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Fakulta záhradníctva
a krajinného
inžinierstva

Ján Mezey

Integrated systems of pome- and stone fruit production

Nitra 2023

Title: **INTEGRATED SYSTEMS OF POME-
AND STONE FRUIT PRODUCTION**

Autor: doc. Ing. Ján Mezey, PhD. (13.90 AQ)
Slovak University of Agriculture in Nitra
Faculty of Horticulture and Landscape
Engineering Institute of Horticulture

Reviewers: Ing. Marián Komžík
Kohaplant s.r.o.

doc. Ing. Ján Kollár, PhD.
Slovak University of Agriculture in Nitra
Faculty of Horticulture and Landscape
Engineering Institute of Landscape Architecture

Acknowledgement:
This work was supported by the project KEGA 010SPU-4/2021 „Internationalization of education and the creation of new teaching texts in the English language for the accredited study program "International Master of Horticulture Science" and for students of Erasmus programme".

Approved by the Rector of the Slovak University of Agriculture in Nitra on 13th November 2023 as an online university textbook for the students of SUA in Nitra.

ISBN 978-80-552-2675-0

Content

AIMS AND PRINCIPLES

Definition

The term Integrated protection was defined in 1973 by the International Organization for Biological Control (OILB / IOBC) as follows: "Integrated protection is a system of regulation of harmful agents that uses all economically, ecologically and toxicologically acceptable methods to maintain harmful organisms below the threshold of economic harmfulness with priority and by deliberate use of natural limiting factors" (Ludvik, 2002).

The basic principles of integrated plant protection were defined at the beginning of the 1960s as a theoretical and practical alternative to the explosive increase in consumption and global application of synthetic pesticides, especially the new generation of organic insecticides. World Food and Agriculture Organization (FAO) "Report of the First Session of the FAO Panel of Experts on Integrated Pest Control" Rome 1967. The classic FAO definition characterizes integrated plant protection as "A complex system of measures aimed at regulating the number of pest populations with regard to ecological, economic, toxicological and hygienic requirements, with the intention of keeping the number of pest populations at a tolerated level, with the deliberate preference and conscious use of natural methods of pest population regulation" (FAO, 1967).

Integrated plant protection, as a crop protection system, was originally developed to minimize pesticide inputs while maintaining economic production. Nowadays, it is understood more comprehensively – as a system integrating the whole range of tactics and procedures to control plant diseases, the spread of weeds and plant pests, and thus agroecosystems as a whole, and is used worldwide in connection with a whole range of crops (Alternative agriculture, 1989).

The definition of the Swiss working group for integrated fruit production is: "In integrated fruit production, the producer tries to grow full-value crops with ecologically adapted and economically viable methods" (Ruegg et al., 2005). Integrated production is the economic and controlled production of fruit of high health quality, which favors ecologically safer procedures, minimizing side effects, reducing the number of phytosanitary interventions and fertilizing, thereby increasing safety for the environment and human health. IP follows stricter rules than conventional production, i.e. it ranges between the principles of Good Agricultural Practice (GAP) and organic production.

The most important characteristics and principles of IPM include tolerance of the presence of pests as a functional component of agrobiocenoses, deliberate diversification of preventive (proactive) and curative (reactive) pest population control methods. The practical unit of IPM is a crop-specific program having the character of an information-expert system. Factors and criteria other than effectiveness (e.g. ecological aspects, hygienic and toxicological criteria) are also applied in the decision-making process and the resulting evaluation (Ludvik, 2002).

Dynamic development and profound changes in content were noted in the definitions of IPM during the years 1990 – 2000. Currently, the definitional continuum of IPM is used, oscillating from integrated conventional protection to integrated bio-intensive protection (Demo, Hričovský, 2002).

The system of integrated fruit production as a set of protective and stress-free cultivation measures applies all appropriate methods of protection in their optimal coordination. Protective measures are aimed at protecting the plant itself and not at eradicating the harmful organism. This also results in a certain coexistence of fruit trees and their harmful organisms at an economically tolerated level. This is primarily about ensuring economic efficiency and growing harmless and healthy fruit.

Integrated fruit production includes a cultivation system in which equal attention is paid to both economic and ecological requirements. That is, it ensures ecological and economic goals by changing the emphasis from greater production to reducing costs and improving the quality of production and cultivation technologies. It is a transitional cultivation system between conventional and organic plant cultivation, which tries to reduce inappropriate interventions in the ecosystem while maintaining current productivity.

The system uses methods of protecting fruit trees in various suitable combinations of chemical sprays, biological preparations, mechanical control, but also measures aimed at eliminating the stresses of fruit trees in the acute form, which could reduce the overall condition of the tree and thus increase its susceptibility to pathogens , respectively ensuring ideal and optimal growth conditions by perfect and well-thought-out technology for the care of not only trees, but also in agrotechnical soil treatment, not disturbing the biodiversity of the surroundings, ensuring the diversity of the surrounding fauna and flora by creating the so-called biocorridors, etc., while it will be guided by the first mentioned principles, taking into account the protection of the environment.

Principles of integrated fruit production:
• the use of such agrotechnical measures that will limit erosion, leakage of harmful substances into underground and surface waters,
• the use of varieties that are not demanding on intensification inputs, which are able to use nutrient reserves mainly from the deeper layers of the soil and from less soluble forms, varieties that are resistant or tolerant to diseases and pests,
• use of integrated protection against harmful agents (diseases, pests, weeds), which is based on chemical, biological and mechanical principles,
• optimization of nutrition and fertilization based on the results of agrochemical analyzes of the content of nutrients in the soil and in plants using diagnostic methods to determine the necessary doses of nutrients,
• prioritizing the use of organic fertilizers or other sources of organic matter added to the soil,
• reduction of energy inputs – use of minimal methods of soil processing, reduction of the need for chemical treatment.

Objectives of integrated fruit production:
• production of high-quality fruit while applying ecologically acceptable cultivation methods and minimizing the undesirable side effects of agrochemicals during their use,
• protection of the natural environment of the orchard and the living organisms that occur in it,
• not violating or harmfully changing or destroying the components of the orchard environment,
• ensuring species diversity of naturally occurring or introduced animal and plant species in orchards and their immediate surroundings,
• increasing the protection of the environment and human health.

PRINCIPLES OF PROTECTION IN AN INTEGRATED SYSTEM

Principles of protection in the integrated system:
• inclusion of mostly resistant varieties of apple trees in plantings;
• use of chemical preparations with low toxicity, friendly to the agroecosystem, including its natural regulatory factors;
• ensuring reliable prognosis and signaling of economically harmful occurrence of diseases and animal pests that justify the use of chemical interventions;
• use of efficient and reliable application technology;
• use of appropriate physical and biotechnical methods of protection;
• preference for biological protection;
• the use of suitable agricultural technologies (cultivation of the soil in orchards, fertilizing, pruning and training), creating conditions for the physiological balance of fruit trees, in which the risk of harmful occurrence of diseases and pests decreases.

