as a larva in the soil at a depth of 10-25 cm.

Monitoring

Adults can be captured by light traps, although pheromone traps should be preferred for monitoring, as they are much more species-specific. Pheromone traps are available from many manufacturers. Here we give an example for the use by the Csalomon® (Plant Protection Institute, Centre for Agricultural Research, HAS, Hungary) turnip moth traps: both sticky delta and funnel traps may be suitable for catching males of *A. segetum*. The former one may be recommended primarily for detection and monitoring flight dynamics. Its sticky insert may become covered with moths within a very short period and so should be changed frequently. For catching large numbers of moths and/or for some quantitative monitoring the latter trap design should be used. Traps should be placed at the height of the top of the crop. In Hungary, trapping should be started generally in mid-May. The second flight usually starts there in mid-July.

Plants and/or the soil may be inspected visually for larvae to monitor and assess population sizes of ***A. segetum***. The economic threshold (larvae per square meter soil) have been established for different crops, which may be used once adapted to the local conditions.

Control in the open field

Prevention and non-chemical control

- ✓ Removal of crop residues from the field
- ✓ Deep ploughing in autumn
- ✓ Weeding (also in neighbouring fields)
- ✓ Systematic and timed irrigation (young larvae do not prefer humid conditions)
- ✓ Use of Steinernema carpocapsae against the larva in the soil
- ✓ Release of Trichogramma spp. (egg parasitoids of the pest)
- ✓ Use of Bacillus thuringiensis serovar. kurstaki against the young larvae

Chemical control

- ✓ Application of adequate insecticides to the soil
- ✓ Seed treatment (seeds dressed with appropriate insecticides)
- ✓ Application of poisonous baits
- ✓ Spraying during late afternoon or around twilight because larvae are most active at night

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Vegetable leaf miner

(Liriomyza sativae)


©Annex 2. - 39.

	What do they look like?	Where can they be found?
Adult	wing length is 1.3-1.7 mm; principally yellow and black in colour, with bright yellow scutellum and yellow femora; accurate identification requires dissection of male terminalia	on the plant
Egg	approx. 0.23 mm in length and 0.13 mm in width, white, elliptical	in the leaf
Larva	up to 3 mm (when full-grown); initially nearly colourless, becoming greenish and then yellowish as it matures, with black mouth parts; legless (maggot)	in the leaf mine
Pupa	1.5 mm in length, slightly flattened ventrally	in the soil or on the leaf surface


©Z. Soltész
Adult


©Annex 2. - 40.
Larva

Host plants

Polyphagous (e.g. melon, cucumber, squash, bean, aubergine, pepper, tomato)

Biology


©Annex 2. - 41.

The species has high reproductive potential. The life cycle can be completed in about two weeks at 30°C, which means it can have many generations under greenhouse conditions. Females insert their eggs into the plant tissue just beneath the epidermis of the leaf. Flies feed on the plant secretions caused during oviposition, and also on natural exudates. Females often make punctures for feeding, particularly along the margins or tips of leaves, without depositing eggs. Larvae hatch within a few days and start creating irregular, serpentine mines, which increase in width from about 0.25 mm to about 1.5 mm as the larva develops. The larva and its faecal deposits can be visible within the mine. Larvae may cause the leaves to dry out and drop, which may lead to yield loss. When fully fed, the larva usually leaves the mine by cutting a slit in the leaf (generally on its upper side), and pupates in the soil.

Monitoring

The pest can be monitored in a variety of ways including by counting mines and/or live larvae in the mines, by using yellow sticky traps for adults, or trays placed beneath infested plants to catch larvae as they fall to the ground to pupate. Yellow sticky traps, however, have the advantage of being able to detect quickly and early the appearance of adults in the given crop.

Control in the greenhouse

ⓘ **Important note: *Liriomyza sativae* is currently on the A2 quarantine list of EPPO!**

©Annex 2. - 42.

Prevention and non-chemical control

- ✓ Proper sanitation
- ✓ Use of healthy planting material
- ✓ Removal of all plant residues
- ✓ Use of the parasitic wasps Diglyphusisaea or Dacnusa sibirica against the larva of the pest

Chemical control

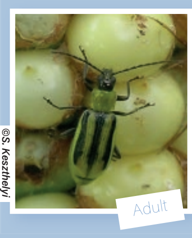
- ✓ As there may be many generations a year and as larvae are internal feeders, it may be difficult to achieve effective chemical control.
- ✓ Anti-resistance strategies should be applied to maintain the effectiveness of insecticides.
- ✓ It is important to choose insecticides and methods of application that are not harmful to biological control agents.

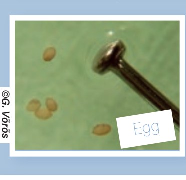
ⓘ **Always follow the label instructions for the dosage, application and safety!**

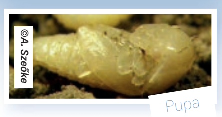
Western corn rootworm

(Diabrotica virgifera virgifera)

	What do they look like?	Where can they be found?
Adult	body length is approx. 4.5-7 mm, with a dark head, a yellow pronotum and a yellow abdomen; the elytra (fore wings) are yellowish, often with three distinct darker stripes; males and females differ to some extent in their markings: on males, nearly the entire posterior half of the elytra is black, whereas on females, the dark stripes are more pronounced; generally, males are smaller than females,males have longer antennae and are darker	on the aerial parts of the plant
Egg	0.5 mm in length, oval, flattened	in the soil
Larva	10 mm (full-grown), slender, white to pale yellow, with a yellowish brown head capsule and a brownish plate on the last abdominal segment	on/in the root in the soil
Pupa	3-4 mm;white, turning brownish before adult emergence	in earthen cells in the soil near plant roots







Host plants

Maize and some other plant species

Biology

The species has one generation per year. The overwintering eggs are generally concentrated in the top5-20 cm of soil (or deeper in dry soils). The larvae usually hatch in May-June, depending on several environmental factors. There are three larval instars, which feed on the roots of maize, a superior host. Newly hatched larvae feed primarily on root hairs. As the larvae grow and their food requirements increase, they burrow into roots. Larval damage is usually most severe after the secondary root system is well established and brace roots are developing. Root tips appear brown and often contain tunnels. In many cases, they are chewed back to the base of the plant. Larvae may be found tunnelling in larger roots and occasionally in the plant crown. Larvae may burrow through plants near the base, causing stunting or death of the growing point and frequently causing tillering. Root feeding commences shortly after plant emergence and early symptoms are expressed as drought or nutrient deficiencies. Plant lodging occurs later in plant development. The rate of development of immature stages depends on temperature, which is optimal at between 21 and 30°C. The pest cannot continue its development in the soil at temperatures either below about 9°C or above 33°C, the latter causing the death of second instar larvae. In Central and Eastern Europe (e.g. in Hungary and Serbia), adult emergence may begin in late June to early July, with a peak emergence often occurring during July. Adult beetles can be observed in the field for many weeks. They cause damage by feeding principally on pollen, silk and young kernels. Silk clipping near the husk during anthesis can cause a reduced seed set in maize, which is only visible at the time of harvest. Females prefer to lay their eggs in moist soil.

The pest can spread both actively and passively over large distances. This can take place in several ways such as by natural dispersal of flying beetles, with the help of weather features (e.g. adults carried by cold fronts), or possibly by consignments of maize.

Monitoring

To detect and monitor adults of the pest, many trap types supplied with pheromone and/or floral baits are available on the market. For example, the Csalomon® trap family (Plant Protection Institute, Centre for Agricultural Research, HAS, Hungary) offers a wide variety of *D. virgifera* traps, indicating their special characters to be considered by the maize grower prior to buying. For further details visit http://www.csalomontraps.com/

"Goose-necking" of the maize stalk prior to flowering indicates root damage, which is often caused by rootworm larval feeding. Larvae can be found in the soil. Economic thresholds may be expressed by (1) the number of larvae per plant in root-soil samples, (2) rating the root damage, or (3) the average and cumulative numbers of adults per plant. For example, (1) about 8-10 third instar larvae per plant root are often estimated to cause economic damage in commercial maize at 60 000 plants per hectare, depending on local requirements, or (3) more than 0.75-1 adult per whole plant on average have to be recorded several times from mid-July until the beginning of August to meet the economic threshold necessary to control *D. virgifera* in the following year, etc. If any of these methods were chosen to help decision-making, they should be adapted to the local conditions.

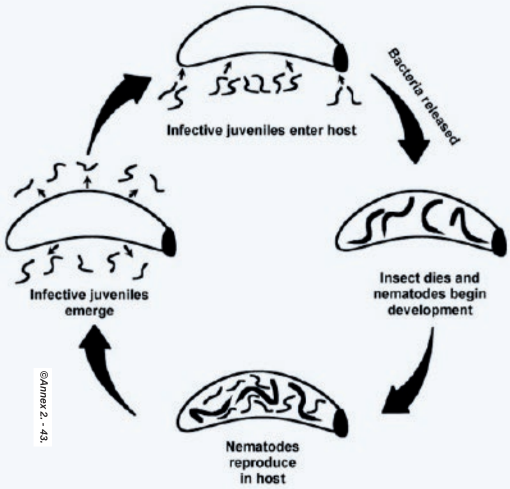
Unfortunately, counting adults or larvae does not provide reliable estimations of absolute population densities, as the distribution of these developmental stages is clumped.

Control in the open field

ⓘ **Important note: *Diabrotica virgifera* is currently on the A2 quarantine list of EPPO!**

Prevention and non-chemical control

- ✓ Crop rotation (notes: soybean or crops belonging to Poaceae are not recommended in long-term rotation with maize fields infested by the pest; furthermore, crop rotation may not be completely effective in 1-year rotations due to the presence of volunteer maize)
- ✓ Choice of hybrids less sensitive to the damage (e.g. characterized by an increased ability to regenerate roots)
- ✓ Delayed sowing(it presumably reduces the availability of maize roots and larval colonization sites, resulting in mortality of the earliest hatching larvae. This may also result in decreased root damage; moreover, it delays initial adult emergence and reduces total emergence)
- ✓ Application of any growing practices that support the development of strong roots
- ✓ Use of the entomopathogenic nematode *Heterorhabditis bacteriophora* against the larvae and pupae of the pest



Chemical control

- ✓ Although there are many chemicals available for *D. virgifera* control, these are broad spectrum insecticides. Therefore, environmental risks posed by their use (e.g. toxicity to bees) must be assessed carefully prior to application. Plant protection consultants should be asked for advice about the proper use of chemicals in western corn rootworm control.
- ✓ Seed or soil treatments with adequate insecticides are possible pest control methods.
- ✓ Adults can be controlled by spraying, but this tactic is usually confined to seed production, as it is generally costly and requires precise timing. Moreover, there are additional limiting factors of application (e.g. toxicity to bees, maize height).

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Western flower thrips

(Frankliniella occidentalis)

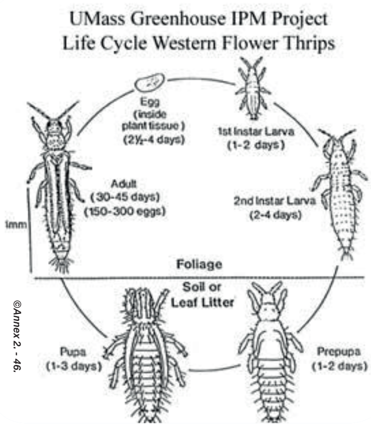
	What do they look like?	Where can they be found?
Adult	1-1.5 mm in length, with narrow body and fringed wings; colour can vary from straw-yellow to brown; the adult must be inspected under a compound microscope to accurately identify the species	in buds, flowers, on leaves or other plant parts
Egg	0.2 mm in length, pearly white, more or less kidney-shaped, depending on the degree of development	in the leaf, stem or petal tissue or in young fruits
Larva	yellowish	in buds, flowers, on leaves or other plant parts
Pupa	usually white	in the soil, growing media, plant debris or on the plant

Host plants

Polyphagous (e.g. carnation, chrysanthemum, roses, *Gerbera*, *Impatiens*, *Saint paulia*, pepper, tomato, cucumber, strawberry)

Biology

Under temperate climatic conditions, the species can survive in greenhouses, where many overlapping generations may develop. Females insert their eggs into leaves, stems, or petal tissue or in young fruits. Hatching occurs within a few days, and the larvae usually remain protected in flower buds or terminal foliage. The species passes through two larval stages on some days, and both instars feed on the plant. Feeding causes plant cells to collapse, which may eventually result in distorted leaves or flowers, if the damage was done while the thrips were feeding within buds and terminals, or scarred, silvery patches and flecking if the damage is to open foliage, petals or fruits. The patches on expanded leaves and petals will also have tiny greenish black faecal specks that are left by the pest. The species can transmit viruses (e.g. INSV, TSWV) which may cause severe damage to greenhouse plants. Towards the end of the second larval stage, the insect stops feeding and usually drops into the soil or plant debris to pupate. Then it passes through a short propupal and a pupal stage, during which no feeding occurs and general activity is minimal. The adults are also primarily found feeding in protected areas of the plant such as flowers and terminals. The rapid development (egg to adult within about two weeks at 24-30°C) and high reproductive potential of *F. occidentalis*, in these protected areas, can allow an undetected infestation to quickly become a major problem. Adults can fly readily (although they are not strong fliers) and can be carried by wind currents, or on clothing, to greenhouses near a site of infestation.



Monitoring

To sample this pest or other flower-inhabiting thrips, a set number of flowers should be selected. Then these flowers should be struck against a light-coloured board (beating card) and the thrips should be counted while still in the field. Another option is that the flowers should be placed in a vial of ethanol and the thrips should be counted later in the laboratory.

Blue sticky traps may also be used to sample thrips in the greenhouse. Blue traps were found to catch more *F. occidentalis* compared to yellow sticky traps, but yellow

sticky traps have the advantage that they may be used to monitor other pest as well (e.g. whiteflies, aphids, leaf miners). Sticky traps of combined colours of blue and yellow are also available from some manufacturers and may be recommended for monitoring several pests including the western flower thrips. The use of sticky traps is suitable for the early detection of the pest as well as for locating centres of infestation. Traps should be hanged above the plant and it is also advisable to place sticky cards near entryways and vents to determine how these insects enter and move within the greenhouse. It is possible to estimate the population of thrips by using sticky traps, but trap catches have rarely been shown to reflect population size accurately or to be accurate predicators of damage. In addition, thrips caught on sticky cards may be difficult to identify to species. For this, a specialist should be requested.

Pheromone lures that attract both males and females are also available on the market to increase the sensitivity of monitoring, particularly at low levels of infestation or in easily damaged crops.

A threshold (e.g. the number of thrips per trap per week) can help the grower to decide whether to apply pesticides. However, as this value is affected by several factors (e.g. design, type, location and number of traps, plant species etc.), it must be set in advance considering the local conditions.

Control in the greenhouse

ⓘ **Important note: *Frankliniella occidentalis* is currently on the A2 quarantine list of EPPO!**

Prevention and non-chemical control

- ✓ Removal of all plants (cultivated ones as well as weeds) and plant debris from the greenhouse at the end of the previous crop or season, and keeping the greenhouse empty for a time without any food source for the pest (this could be best carried out in winter)
- ✓ Use of adequate insect exclusion screens
- ✓ Use of UV-reflective mulch (which interferes with the host-finding behaviour of thrips)
- ✓ Avoidance of introducing infested plants (symptoms of damage and thrips specimens on the planting material should be looked for carefully before it is introduced in the greenhouse)
- ✓ Avoidance of wearing clothing attractive to the pest (i.e. blue or yellow in colour) and of moving from an infested greenhouse to other greenhouses
- ✓ Removal of infested plants and/or plant parts from and around the greenhouse
- ✓ Use of biological control agents such as parasitic nematodes (Steinernema feltiae), predatory bugs (Orius insidiosus, O. laevigatus, O. majusculus, O. strigicollis), predatory beetles (Athetacoriaria), predatory mites (Amblydromalus limonicus, Amblyseius degenerans, A. swirskii, Gaeolaelaps aculeifer,Macrocheles robustulus, Neoseiulus cucumeris, Stratiolaelaps scimitus) and/or entomopathogenic fungi (Beauveria bassiana)

Chemical control

- ✓ Propupae and pupae in the growing medium and eggs in the plant parts are not affected by most insecticides. Therefore, repeated treatments at intervals of a few days may become necessary during the cropping period because a single spray of chemicals will only kill the susceptible stages (larvae, adults) present at the time of treatment or during the time the chemical remains active. Furthermore, as these latter stages are often found hidden in protected parts of the plant, the use of equipment that produces small spray particles (< 100 microns) and thorough coverage are necessary to reach adequate penetration.
- ✓ There are many insecticides available on the market for western flower thrips control, but populations of the species resistant to one or other of them have become established. Therefore, anti-resistance strategies should be applied to maintain the effectiveness of insecticides.
- ✓ It is important to choose insecticides and methods of application that are not harmful to biological control agents.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Woolly apple aphid

(*Eriosoma lanigerum*)

	What do they look like?	Where can they be found?
Adult	**a/wingless female:** 1.2-2.6 mm in length, oval, reddish brown, covered with thick, white, flocculent wax; with red hemolymph **b/winged female:** 1.8-2.3 mm in length, with a black head and thorax and reddish brown abdomen, and with a covering of woolly, white wax posteriorly; with red hemolymph	on the woody plant parts (roots, trunk, branches, twigs) and shoots

Adult

Red hemolymph

Host plants

Apples and other species of Rosaceae (e.g. pear, quince, Cotoneaster, Crataegus, Pyracantha, Sorbus)

Biology

The species is characteristically viviparous and reproduces via parthenogenesis in Europe. This means that the populations contain asexual females that give birth to living larvae without prior mating. Apple is the main host of *E. lanigerum*, on which the colonies may be found on all of the woody parts (roots, trunk, branches and twigs) and the shoots (up to the leaf stalks) of the plant. However, the leaf surface, flowers and fruits remain free of the pest (although honeydew produced by the aphid may cover these plant parts as well and thus damage to them may occur in this way). Colonies are formed often on sheltered parts (e.g. wounds, axils) of the trunk, branches or twigs, and they can be recognized easily on trees due to the white waxy secretion produced by the insect. The pest has piercing and sucking mouth parts. Feeding results in deformations, blisters, splitting and cancer-like swellings of the bark. Root infestations also cause galling. This damage leads to disruption of nutrient balance of the tree. The species can have many generations a year and it can overwinter on the roots or within bark crevices. Colonies start to increase in spring, and the size of the populations fluctuates during the year,depending on several factors (e.g. temperature). Specimens can move between the roots and aerial parts of the plant throughout the vegetation period.

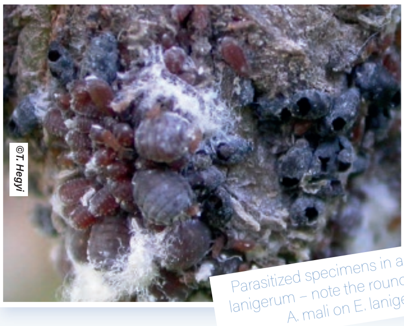
Monitoring

The colonies covered with white waxy secretions can be detected by regular checking of the aerial parts of apple trees. Special attention should be paid to wounds (e.g. healing pruning scars) and other protected sites (e.g. axils, including the axil of leaves) of the trunk, branches, twigs and shoots during monitoring. Root suckers should also be visually inspected for the presence of newly forming colonies. In spring, specimens moving upwards from the roots in the direction of the canopy should be looked for because these individuals, which are responsible for establishing new infestations, lack the waxy secretion and are thus more sensitive to chemical treatments. The occurrence and activity of the parasitoid wasp *Aphelinus mali* should be monitored by searching for parasitized *E. lanigerum* specimens, which can be recognized by the round exit hole of the wasp present on the body of the pest.

Control in the open field

Prevention and non-chemical control

- ✓ Use of healthy planting material
- ✓ Use of rootstocks less susceptible to the pest (e.g. MM. 106, MM. 111)
- ✓ Removal of any alternate non-commercial host plants of the pest
- ✓ Provision of balanced nutrient and water supply
- ✓ Adequate pruning and removal of root suckers
- ✓ Use of (pruning) wound paints
- ✓ Introduction of the parasitoid *Aphelinus mali* in the frame of classical biological control programmes



Parasitized specimens in a colony of E. lanigerum – note the round exit holes of A. mali on E. lanigerum

A. mali adults attackingE. lanigerum

Parasitized E. lanigerummummies – note the yellow body of the immature A. mali in the opened mummy of the host

Chemical control

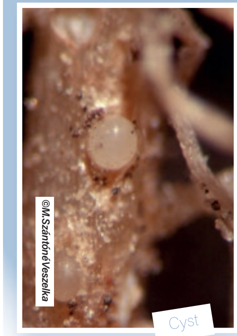
- ✓ A properly applied dormant oil spraying with good coverage may be effective enough against the pest.
- ✓ A spreader sticker added to the tank mix can improve the efficiency of control during the vegetation period.
- ✓ In order to save beneficial arthropods that may be able to control populations of the pest, the use of broad spectrum insecticides (e.g. organophosphates, carbamates, pyrethroids) should be avoided and treatments with chemicals should be timed and minimized based on the seasonal occurrence of the pest and the activity of natural enemies, especially that of *A. mali.*
- ✓ In some cases, the infestation is localized and a spot treatment may be sufficient for control.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Yellow potato cyst nematode

(*Globodera rostochiensis*)

	What do they look like?	Where can they be found?
Adult	**a/female/cyst:** spherical, 0.4-0.9 mm in diameter, pure white initially, turning golden yellow and finally brown during maturation; cysts contain the eggs **b/male:** thread-like (vermiform), 1 mm in length Identification of the species requires special techniques.	on the roots (females), in the soil (both sexes)
Larva	thread-like (vermiform), 0.4-0.5 mm in length	in/on the roots, in the soil



Cyst

Host plants

Potato, tomato, aubergine and other species of Solanaceae

Biology

The species overwinters as a cyst in the soil. The spherical cyst, which is formed from the hardened dead cuticle of the female, can survive for many years or even decades and contains several hundred eggs. Hatching of (already second instar) larvae from the eggs is affected by several factors, including soil temperature (the optimum is around 15°C), moisture and the presence of host plants. The young larvae penetrate the root of the host just behind the root tip and soon set up a feeding site, which will become their nutrient source. In the case of heavy infestations, the damaged plants grow poorly and may show additional symptoms such as chlorosis and wilting because of nutrient deficiencies and water stress. Affected potato plants produce less and smaller tubers compared to healthy ones. The life cycle of the pest finishes in5-7 weeks at 15-20°C. During this time, the newly formed thread-like males leave the root and mate with as many females as possible before dying, while females become spherical and their posterior end protrudes through the root cortex, ready for mating. Once fertilized, the body of the female will become a cyst forming a protective layer around the eggs, and remains in the soil.

Monitoring

As *G. rostochiensis*, like other cyst nematodes, does not cause specific symptoms of infestation, to be confident that the symptoms observed are caused by potato cyst nematodes and to estimate population densities, soil samples must be taken or the females or cysts on the roots of the host must be inspected directly. Detection based on host plant symptoms and identification by morphological and molecular methods are detailed in EPPO (2009). The economic threshold can be determined based on the mean number of eggs per unit (g) of soil (among other methods). The exact level must be set according to the local conditions.

Control in the open field

ⓘ **Important note: *Globodera rostochiensis* is currently on the A2 quarantine list of EPPO!**

Prevention and non-chemical control

- ✓ Use of planting material originating in areas free from any developmental stages of the pest.
- ✓ Appropriate crop rotation (potato should not be sown at the same site within six years)
- ✓ Use of clean machinery
- ✓ Removal of any alternate non-commercial host plants (weeds belonging to the family Solanaceae)
- ✓ Trap cropping (i.e. potatoes grown in order to cause the larvae of the pest to hatch, and the larvae are let penetrate the root and develop into young adults, but, based on the continuous monitoring of soil temperature, the crop is destroyed prior to the calculated time of mating of the species and formation of new eggs by females)
- ✓ Provision of balanced nutrient supply
- ✓ Removal of all plant residues after harvest
- ✓ Growing susceptible and resistant varieties of potato alternately, thus reducing the possibility of selecting a highly virulent or new pathotypes
- ✓ Soil solarization (not effective enough under cooler climate conditions and beneath 10 cm in the soil)

Chemical control

- ✓ The use of certain fumigant or non-fumigant nematicides may provide satisfactory control but is not preferred due to environmental and other concerns.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Integrated pest management of major pests and diseases in eastern Europe and the Caucasus

DISEASES

Anthracnose of citrus

(Colletotrichum gloeosporioides)

	Symptoms
Leaf	more or less circular, flat spots, light brown in colour with a prominent purple margin; at a later phase of infection, the fruiting bodies of the fungus (tiny dispersed black flecks) will appear
Fruit	brown to black spots of 1.5 mm or larger in diameter; the decay is usually firm and dry but if deep enough, it can soften the fruit; pinkish spore masses appear under humid conditions, but they appear brown to black in dry conditions;on fruits degreened with ethylene, lesions are flat and silver in colour with a leathery texture, and much of the rind is affected; the lesions will eventually become brown to grey-black leading to soft rot

Host plants

A wide range of plant species,including citruses

Biology

The fungus causes the disease commonly known as anthracnose on many plant species in tropical, subtropical, and temperate regions. It can occur on leaves, stems and fruits of its host plants. However, the organism has seldom been reported to be a primary pathogen of citrus species. It grows on injured plant tissues,dead wood as well as plant debris and produces spores that are spread by water (e.g. overhead irrigation or rain splash) to the surface of young leaves and immature fruits during the growing season. Being a week pathogen, the fungus can enter the host through injured (e.g. because of sunscald, chemical burn or damage by pests), weakened and old (e.g. because of extended storage) tissue. The disease is especially troublesome on fruits that are harvested early and degreened for over 24 hours, because ethylene stimulates the growth of the fungus.Infected tissue remains asymptomatic and the disease only becomes apparent when plants are getting old or have suffered from stress. Disease symptoms are rarely evident on the rind of fruit during the pre-harvest period, but during post-harvest, they may appear as dark brown irregular lesions that become sunken on the rind tissues. Under moist conditions these lesions can also ooze pinkish spore masses from the acervuli. Damaged fruits become unmarketable.

Monitoring

Citrus plants in orchards as well as in storehouses should be inspected regularly to find and identify the symptoms of anthracnose on leaves and fruits as early as possible. Prolonged wet conditions (e.g. significant rainfall during certain periods of the season or regular overhead irrigation) and injured fruit surface as well as early harvest, degreening with ethylene and extended storage of fruits increase the probability of infestations.

Control in the open field and in the storehouse

Prevention and non-chemical control

- ✓ Use of healthy planting material
- ✓ Provision of optimal nutrient and water supply
- ✓ Removal and destruction of dead wood, infected plant parts and plant debris
- ✓ Avoidance of /minimizing any types of fruit injury during the growing season (e.g. by the adequate control of pests), harvest, transportation, packaging and storage
- ✓ Delay in harvesting for better natural fruit development
- ✓ Washing the fruit after harvest removes at least some of the fungal structures present on the rind surface. However, washing before degreasing is not advisable.
- ✓ Proper management with ethylene (adequate concentrations and duration) in the case of degreening
- ✓ Storing of packed fruits at temperatures below 4°C (to help suppress development of the disease)
- ✓ Avoidance of storing fruits for extended periods

Chemical control

- ✓ Both pre- and post-harvest chemical control may be possible using adequate pesticides registered for use in citrus plants.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

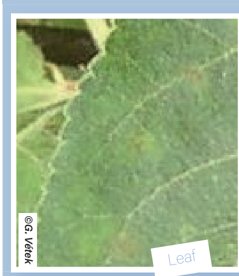
Apple scab

(Venturia inaequalis)

Apple scab

Symptoms

Leaf	the lesion is usually circular in shape and first appears as an area which is a lighter shade of green than the surrounding leaf; as it increases in size, it becomes olive-coloured and velvety due to the production of conidia; lesions on young leaves may be more than 1 cm in diameter, while those formed on expanded leaves are usually smaller because older leaves are more resistant to infection; affected tissues may become distorted and puckered, and the leaf lesions often become cracked and torn; lesions on the leaves are generally blistered and "scabby" in appearance, with a distinct margin
Fruit	the earliest noticeable symptom on fruit is water-soaked areas which develop into velvety, green to olive-brown lesions; lesions on the fruit are generally blistered and "scabby" in appearance, with a distinct margin; older lesions are corky in appearance; early infections often result in large fruit lesions and severely cracked and malformed fruit; if the fruit is infected late in the summer or just before harvest, black, circular, very small (0.1-4 mm in diameter) lesions called "pin-point scab" will appear during storage

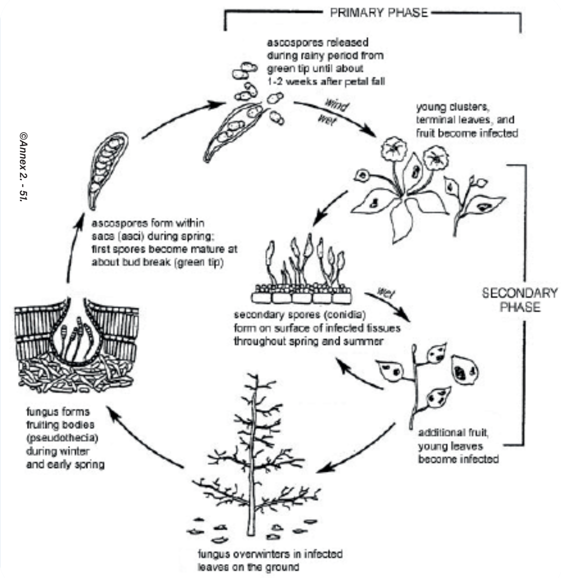


Host plants

Apples

Biology

Apple scab occurs everywhere in the world where apples are grown and causes more losses than any other apple disease. The fungus usually overwinters in the fallen leaves as mycelium and pseudothecial initials, the latter formed soon after leaf fall, then entering dormancy. In the spring, the pseudothecial initial develops into a pseudothecium, a cavity located within a dense mat of fungal mycelium (stroma). Inside this cavity the asci and ascospores are formed. When the mature pseudothecia in the fallen leaves becomes wet, it swells and protrude from the surface of the leaf and the asci expands through the top of the pseudothecium. The ascospores are discharged into the air, where they are spread by wind and rain. If there is sufficient moisture from rain or dew and the temperature is adequate, the ascosporesthat land on apple blossoms and young unfolding leaves can germinate and initiate infections. In most years, ascospore release coincides with the period from bud break to the end of bloom. Within a few weeks, the primary lesions produce conidia, which are dispersed to other leaves and developing fruit, where they establish secondary infections. The production of conidia is affected by humidity: levels of at least 60-70 percent are required for spore production. The infection of leaves by ascospores and conidia largely depends on how long the leaves or fruits stay wet, and on the average temperature. Several secondary cycles of conidial infection may occur during the growing season, depending on the frequency of periods suitable for infection and the susceptibility of host tissue. As plant parts mature and the weather gets warmer, susceptibility to the disease decreases. Apple scab is most serious in areas that have cool, wet weather during the spring and is of less importance in dry climates.



Apple scab

Monitoring

Apple scab outbreaks can be predicted based on temperature and moisture conditions. The Mills table relating leaf wetness duration and temperature is used to determine the likelihood that infection will occur if conidia is present. For example, at an average temperature of 18°C (65°F), light infection will result if leaves remain wet for nine hours, but if leaves are wet for 18 hours or more heavy infection will occur. Lesions will produce spores after nine days if the temperature averages 18°C (65°F), but not until 17 days if the temperatures are lower, averaging only 8°C (49°F).

If wet periods are intermittent, their durations should be accumulated until there is a period of at least six hours of continuous dryness. If the dry period is sunny, and drying is quick and thorough, it is assumed that six hours after the trees have dried, the danger will have passed. If drying is slow, and humidity remains high, then the six-hour dry period is extended by a safety margin of three to four hours.

The Mills table continues to be revised as more data are gathered from different regions.

Nevertheless, orchards should be periodically monitored to visually identify scab lesions on plants throughout the season.