In the practical application of integrated production, the following principles must be observed:

• preferably use biological and biotechnical protection methods to control animal pests (introduction of the predatory mite (*Typhlodromus pyri*), support of natural insectivorous birds and feathered predators in fruit plantings, etc.);
• through appropriate agrotechnical measures (varietal regionalization, soil care, fertilizing, pruning) to create deliberate conditions for achieving the necessary vitality of fruit trees, or their resistance to attack by diseases and pests;
• continuously monitor the occurrence of harmful agents in orchards. To do this, use appropriate aids (signaling devices, visual and light traps, etc.);
• treatment of fruit orchards should be done only when favorable conditions for the development of diseases are detected, or when pests multiply;
• when detecting the harmful occurrence of a certain harmful agent, use only selective pesticides that do not destroy useful animals (predators, parasites) and are ecologically harmless;
• when protecting, work only with high-quality application technology that will allow the volume of the spray liquid to be reduced during application;
• to check compliance with the principles of integrated protection, it is necessary to register the application of pesticides, documented by the detected occurrence of harmful agents.

Prophylactic protection

The task of prophylactic (preventive, indirect) protection is to use the most suitable agrotechnical or with special interventions, either to prevent diseases of healthy plants or to prevent the onset of the disease and its spread in a certain crop and in a certain habitat. We distinguish agrotechnical methods according to the purpose and technology of use, according to the duration of action and mechanisms of action. Many of them cause the activation of biological processes of the soil, which are directed to the regulation of harmful organisms or reduce crop losses caused by them. It should be emphasized that agrotechnical methods, compared to other methods, largely cause a change in the ecological environment in favor of humans, which affects the development and population dynamics of harmful organisms and their natural enemies. The effects of agrotechnical methods of protection are very variable in their activity, but despite this, the main role of agrotechnics in plant protection is to create unfavorable conditions for the reproduction of the most important harmful organisms and, on the other hand, to create for cultural plants the so-called executive environment, i.e. conditions for their undisturbed growth and development and enable their productive capabilities.

Repressive protection

Repressive protection is applied in cases where it was not possible to prevent the occurrence, spread or proliferation of harmful organisms (harmful agents) by preventive protection. Similar to preventive interventions, direct interventions need to be specified with regard to the nature of the harmful organism (harmful agent) and its spread in a certain crop and the ecological conditions of the site.
According to statistical data, the share of individual harmful factors in fruit losses is 35% worldwide. Animal pests cause 13.8% of damage, diseases 11.6% and weeds 9.6%
In integrated fruit growing, a rational system of chemical protection aimed at its minirization is applied to reduce or limit the mentioned losses and damages.

Alternative measures

In the integrated system, the so-called alternative measures that, under certain circumstances, fully replace chemical methods of protection. These include e.g. the following measures:
• **anti-powdery mildew cut** – shoots attacked by apple powdery mildew are removed by cutting in the pre-spring period, which largely eliminates a possible source of infection for the growing season,
• **methods of confusing males** – it is mainly used in areas where the apple borer occurs, where the use of chemical sprays is reduced or completely eliminated in case of a weaker occurrence, thereby reducing the risk of the pathogen developing resistance to the active substance of the preparation,

• **alcohol traps** – in the number of approx. 8 pcs/ha are considered to be the most effective measures in the fight against pear blight beetle (*Xyleborus dispar*),
• **reproduction of useful organisms** - and their introduction, especially predatory parasitoids, which are more effective in the long term than chemical methods of protection.

Management of resistance

Resistance of harmful organisms against groups of active substances of chemical protection can cause many difficulties. It is therefore very important to take measures to prevent this phenomenon. One of the goals of the integrated system is to first use all possible non-chemical methods of protecting apple trees.

In order to prevent the emergence of resistance, it is necessary to observe the following basic principles:
• reduction of the use of chemical means for plant protection – every case of saving the use of chemicals is a step towards preventing the emergence of resistance. In the case of the necessary use of chemical protection, the use of the active substance must be thoroughly considered and only then used,
• a prerequisite is a perfect knowledge of the bionomics and life cycle of the pathogen. Choosing the right active substance, application date, dose, agroclimatic conditions and application technique will create an optimal model of effectiveness and can save subsequent repeated use of the preparation.
• use of alternative means of protection – (will be specified in detail),
• protection and support of useful organisms – (will be specified in detail),
• change of groups of active substances – according to experience so far, some groups of active substances have an increased tendency to resistance, especially strobilurins.

Choice of protection substances

The goal of integrated production is to burden the environment as little as possible with unwanted chemical substances, or use those that do not have an undesirable negative impact on the environment. The use of chemical substances in the system of integrated protection is only possible if the economic threshold of harmfulness of the given pathogen has been exceeded on the basis of monitoring, signaling, forecasts and direct diagnostics in the stand.

Before using an insecticide or acaricide, it is necessary that the raid and occurrence of:
• first, second, or third generation codling moth,
• apple sawfly in the period after flowering, as well as summer generations,
• mites.

Of the permitted means of protection, priority will be given to those which
• they do not endanger the person applying the spray, nor other people,
• suppress the pathogen to an economically tolerated level and at the same time do not reduce the occurrence of harmful animals, including insects,
• they do not unreasonably burden the air, soil and water resources,
• leave as little residue as possible in the fruit and in the environment.

In the system, it is also necessary to take into account the protection of predatory mites and limit the use of pesticides that could harm them. For this reason, the application of some active substances is limited for a season. In addition, it is necessary to leave a longer break between two treatments with the same active substance, or alternate them with another group of active substance.

Amount of protection substances

The amount of protection substances per hectare per year depends on these three factors

• dosage – if possible, it is necessary to choose the lowest of the permitted doses. Doses of individual substances must of course not be exceeded. The full dose of a chemical is rarely used in insecticides and acaricides. The aim of the integrated system is not to eliminate 100% of the pathogen, because it is relatively expensive, promotes the emergence of resistant strains and disproportionately burdens the environment.
• the amount of water used – it varies according to the cultivation system, the height of the trees and the concentration of the preparations. At a normal concentration, the recommended amount of water per hectare is 500 l for one meter of tree height. In the case of microsprays and fogging and a higher concentration of the spray substance, it is necessary to reduce water consumption.
• the number of sprays – depends on the infection pressure (tolerated economic damage), the course of agroclimatic elements. We spray on the basis of signalling, forecasts and monitoring of the stand.

Application technique

For applying pesticides to control insect pests and diseases in fruit farms, the most commonly used spray equipment is radial air-assisted sprayers (Zhu et al., 2017). These conventional sprayers deliver pesticides at a constant rate and usually apply pesticides to the entire field regardless of plant absence or plant structure variation, resulting in underspraying or overspraying (Zhu et al., 2008). A large proportion of the spray drift is delivered to nonplant areas, such as ground and air (Zhu et al., 2006a), leading to pesticide loss and risk of environmental contamination, which increases the costs of production and exposure to pesticides for applicators, workers, and other people near the farms. A wide range of spray methods has been evaluated to improve the delivery of pesticides (Stover et al., 2003; Zhu et al., 2006).

Tunnel sprinklers are among the sprinklers that have the least impact on the environment. In order to maximally prevent the leakage of the spray substance into the air or into the soil, it is necessary to set the sprayer in such a way that the most of the spray substance goes to the sprayed wood. It is absolutely necessary to close the nozzles from which the spray substance reaches above or below the wood.

Sprinklers must be checked and calibrated annually. Measures for maintaining the application technique, testing, setting and calibration must be entered in the company notebook. Every company is obliged to professionally check every sprinkler at a certified place at least once every 5 years. In the system of integrated production, it is possible to use only those sprayers that have been checked in the last 5 years at a certified place.

To increase the efficiency of pesticide use on fruit farms, a laser-guided variable-rate intelligent sprayer was developed (Chen et al., 2012; Shen et al., 2017). The sprayer discharges appropriate variable amounts of pesticides in real time. Application rate is controlled by adjusting the spray output of each nozzle based on the presence, structure, and foliage density of plants, and sprayer travel speed. Chen et al. (2013) reported the intelligent variable-rate sprayer reduced spray volume by 57% at the full-foliage stage and 73% at the leafing stage of apple while remaining comparable spray deposition on target areas compared with a conventional constant-rate sprayer.

COMPLEX PROTECTION IN IPO SYSTEMS

- **preventive** (indirect, prophylactic),
- **repressive** (direct, repressive, therapeutic, curative).

PREVENTIVE PROTECTION

Prevent diseases of healthy plants or prevent the onset of the disease and its spread in the most suitable agrotechnical interventions. The main task is to create unfavorable conditions for the reproduction of harmful organisms. Create a stress-free environment for cultural plants.

Site selection and variety selection

It is necessary to respect the requirements of individual varieties for the given soil and climatic conditions, i.e. requirements for heat, precipitation, length of the growing season, the possibility of combining the variety with rootstock, sensitivity to frost, diseases and pests. The quality of the fruits of each variety is highly dependent on the climatic and soil conditions of the site, the level of agricultural technology, the method of storage and other factors.
The priority criterion is the selection of resistant or at least tolerant varieties of fruit trees. This not only reduces the consumption of chemical preparations, but also the risk of environmental contamination, stabilizes yields and the quality of fruit.

Selection of rootstocks

It significantly affects growth, the beginning of fertility, overall fertility, the rhythm of the tree's birth, resistance to low temperatures, the quality and storability of fruits, resistance to various pathogens. We recommend only elite virus-free planting material. Virus-free material demonstrably increases growth and fertility by 30%.

Groving shape. Pruning and training

The pruning must be regular and annual, it must also be carried out in the summer. We prefer more natural growing shapes over strict shapes. It is not recommended to use non-selective pruning methods (uniform pruning) on a larger scale. They disturb the physiological balance of the trees and lead to a greater occurrence of diseases and pests. Irregular pruning, with subsequent thickening of the crowns, is not recommended, it cannot be schematic, but must result from the growing conditions. It must take into account the variety, the growing form, the strength of growth and the age of the tree. It is necessary to pay attention to the interaction of pruning, fruit set regulation, fertilization and soil care. We are moving towards the physiological balance of trees (shrubs), balanced fertility and good fruit quality, the goal is the so-called silent tree. The crown is brightened, branches bent to the ground are removed so that they do not hinder the application of herbicides and the mechanical destruction of weeds in the lateral strips. Sufficient lighting of the fruits during the entire growing season. The shape must be adapted to the variety, rootstock, soil and climatic conditions of the region. Systems that require less herbicides are chosen, the ideal shape are spindle forms and types.

Regulation of fruit set and fruit quality

The quality of production is a priority in the mature fruit market, by thinning it is possible to limit alternations and therefore achieve relatively stable yields every year. It is possible to increase the price with quality indicators. In the case of stone fruit, as well as stone fruit, the following indicators are affected by thinning: fruit size, covering color, nutritional substances in the fruit. A basic measure, in addition to an appropriately chosen rootstock, variety and overall agrotechnics, is the regular cutting of trees, which fundamentally affects the quality of production. In older plantings, where we observe slowed growth and reduced fruit quality, it is advisable to make a radical (deeper) cut in order to restore young fruitful wood, or to dispose of the planting. However, with good flowering and pollination, even optimally shaped trees will produce an excessive number of fruits. In such a case, their reduction is necessary either manually or chemically, manual thinning is very effective, but laborious. It is taken at a distance of 10 – 15 cm depending on the species, variety, age and physiological state of the trees, preferably by the end of July. Early thinnings are more effective, they eliminate competition between fruits and shoots in time. Late pruning has only a partial effect on the final size of the fruit, especially in apple trees, but does not affect the formation of flower buds at all. Chemical thinning is aimed at reducing the number of fruits and overcoming the tendency to alternate fertility, it is used by spraying the flower when the fruit size is 18 – 25 mm. The principle consists in burning the stamens and spikelets, which makes subsequent pollination impossible.

Soil treatment and mulching

We work for the entire life of the orchard, to ensure the necessary yields of healthy fruit and environmental protection. It is necessary to protect soil fertility, limit the application of herbicides, industrial fertilizers and other agrochemicals. A treatment system with 60-70% of the soil area covered by plants is suitable. After planting, green manure plants can be sown in the interrow at the end of June, or every other interrow can be grassed with a mixture of low-growing grasses suitable for the area. Weakly growing varieties of red fescue, dogwood, compressed linden, meadow linden and others have proven to be the best in the system of mowed grass, e.g. a combination of 70% red fescue, 15% dogwood and 15% compressed sedge. Grass is sown in the spring to mid-June on a well-prepared and leveled surface of the soil, the seed is planted to a depth of 5 to 10 mm. After sowing, we roll the land. The lawn emerges in 3 to 4 weeks after sowing. In the year of sowing, the grass is mowed only after the soil has dried. The grass is sown close to the trees so that an unsown strip with a total width of 0.8 m (0.4 m on each side of the row) remains around the trunk. The maximum growth of grasses is in the period from May to the beginning of July. Replacing cultivated grasses with "natural turfing" of wild weeds requires a greater number of mowings than with cultivated grasses.