Wetting period (HOURS)					
Average Temperature (F)	Average Temperature (C)	Light Infection	Moderate Infection	Heavy Infection	Incubation Period (days)
78	25.6	13	17	20	...
77	25.0	11	14	21	...
76	24.4	9.5	12	19	...
63-75	17.2-23.9	9	12	18	9
62	16.7	9	12	19	10
61	16.1	9	13	20	10
60	15.6	9.5	13	20	11
59	15.0	10	13	21	12
58	14.4	10	14	21	12
57	13.9	10	14	22	13
56	13.3	11	15	22	13
55	12.8	11	16	24	14
54	12.2	11.5	16	24	14
53	11.7	12	17	25	15
52	11.1	12	18	26	15
51	10.6	13	18	27	16
50	10.0	14	19	29	16
49	9.4	14.5	20	30	17
48	8.9	15	20	30	17
47	8.3	17	23	35	17
46	7.8	19	25	38	17
45	7.2	20	27	41	17
44	6.6	22	30	45	17
43	6.1	25	34	51	17
42	5.5	30	40	60	17

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Table: Wetting period (in hours) required for apple scab infection at different air temperatures, and time required for development of conidia by lesions at different air temperatures (W. D. Mills, Cornell University, as modified by A. L. Jones, Michigan State University)

Control in the open field

Prevention and non-chemical control

- ✓ Growing resistant apple cultivars or varieties less susceptible to apple scab(note: relying solely on apple scab resistance is not a sustainable IPM practice)
- ✓ Removal of any alternate non-commercial host plants of the disease
- ✓ Adequate pruning to enhance air movement and to allow sunlight to penetrate (to speed up drying of leaves and fruits)
- ✓ Avoidance of overhead irrigation
- ✓ Removal or shredding of plant debris containing infected leaves(decomposition can be speeded up by shredding)
- ✓ Application of a foliar fertilizer of zinc sulphate and urea in autumn hastens leaf fall and speeds decomposition of fallen leaves, which in turn reduces the level of overwintering apple scab inoculum (e.g. a spray of 5 percent urea solution to trees about one week before leaf fall or to already fallen leaves in autumn may give good results)
- ✓ Application of dolomitic lime to leaf litter in the orchard in autumn has been shown to have similar effects to urea application.

Chemical control

- ✓ The main objective in apple scab management is the reduction or prevention of primary infections in spring because in the case of extensive primary infections disease control during the season will become more difficult.
- ✓ By using non-chemical control methods, infection pressure can be reduced, and this gives the chance for moderate chemical control, which can delay the development of fungicide resistance.
- ✓ Exact timing of sprayings based on adequate monitoring, the proper use of fungicides (preventive/protectant and curative) and good coverage are key factors of successful control.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Bacterial canker of tomato

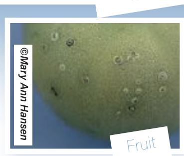
(Clavibacter michiganensis subsp. michiganensis)

Symptoms	
Stem and leaf	gradual withering of leaves, slow desiccation (whole or partial) of the plant;in advanced infection, vascular discoloration is seen as brown streaks on the stem and petiole; by cutting stems, petioles and peduncles, particularly at their junctions, a creamy white, yellow or reddish brown discoloration of vascular tissue and pith, and cavities within the pith will be evident; yellowish liquid may be exuded if the stem or petiole are squeezed; the brown streaks on the stem or petiole may darken and split open as cankers; secondary infections later in the growing season may cause marginal leaf necrosis, and a yellow margin may border the brown tissue; affected leaves tend to curl upward
Fruit	"bird's eye" spot lesions (white spots with a raised necrotic centre) of 2-3 mm in diameter is a characteristic symptom on the surface of the fruit

Stem and leaf

Stem and leaf

Stem and leaf



Fruit

Host plants

Tomato and other species of Solanaceae

Biology

The main sources of infection are contaminated seeds and plant debris. Infected seeds will give rise to infected seedlings, while the pathogen can enter the plants via roots. Contaminated tools and equipment used during growing are also sources of infection. The disease maybe spread by tools of cultivation and by general handling operations (e.g. transplanting, tying, suckering, de-leafing, picking) as well as by water splash(e.g. because of overhead irrigation).Practically, any type of natural opening or wound on the plant tissue may be suitable for the pathogen to enter the host. The vascular infection of plants leads to stunting of growth, withering and early plant loss. The characteristic symptom of "bird's eye" spots on the surface of tomato fruits appears if the pathogen gets there by water splash. High temperature (24-28°C) and 80-85 percent relative humidity are optimal conditions for the pathogen to develop. Even only a few infected plants could be enough to initiate an epidemic of bacterial canker. The disease may cause serious losses to both greenhouse and field tomato crops either by killing the young plants or reducing marketable yields.

Monitoring

Early detection of symptomatic plants, their isolation and eradication are crucial for limiting the spread of the disease. Exact identification of the pathogenic organism should be carried out by a specialist. For plant disease diagnosis, representative plants showing early symptoms should be chosen.

Control in the greenhouse and in the open field

Important note: *Clavibacter michiganensis* subsp. *michiganensis* is currently on the A2 quarantine list of EPPO!

Prevention and non-chemical control

- ✓ Proper sanitation in greenhouses (e.g. removal and destruction of plant debris, use of sterilized containers and media for seeding/ transplanting)
- ✓ Hand hygiene, and the use of disinfected (sterilized) tools (the latter managed by e.g. 10 percent bleach)
- ✓ Appropriate crop rotation (and keeping adequate isolation distances from infested fields)
- ✓ Growing in soilless medium in greenhouses (to reduce the risk of infestation)
- ✓ Growing cultivars less susceptible to the disease
- ✓ Use of healthy (certified) seeds and transplants (infected seeds may be treated; e.g. treatment of tomato seeds with hot water at 50°C for 25 min has been found effective in disinfection without impairing seed germination and seedling emergence)
- ✓ Avoidance of / minimizing any types of injury to the plant during growing (including special handling operations)
- ✓ Avoidance of overhead irrigation(and water plash in general) and of handling of plants when the foliage is wet
- ✓ Optimizing the time of irrigation, heating and ventilation
- ✓ Removal of symptomatic plants (in the case of limited occurrence of the disease)

Chemical control

- ✓ Copper-based chemicals may be sprayed on tomato for controlling superficial pathogen populations to some extent.
- ✓ During prolonged wet periods (e.g. regular overhead irrigation, frequent rainfall) and high temperature, and by growing susceptible cultivars, the impact of chemical control will be highly limited.

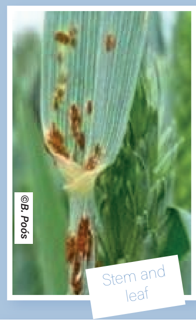
Always follow the label instructions for the dosage, application and safety!

Black (stem) rust of wheat

(Puccinia graminis)

Symptoms

Stem and leaf	**a/wheat**: oval uredinia of powdery, brick-red urediniospores breaking through the epidermis of the stem, leaves (both surfaces) or leaf sheaths (occasionally also formed on the head and seeds); later in the season, telia of black teliospores start to form
Leaf	**b/barberry**: pycnia appear in the spring, usually on the upper leaf surfaces, they are often in small clusters and exude pycniospores in a sticky liquid; a few days later, yellow, cup-shaped structures, filled with orange-yellow, powdery aeciospores break through the lower leaf surface



Stem and leaf

Stem and leaf

Leaf

Host plants

Wheat and some other species of Poaceae; *Berberis*, *Mahonia*

Biology

The life cycle of the pathogen starts with the introduction of either an aceciospore or a urediniospore to a wheat plant. The first rust spores to infect wheat in the spring in temperate regions may be aeciospores from barberry (*Berberis*spp.), the alternate host, or urediniospores from infected wheat in distant regions with milder winters. If barberry bushes are present near wheat fields, they will become significant and consistent sources of aeciospores for the earliest infections of wheat in the spring. The pathogen overwinters as black teliospores on wheat (or other main hosts). These teliosporesrequire extended periods of exposition to cold temperatures to germinate in the spring, when they produce basidiospores, which infect barberry (or other alternate hosts).Germinating basidiospores produce mycelium, which colonizes the leaf tissue. From the mycelium, pycnia (spermagonia) are formed inside the leaf but with the tops extending through the surface, usually the upper surface, of barberry leaves. Soon afterwards, the so called dikaryotic myceliumgrows through the barberry leaf until a new structure, the aecium, breaks through the lower surface of the leaf to discharge the dikaryotic aeciospores, which will infect wheat. On wheat, aeciospores germinate, and the fungus grows as dikaryotic mycelium in the plant. Within a week or two, the mycelium in each infection produces a uredinium filled with urediniospores, which breaks through the leaf or stem epidermis. In heteroecious rusts (which alternate hosts) such as *P. graminis*, this important spore stage is called the "repeating stage", because urediniospores are the only rust spores that can infect the host plant on which they are produced. Under favourable environmental conditions (25-30°C during the day, 15-20°C at night, and some hours of free moisture), multiple, repeated infections of the same and neighbouring wheat plants can result in explosive epidemics. Towards the end of the growing season, the overwintering teliospores are formed in telia, and the life cycle is completed. Black (stem) rust epidemics can occur even in the absence of barberry. In this case, the first spores of *P. graminis* to reach wheat in the spring are windborne urediniospores originating in the south. Grain is shrivelled due to the damage to the conducting tissue. Severe disease can cause straw breakage.

Monitoring

It is advisable to begin monitoring symptoms from flag leaf emergence and inspect wheat crops every (4-) 7-10 days (depending on the risk of infection) from that time to early dough grain development.

The source of infection can be predicted from the pattern of the disease in the field. If inoculum comes from barberry (i.e. a point source), the resulting disease pattern is usually fan-shaped with the alternate host at the apex of the fan. If the disease has a more uniform pattern, the inoculum source is usually from a broad area, such as the southern wheat crops from which urediniospores are released. Scattered infections mainly on the top leaves in a wheat field indicate that airborne spores were carried into the field from an external source. Stem rust is most severe in susceptible varieties when it begins to develop in the crop before flowering. In these circumstances crop losses of 50 percent are possible. Yield losses from later infections are possible, but not as severe.

Control in the open field

Prevention and non-chemical control

- ✓ Appropriate crop rotation(and the elimination of volunteer plants)
- ✓ Stubble shelling and deep autumn ploughing
- ✓ Weed management and removal of alternate host species
- ✓ Growing resistant cultivars or varieties less susceptible to the disease
- ✓ Late sowing in the autumn or early sowing in the spring and the use of early-maturing cultivars may help reduce the time of exposure of the crop to the pathogen (these are feasible if inoculum is exogenous and arrives well into the cropping season)
- ✓ Avoidance of over-fertilization (with nitrogen)

Note: growing several cultivars differing in genetic and agronomic characteristics (e.g. disease resistance and time of maturity), known as cultivar complementation, can help avoid significant losses in years with severe rust epidemics.

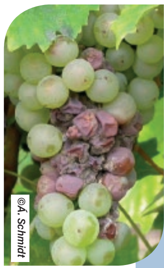
Chemical control

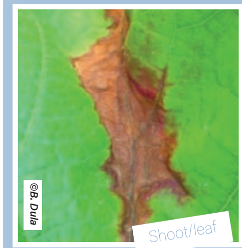
- ✓ If necessary, adequate fungicides should be applied in time to prevent epidemics.
- ✓ Development of fungicide resistance in the pathogen populations should be avoided by anti-resistance strategies and by spraying only when necessary (determined by several conditions such as the susceptibility and growth stage of the cultivar, weather conditions, and the risk of infection from external sources).

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Botrytis bunch rot and blight

(Botrytis cinerea)

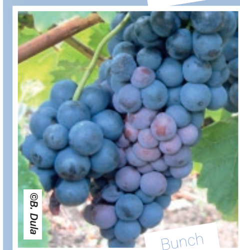




Shoot/leaf

Bunch

Bunch



Bunch

Bunch

Symptoms

Shoot/leaf:
young shoots may become infected in early spring, they turn brown,and then dry out with drier weather; before bloom, large, irregular, reddish brown patches appear on a few leaves of the vine and are localized near the edge of the leaf blade or on major veins; irregular lesions may appear on the surface of the shoots; in humid, wet weather conditions, affected plant parts may be covered with grey fungal growth (conidia)

Bunch:
Entire flower clusters may dry out and fall off in severe infections; at the end of bloom, the fungus develops on the caps, stamens, and aborted berries trapped or still attached to the cluster, and from there, it attacks the pedicel or the rachis, forming small, brown lesions that eventually turn completely black; near the end of summer, these lesions may completely surround the pedicel or rachis and portions of the cluster below the necrotic area may drop off;
beginning at veraison, the fungus progressively invades the entire cluster and rot develops on it; berries become discoloured; wounded berries also become infected; in humid, wet weather conditions, a fuzzy, brownish or grey fungal growth appear on the surface; infection by secondary pathogens may occur and can lead to sour rot or other non-specific rots; severely infected bunches eventually dry and form a “mummy”; small, black, fungal bodies (sclerotia) are formed on mummified fruits

Host plants

Over 200 (mainly dicotyledonous) plant species, including grapevine

Biology

Being a fungus with a wide host plant range, the main sources of infection may occur both within and in the vicinity of vineyards. Regarding grapevines, the species can overwinter in the form of many tiny, black, resting structures (sclerotia) as well as mycelium in canes. Mummified bunches may also serve as overwintering sites. In the spring, sclerotia and mycelium produce large numbers of spores (conidia). Wind, water splash and human activity can spread the conidia in vineyards, throughout the season, depositing them on plant tissues. Temperatures around 20°C, free moisture on plants and high relative humidity are suitable conditions for infection and disease development. Fruit infections are initiated near late-bloom. The pathogen then penetrates through susceptible tissues such as senescing blossom parts, cap scars, and parts of old blossoms. Fruit infections prior to veraison often remain latent until fruit begins to ripen, although the grey, fungal growth(conidia) may appear on green, hard berries during cool and rainy summers. The amounts of conidia increase and berries become more susceptible to the disease after veraison. As ripening berries,accumulating sugar, become increasingly susceptible during pre-harvest, the fungus can spread rapidly through the cluster by berry-to-berry contact. Wounds on berries caused by pests (e.g. moths, wasps and birds), powdery mildew(i.e. splits by former infections) or adverse weather conditions (e.g. hails) etc. can also be readily colonized by the fungus. Serious yield losses can occur during the post-veraison/pre-harvest period. The disease causes direct crop loss when fruit is affected to such an extent that it is unsuitable for wine production. Flavour, colour and storage stability of wine may be reduced. An additional problem is that the threat of infections in autumn may dictate that grapes are harvested before they have reached the parameters required for a particular end use. Economic costs can also result from the need to sort and dispose of damaged bunches. (Note: In certain cultivars and under certain weather conditions, a specific form of botrytis bunch rot, known as “noble rot”, is a desired rot that contributes to the production of exceptionally sweet wines.)

Monitoring

Monitoring weather conditions as well as symptoms described is important throughout the season, particularly during bloom and after veraison. The role of prevention (actions taken before infections occur and/or symptoms appear on plants) is outstanding in grey mould control.