It is necessary to mow or mulch the weeds in the period before the fruit is harvested (herbicides cannot be used). Unproductive water losses from the orchard are prevented by frequent mowing of the grass. The height of the grass should not exceed 15 cm, 10 cm in the dry season and when the trees are flowering. After harvesting the fruit in autumn, the grass must be mowed, the mowed grass is left as mulch on the spot. During the growing season, the mowed grass can be used to lay strips under the crowns of trees. Grassed orchards do not need to be fertilized with organic fertilizers. In areas where the annual rainfall does not reach 600 mm and where mown grassing is mostly not expected, a suitable soil treatment system is shallow cultivation with annual planting of plants for green manure or grassing every second row. It is cultivated to a maximum depth of 4 cm, it is possible to cultivate the soil deeper (up to 5-8 cm) when adding fertilizers and plants for green manure in the fall after harvesting the fruit. The effectiveness of the cultivation intervention against weeds is longer, the drier the soil is at the time of treatment. In areas with annual precipitation above 700 mm, or, with the possibility of supplementary irrigation, it is recommended to apply a system of inter-row grassing instead of soil cultivation (black fallow) in the inter-rows.

Fertilization of fruit orchards

Disproportions in nutrition can be the cause of increased susceptibility to diseases and pests. Trees with adequate nitrogen nutrition end the growth of shoots early. With the cessation of growth and partial maturation of new leaves, susceptibility to scab infections ends. After rejuvenation or excessive fertilization with nitrogen, the trees continue to grow until the onset of winter. They can harbor the conidial stage of apple scab until the following spring. Excessive and inappropriate use of nitrogen fertilizers leads to contamination of drinking water sources, oversaturation of the soil with potassium worsens the soil structure and its water and air regime. Phosphorus, accumulated inefficiently in the top layer of the soil beyond the reach of fruit tree roots, represents a threat to the ecological balance in water reservoirs on erosive slopes. At intervals of 3 years, it is necessary to carry out a control of the agrotechnical properties of the soil, fertilizing only on the basis of these analyses. Favoring foliar nutrition, more efficient distribution of nutrients.

Irrigation

Regular water supply is necessary for regular plant growth and harmonious fruit development. However, irrigation must be adapted to the needs of the crops, preferably on the basis of AMS signaling and software programs. The main critical period of increased water demand is the period after fruit drop in June, in addition, it is the period before flowering and the period of intensive fruit growth. Autumn varieties of apple trees are irrigated from the end of May to the last third of August, a dose of 120 to 150 mm, and in a dry year up to 200 mm of water. Winter varieties of apple trees are irrigated as needed from the end of May to the end of September, dose 180 to 220 mm, in a dry year up to 250 mm. Irrigation will be stopped about 14 days before fruit harvesting. Plantings on collapsing rootstocks are more sensitive to fluctuations in soil moisture. Water from natural precipitation is quickly consumed in the layer of their rooting, or drains to lower layers, plants have to expend increased energy to pump water that is more difficult to access – additional irrigation is necessary.

Physiological state and balance of fruit trees

They are mainly affected by:
– winter and summer cut,
– by the number of developing fruits,
– by soil treatment,
– by fertilizing,
– irrigation,
– intensity of attack by diseases and pests.

The measures in the first years after planting must be directed so that the planting enters the period of fertility as soon as possible. The basic prerequisite is the creation of optimal conditions for growth and the creation of the necessary volume and set of fruits, a sufficient level of harmonious nutrition, targeted integrated protection, a method of tillage that ensures the most favorable water balance for plants.

Physiologically balanced trees should not have the longest one-year increments under 20 cm, but not longer than one meter. Excess fruit set must not be tolerated on the trees (thinning is necessary), the optimal ratio between fruit set and leaf area must be maintained. Fruits from integrated production must be healthy, transportable and storable, fully developed according to the nature of the variety and must comply with quality regulations. They must achieve good internal quality (sugars, acids, vitamins, minerals, aromatic substances).

The control of the physiological balance and quality of the fruits is done 5 weeks before the harvest, the growth of the shoots, fruit set, fruit size, lighting of the fruits and the external appearance of the fruits are subjectively evaluated during the inspection. Evaluation in five grades:
– too weak or small,
– weak or small,
– optimal,
– big or strong,
– too big or strong.

REPRESSIVE (DIRECT) PROTECTION

It is applied in cases where it was not possible to prevent the occurrence, spread or multiplication of harmful organisms by preventive protection. Direct interventions must be specified with regard to the nature of the harmful organism and its spread in a certain crop and the ecological conditions of the site.

Diagnosis – Diagnostics

Qualitative detection and precise determination of the causative agents of diseases, pests and weeds and the damage caused by them. The tasks of diagnostics are to determine the originator or causes of the monitored harmful phenomenon, determining the characteristics, i.e. the causes and extent of harmful effects on plant production, including determination of harmfulness thresholds. To determine a more detailed specification of a harmful organism, a deeper knowledge of biological properties, to determine the physical or chemical essence of a harmful phenomenon. The possibility of using effective measures to eliminate or suppress them. Development of reliable evidence of the occurrence of a harmful organism (it is about keeping the documentation yourself).

Record of occurrence of harmful organisms:

a) Survey of their territorial expansion,
b) Systematic monitoring of the development of harmful organisms and crop growth,
c) Quantitative assessment of the occurrence of harmful organisms and damage to the stand.

Diseases:

a) Determine the degree of disease development (% of diseased plants or organs) and the center of attack of individual organs,
b) Analysis of the incidence of diseases in cultivated plant stands,
c) Determining the intensity of the disease.

Pests

a) Detection of pests on plants
- direct deduction,
- laboratory determination.

b) Determining the number of pests
- the number of pests on a plant, area, soil sample.

a) Spread of pests
- attacked area.

a) Determining the degree of damage
- attacked, damaged parts, which parts.

a) Determining damage and losses
- directly, experimentally, by estimation by calculation.

Weeds

a) determining the potential danger of weeds,
b) analysis of the occurrence of weeds in stands of cultivated plants,
c) continuous keeping of evidence of weed growth,
d) finding out the sources of the spread of reproductive organs.

Signalling and prognoses

Anticipating future development possibilities. Determine the necessary measures and interventions on the basis of analysis and knowledge of laws. Define existence, induction and production areas and predict the probability of phenomena that may occur in a certain time and space.

The prognosis is based on prognosis, i.e. scientific discipline, which as the most complex and exact information system serves to predict future development possibilities. The function of the forecast is to determine the necessary measures and interventions on the basis of analysis and knowledge of laws. The task of the forecast is to define the existence, induction and production areas and predict the probability of phenomena that may occur in a certain time and space. Based on the established basis of these parameters, predict the occurrence of pests, diseases, weeds, the emergence of infections and the emergence of epidemics (Gallo, Šedivý, 1992). Herbalists have been using various pathogen prediction models for a long time with the aim of precise timing of protective intervention.

The application of the models assumed the use of curative preparations, even though there are various other tactical variants of the use of other groups of protective preparations as well (Aluja, 2009).
By prognosis in plant protection, we understand the prediction of the intensity of occurrence, or the mass spread of harmful organisms (or agents) in a given location or in a certain area with a certain advance. Therefore, the prognosis predicts, based on the evaluation of data from the past and present, a certain phenomenon or the course of phenomena in the future. (Gallo, Šedivý, 1992) In order to establish accurate forecasts, it is necessary to take into account several factors and the specifics of individual pests. Most models mainly take into account the relationship between the life cycle of the pest and the phenological phase of the host (Aluja, 2009).
The prognosing makes it possible to realistically plan the production or import of plant protection products (pesticides, sprayers, etc.), their correct and timely distribution, the choice of optimal protection programs (including breeding for resistance, and other protection methods) and a good organization of own protection measures. It also allows the correct planner of the research work program in plant protection, to improve the structure of the plant medicine service and also to train the necessary experts. (Gallo, Šedivý, 1992) Prediction of the occurrence of pathogens on apple trees helps to significantly reduce the number of protection interventions compared to protection systems that were based only on phenological models of the development of the plant itself, while the quality of production is also improved and better controlled (Aluja, 2009).
In order to be able to plan and organize work in plant protection, we distinguish 3 groups of prognosing, of which each group has its own specific purpose, infiltration security, regular and correct use (at the level of farms, cooperatives, regions, areas or republics). (Gallo, Šedivý, 1992) In the end, the use of forecasts also helps to reduce the negative consequences of pesticide application, which is reflected in the protection of the environment and the health of consumers (Aluja, 2009).

1. Multi-year prognoses are used for planning material-technical, organizational and personnel support for plant protection, scientific activities, for improving the strategy and tactics of plant protection. (Gallo, Šedivý, 1992) Prognostic models monitor the occurrence and spread of pathogens with the aim of precise timing of protective interventions, or whether it is at all necessary to make a protective intervention. (Aluja, 2009). The basic source of information for compiling multi-year forecasts are annual reports from stations (ÚKSÚPu) and also materials reflected in long-term forecasts. This information makes it possible to analyze the state and variability of the conservation situation for the previous 5 – 10 years and gives the possibility to refine the regionalization in a certain area of the republic (Gallo, Šedivý, 1992).
2. Long-term prognoses characterize the stationary distribution, population density, expected harmfulness of individual types of harmful organisms on crops, in a certain space in the following period of the year, or even longer period of time. On the basis of these data, the organization of prophylactic plant protection measures is compiled at the company level and also in any region of the republic during the growing season or year. The goal of long-term forecasts of the occurrence of harmful organisms is to prepare a plan of integral methods of protection and to recalculate material security and costs within areas, districts, regions, or the state. Long-term forecasts will become the basis for planning the need for pesticides, the distribution of machinery and equipment for plant protection (Gallo, Šedivý, 1992).
3. Short-term prognoses are compiled for a few days, up to one month, they are intended for urgent (terminated) warnings about changes in the phytosanitary (protection) situation and the adoption of necessary methods for its optimization. Short-term forecasts are generally aimed at better use of pro¬phylactic and curative measures. The short-term prognosis is based on the phenological development of the harmful organism and on the detection of the most harmful stages on a certain host plant (Gallo, Šedivý, 1992).

Signaling is an operational message for agricultural enterprises about the necessity of taking defensive measures where it is economically, toxicologically and ecologically expedient. Signaling is actually establishing the fact that a certain phenomenon has occurred or is ongoing. The goal of signaling is to draw attention to a certain phenomenon (threat), to determine the optimal date of protective intervention (time limitation of intervention), as well as to determine the necessity of immediate protective measures based on known facts about the development and spread of harmful organisms, with the maximum profitability of the intervention. (Gallo, Šedivý, 1992). Pest signals are an important element characterizing systems of integrated fruit production based on early warning based on biophysical methods and thus allowing intervention to be carried out at the right time, thereby minimizing damage to the cultivated culture, thereby reducing production costs (Abrol, 2012).

Modern methods of prognosing and signaling today, with the wide development of technology, cannot do without the use of electronic computing technology and without the use of modern technology for long-distance transmission of information. It is expected that forecasting and signaling methods, using electronic computing technology, will play a decisive role in the strategy and tactics of plant protection. New forecasting and signaling methods will systematically use remote and automated means for assessing the state and development of harmful organisms and ecological conditions (Gallo, Šedivý, 1992).

The basic unit for professional signaling systems are automatic weather stations, which consist of an integrated sensor unit, a console and the sensors themselves. The information and data transmission systems take place via a wireless connection with a radio signal, when the proximity of the AMS and the PC must be ensured (approx. 200m). Signal repeaters (2km) are used for longer distances. The most common data transmission systems are GSM and satellite systems, when the distance between the AMS and the PC, laptop, tablet, or smartphone does not matter. In the past, the system used was cable transmission and an RS233 converter.

The system includes software programs that can be divided into two groups. The first is the AMS software itself, which processes and evaluates elements measured using sensors, either individually or in combination. It models continuous curves, basic quantities and derived quantities. The second group of SW are programs for evaluating and signaling the diseases and pests themselves. Depending on the SW, it is possible to signal all diseases for which the methodology for calculating the infectious pressure is known. Most of them are pre-programmed modules for apple scab, apple powdery mildew and rose blight. After acquiring addiction, other diseases can be added. In the case of pests, it is possible to signal all pests for which the sum of the effective temperatures for the individual development stages of the infectious pressure is known. They are mostly pre-programmed modules for the apple peeler, plum saw and cherry spinner. After obtaining data from the flight curves, it is possible to add other pests, such as apple borer, 2nd and 3rd generation, spiral borer (1st and 2nd generation), peach borer, plum borer, but also other pests, such as *Grapholitha janthinana, G. lobarzewski, Heidya dimidioalba, Pandemis heparana, Lyonettia clerkella* and others.

Protection (mechanical, biological, biotechnological, chemical)

The share of individual harmful factors in fruit losses is 35% worldwide (animal pests 13.8%, diseases 11.6% and weeds 9.6%). We strive to include predominantly resistant varieties in plantings, use chemical preparations with low toxicity, ensure reliable prognosis and signaling. Use of powerful and reliable application technology, use of suitable physical and biotechnical methods of protection. Preference for biological protection. Use of appropriate agrotechnologies (cultivation of the soil in orchards, fertilizing, shaping and cutting). Creating conditions for physiological balance.

Mechanical methods of protection are the destruction of pathogens during the dormant period. **Biological methods of protection** consist in the deployment of antagonists – bioagents, mainly against animal pests.

Biotechnological methods of protection do not primarily have a toxic effect on the targeted harmful organism (pheromone traps and various colored adhesive plates).

Chemical methods of protection use approved chemical protection preparations.

Mechanical methods of protection

Mechanical protection of fruit trees is an important part of integrated protection. Compared to the chemical method, it requires a lot of manpower, but it is very effective and economically advantageous, and sometimes it remains the only way to protect against diseases and pests of fruit trees.

The preventive mechanical method consists in the destruction of the pathogen during the dormant period, that is, before the disease or pest starts to develop. Direct mechanical methods of protection create obstacles against the spread, limiting the occurrence of diseases and pests.