Control in the vineyard

Prevention and non-chemical control

- ✓ Establishing new vineyards in well-drained sites with good air movement (e.g. by orienting the rows in the direction of prevailing winds)
- ✓ Use of cultivars that are less susceptible to the disease (note: in general, cultivars with compact clusters may be more affected by bunch rot compared to varieties with loose clusters; also, thin-skinned cultivars, being prone to splitting, may be more at a risk of becoming infected)
- ✓ Proper pruning of grapevine, thinning of shoots and bunches, and fruit-zone leaf removal (to increase air circulation and to render the crop more accessible to fungicides)
- ✓ Avoidance of overhead irrigation
- ✓ Avoidance of over-fertilization (with nitrogen)
- ✓ Adequate weed control (to decrease humidity)
- ✓ Adequate control of pests that damage fruits,as well as of powdery mildew (the latter may cause the berries to split open and become susceptible to additional infection by grey mould)
- ✓ Timing of harvest, considering weather forecasts (i.e. before it gets cool and rainy) (note: grapes may not reach the quality parameters required for a particular end use if harvested early because of adverse weather conditions)
- ✓ Removal and destruction of infected fruits and plant debris (e.g. by burying them in the ground)
- ✓ Use of *Bacillus sublitis*, *Alternaria oudemansii*, *Aureobasidium pullulans* or *Trichoderma* in biological control

Chemical control

- ✓ Fungicides are an important disease management tool, but are generally not effective unless they are timed properly and used in conjunction with the practices mentioned above. Actually, non-chemical cultural practices are more useful in controlling grey mould than any other fungal diseases of grapevine.
- ✓ Fungicide applications at late-bloom, pre-bunch closure, veraison, and 2-3 weeks pre-harvest are important sprays for botrytis bunch rot control. Bloom and cluster-close sprays limit the establishment of primary infections, while veraison and pre-harvest sprays limit the spread of the disease. (Foliar lesions may appear in wet conditions but these usually dry out and do not spread if hot weather soon arrives.) Under prolonged wet conditions and/or in the case of any unexpected damage (e.g. by pests or hails), additional sprayings may be necessary during fruit development (note: the time of harvest must be closely considered before choosing and applying fungicides for treatments). On the other hand, dry and hot periods may make chemical control of grey mould unnecessary.
- ✓ Good coverage is essential for adequate grey mould control.
- ✓ There are many fungicides available on the market for the control of the disease, but resistance to one or other of them has become established. Therefore, anti-resistance strategies should be applied to maintain the effectiveness of chemical pesticides.

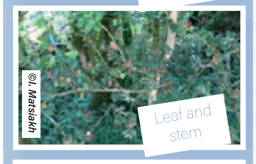
ⓘ **Always follow the label instructions for the dosage, application and safety!**

Box blight

(*Calonectria pseudonaviculata*)

Symptoms

Leaf and stem:
dark or light brown leaf spots with a concentric pattern or zonate lines often in a circular pattern, which may coalesce to cover whole leaves; infected leaves may turn brown or straw coloured and infected plants look "blighted"; under high humidity, white fuzzy spore masses containing large numbers of spores are sometimes visible to the naked eye or with a handlens on infected stem and leaf tissue; straw to bronze discoloration of the foliage; black streaks on stems that appear to progress from the bottom of the plant to the top; defoliation may occur very quickly after initial symptoms, and heavily infected plants drop down most of their leaves



Host plants

Buxus spp. and other species of Buxaceae

Biology

The pathogen can survive as mycelium in cankers on infected stem tissues and in leaf debris for at least 5 years. The fungus can produce and survive in resting structures as microsclerotia (hardened spores or mass of hyphal structures in host tissue that can survive as long as 15 years in soil) and chlamydospores in infected leaves. The disease cycle of fungus can be completed in one week. Infection may take place very quickly under warm (18-25°C) and wet conditions. The pathogen can penetrate leaves through the cuticle in 5 hours without forming an appressorium (a specialized organ of many fungal pathogens used for infection). Fungal growth can occur intercellularly in the plant tissue. Conidia, borne on conidiophores, can cover the underside of the leaf after a week. The pathogen can enter the petiole and the stem and spread rapidly in the infected plant (though new shoots may continue to grow on healthy twigs and the root system may remain intact) when conditions are favorable, and in shady areas. The disease can seriously impact the appearance and aesthetics of the host and can also kill plants. Spread of the pathogen may take place by splashing water but also by animals (e.g. insects) as well as by human activities (e.g. by tools for pruning, shoes, gardening shears, lawn mowers). Long distance dispersal can occur through the transport of infected (but visibly asymptomatic) nursery stock (including cuttings). Undoubtedly, the spreading of this pathogen occurs via the movement of apparently healthy plant material between nurseries and countries. Also, the phenomenon "Trojan horse" takes place when some fungicides can suppress the disease but not kill or eradicate the fungus and plants look healthy for some time until the fungicide is no longer effective. As results, the pathogen resumes killing the plants.

Monitoring

A visual survey should be carried out to look for symptomatic plant tissue. Plants should be regularly examined, especially during warm, wet weather. Special attention should be paid to the lower and interior parts of Buxus bushes while searching for symptoms of the disease. To confirm the identity of the pathogen, a specialist should be consulted. Samples containing suspect leaves and stems should be placed in sealed and labelled ziplock bags and stored in a fridge before being shipped to the diagnostic laboratory.

Control in the open field

Prevention and non-chemical control

- ✓ Use of healthy planting material
- ✓ Use of disinfected (sterilized) tools for pruning
- ✓ Improving air circulation (e.g. by adequate spacing of plants and proper pruning/thinning of bushes and hedges)
- ✓ Optimizing the method and time of irrigation (e.g. avoidance of overhead irrigation)
- ✓ Use of the foliar fertilizer Topbuxus Health-Mix during the vegetation period
- ✓ Removal and destruction of infected plants and/or plant parts as well as of plant debris (with topsoil)
- ✓ Planting alternative ornamental plant species not belonging to Buxaceae in place of susceptible hosts

Chemical control

- ✓ If chemicals are applied, good coverage of the foliage should be ensured(e.g. by using an electric backpack sprayer and adding a spreader sticker to the tank mix)

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Brown (leaf) rust of cereals

(Puccinia recondita)

Symptoms

Leaf:
round to ovoid uredinia(up to 1.5 mm in diameter) of orange-brown urediniospores breaking through the epidermis on both surfaces (but mainly on the upper side) of the leaf of wheat; later in the season, telia of brown-black teliospores may start to form beneath the epidermis, primarily on leaf sheaths and blades

Leaf

Leaf

Host plants:

Wheat and some other species of Poaceae; *Thalictrum*

Biology

Urediniospores are spread by wind and splashing water. They land on healthy wheat plants and initiate new infections of leaves. Optimal conditions for infection are 15-20°C and at least six hours of free moisture on the leaf surface. Under optimal conditions for disease development (wet weather and 20-25°C), new uredinia are formed within about a week after infection, and the cycle of spore production is repeated. Thus, the urediniospore is the "repeating stage" of the leaf rust fungus. Teliospores can survive the winter. However, they play an important role in the disease cycle only in regions where alternate hosts of the brown (leaf) rust fungus exist. Therefore, teliospores are regularly not epidemiologically as important as are urediniospores. The pathogen can survive the winter as mycelium or uredioniospores on volunteer or overwintering wheat crops in mild winters or in southern regions. If overwintering occurs, leaf rust can be detected earlier in the growing season. Urediniospores may be carried by windfrom the south to northern areas.

Monitoring

Infection of wheat usually takes place when the wheat plants transitions from vegetative to reproductive stages. Scouting in wheat fields during cool moist spring weather is highly advised. It is important to eliminate the infection at an early stage.

Control in the open field

Prevention and non-chemical control

- ✓ Appropriate crop rotation (and the elimination of volunteer plants)
- ✓ Stubble shelling and deep autumn ploughing
- ✓ Weed management and removal of alternate host species
- ✓ Growing resistant cultivars or varieties less susceptible to the disease
- ✓ Late sowing in the autumn or early sowing in the spring and the use of early-maturing cultivars may help reduce the time of exposure of the crop to the pathogen
- ✓ Avoidance of over-fertilization (with nitrogen)

Note: growing several cultivars with different genetic and agronomic characteristics (e.g. disease resistance and time of maturity), known as cultivar complementation, can help avoid significant losses in years with severe rust epidemics.

Chemical control

- ✓ If necessary, adequate fungicides should be applied in time to prevent epidemics.
- ✓ The development of fungicide resistance in the pathogen populations should be avoided by anti-resistance strategies and by spraying only when necessary (determined by several conditions such as the susceptibility and growth stage of the cultivar, weather conditions, and the risk of infection from external sources).

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Brown rot of fruits, blossom blight of fruit trees

(*Monilinia fructigena, Monilinia laxa*)

Symptoms

Fruit:

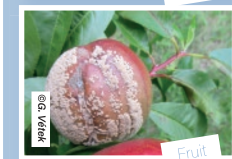
a/*M. fructigena*:
fruit rot: fruit lesions are brown and circular, and eventually the whole fruit decays and turns brown; tufts of mycelium and conidia (2-3 mm in diameter and cream-white to yellowish beige in colour) sprout from the skin of the infected fruit, often arranged in concentric rings on pome fruits (however, when the relative humidity is low and/or when the fruits are not ripe, very few or no tufts develop); rotted fruits may either fall to the ground or dry out and remain attached to the tree, leaving a hard, shrivelled"mummy";
a symptom referred to as "black apple" may also develop during storage: the colour of the rot is initially brown, but becomes black as the rot progresses; the skin of the apple then has a shiny smooth surface, usually not ruptured by conidiophores

a/*M. laxa*:
fruit rot: fruit lesions are brown and circular, and eventually the whole fruit decays and turns brown; tufts of mycelium and conidia (ash-grey-brown in colour) sprout from the skin of the infected fruit and are scattered on its surface; later, rotten fruits become "mummies"

Blossom and twig:
***M. laxa*:**
wilting and browning blossoms on twigs and necrotic areas on invaded woody parts; a gummy substance usually exuding from the cankers; under humid conditions, ash-grey-brown sporodochia bearing conidia formed on the surface of diseased blossoms and twigs

Fruit

Fruit



Fruit

Fruit

Blossom and twig

Host plants:

a/M. fructigena: pome, stone (e.g. sweet cherry, apricot, peach, plum) and some other (e.g. hazelnut, fig) fruits
b/M. laxa: stone (e.g. sour cherry, apricot, plum) and some other (e.g. almond) fruits

Biology

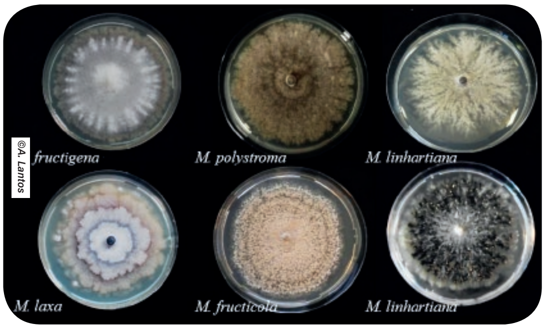
a/*M. fructigena*:

The fungus overwinters mainly in or on diseased mummified fruit either attached to the tree or on the ground. Other infected tissues on trees, such as twigs, peduncles and cankers on woody parts, can also serve as sources of primary inoculum. In the spring or early summer, under favourable conditions, dense velvety tufts of conidiophores (sporodochia) form on the surface of the mummified fruits and infected tissues, and bear chains of conidia. Conidia are dispersed by wind, water (e.g. rain splash) or insects to young fruits. Initial infection takes place via wounds (caused e.g. by pests). Subsequent spread by contact between adjacent fruits may also cause infection. Any infected tissue in which the moisture content is sufficient for sporulation may serve as a source of secondary inoculum. Infection of fruits can occur at any time during fruit development, but the disease is only severe in ripe or ripening fruits. Infections of fruitlets during, or shortly after, flowering may result in latent infections on green fruits, and become active before or after harvest. On healthy fruits contaminated with spores at harvest, fruit rots can develop during the post-harvest period (storage and sale). The fungus can survive long periods of adverse environmental conditions as mycelium within mummified fruits, twigs, cankers and other infected tissues. *M. fructigena* is a pathogen of warm and humid conditions; brown rot of fruits is rare in arid climates.

b/*M. laxa*:

In the case of *M. laxa*, the opening blossoms of the host plant species provide the first susceptible tissue for infection in the spring. The sources of blossom blight inoculum and means of dispersal of conidia are practically the same as in *M. fructigena*. Blossom infection (via anthers and pistils) caused by *M. laxa* highly depends on the duration of wetness and temperature. For this, 5 and 18 hours of wetness are necessary at 24 and 10ºC, respectively, to occur. The fungus invades the floral tube, the ovary, peduncle, and usually the twig to which the peduncle is attached. The time required for the appearance of symptoms may be only a few days to 1-2 weeks, depending on the temperature. Wilting and browning blossoms on twigs and cankers (necrotic areas) on invaded woody parts are typical symptoms of infection by *M. laxa*. A gummy substance usually exudes from the cankers. Under humid conditions, ash-grey-brown sporodochia bearing conidia form on the surface of diseased blossoms and twigs. Very few blighted blossoms may be enough to cause severe fruit rot if environmental conditions are optimal as fruits ripen. Additional sources of inoculum for fruit infection may be cankers on woody parts and diseased fruits (including mummified fruits from former years).

Monitoring



Symptoms caused by either of the diseases are relatively easy to recognize. Monitoring of weather conditions and pests of fruits in the orchard are important so that preventive control tactics can be properly applied (i.e. fungicides can be sprayed according to weather conditions,depending on whether or not they are effective against infection by *M. laxa* at the time of blossoming, and the adequate control of pests that can cause injuries to fruits may reduce the risk of infection of fruits by *Monilinia* spp.) To distinguish related (these and other) Monilinia species from each other, investigation of the morphological characteristics of cultures and molecular tests may be carried out in the laboratory.

Control in the orchard and in the storehouse

Prevention and non-chemical control

- ✓ Growing resistant cultivars or varieties less susceptible to the diseases (note: consumer preferences may not coincide with that of the growers' regarding apple cultivars with resistance to brown rot)
- ✓ Removal of any alternate non-commercial host plants of the diseases
- ✓ Adequate design of orchards and pruning to enhance air circulation
- ✓ Removal and destruction (e.g. by burying) of immature fruits that fall during the vegetation period (because of e.g. thinning or damage by pests), as well as of plant debris possibly including infected plant parts (e.g. mummified fruits)
- ✓ Balanced water supply (to reduce the risk of fruit cracking, especially in sweet cherry)
- ✓ Avoidance of over-fertilization (with nitrogen)
- ✓ Adequate control of pests that damage fruits
- ✓ Application of anti-hail nets (to reduce damage to fruits)
- ✓ Proper timing of harvest
- ✓ Avoidance of mechanical damage to fruits during field practices, packing and storage
- ✓ Removal and destruction of infected fruits and twigs
- ✓ Removal of infected fruits during storage
- ✓ Provision of adequate conditions during storage (e.g. by hydrocooling or forced air cooling)
- ✓

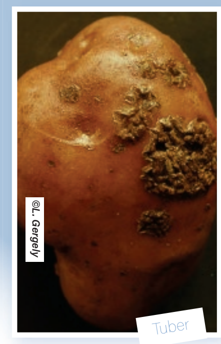
Chemical control

- ✓ Fungicides cannot control *M. fructigena* adequately if applied after mechanical injuries have become inoculated by the pathogen (hence proper pest control with adequate insecticides is essential for reducing the risk of occurrence of brown rot).
- ✓ Protective fungicidal treatments may provide effective control of blossom blight (and brown rot).
- ✓ Blossom blight may be controlled effectively by a limited (1-3) number of treatments applied during blossoming (from first bloom until petal fall).

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Common scab of potato

(Streptomyces scabies)



Symptoms

Tuber:
more or less circular, brown, roughened areas, with irregular margins; the spots may be raised or warty in appearance, level with the surface, or somewhat sunken; superficial russeting to deep (3-4 mm) pitting may occur; the affected tissue may be further enlarged or deepened by soil-dwelling pests

Host plants:

Potato and other root crops (e.g. beets, carrot, radish)

Biology

The organism can survive in the soil as spores for several years. Decomposing contaminated plant debris may also be sources of infection. *Streptomyces scabies* prefers loose and dry soils, mild alkalinity and soil temperatures around 20ºC for its development. Germinating spores can infect the tubers directly through the tender skin of the forming potato (older tissue may also become infected via wounds or natural openings). The organism slowly continues to grow until the crop is harvested. Once *S. scabies* has entered the host, it grows both between and through cells and incites multiple cork layer formation, which results in the scabby appearance of the lesions. As the tuber grows, the lesions also enlarge. The organism may be spread by water, wind-blown soil, infected planting material and contaminated machinery. Significant infestation may occur in the field if the same crop is grown year after year without rotation. Although scab does not usually affect total yields, the presence of lesions reduces the marketability of the crop.

Monitoring

As there are no above ground symptoms of infection by common scab in the field, it is necessary to take samples of plants and examine the occurrence of the symptoms on tubers (or roots).