Biological methods of protection

Biological protection has an irreplaceable place in integrated protection in the regulation of the occurrence of diseases and pests by various biological methods. Biological methods of protecting fruit trees consist in the deployment of antagonists – bioagents. In some cases, a simple application is sufficient, in others, the application must be repeated regularly to achieve the desired effectiveness against the targeted organisms. Biological protection in the orchard is mainly used against animal pests. It includes the use of living organisms (predators, parasitoids), products of their activity (spores of bacteria and fungi), or their synthetic analogues.

In the current effort to biologize agricultural technology and protection with the maximum use of bio-preparations or bio-agents, we consider it necessary to emphasize that bio-preparations or bio-agents are used under suitable conditions for their application in order to achieve their maximum effectiveness. These special conditions for application should be precisely characterized for each preparation or agent separately and precisely, so that the user has accurate information and can comply with them and avoid the risk of an event. ineffectiveness. Already during pre-registration trials and evaluations, specific conditions should be taken into account so that the results can be compared with chemical equivalents.

Biopesticides, in general, have shorter residual activity than synthetic insecticides because of sensitivity to environmental degradation when exposed on the surface of the plant (Wise 2016). Therefore, evaluating the potential of biopesticides for tree fruit IPM (Integrated Pest Management) should include consideration of delivery systems that will optimize their performance.

Resistant and tolerant varieties

Biological methods of protection include the current trend of introducing new, resistant and tolerant varieties into cultivation, which do not show symptoms of the most important diseases. Nowadays we use resistant varieties by mostly in apples againt Apple scab and powdery mildew and in plums against plum pox virus.

Natural enemies

The most common protection, apart from resistant and tolerant varieties, is the use of natural enemies of diseases and pests. (check the chapter „The role of entomopathogenic insects in the IPO system“).

Plant extracts

Various extracts from plants are used against fungal diseases, which stop or slow down the development and spread. These include e.g. extracts from *Azadirachta indica, Chrysanthemum sp., Quassia amara*, horsetail, orange, fennel, sunflower oil, various preparations based on pinolene, fructose, lecithins, vinegar, sucrose, potassium bicarbonate, whey, repellents of plant and animal origin and many others. This also includes basic plant protection products based on sulfur and copper.

Mating disruption

Like many moth species, the female codling moth emits a species-specific pheromone (called codlemone), which attracts male moths for mating. Males easily follow the pheromone “plume” directly to the female. When an orchard is saturated with synthetic codlemone, mating is "disrupted" as the males are limited in their ability to find females. Codling moth mating disruption requires large, contiguous areas of orchard to work successfully. Five hectares of solid apple and/or pear trees is the minimum size. Ideally, border edges are minimized (i.e., mating disruption works better in a square-shaped orchard than in a long, narrow rectangular orchard). Expansion of mating disruption to cooperating, neighboring orchards (of the minimum size) will improve effectiveness. Newly planted orchards are not ideal for mating disruption because the pheromone quickly dissipates due to lack of foliage. Know your initial codling moth population. If you have never used mating disruption, the orchard may have high codling moth pressure. In this case, be prepared to apply well-timed insecticide treatments as you would without mating disruption for the first one to two seasons. Once the population declines, it is possible to use mating disruption with few, or even without, supplemental treatments. Mating disruption dispensers should be placed in the orchard at or shortly before biofix (first male flight) to prevent/delay mating. Ideally, a biofix for each orchard should be determined either by the trap-method using a nearby apple or pear tree not affected by mating disruption or by using the site-specific fixed biofix method. Product labels will instruct on dispenser placement in the orchard, but in general: Hang dispensers singly, and evenly, in the top third of the orchard canopy. (Do not bunch many dispensers together in fewer locations). Choose sturdy branches for hanging so that dispensers remain attached even in high winds. Dispensers last just one season; a fresh batch should be reapplied each spring. Store leftover dispensers in the freezer for up to one year. Use latex gloves when applying dispensers to prevent the possibility of a skin rash (rare). For new mating disruption orchards, consider doubling the application rate on the borders and at problematic fruit injury "hot spots". As moth population decreases, you can consider lowering the application rate within the orchard (not on the borders) to save costs. Monitor the codling moth population and injury carefully to assess effectiveness (Murray 2020).

The sterile insect technique
Is a complementary technology to the existing IFP program (Walker 2017). It involves the mass rearing and release of sterile males which compete with the wild males to mate with wild females, reducing the number of successful matings and offspring, and thereby suppressing the wild population. (Knipling 1979, Vreysen 2010). There are many known biological and logistical challenges found in the cost-effective application of the SIT, e.G. asynchrony in mating between sterile and wild populations due to weather and potentially aggregated populations, but also the requirement for already low population density to be effective. This is in contrast to tactics such as mating disruption and particularly insecticides which are effective at higher population densities. With very low codling moth densities already, we aimed to test the potential for the sterile insect technique (SIT) to supplement mating disruption and insecticides to achieve local eradication or at least major suppression of this pest (Horner 2020).

Biotechnological methods of protection
Disease and pest monitoring is a primary prerequisite for implementing integrated production systems in orchards. Insects and pests of fruit trees are not able to independently regulate their body temperature, therefore their development is dependent on external factors, especially air temperature. Pheromones are chemical substances secreted by an organism to which individuals of the same species react. (Cagáň, 2010) and enable specific communication (Abrol, 2012). Sex pheromones are especially important in plant protection. Currently, the sex pheromones of a large number of insect species have been synthesized. The pheromone is usually impregnated in a rubber or plastic package. Alternatively, it can be located in a storage tank, from which it is gradually released into the air. There is an adhesive surface in the pheromone trap, on which the insect sticks to the synthetic bait after flying in (Cagáň, 2010).
As stated by Abrol (2012), despite the progress in this field, catches in traps may not always reflect the actual status of pests in the orchard, as the situation can be influenced by many factors, such as hormone selectivity (Arn, 1997), trap shape (Fadamiro, 2004, Spear-O-Mara and Allen, 2007), as well

as trap location (Reardon, 2006, Gallardo, 2009). According to the dynamics of the attack of butterflies in the traps (and/or in combination with other monitoring methods), the necessity or the date of treatment can be determined. An important role is played by the determination of the flight wave. A summer wave means a significant increase in catches in traps, usually a catch 2 – 3 times higher than one of the two previous catches. (Lánský, 2005) A very important indicator is the capture of the first butterflies, adults in traps, which signal the beginning of activity in a specific area (Knutson and Muegge, 2010). For a certain type of pest, it is necessary to use the most effective type of pheromone or trap design, especially in those cases where the detected flight wave serves as a so-called Biofix. Biofix is an alternative to the sum of effective temperatures. They are biologically dated sums of effective temperatures, a modification of SET, in which effective temperatures start counting from the date of reaching a certain phenological phenomenon, for example, the first catch in a pheromone trap, egg laying, pupation of caterpillars, etc (Lánský, 2005).