Control in the open field

Prevention and non-chemical control

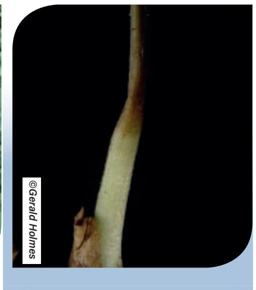
- ✓ Avoidance of loose, dry and alkaline soils for growing
- ✓ Crop rotation (and keeping adequate isolation distances from infected fields)
- ✓ Use of healthy (certified) seed tubers
- ✓ Use of resistant cultivars or varieties less susceptible to the disease
- ✓ Keeping the soil reasonably wet by irrigation for several weeks while the tubers are beginning to form. (Note: irrigation may not always be practical, especially for soils with low water holding capacity. Furthermore, other disease problems may be aggravated by excessive irrigation.)
- ✓ Avoidance of applying fertilizers or other materials (e.g. lime, ashes, poultry manure) that tend to make the soil highly alkaline
- ✓ Rational use of acidifying fertilizers (e.g. ammonium sulphate) (note: testing of soil pH should be carried out each year so that the risk of the soil becoming too acid for any crops in the rotation can be prevented)
- ✓ Use of clean machinery
- ✓ Removal of all plant residues after harvest
- ✓ Selection and destruction of damaged tubers before storage

Chemical control

- ✓ The possibilities of chemical control of common scab of potato are quite limited,and thus methods of prevention are very important in the control of the disease

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Damping-off of seedlings



Seed/seedling

Symptoms

Seed/seedling:
if infected by T. cucmeris: severely infected seeds do not germinate; seedlings may die before reaching or shortly after growing above the soil surface; water-soaked, later brown and constricted stem or root neck at or just below the soil line, causing the seedling to fall over and die; reddish brown lesions near the soil surface on the stem / root neck of older plants (these plants may break / wilt, and die later in the season)

Biology

Damping-off is a disease caused by several different soil-borne fungi, which can infect seedlings and cause them to collapse and decay. A wide range of plant species may be affected. The disease is often a problem under damp conditions (e.g. in overly wet, poorly drained soils)both in protected cultivation (e.g. in glasshouses) and outdoors around the time of emergence and early in the season. Slow-growing or weak plants are more susceptible to damping-off than vigorous fast-growing seedlings.

One of the most widespread causal organisms is *Thanatephorus cucumeris*. It can survive in the soil and on plant tissues as tiny (1-3 mm), brown-black, and irregular-shaped bodies, called sclerotia, for several years. It also survives as mycelium by colonizing soil organic matter as a saprophyte, particularly as a result of plant pathogenic activity. (The species does not produce conidia and only rarely produces basidiospores.) Sclerotia and/or mycelium produce vegetative threads (hyphae) that can attack the hosts via either intact or wounded tissues. The fungus primarily attacks plant parts below ground, such as the seeds, hypocotyls, and roots, but is also capable of infecting plant parts above ground (e.g. stems, leaves, and fruits) if these are located on or close to the soil surface. *Globisporangiumdebaryanum* (syn. *Pythiumdebarianum*) is another fungal organism causing damping-off of many plant species. It affects young seedlings, and the general symptoms caused by it are quite similar to those by *T. cucumeris*. *Globisporangiumdebaryanum* prefers wet and acidic soils for its development. These and other fungi responsible for damping-off of seedlings may be spread by infected plants as well as by contaminated soil, tools and equipment during cultural practices.

Monitoring

Any suspect seedlings should be revealed as soon as possible based on scouting for symptoms around the time of emergence. The high incidence of the disease should call the attention of the grower to take steps to prevent the fungi involved in the problem from spreading further.

Control in the open field and in the greenhouse

Prevention and non-chemical control

- ✓ Provision of any environmental conditions (e.g. fine seedbed, balanced nutrition supply) that contribute to the proper germination of seeds and fast growth of young seedlings of the particular plant species
- ✓ Avoidance of poorly drained soils/media and of over-irrigation that may lead to standing water accumulation in the seedbeds
- ✓ Use of healthy (certified), young seeds for sowing
- ✓ Thinning of seedlings in seedbeds if necessary (to improve air circulation)
- ✓ Proper sanitation in greenhouses
- ✓ Disinfection of tools and equipment (tables, trays, containers etc.) with a weak solution of bleach (10 percent)
- ✓ Soil solarization by applying transparent plastic sheets for 10-12 weeks has been shown to give good control of *G. debaryanum*
- ✓ Steam sterilization of the soil(at temperatures around 95-100°C for 30-40 min.) in the greenhouse. (Note: sterilization will kill not only the pathogens but also the beneficial organisms; hence recontamination of the sterilized soil by pathogenic species may occur soon in the case of the lack of proper hygiene in the greenhouse.)
- ✓ Removal and destruction of infected plants and plant debris
- ✓ Use of beneficial organisms such as *Bacillus subtilis*, *Burkholderia cepacia*, *Trichoderma*or *Streptomyces*, depending on the pathogenic species involved, in biological control

Chemical control

- ✓ Seed treatment (seeds dressed with appropriate fungicides).
- ✓ Chemicals should be applied in a preventive programme to avoid infections at germination and emergence as well as at planting.
- ✓ Fungicides (with the adequate active ingredients) should be chosen according to the fungal species present/dominant in the soil, and should be applied just after sowing and again just after emergence of seedlings from the soil.
- ✓ The use of soil fumigants may provide satisfactory control but should not be preferred because of environmental and other concerns.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Downy mildew of grapevine

(*Plasmopara viticola*)

Symptoms

Leaf:
generally yellow circular spots with an oily appearance ("oil spots") develop on young leaves, which may coalesce under favourable weather conditions; after suitably warm, humid nights, a white, downy fungal growth (sporangia) will appear on the underside of the leaves;
later in the season, the growth of the pathogen is restricted by veins of older leaves, hence lesions appear as smaller,yellow to reddish brown,angular spots forming a characteristic mosaic-like pattern

Bunch:
inflorescences, small young berries and the peduncle become discoloured, and white sporangia may appear on their surface; they turn brown, wither and die;
later, the infected older berries shrivel (starting from the point where attached to the pedicel), turn grey or brownish, dry and die; the flesh of shrivelling berries turns brown quickly following infection; regularly no sporangia develops on the surface of diseased older berries

Host plants:

Grapevines

Biology

The pathogen usually overwinters as oospores in fallen leaves infected in the previous season. Germination of oospores occurs in the spring when temperatures reach about 10°C and vineyard soils are wet (min. 10 mm of precipitation is needed within a 1-2 days). Then macrosporangia are formed, which release zoospores. These are splashed by rain or carried by wind to the lower leaves. Infection takes place via the stomata of leaves. The fungus grows in an intercellular manner and damages the cells of the host. The period between infection and the appearance of the first symptoms (incubation time) depends on temperature and ranges from about three days to three weeks, with an average of 7-10 days. The incubation period is shortest on young leaves and at temperatures of 20-25°C. Sporulation through stomata occurs during warm, humid nights, when a white fungal growth (sporangia) will appear on infected plant parts. Sporangia and zoospores formed are dispersed to new sites of infection by rain splash and wind. At optimal temperatures (approx. 20°C) infection can take place in two hours of surface wetness. Secondary cycles of infection may occur repeatedly throughout the growing season if weather conditions are favourable. Oospores develop towards the end of the season in diseased leaves. Potential yield losses may reach 100 percent.

Monitoring

In the field, "oil spots" appearing on leaves should be noticed. The upper leaf surfaces should be inspected for this symptom by gently moving the shoots and leaves, spending about 30 seconds per vine for 200-300 vines. If a primary infection is observed, that spot should be monitored for the first secondary infections, which are usually within 1 m of the original primary "oil spots". Vines should be inspected every 1-2 weeks, or as necessary based on weather conditions. Computer training programmes have been developed for improved accuracy of disease assessments.

Weather stations are commercially available and can be set to obtain the necessary data on microclimatic conditions of different vineyards. Computer-based forecasting models and decision tools have been developed in many countries and can be used once adapted to the local conditions.

Confirmation of active downy mildew can be made by the "bag test". To do this test, suspect diseased leaves and/or fruit bunches should be placed in a moistened (not wet) plastic bag and incubated in a warm (13-28ºC), dark place overnight. Fresh, white, downy sporulation beneath suspect oil spots or on bunches can be observed in the case of infection. (Note: even though being infected, mature berries may not support sporulation even if ideal conditions are provided.)

Control in the vineyard

Prevention and non-chemical control

- ✓ Establishing new vineyards in well-drained sites with good air movement (e.g. by orienting the rows in the direction of prevailing winds)
- ✓ Use of cultivars that are less susceptible to the disease (note: consumer preferences may not coincide with that of the growers')
- ✓ Proper pruning of grapevine, thinning of shoots and fruit-zone leaf removal (to increase air circulation and to render the crop more accessible to fungicides)
- ✓ Avoidance of overhead irrigation and of keeping the soil wet for long periods
- ✓ Removal and destruction of plant debris (e.g. by burying them in the ground)
- ✓ Adequate weed control (to decrease humidity at soil level)

Chemical control

- ✓ The control of the disease is primarily based on chemical methods at present, although non-chemical cultural practices are important to apply to help prevent severe epidemics.
- ✓ The exact timing of sprayings based on adequate monitoring, the proper use of fungicides (preventive/protectant and curative) and good coverage are key factors of successful control. Preventive fungicides should be applied before infection takes place. Post-infection fungicides should be applied as soon as possible after an infection event and prior to the appearance of oil spots. These fungicides are best used in conjunction with a forecasting programme, which assesses the likelihood of infection from canopy microclimate data.
- ✓ In general, first sprayings,by using contact fungicides, should be applied from the stage the shoots bear 3-6 leaves. The most critical period of control is from bloom until 3-4 weeks post-bloom. During this time, repeated treatments, depending on the weather conditions, with fungicides containing different active ingredients of systemic and contact properties should be carried out. Later in the season, control should be continued with contact fungicides, taking into consideration the weather conditions as well as the time of harvest.
- ✓ Copper-based fungicides may cause chemical burn to the tissues of some cultivars,hence their use should be avoided in these varieties throughout the vegetation period.
- ✓ There are many fungicides available on the market for the control of downy mildew of grapevine, but resistance to one or other of them has become established. Therefore, anti-resistance strategies should be applied to maintain the effectiveness of chemical pesticides.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Fire blight

(Erwinia amylovora)

Symptoms

Flower:
the flower receptacle, ovary and peduncles become water-soaked and greyish green; later these tissues shrivel and turn brown to black; in high humidity, small droplets of bacterial ooze (initially creamy white, later becoming amber in colour) may be formed

Shoot:
tips of shoots may wilt rapidly to form a “shepherd’s crook”; leaves may blacken along the midrib and veins before becoming fully necrotic; the affected, dry leaves remain attached to the plant; numerous diseased shoots give the tree a burnt, blighted appearance; bacterial ooze may appear under humid conditions

Fruit:
water-soaked lesions, later turning brown to black, appear on the surface; droplets of bacterial ooze may form on lesions, usually at lenticels; severely diseased fruits blacken completely and shrivel

Woody parts:
bark on younger branches becomes darkened and water-soaked; later, cracks will develop in the bark, and the surface will be slightly sunken; amber coloured bacterial ooze may be present on the bark; wood under the bark will show streaked discolorations

Flower

Shoot

Fruit

Woody parts

Host plants:

Pome fruits

Biology

The bacterium overwinters in cankers formed on woody parts during the previous season. In the spring, as the temperature increases, the organism becomes active and free bacterial cells are released onto the surface of the bark, sometimes as visible ooze. Bacteria may be dispersed to blossoms by rain splash, animals (e.g. insects such as flies and bees) or contaminated pollen. Preferable conditions for infection are mean temperatures above 18°C, a wet surface and more than 75 percent relative humidity. The pathogen can then enter the plant via the flowers and initiates blossom blight. The bacterium can spread within the living tissue of shoots and woody plant parts and may damage large portions of the tree. Wounds caused by human activity (e.g. pruning), insects or severe weather etc. on different parts of the plant may also become invaded. The bacterium can get into the rootstock as well. Infections can expand throughout the summer, and their severity depends on several factors (e.g. host species, cultivar, age and nutritional status of the host tissues).

Monitoring

If the disease has not been observed to cause damage in the orchard previously, searching for symptoms should be started at bloom and continued during the season, focusing on periods with a major risk of infection posed by the factors described above and/or because of other circumstances (e.g. in the case of the vicinity of abandoned pome fruit orchards or if new planting material has been introduced in the orchard). Monitoring should be concentrated on blocks with host species (e.g. quince and pear)and/or cultivars being more susceptible to the disease.

Epidemiological models (e.g. MARYBLYT) are available and may be used to predict the likelihood of blossom blight epidemics (and hence to time control tactics) based on observed climatic conditions.

Control in the orchard

ⓘ **Important note: *Erwinia amylovora* is currently on the A2 quarantine list of EPPO!**

Prevention and non-chemical control

- ✓ Establishing new orchards in well-drained sites
- ✓ Avoidance of the vicinity of abandoned pome fruit orchards and removal of any alternate non-commercial host plants of the disease
- ✓ Use of resistant cultivars (and rootstocks) or varieties less susceptible to the disease(note: consumers' preferences may not coincide with that of the growers')
- ✓ Use of healthy planting material
- ✓ Balanced water supply and avoidance of overhead irrigation
- ✓ Avoidance of over-fertilization (with nitrogen)
- ✓ Removal of blossoms from young, non-bearing trees before opening (during dry weather and when no rain is expected over the next 24-48 hours)
- ✓ Adequate control of pests that may damage shoots, fruits or woody parts
- ✓ Application of anti-hail nets (to reduce damage to different plant parts)
- ✓ Proper pruning, and removal and destruction of infected plant parts (notes: pruning should be avoided during wet weather or when severe weather, e.g. hail or heavy rain is expected in the next 24 hours;cuts during pruning should be made 30-40 cm below the visible end of the expanding canker, and pruning tools must be disinfected with alcohol or 10 percent bleach by dipping the tools in either of the solutions between cuts)
- ✓ Use of (pruning) wound paints
- ✓ Use of the beneficial microorganisms *Aureobasidium pullulans*, *Bacillus subtilis*, *Pantoea agglomerans*or *Pseudomonas fluorescens* in preventive biological control of fire blight

Chemical control

- ✓ Considering the limited possibilities of chemical control, the significance of non-chemical control methods in disease management must be emphasized.
- ✓ Chemical control is not effective if carried out after symptoms appear.
- ✓ In the case of using chemicals, the prevention of blossom infection is paramount in fire blight control.
- ✓ Copper-based bactericides are effective but careful application is needed as they may cause chemical burn to the tissues of host plants.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Fusarium ear blight (scab)

Head

Head

Symptoms

Head (ear):
diseased spikelets exhibit premature bleaching as the pathogen grows and spreads within the head; later, the bleaching may progress throughout the entire head; under warm and moist conditions, a salmon-pink to red fungal growth may be seen along the edge of the glumes or at the base of the spikelet; later in the season, spikelets may become speckled as a result of the development of bluish black spherical fungal bodies, giving the "scabbed" appearance (such fungal bodies are commonly associated with heads infected with *G. zeae* (syn. *F. graminearum*); grains shrivel and discolour (ranging from pale pink, soft grey to light brown in colour)

Important note: different symptoms may occur even on the same host plant species, depending on the causal organism(s), soa specialist should be requested for the exact identification of the species involved in the disease complex concerned.

Host plants:

Wheat and other cereals

Biology

The disease complex, often affecting wheat and other cereals, has been associated with more than ten causal organisms belonging to different taxonomic groups of fungi such as *Fusarium*, *Gibberella* and *Monographella*. However, in hotter regions of the world, including Central Europe, *G. zeae* (syn. *F. graminearum*) is generally regarded as the most important species causing the disease. The *Fusarium* species, which infect cereals, are capable of surviving saprophytically on crop debris. According to some information, probably the most obvious source of inoculum for the development of an ear blight epidemic arises from *Fusarium* foot rot in a growing cereal crop, although the relationship between that and *Fusarium* ear blight still needs further research. The mode of dispersal of inoculum to ears still needs to be investigated, but contaminated arthropod vectors, systemic fungal growth through plants, wind and rain-splash dispersal of spores have been proposed. Infection of wheat ears has been shown to occur mainly during anthesis. Moderately warm and moist conditions have been shown to be generally required for the development of the disease. Besides causing direct economic damage, *Gibberellazeae* (as well as many other related species) produces mycotoxins that pose a significant threat to the health of domestic animals and humans.

Monitoring

Monitoring weather conditions and plant growth may help growers predict, or at least prepare for epidemics. Extended periods of high moisture or relative humidity and moderately warm temperatures present around the time of anthesis (flowering) may lead to major infections and the optimal development of *Fusarium* ear blight. Disease forecasting models have been developed and may be used once adapted to the local conditions.

Control in the open field

Prevention and non-chemical control

- ✓ Adequate crop rotation (by avoiding cereals, including maize, amongst the rotational crops)
- ✓ Removal and destruction of plant debris by stubble shelling and deep autumn ploughing
- ✓ Provision of a high level of plant vigour by appropriate, balanced fertilization and irrigation
- ✓ Use of cultivars that are less susceptible to the disease

Chemical control

- ✓ Seed treatment (seeds dressed with appropriate fungicides)
- ✓ Spray applications around the period of anthesis (flowering) of wheat may provide some control of the disease.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Grey mould of strawberry

(*Botrytis cinerea*)

Symptoms

Flower:
flowers turn brown, wilt, dry, and die; they may become covered with grey, powdery fungal spores (conidia) in humid conditions

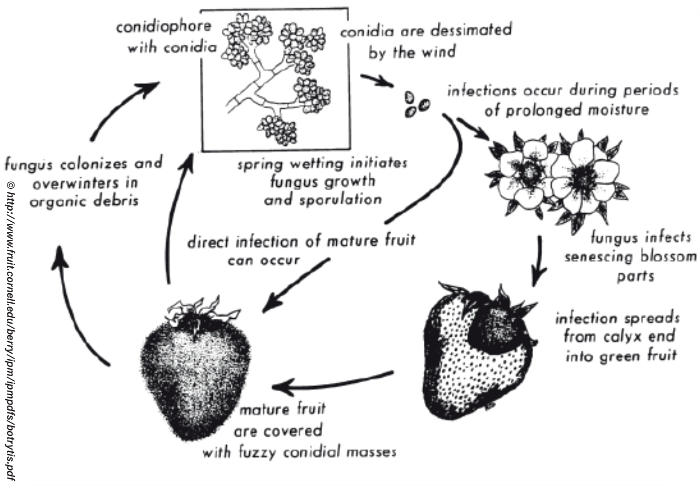
Fruit:
symptoms start as a discoloration(browning) and typically at the calyx end if infection has taken place during bloom; on mature but previously not infected fruits, browning may start at wounds or at any points where the fruit comes into contact with the soil, already rotting fruits or dead leaves; infected berries shrivel, dry and eventually form a "mummy"; the fruit is covered with grey, powdery fungal spores; small, black, fungal bodies (sclerotia) are formed on mummified fruits

Host plants:

Over 200 (mainly dicotyledonous) plant species, including strawberries

Biology

The fungus overwinters in the form of many tiny, black, resting structures (sclerotia) and as mycelium in plant debris (e.g. infected leaves and rotten and mummified fruits) in and around the growing area. In the spring, sclerotia and mycelium produce large numbers of spores (conidia). Wind, water splash and human activity spread the conidia throughout strawberry plantations, depositing them on practically all aerial plant parts, including blossoms and fruits. Spores germinate when a film of moisture is present, and infection can occur within a few hours. Temperatures between 15-20°C and free moisture on plants from rain, dew, fog, or overhead irrigation are suitable conditions for disease development. Strawberries are susceptible to the pathogen during bloom and again as fruits ripen. Most fruit infection actually occurs during bloom; however, symptoms usually do not develop until close to harvest. During bloom, the fungus colonizes healthy or older flower parts, often turning the blossoms brown. These blossom infections establish the fungus, but infections generally remain latent in young, developing (green) fruits until they start to mature, at which time the characteristic symptoms (rot) appear. Grey, powdery conidia that cover the diseased fruits are easily dispersed by wind and splashing water to other fruits, where they can cause additional infections. Healthy, mature fruits may also become if they come into direct contact with rotten fruits. Humid weather conditions in the harvest period increase the risk of infections. On healthy fruits contaminated with spores at harvest, fruit rots with the grey fungal cover can develop during the post-harvest period (storage and sale).



Monitoring

Monitoring of weather conditions is particularly important during bloom and harvest and/or in fields where there is dense foliage. The role of prevention (actions taken before infections occur and/or symptoms appear on plants) is especially important in grey mould control.

Control in the open field and in the storehouse

Prevention and non-chemical control

- ✓ Establishing new plantations in well-drained sites with good air movement
- ✓ Adequate design of strawberry plantations (e.g. proper plant spacing within and between rows;orienting the rows in the direction of prevailing winds) and any practices applied during growing (e.g. weeding) and storage to enhance air circulation
- ✓ Laying of straw mulch (or other materials, e.g. polyethylene sheets) between rows or around plants to help reduce fruit contact with the soil as well as to control weeds
- ✓ Use of cultivars that are less susceptible to the disease
- ✓ Avoidance of overhead irrigation (and water splash in general) by applying drip irrigation and of handling of plants when the foliage is wet
- ✓ Avoidance of over-fertilization (with nitrogen)
- ✓ Avoidance of / minimizing any types of injury to the fruits during growing and storage (e.g. by proper control of pests, and by careful picking and handling of harvested berries)
- ✓ Proper timing of harvest (i.e. fruits should be picked in time to prevent them from becoming overripe on plants, and also mature berries should be harvested promptly if wet weather is prevalent in the field during ripening)
- ✓ Removal and destruction of infected fruits during field practices, packing and storage
- ✓ Removal and destruction of plant debris
- ✓ Refrigeration of harvested fruits promptly at 0-10°C
- ✓ Growing strawberries in plastic tunnels
- ✓ Use of *Bacillus subtilis* in biological control

Chemical control

- ✓ Fungicides are an important disease management tool, but are generally not effective unless they are timed properly and used in conjunction with the practices mentioned above.
- ✓ The most critical period for applying fungicides to control grey mould is during bloom.
- ✓ Grey mould can usually be controlled with two well-timed fungicide applications during bloom. The first application should be made at early (ca. 10-20 percent) bloom followed by another, close to the end of bloom (ca. 80 percent of flowers over bloom). During prolonged bloom and/or under wet conditions, additional sprayings may be necessary during flowering and/or fruit development (note: the time of harvest must be considered strictly before choosing and applying fungicides for treatments). On the other hand, dry and hot periods may make chemical control of grey mould unnecessary.
- ✓ Good coverage is essential for adequate grey mould control.
- ✓ Anti-resistance strategies should be applied to maintain the effectiveness of available fungicides.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

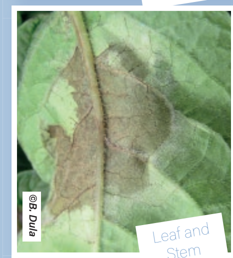
Late blight of potato

(Phytophthora infestans)

Symptoms

Leaf and stem:
at first, small, water-soaked lesions or lesions with chlorotic borders appear, which rapidly expand and turn brown and necrotic; under humid conditions, a white fungal growth (sporangia) will appear at the leading edge of lesions on the underside of the leaves or on the infected stems; the lesions may coalesce leading to the quick death of the whole plant

Tuber:
shallow, brownish or purplish lesions appear on the surface; a reddish brown, dry, granular root extending into the flesh to some extent may be seen in cut tubers; under humid conditions, a white fungal growth will appear on the surface; infected tubers may be invaded by soft rot bacteria



Host plants:

Potato, tomato and other species of Solanaceae

Biology

If potato tubers are left behind after harvest (or dumped at the edges of fields), the fungus can overwinter as mycelium in infected tubers, and produce sporangia on the tubers or new sprouts in the spring. Sporangia are carried by the wind to the foliage of healthy plants. Under cool and wet conditions, sporangia produce zoospores that can infect the host plants via natural openings and the epidermis. Several days after infection, new sporangia are formed on sporangiophores emerging from stomata of the plant, and these sporangia may be further dispersed by wind and water. Sporangia may also be washed in the soil,where they can infect potato tubers generally via cracks, eyes or lenticels. For sporulation, optimal conditions are18-22°C and >90 percent relative humidity. Infections may become severe and even 100 percent of the plants may be destroyed within a short period with cool nights and warm days with extended wet conditions. The development of the pathogen and further infections may take place if harvested tubers, including infected ones, are stored in inappropriate (i.e. too humid) conditions.

Monitoring

Monitoring should be started as soon as foliage(green tissue) emerges in the field. Scouting for symptoms should be carried out first at sites where plants are expected to remain wet for prolonged periods (e.g. parts of the field lying low and/or close to woods, hedgerows, dense crops or any features that might shade potato plants). Recording actual temperature, relative humidity and rainfall data as well as following information of local weather forecasts may help growers assess the risk of infections during the growing season and plan fungicide applications accordingly. Several forecast systems (e.g. Blitecast) have been developed, and they can be used in late blight management once validated under local conditions.

Control in the open field and in the storehouse

Prevention and non-chemical control

- ✓ Establishing new potato fields in well-drained sites with good air movement
- ✓ Avoidance of fields bordered by woods or dense vegetation
- ✓ Appropriate crop rotation (and keeping adequate isolation distances from alternate host crops possibly infected by the disease)
- ✓ Removal and destruction of any alternate non-commercial host plants (weeds belonging to the family Solanaceae)
- ✓ Use of cultivars that are less susceptible to the disease
- ✓ Use of healthy (certified) seed tubers
- ✓ Hilling (to help weed control and hence decrease humidity, and to minimize tuber infections by sporangia washed off the foliage)
- ✓ Optimizing the time of irrigation to prevent leaves from remaining wet for extended periods (i.e. irrigation should not be carried out early morning, late afternoon or early evening)
- ✓ Avoidance of over-fertilization (with nitrogen)
- ✓ Removal and destruction of all plant residues after harvest (e.g. by burying them at least 1 m deep in the ground) and elimination of volunteer plants in the spring
- ✓ Selecting and destroying damaged tubers before/during storage
- ✓ Provision of adequate conditions (e.g. appropriate ventilation) during storage
- ✓ Use of *Bacillus subtilis* in biological control (both in the field and during storage)

Chemical control

- ✓ The application of fungicides is important in late blight management, particularly in humid areas and/or under cool and rainy weather conditions.
- ✓ Timing of sprayings based on adequate monitoring, weather forecast, and the proper use of fungicides as well as good coverage are key factors of successful control.
- ✓ Chemical control is not effective if carried out late after severe infections.
- ✓ There are many fungicides available on the market for the control of late blight of potato, but anti-resistance strategies should be applied to maintain the effectiveness of chemical pesticides.
- ✓ Desiccation of foliage with adequate herbicides prior to harvest may help prevent tubers from possibly becoming infected by the pathogen during harvest.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Leaf curl of peach

(Taphrina deformans)

Symptoms

Leaf:
the most common symptoms occur on leaves: they become deformed (puckered, thickened and curled) and discoloured (ranging from light green and yellow to shades of red and purple); a greyish, dusty fungal growth (naked asci) appears on the surface; later, the leaves turn brown, shrivel, and drop from the tree; in the cases of severe infections, all leaves on shoots may show the symptoms, the stem of the shoot may become swollen and stunted, and the shoot may die

Fruit:
it may become discoloured and bear deformities with a greyish, dusty fungal growth; severely infected fruits may drop early

Leaf

Leaf

Fruit

Host plants:

Peach, nectarine, almond

Biology

The fungus overwinters as blastospores in crevices of the bark and on/around buds of the tree. The overwintered spores are washed into the buds by rain (or irrigation). Primary infections are the most damaging. These occur during early spring from bud swell, when the bud scales loosen, until the full emergence of the first young leaves from the bud. Relatively low temperatures (10-21°C)and humid conditions are suitable for the infection. The pathogen can develop at temperatures as low as 4°C. Only young plant tissues are susceptible to infections, so if no spore germination occurs at bud break, then little damage results for that year. Secondary infections may take place during periods of wet, cool weather. Spores can remain inactive for several years on the tree until conditions are right for infection to occur.

Monitoring

Weather conditions should be monitored so that the grower can assess the risk of infection in the given year. Scouting for symptoms in the spring is done largely for the purpose of assessing the effectiveness of the control programme applied as well as for planning for next season.

Control in the orchard

Prevention and non-chemical control

- ✓ Avoidance of low-lying lands with frost pockets when establishing new orchards
- ✓ Improving air circulation (e.g. by adequate spacing of plants and proper pruning)
- ✓ Use of cultivars less susceptible to the disease
- ✓ Balanced water supply and avoidance of overhead irrigation
- ✓ Avoidance of over-fertilization (with nitrogen) (note: extra fertilization may be needed to stimulate new growth that can compensate for the leaf loss caused by the disease)
- ✓ Removal and destruction of infected plant parts when pruning

Chemical control

- ✓ The application of copper-based fungicides before bud swell in the spring (to reduce the number of overwintering spores) is essential in peach leaf curl control programmes.
- ✓ During the vegetation period, copper hydroxide should be sprayed at bud burst of buds on shoot ends (but when the lower buds are still at the bud swell stage), and further (generally 2-3) applications with other types of adequate fungicides should be carried out in the spring, depending on the weather conditions (note: in the early period with high risk of infection, sprayings repeated at intervals of more than a week may result in lower efficiency of disease control).
- ✓ Chemical control is not effective if carried out following the appearance of symptoms.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Loose smut of wheat

(Ustilago tritici)

Symptoms

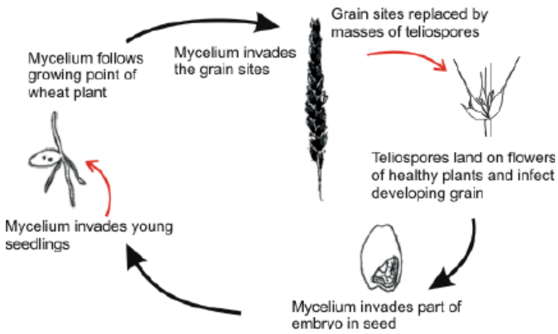
Head (ear):
black, powdery spore masses appear in place of the grains

Host plants:

Wheat and some other species of Poaceae

Biology

During flowering, wheat plants become infected by wind-blown spores of the fungus originating in diseased heads of nearby plants. Once the spores have been deposited on open flowers, they soon germinate. The mycelium that forms penetrates the ovary and reaches the embryo of the developing seed. After colonizing the embryo of the kernel, the mycelium of the fungus becomes dormant. Infected kernels do not seem different in appearance from healthy ones. When infected kernels sown germinate, the pathogen becomes active again, and it expands toward the growing point of the plant. At the time of head formation, the whole young head, except the rachilla, is invaded. Later, teliospores will be formed,and the head produced by the infected plant will contain black teliospore masses in place of the grains, resulting in the rachis becoming barren. The spores are easily spread by wind, and infect flowering wheat plants. Relatively cool and humid weather conditions are favourable to the development of the pathogen.



https://cereals.ahdb.org.uk/cereal-disease-encyclopedia/diseases/loose-smut.aspx

Monitoring

Symptoms of the disease can be recognized easily in the field. It is important to note that infected heads often emerge from the boot a bit earlier than those of healthy plants.