The dynamics of the raid of individuals into traps indicates the need for treatment or the initiation of other activities necessary to determine the degree of occurrence and decide on a protective measure. For some types of pests, it is possible to determine in which generation it is in a given year and at a certain position based on the raids of males on traps. Alternatively, how numerous is the given generation. Multi-year monitoring of flight activity is used to estimate trends in the increase and decrease in importance. (Nečas, Krška, 2006). Visual inspections consist of inspecting the plant parts attacked by pests and the pests found in the initial phase, their developmental stages or damage. We carry out inspections at 14-day intervals, or according to our own experience during the period of occurrence of pests that can cause economically significant damage in a given year. (Lánský, 2005). Currently, the SOPRA (Schadorganismen-Prognose auf Apfel) signaling system is used. It is based on specific models of phenophases. It is effectively used for timing, monitoring, regulation and control of the apple borer (*Cydia pomonella*) and the cherry borer (*Grapholita lobarzewskii*). The SOPRA system is based on monitoring temperatures in relation to the developmental stages of individual types of pests. Software technology is fully used, meteorological stations installed directly in the orchard (Tresnik, 2007).

The time limit for the installation of traps is at the latest before the start of the significant flight of the 1^{st} generation pest (Lánský, 2005), when SET_{10}(d)=50 °C is reached and raid inspections are carried out preferably twice a week. We record the number of males caught in the traps, and when the flight wave is detected, we check the temperature conditions for egg laying. By flying wave we mean

a significant increase in catches in traps, usually a catch 2 – 3 times higher than one of the two previous catches. When the conditions for laying are met (the temperature at 9:00 p.m. is at least 17 °C), we check the area with MD for the occurrence of eggs. (Falta, 2008) The pheromone trap consists of the following parts: the trap itself (differently shaped paper or plastic box), a replaceable pheromone vaporizer (capsule) and a replaceable paper glue plate used to capture images attracted by the pheromone in the vaporizer (Lánský, 2005).

We check catches in traps at least twice a week. In the period of the expected flight wave (according to the presence of pupae and e.g. due to the expected warming), it is worth checking daily for key pests in the critical period, which is especially true if we want to use ovicides preventively during the treatment. We make the recording of the data as clear as possible, it is advisable to regularly process the records from the field in the form of a graph. From the created graph, the course of the flight waves is very clearly visible, which enables a faster decision on the date of the intervention. The data of the curve always represent the average value of the catch of the set of traps chosen by us (e.g. from one location) (Lánský, 2005).

In addition to pheromone traps, optical traps are also used in fruit growing. White glue boards, we use them mainly for sawmills. The action consists in the fact that female sawflies look for white plum flowers, or apples, peaches and cherries and lay eggs in them. They are attracted by the white color of the boards, which are painted with non-drying glue and the saws stick to them. In this way, the amount of sawdust that would otherwise fly into the flowers and damage them will be significantly reduced.

Yellow spherical traps with non-drying glue are used for signaling against the cherry weevil (*Rhagoletis cerasii*) and the walnut weevil (*Rhagoletis completa*). Female moths lay their eggs on yellowing fruits and look for sources of nectar – flowers. Therefore, they are attracted by the bright yellow color. The yellow board is painted with a non-drying glue and catches flying adult cherry and walnut moths. To strengthen the effect, it is recommended to install a pheromone dispenser together with the optical trap, depending on the target pest.

Chemical protection

Preparations used for direct protection are called pesticides from the Latin word pestis – plague, epidemic, infection, destruction.

They are compounds of chemical substances of synthetic or natural origin, intended for suppressing the growth and destruction of pests, unwanted plant cultures and animals, carriers of diseases and for the destruction of insects bothering humans and animals. Pesticides are characterized by a significant biological effect. Many of them can significantly change the species composition and viability of the edaphon (a complex set of organisms inhabiting the soil layer) or the vegetation cover.

According to biological effects, we divide pesticides into:
- **zoocides** – preparations for destroying animal pests,
- **herbicides** – preparations for destroying weeds,
- **fungicides** – preparations for destroying fungi, or for limiting or stopping their development,
- **growth regulators** – preparations stimulating or inhibiting plant growth,
- **other** – e.g. repellents, attractants, repellents, baits and more.

Zoocides are further divided into:
- insecticides – against unwanted insects,
    - ovicides – destroy eggs,
    - larvicides – destroy larvae,
    - adulticides – kill adult insects,
- acaricides – against mites and spiders,
- rodenticides – against rodents,
- nematocides – against nematodes,
- molluscicides – against molluscs,
- repellents – repel insects,
- attractants – attract insects.

Herbicides are further divided into:
- desiccants – substances for drying cultivated plants,
- defoliants – substances to defoliate cultivated plants,
- morphoregulators – substances with stimulating or inhibiting properties.

Fungicides are further divided into:
- inorganic,
- organic,
- mordants – for pickling plants before sowing.

According to the mode of action, we know contact and systemic pesticides.

Contact pesticides are applied only after emergence (during vegetation) and protect only the part of the plant that was affected by them. The active substance is not distributed in the plant and does not protect new plant growth.

Systemic pesticides can be predominantly foliar and applied post-emergence. Pesticides with a predominant effect through the roots are applied either before sowing, or pre-emergent – between sowing and emergence of the plant. They are based on the requirement that as much of the active substance as possible penetrates the treated plant as quickly as possible. In order to achieve high efficiency, redistribution of the active substance is necessary through the conductive system of the plant and into unaffected tissues. Systemic pesticides penetrate the conductive pathways of plants and are distributed through the system of vascular bundles.

Among the advantages of using pesticides is their use, which creates several mainly economic advantages, especially for farmers. They maximize agricultural yields and quality of agricultural products and minimize the amount of labor input. By reducing the need for plowing and cultivating the soil, they can contribute to limiting soil erosion and help ensure a reliable supply of a wide range of affordable agricultural products. They are an important means of meeting plant health requirements and enabling international trade in agricultural products.

The disadvantages of using pesticides are the disruption of self-regulatory mechanisms in ecosystems. In the natural or in a semi-natural ecosystem, predators, parasites and pathogens can regulate pest populations, while in chemically treated agroecosystems, the biological enemies of pests are often decimated more than the target organisms. Pesticide residue often ends up in the air, water, soil and food chains of ecosystems, and pesticide use has created genetic resistance in more than 520 species of insects and mites, in more than 10 species of rodents, including rats, and in more than 270 species of weeds, and in more than 150 plant pathogens. Farmers are forced to use increased doses of pesticides, to repeat them more often, which is also uneconomical for them, and pesticide residues and metabolites can enter the human body by contaminating groundwater, soil, food products, but also the air.

In the integrated protection of fruit trees, chemical protection has an important place and is often irreplaceable by other methods. When applying it, it must be based on scientific knowledge about the development, bionomy and epidemiology of individual harmful organisms, as well as the correct choice of the most modern and effective chemical preparations, taking into account their impact on the environment.