Control in the open field

Prevention and non-chemical control

- ✓ Use of healthy (certified) seeds
- ✓ Growing resistant cultivars or varieties less susceptible to the disease
- ✓ Use of the growth-enhancing liquid nutrient seed treatment Awaken ST for better plant health and vigour

Chemical control

- ✓ Seed treatment (seeds dressed with appropriate systemic fungicides) is necessary if seeds originating in infected fields were used for sowing.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Powdery mildew of grapevine

Powdery mildew of grapevine

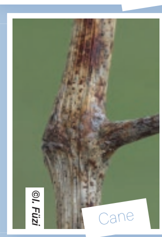
(Erysiphe necator)

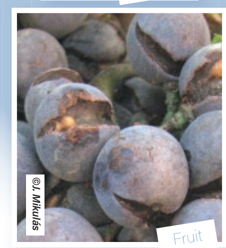
Symptoms

Leaf/shoot:
dusty appearance or white or greyish white powdery fungal growth (mycelium and conidia)in patches on the surface (on both surfaces in the case of leaves); when young, expanding leaves are infected, they may become distorted and stunted; severely affected leaves may curl upward, dry out and drop; dark brown to black blotchy lesions form on diseased shoots; later, small, brown-black, spherical fungal bodies (chasmothecia) appear on the surface

Cane:
brown patches on the surface of dormant canes (symptoms of former infections of the shoots)

Fruit:
white or greyish white powdery fungal growth on the surface;infected berries often are misshapen or bear rusty spots; severely diseased fruit may split open, often making the green flesh and seeds visible; if berries of purple or red cultivars become infected during ripening, they fail to colour properly, resulting in a blotchy appearance at harvest;later, small, brown-black, spherical fungal bodies appear on developing fruits



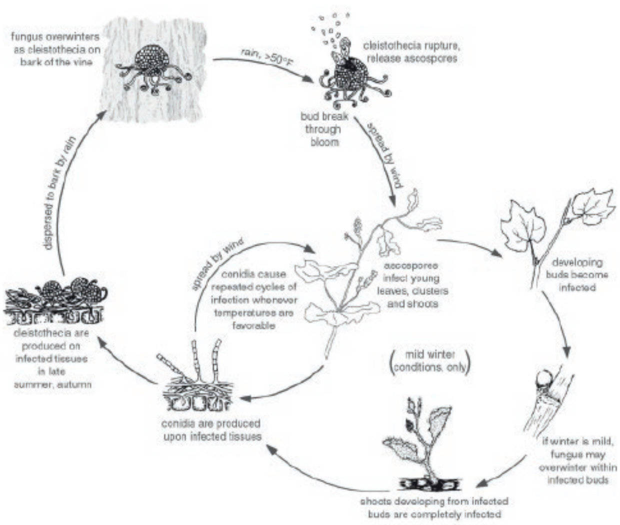


Host plants:

Grapevines

Biology

The fungus can overwinter as fruiting bodies (chasmothecia, also called cleistothecia) either on plant debris (infected fallen leaves and fruits) or in bark crevices on grapevines, or as mycelium in dormant buds of the host. The latter can occur if temperatures do not fall below -15°C for prolonged periods during winter. In the spring, ascopores released by chasmothecia and conidia forming on the mycelium covering the emerging diseased shoots can infect the developing green tissues. Infection by ascospores takes place if temperatures are at or above 10°C and there is 2.5 mm of rain (or overhead irrigation). However, even if there is no rainfall, heavy dews and prolonged dense fog that can provide a sufficient wetting duration may lead to infections. Ascospore infections appear as random colonies distributed throughout the vineyard, largely confined to the lower surface of basal leaves. Later in the vegetation period, conidia formed on mycelium and spread by wind can cause repeated infections, which may become severe especially in mild temperatures (around 25°C)coupled with high levels of relative humidity (approx. 85 percent). Low, diffuse light also encourages powdery mildew development. The presence of free water, however, is detrimental to the survival of conidia. Chasmothecia are produced on affected plant surfaces in the second part of the growing season.



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Monitoring

Symptoms of the first infections of the season (primary infections) caused by ascospores are small and inconspicuous, usually occurring on small leaves near the trunk of the grapevine where chasmothecia had overwintered. Pertinacious scouting for these symptoms, sometimes requiring the inspection of hundreds of leaves, is necessary so that early infections can be revealed in time. Weather stations are commercially available and can be set to help determine when conditions are suitable for infections by ascospores to occur. Furthermore, the incidence of diseased shoots emerging from infected buds should also be checked.

According to some interesting observations, grapevine powdery mildew control should be initiated when first symptoms of powdery mildew of rose (*Podosphaera pannosa*) appear on roses planted in the vicinity of the vineyard.

Later in the season, monitoring should be continued, taking into consideration that mild temperatures with high relative humidity encourage powdery mildew development.

Control in the vineyard

Prevention and non-chemical control

- ✓ Establishing new vineyards in well-drained sites with good air movement (e.g. by orienting the rows in the direction of prevailing winds)
- ✓ Use of cultivars that are less susceptible to the disease
- ✓ Proper pruning of grapevines, thinning of shoots (prior to bloom) and fruit-zone leaf removal (early in the period of peak fruit susceptibility) to increase air circulation and to render the crop more accessible to fungicides
- ✓ Avoidance of overhead irrigation
- ✓ Avoidance of over-fertilization (with nitrogen)
- ✓ Adequate weed control (to decrease humidity)
- ✓ Removal and destruction of plant debris (e.g. by burying them in the ground)
- ✓ Use of *Ampelomyces quisqualis* in biological control

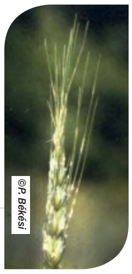
Chemical control

- ✓ The control of the disease is largely based on chemical methods, although non-chemical cultural practices are important to apply to help prevent severe epidemics.
- ✓ Exact timing of sprayings based on adequate monitoring, the proper use of fungicides (preventive/protectant and curative) and good coverage are key factors for successful control.
- ✓ In general, sprayings may be required from as early as early shoot growth, and should not be delayed beyond the immediate pre-bloom stage. Fungicide applications depend on the disease levels in the previous year, the incidence of emerging diseased shoots, the rate of shoot development, and the weather conditions. The most critical period of control is from the immediate pre-bloom stage (rachis elongation) through four weeks post-bloom (three weeks post-fruit set). During this time, repeated treatments (depending on the weather conditions) with fungicides containing different active ingredients of systemic and contact properties should be carried out. Later in the season, control should be continued with contact fungicides, taking into consideration the weather conditions as well as the time of harvest.
- ✓ Sulphur is hardly effective if applied at low temperatures, while it may cause chemical burn to plant tissues if sprayed above 25°C. Moreover, it is phytotoxic on some varieties; hence its use should be avoided in these cases throughout the vegetation period. Wine grape varieties should not be treated with sulphur-based fungicides within about a month prior to harvest as sulphur may have an adverse effect on wine quality.
- ✓ There are many fungicides available on the market for the control of powdery mildew of grapevine, but resistance to many of them has become established. Therefore, anti-resistance strategies should be applied to maintain the effectiveness of chemical pesticides.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Powdery mildew of wheat

(Blumeriagraminis f. sp. tritici)



Symptoms

Leaf/stem/head (ear):
white, cottony patches (mycelium and conidia) on the surface; individual patches often merge and cover large areas of the stem, leaf surface, or head; later,the patches turn grey-brown, and small, brown-black, spherical fungal bodies (chasmothecia) form in the mycelium mass; the underside of the leaf corresponding to the mycelial mat will show chlorosis, later browning; symptoms progress from lower to upper leaves; severe infections may lead to stunting of wheat plants

Leaf/stem/head

Leaf/stem/head

Host plants

Wheat and some other species of Poaceae (note: the powdery mildew of cereals B. graminis has evolved into several forma especiales, and each of them specifically infects certain host species)

Biology

The fungus can overwinter as mycelium and conidia on winter shoots of wheat. Ascospores, produced by fruiting bodies (chasmothecia) that survive on plant debris, can also be sources of infections in the spring. Conidia and ascospores are carried by the wind to healthy plant tissues. After infection has taken place, mycelium soon starts to grow on the plant surface. Symptoms of powdery mildew are most common on leaves but they may appear on all aerial parts of the plant. During the vegetation period, conidia produced regularly by the fungus on mycelium developing on living plant tissues will initiate further infections of the main crop or volunteers. Cool weather (15-22°C) and high relative humidity (but not free water on the plant surface) are favourable for development of the pathogen. Ascospores released by chasmothecia, which become fully developed by the summer and are able to survive on plant debris after harvest, can infect volunteers and new winter wheat crops. The earlier in the spring powdery mildew begins to develop on the plant and the higher on the plant it develops by flowering, the greater the yield loss will be.

Monitoring

Mild temperatures, high relative humidity and dense wheat stands encourage the development of powdery mildew. Therefore, scouting for symptoms is highly recommended under these conditions, and should be concentrated on the period from tiller elongation through flowering stages of growth. Symptoms are generally most prevalent on the upper side of lower leaves of susceptible varieties.

Control in the open field

Prevention and non-chemical control

- ✓ Avoidance of low-lying, humid lands for growing
- ✓ Appropriate crop rotation (and the elimination of volunteer plants) as well as keeping adequate isolation distances from other wheat stands
- ✓ Stubble shelling and deep autumn ploughing
- ✓ Weed management and removal of alternate host species
- ✓ Growing resistant cultivars or varieties less susceptible to the disease (note: the use of seed mixtures of cultivars with different levels of resistance has been shown to hinder the spread of the disease)
- ✓ Optimizing seeding rates (to avoid the formation of dense stands)
- ✓ Late sowing in the autumn
- ✓ Avoidance of frequent and light irrigations
- ✓ Avoidance of over-fertilization (with nitrogen)

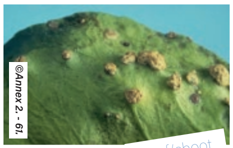
Chemical control

- ✓ Depending on the results of scouting, adequate fungicides can be applied in the period described above to prevent epidemics. It is important to keep the top two leaves of the plant as free of the disease as possible so that the plant can use its full potential to fill the grain.
- ✓ Fungicides can be applied based on the level of disease in the field, the known susceptibility of the variety, the weather forecasts favourable to disease development, and the sale price of the grain.
- ✓ There are many fungicides available on the market for the control of powdery mildew of wheat, many of them have become resistant. Therefore, anti-resistance strategies should be applied to maintain the effectiveness of chemical pesticides.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

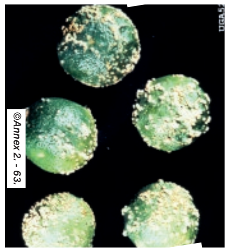
Scab of citrus

(*Elsinoë fawcettii*)

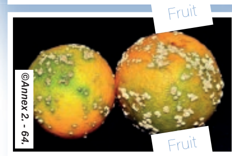


Leaf/shoot

Leaf/shoot



Fruit



Fruit

Symptoms

Leaf/shoot:
lesions on young leaves begin as minute water-soaked spots which subsequently evolve into amphigenous, creamy-yellowish or variously bright-coloured pustules; these grow as irregular, globose or conical excrescences which coalesce and extend mostly along the main veins to cover a large part of the blade, particularly on the lower surface; the central area of these wart-like outgrowths is depressed and becomes drab, greyish and velvety when the fungus is fruiting; old scab lesions have a rough surface, are dusky-coloured and become cracked; affected leaves become stunted, malformed, wrinkled or puckered, with irregular torn margins; defoliation may occur;
warty lesions and corky eruptions may be formed on young twigs, tender shoots and stems of nursery plants which can grow bushy and stunted

Fruit:
fruits are infected in the early stages of their development, grow misshapen and are subject to premature fall; on the rind of developed fruits, raised lesions are formed with different a shape, size and colour depending on the species and cultivar affected; they appear as scattered protuberances, conical projections or crater-like outgrowths or they coalesce to give scabby patches or extensive areas of fine eruptions; scabs are typically irregular, warty and deeply fissured; scabs do not extend to the flesh

Note: symptoms caused by the scab of citrus described above may be confused with those of other diseases such as bacterial canker and melanose, or with injuries caused by various agents

Host plants:

Citruses(e.g. sour orange, lemon and grapefruit)

Biology

The pathogen survives on diseased leaves, twigs and fruits within the tree canopy and in citrus plant debris. New infections are initiated by conidia from scabs formed on the mentioned plant parts as well as on shoots of susceptible rootstocks. Conidia are produced abundantly on wet scabs under highly humid conditions and at 20-28°C. Spores of the fungus are primarily spread by splashing water (e.g. rain, overhead irrigation), but other means of dispersal (e.g. by insects, or on infected planting material or fruit) may also occur. Germination of conidia and infection do not require free water; they may take place in the presence of dew, fog or high moisture. A wet period of a few hours and temperatures around 20°C are required for conidial infection to occur. A similar temperature is favourable for the development of the pathogen. Leaves, shoots and fruits may become infected when they are young (i.e. when leaves are up to 15 mm wide and fruits are less than 20 mm in diameter). In citrus orchards, the pathogen affects mostly sour oranges and susceptible cultivars of lemons, mandarins, tangelos and grapefruits. Severely infected fruits are scarred and distorted, and consequently become unmarketable. The disease is particularly serious in the nursery on susceptible rootstocks such as sour oranges or rough lemons. It may stunt seedlings or make them bushy and difficult to bud.

Monitoring

The disease may cause a problem if new flush and fruit setting coincide with spells of relatively warm and humid weather. Damp, low-lying lands with dense, shaded citrus orchards consisting of susceptible citrus species and cultivars are at increased risk of infection. In areas with limited annual rainfall (less than 1 300 mm), long-lasting hot seasons (mean monthly temperature above 24°C) or dry summers, the disease is not a problem. The regular monitoring of local weather conditions and plant growth of the species and cultivars grown may help the grower assess the risk of the disease and plan management tactics accordingly.

Control in the open field

Prevention and non-chemical control

- ✓ Avoidance of low-lying lands when establishing new orchards/nurseries
- ✓ Proper design of orchards/nurseries and pruning to enhance air circulation (and improve spray application efficiency)
- ✓ Use of resistant cultivars or varieties less susceptible to the disease
- ✓ Use of healthy planting material
- ✓ Avoidance of overhead irrigation (drip or micro-sprinkler irrigation should be introduced)
- ✓ Removal of shoots from below the graft as soon as possible
- ✓ Removal and destruction of dead wood and infected plant parts as well as of plant debris
- ✓ Laying down new mulch in spring to act as a barrier

Chemical control

- ✓ In general, two to three sprays with adequate fungicides (one at about a quarter expansion of the spring flush, the second at petal fall and the third about three weeks later)may give satisfactory results. However, the number of treatments needed is largely dependent on the weather conditions.
- ✓ Anti-resistance strategies should be applied to maintain the effectiveness of available fungicides.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Shot hole of stone fruit

(Stigmina carpophila)

Symptoms

Leaf:
round or slightly oval, a few millimetres across, purple to brown spots; the centre of the spots soon dry out and usually drop out from the leaf, giving the "shot hole" appearance

Shoot/twig:
oval, elongated, purplish brown lesions on shoots, often around diseased buds; the centre of the lesions is grey, often with a ruptured surface, on twigs; infected buds may die, as can stem portions (tips) if the lesion girdles the stem; exuded gum is often present at the lesions

Fruit:
round, purplish spots of a few millimetres across, later becoming raised, greyish and corky in the centre; lesions do not extend to the flesh;exuded gum is often present at the lesions

Leaf

Shoot/twig

Fruit

Host plants:

Stone fruits (e.g. apricot, peach, almond)

Biology

The fungus can overwinter in/on infected buds and lesions on woody parts of the host plants, as well as in infected plant debris (e.g. fallen leaves). Spores (conidia), produced in large amounts by springtime,are dispersed to healthy tissues by rain splash. Infection can easily take place under sustained moisture and at low temperatures. Therefore, rainy and cool springs pose a major risk of damage to the hosts. Although unsightly and often unmarketable, damaged fruits can be used for canning or consumption with more peeling losses.

Monitoring

Weather conditions should be monitored so that the grower can assess the risk of infection in the given year. Scouting for symptoms already present on leaves and fruits in the spring and early summer is done largely for the purpose of assessing the effectiveness of the control programme applied as well as for planning for next season. Nevertheless, the incidence of symptoms on twigs in the winter may call the grower's attention to the important sources of infection. Therefore,scouting during the dormant period may help the grower plan management tactics adequately.

Control in the orchard

Prevention and non-chemical control

✓ Avoidance of low-lying lands with frost pockets when establishing new orchards
✓ Use of cultivars less susceptible to the disease
✓ Adequate spacing of trees (to improve air circulation)
✓ Proper pruning (does not only increase air movement but also renders the plant more accessible to fungicides)
✓ Applying drip irrigation (or if the orchard is sprinkler irrigated, sprinkle heads should be angled low enough to keep from wetting the canopy)
✓ Avoidance of over-fertilization (with nitrogen)
✓ Removal and destruction of infected twigs when pruning
✓ Removal and destruction of plant debris (e.g. by burying them in the ground)

Chemical control

✓ The application of copper-based fungicides during the dormant season(before bud break)is essential in shot hole disease control programmes. In severe infections, it may also be recommended to apply a treatment at 50 percent leaf drop in autumn.
✓ During the vegetation period, the most critical period of infection (and thus control)starts at around first bloom and lasts until a few weeks after that. The timing and the number of sprayings largely depend on the weather conditions.
✓ A spreader sticker added to the tank mix can improve the efficiency of fruit protection.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

Stinking smut of wheat

(Tilletia caries, T. laevis)

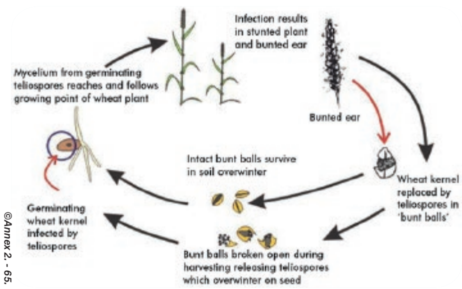
Symptoms

Head (ear):
infected plants may be stunted; after heading, the spikelets tend to "flare-out" and take on a greasy, off-green colour because of the expansion in size of the infected seeds that have become filled with black spores (teliospores); in cultivars that normally produce long awns, infected heads may have shorter awns, or even no awns; in place of normal seeds, infected kernels develop into "bunt (i.e. "burnt") balls", containing the black mass of teliospores within the intact seed coat; the spores released when the heads go through the combine harvester may appear as a cloud of dust (in the cases of severe infections) and smell like stinking (rotting) fish

Host plants

Wheat and some other species of Poaceae

Biology



Black spores (teliospores) of the causal fungal agents formed in infected kernels and released when the heads go through the combine harvester can overwinter on the surface of healthy seeds or in the soil. They can remain viable for many years. The two *Tilletia* species have the same life cycle. Cool (approx. 5-10°C) and moist soil conditions encourage infections. As the infected plant grows, the fungus also grows internally within the shoot. Just when the head is formed, the pathogen invades the newly developed seeds. Eventually the fungus replaces the cells of the seeds, forms teliospores, and leaves only the seed coat intact. Healthy seeds may become contaminated when harvested together with diseased wheat and/or when sown in soils to where released teliospores have been spread by the wind.

Monitoring

Symptoms of the disease can be recognized in the field during heading. The earliest evidence of infection occurs shortly after ovaries would normally be pollinated. Infected ovaries appear greasy with a dark green cast. When squeezed, such ovaries reveal a mass of black spores (teliospores) that smell like rotting fish. As the heads and kernels mature, the "bunt balls" develop into a hardened mass that looks like miniature footballs.

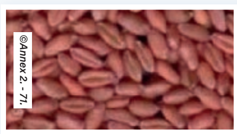
Control in the open field

Prevention and non-chemical control

- ✓ Use of healthy (certified) seeds
- ✓ Growing resistant cultivars or varieties less susceptible to the disease
- ✓ Use of clean machinery
- ✓ Stubble shelling and deep autumn ploughing
- ✓ Seeding winter wheat early autumn, or seeding spring wheat late spring (i.e. when the soil temperature is above 20°C, which is not optimal for infection)
- ✓ Use of skim milk powder (to provide some control of the disease)
- ✓ Use of the growth-enhancing liquid nutrient seed treatment Awaken ST for better plant health and vigour

Chemical control

- ✓ Seed treatment (seeds dressed with appropriate fungicides) is currently the most widespread and most effective method for controlling Stinking smut of wheat.



ⓘ **Always follow the label instructions for the dosage, application and safety!**

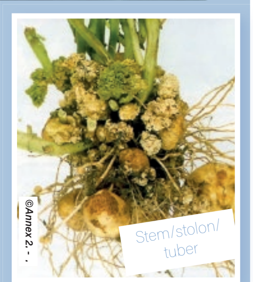
Wart of potato

(Synchytrium endobioticum)

Symptoms

Stem/stolon/tuber:
large, warty galls on the stem base, stolon buds and tuber eyes; these below ground galls are white to brown, turning black as they begin to decay; tubers may be disfigured or become almost unrecognizable if infected early in development and replaced by galls

Note: Symptoms associated with the wart of potato may appear similar to some of the symptoms caused by other pathogens or further factors. Therefore, laboratory confirmation is needed to identify the presence of S. endobioticum.



Host plants

Potato

Biology

The fungus overwinters as resting sporangia in decaying warts and soil. These resting structures can remain viable for decades at depths of up to 50 cm in the ground. In the spring, zoospores are formed, which can move in soil water for a limited distance (max. a few centimetres) and infect susceptible host tissues. Infection eventually results in the appearance of warty galls. During the disease cycle, resting sporangia are also produced. They may be responsible for long distance dispersal via infected seed tubers (which may have incipient warts that pass undetected), contaminated soil (e.g. adhering to tubers or equipment), soil-dwelling animals, manure, wind-blown soil or flowing surface water. Cool and wet soils during tuber development are favourable to the pathogen. Cool summers with average temperatures of 18°C or less, winters of approximately 160 days at or below 5°C, and annual precipitation of 700 mm are important for the development of the disease, which is generally limited to environments with these characteristics.

Synchytrium endobioticum is considered to be the most important world-wide quarantine plant pathogen of cultivated potatoes. Resting sporangia released from infected tissues can render the soil unsuitable for potato production for decades. (Note: Although infected tubers may become disfigured or even unrecognizable, they do not pose any threat to human health if consumed.)

Monitoring

As symptoms on aerial plant parts are usually not apparent, it is necessary to take samples of plants and examine the occurrence of the symptoms on tubers (stolons).

Control in the open field

ⓘ **Important note: *Synchytrium endobioticum* is currently on the A2 quarantine list of EPPO!**

Prevention and non-chemical control

- ✓ Long crop rotation
- ✓ Establishing new potato fields in well-drained sites
- ✓ Use of healthy (certified) seed tubers
- ✓ Use of resistant cultivars or varieties less susceptible to the disease
- ✓ Use of clean machinery
- ✓ Removal and destruction of all plant residues after harvest

Chemical control

- ✓ There are no chemical control methods available.

Wilt of pepper

Symptoms

Shoot/leaf:
wilting; by cutting the stem, brown streaks in the vascular tissue may be observed; dark brown, sunken, and eventually girdling cankers may be seen at the base of the plant

Important note: as similar symptoms may be initiated by different pathogens, which may give rise to confusion, for the exact identification of the causal organism(s) a specialist should be requested

Biology

Wilt of pepper may be caused by several fungal organisms, e.g. *Fusarium* and *Verticillium* species. The latter pathogens can survive in the soil for a long time and can infect the host at any stage of development. The wilt organisms usually enter the plant through young roots. They get into the water conducting vessels of the roots and stems, and restrict the water transport to leaves. With a limited water supply, leaves may begin to wilt on sunny days and recover at night. Wilting may first appear in the top of the plant or in the lower leaves. As the disease progresses, the entire plant may be affected (e.g. wilted, stunted) and may eventually die. The pathogens may be spread by contaminated soil, tools and equipment during cultural practices.

Monitoring

Any suspect plants should be revealed as soon as possible based on scouting for symptoms throughout the vegetation period. See also note at Symptoms. The incidence of the disease should call the attention of the grower to take steps to prevent the fungi involved in the problem from spreading further.

Control in the open field and in the greenhouse

Prevention and non-chemical control

- ✓ Long crop rotation (4-6 years), with cereals if feasible, to reduce populations of these fungi, and keeping rotational crops weed-free
- ✓ Provision of a high level of plant vigour by appropriate fertilization and irrigation
- ✓ Removal and destruction of infected plants (also at transplanting) and plant debris
- ✓ Proper sanitation in greenhouses
- ✓ Disinfection of tools and equipment (tables, trays, containers etc.) with a solution of bleach
- ✓ Optimizing the time and method of irrigation and ventilation
- ✓ Soil solarization by applying transparent plastic sheets for several weeks, depending on the local and actual temperature conditions, to reduce populations of the pathogens
- ✓ Steam sterilization of the soil in the greenhouse. (Note: sterilization will kill not only the pathogens but also the beneficial organisms; hence recontamination of the sterilized soil by pathogenic species may occur soon in the case of the lack of proper hygiene in the greenhouse.)
- ✓ Use of beneficial organisms such as *Bacillus subtilis*, *Burkholderia cepacia*, *Trichoderma* or *Streptomyces*, depending on the pathogenic species involved, in biological control

Chemical control

- ✓ The use of soil fumigants may provide satisfactory control but should not be preferred due to environmental and other concerns.

ⓘ **Always follow the label instructions for the dosage, application and safety!**

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Annex 1

ENVIRONMENTAL AND SOCIAL MANAGEMENT GUIDELINES

+ Environment and Social Standard 5 (E&SS5) + E&SS5 : Pest and Pesticide Management

Online: http://www.fao.org/environmental-social-standards/en/

Introduction

E&SS5 defines pesticides as any substance, or mixture of substances of chemical or biological ingredients intended for repelling, destroying or controlling any pest[1], or regulating plant growth.

E&SS5 recognizes that pesticides can contribute to effective crop and food protection during production and in storage. Pesticides are also used in forestry, livestock production and aquaculture to control pests and diseases. At the same time pesticides are designed to be toxic to living organisms, are intentionally dispersed in the environment and are applied to food crops.

It recognizes that exposure to pesticides poses risks to the people who use them, to others nearby, to consumers of food and to the environment. Risks are often elevated by overuse or misuse. Many countries also lack effective regulatory control thereby compounding problems.

ES&SS5 follows the guidance on the life-cycle management of pesticides as provided by the International Code of Conduct on Pesticide Management[2] and its supporting technical guidelines that are drawn up by a FAO\WHO expert panel and expand on specific articles.

Objectives

The primary objective is to promote sustainable agriculture through Integrated Pest Management, reduce reliance on pesticides and avoid adverse impacts from pesticide use on the health and safety of farming communities, consumers and the environment during and after the project life-cycle. Pesticide can be part of that. If so, their use needs to be managed carefully.

Scope of application

The applicability of E&SS 5 is determined during environment and Social screening and applies to any FAO supported activity that provides or facilitates the use or the disposal of pesticides in any quantities.

Include the application of subsidies, voucher schemes or incentives for the provision of pesticides as well as direct provision of pesticides, and the indirect provision as treatments on seeds and other planting materials.

Applies to FAO activities that in an indirect manner may increase pesticides use, such as establishment of irrigation schemes, crop intensification, etc. ESS5 should also be triggered by any activities that require pesticides to be used or handled in projects, even if the pesticides were not supplied through the project.

1 A pest is defined as any species, strain or biotype of plant, animal or pathogenic agent injurious to plants and plant products, materials or environments and includes vectors of parasites or pathogens of human and animal disease and animals causing public health nuisance.

2 The International Code of Conduct on Pesticide Management, FAO/WHO 2014.http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Code/CODE_2014Sep_ENG.pdf

Requirements

General

FAO promotes Integrated Pest Management (IPM) as a pillar of sustainable agriculture- **IPM** means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human and animal health and/or the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

Pest Management Plan

If provision or use of large volumes of pesticides is foreseen, a Pest Management Plan (PMP) needs to be prepared to demonstrate how IPM will be promoted to reduce reliance on pesticides, and what measures are taken to minimize risks of pesticide use. Such a PMP needs to be an integral part of the Environment and Social Commitment Plan.

Selection of pesticides

If after having considered available IPM approaches, pesticide use is deemed to be justified, then careful and informed consideration should be given to the selection of pesticide products. Factors to be taken into account include **hazards and risks to users**, **selectiveness** and **risk to non-target species**, **persistence in the environment**, **efficacy** and **likelihood of development or presence of resistance** by the target organism. Minimum environment and social analysis are needed.

FAO does not maintain a list of permitted or non-permitted pesticides because many locally specific conditions govern which pesticides may be used. However, in line with the provisions of the FAO/WHO International Code of Conduct on Pesticide Management and relevant multilateral environmental agreements that include pesticides, the following list of criteria will need to be met in order for a pesticide to be considered for use in an FAO project:

The **product should be registered in the country of use**, or **specifically permitted by the relevant national authority if no registration exists**. Use of any pesticide should **comply with all the registration requirements** including the crop and pest combination for which it is intended.

Users should be able to manage the product within margins of acceptable risk. FAO will not supply pesticides that meet the **criteria that define Highly Hazardous Pesticides** (HHPs)[3]. Pesticides that fall in WHO Hazard Class 2 or GHS Acute Toxicity Category 3 can only be provided if less hazardous alternatives are not available and it can be demonstrated that users adhere to the necessary precautionary measures[4].

Preference should be given to products that are less hazardous, more selective and less persistent, and to **application methods that are less hazardous, better targeted and requiring less pesticides**.

Any international procurement of pesticides must abide with the provisions of the Rotterdam Convention on the Prior Informed Consent (**PIC**) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade. http://www.pic.int/Implementation/Pesticides

3 The criteria for HHPs have been listed by WHO and FAO as follows:
Pesticide formulations that meet the criteria of classes Ia or Ib of the WHO Recommended Classification of Pesticides by Hazard (www.who.int/ipcs/publications/pesticides_hazard/en/index.html);\
or Pesticide active ingredients and their formulations that meet the criteria of carcinogenicity Categories 1A and 1B of the Globally Harmonized System on Classification and Labelling of Chemicals (GHS);
or Pesticide active ingredients and their formulations that meet the criteria of mutagenicity Categories 1A and 1B of the Globally Harmonized System on Classification and Labelling of Chemicals (GHS);
or Pesticide active ingredients and their formulations that meet the criteria of reproductive toxicity Categories 1A and 1B of the Globally Harmonized System on Classification and Labelling of Chemicals (GHS);
or Pesticide active ingredients listed by the Stockholm Convention (www.chm.pops.int) in its Annexes A and B, and those meeting all the criteria in paragraph 1 of annex D of the Convention;
or Pesticide active ingredients and formulations listed by the Rotterdam Convention (www.pic.int) in its Annex III;
or Pesticides listed under the Montreal Protocol (www.ozone.unep.org/Ratification_status/montreal_protocol.shtml);
or Pesticide active ingredients and formulations that have shown a high incidence of severe or irreversible adverse effects on human health or the environment.

4 The hazard classification concerns the formulated product. Formulations with a low concentration of active ingredient are less hazardous than formulations with a high concentration of the same active ingredient. The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification (http://www.who.int/ipcs/publications/pesticides_hazard/en/) classifies technical products based on acute oral and dermal toxicity. It includes a conversion table that allows determination of the hazard class for the pesticide formulation under consideration. Towards 2008, this list will be replaced by the Globally Harmonized System of Classification and Labelling of Chemicals, which in addition to acute toxicity also takes into consideration chronic health risks and environmental risks (http://www.unece.org/trans/danger/publi/ghs/ghs_welcome_e.html) The term "pesticide formulation" means the combination of various ingredients designed to render the product useful and effective for the purpose claimed; the form of pesticide as purchased by users. The term "active ingredient" means the biologically active part of the pesticide.

Annex 2

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    map: http://www.fao.org/fileadmin/user_upload/Europe/documents/docs/IPMpotatoArm_en.pdf
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Integrated pest management
of major pests and diseases
in eastern Europe and the Caucasus

The Integrated Pest Management IPM is an ecosystem approach to managing pests through understanding the crop ecosystem as a basis of good crop management decisions and support the sustainable intensification of crop production and pesticide risk reduction.

Often, low levels of populations of some pests are needed to keep natural enemies in the field and the aim of IPM is to reduce pest populations to avoid damage levels that cause yield loss. The IPM is still directly associated with pests and defined as a knowledge-intensive process of decision making that combines various strategies (biological, cultural, physical and chemical, regular field monitoring of the crops etc.) that focuses on reduction of pesticide use to sustainably manage dangerous pests.

This book is intended to guide farmers in the integrated management of pest and diseases, helping them with decision making. It provides a description of the most dangerous pests and diseases, including symptoms, possible location, types of plants, biology as well as ways of monitoring. It also describes the main components of specific Integrated Pest Management.

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