When using pesticides in the integrated protection of fruit trees, it is necessary to observe the necessary basic principles:

- use chemical preparations in a targeted manner, only in justified cases and carry out the application on the basis of signaling.
- action is usually taken against pests only after they have been detected,
- preventive measures are taken against economically important diseases according to methodological instructions taking into account both weather conditions and the demands of the causative agents of individual diseases,
- the prescribed length of the hygienic protection period of individual preparations is unconditionally observed. The protection period means the minimum interval in days between the last treatment and the collection of the products,
- before applying the individual preparations, you must carefully study their instructions for use, which contain information on the toxicity of the preparation not only for humans, but also for bees, fish, game and domestic animals, about the active substance, about the prescribed protective equipment when using it, about the classification of the preparation in the flammable class, on first aid in case of ingestion, inhalation, or contact with the skin, on storage, on methods of disposal of packaging and residue of the preparation, on the effect and scope of use of the preparation with detailed instructions for application,
- preparations are applied in prescribed doses or concentrations. Lower doses not only result in a weaker effect, but also promote the emergence of disease and pest resistance against chemical preparations. Higher doses of preparations can seriously damage the plants.
- at high temperatures, some preparations (especially sulfuric ones) can have a phytotoxic effect, therefore it is recommended to treat plants in the morning or evening,

• do not use preparations that are for cultivated crops or phytotoxic to individual varieties, this can be achieved under the conditions of using only registered preparations,
• a preparation with the same active substance should not be used twice in a row to treat a certain crop,
• when treating plants with a waxy surface or with smooth leaves, a wetting agent is added to the spray liquid,
• during storage, powder preparations are protected from wetting, liquid preparations from freezing,
• if it is intended to carry out chemical spraying in the garden near neighboring plots, the neighbors must be notified in advance so that they can protect their ripening fruits from being affected,
• under no circumstances should flowering plants be treated with preparations for poisonous bees,
• flowering plants can be treated in the most necessary cases only with preparations harmless to bees,
• preparations harmful to bees can only be used when the bees are not flying (in the morning or in the evening), but the beekeepers and, possibly, the municipal authorities must be informed in advance of their intention.
• the ban on treating flowering plants also applies to non-flowering plants, when there are flowering weeds, under-crops on the plot, or there is a large amount of "honeydew" secreted by aphids on the plants,
• give preference to biological and selective preparations, which are gentler on natural enemies as well as the environment, as broad-spectrum.

TEMPERATURE MODELS OF DEVELOPMENT – SUMS OF EFFECTIVE TEMPERATURES

Temperature is a condition for the development of some organisms. The amount of heat required to reach a certain stage of development does not vary. (Agriculture and Natural Resources, 2016) Daily temperature totals are a more accurate term than calendar days because insects have a predictable development based on heat accumulation. Insects are an exothermic group of animals and their development depends primarily on the ambient temperature. Each individual needs to accumulate a consistent amount of heat to reach a certain stage of development, such as hatching of eggs, or flight of adults. Daily temperature adders accurately interpret this heat accumulation. (Murray, 2008) The lower and upper temperature limits of the development of some organisms were investigated in strict laboratory conditions and subsequently also in field conditions. The lower developmental limit means that it is the temperature below which development ends and is given by the physiology of the animal itself. It is independent of the method of calculating the sums of effective temperatures. The upper developmental threshold is the temperature at which the growth and development of the organism slows down or stops. (Agriculture and Natural Resources, 2016). The total amount of heat that is needed to reach a certain developmental stage between the lower and upper limits of development for the organism is calculated in units called daily degrees. One daily degree is one day (24 hours) above the lower developmental temperature limit by one degree. For example if the lower development temperature is 10 °C and the air temperature remains at 11°C for 24 hours, 1 daily degree is accumulated (Agriculture and Natural Resources, 2016).

Sum of Effective Temperatures – SET (°C) is the sum of effective temperatures above the lower development threshold (SPV) for a certain period.

It is calculated according to the formula: : $SET_{SPV} = \sum_{i=1}^{n}(Ti - SPV)$

SPV = lower development threshold, T_i = average temperature

Note: negative values of the difference are not counted

Temperatures are measured in the simplest case with external mercury or alcohol thermometers. The daily average is then determined according to the formula: $T_7 + T_{14} + 2.(T_{21})/ 4$, where T_7 is the temperature at 7:00 a.m., T_{14} at 2:00 p.m. and T_{21} at 9:00 p.m. or when using maximum-minimum thermometers according to the formula $T_{min}+T_{max}/2$, where T_{min} is the minimum and T_{max} is the maximum daily temperature (Lánský, 2005).

The sum of the daily effective degrees is a measurement of temperature units calculated from the daily maximum and minimum temperatures. They are based on the lower and upper temperature limits at which insects develop. The minimum temperature at which the insect begins its development is called the lower developmental limit, the maximum temperature at which the insect ends its development is called the upper developmental temperature. These limits vary by species and are known in many, but not all, insect species. (Murray, 2008) Verification of temperature models of development and sums of effective temperatures is done by comparing real and simulated phenological and developmental data of the pest based on direct observations in the stand. They are a simultaneous determination of potential error, or deviations (Knutson and Muegge, 2010).

Despite the fact that the sums of effective temperatures are calculated for a 24-hour period, the most used model is when the sums of effective temperatures are calculated from the period we call biofix. Biofix can be some biological event, such as the date of the appearance of the first butterflies, or even a calendar day, such as March 1. For most pests, biofix is used, or an effective temperature of 10 °C, or March 1, because pest development usually does not occur by this date (Murray, 2008). Although it is easy to calculate daily totals at constant temperature under laboratory conditions, calculating daily totals under field conditions is somewhat more difficult due to the temperature fluctuations that occur in nature. Several calculation methods are used, taking into account daily maximum and minimum air temperatures. They are all only approximate values of the current

cumulative daily degrees, which have been accumulated as a set of daily air temperatures and development limits, and therefore do not correspond to the exact values of the daily degrees. Various mathematical models are used for the calculation, such as single triangle method, double triangle method, single sine wave, double sine wave and Huber method. All these methods are linear because the determination is expressed as a linear straight line directly dependent on temperature. There are also non-linear methods, but they are primarily used in research (Agriculture and Natural Resources, 2016).
With the ***simple triangle method***, a straight line is drawn from the daily minimum air temperature to the daily maximum air temperature and it is connected to the minimum daily air temperature on the following day, a triangle is created. With this method, the temperature curve is symmetrical around the maximum temperature. Daily amounts are determined by calculating the area inside the triangle as well as between the boundary temperatures (Agriculture and Natural Resources, 2016).

The ***double triangle method*** uses two 12-hour or half-day calculations, a straight line is drawn between the daily minimum and maximum, and another straight line is drawn vertically from the daily maximum, creating two sides of the triangle. Daily amounts are determined by calculating the area inside the triangles and between the limit values. The second 12-hour period uses the same configuration with the next day's temperature minimum. The daily degrees for the respective day are the sums of the daily degrees for the two halves of the day (Agriculture and Natural Resources, 2016).

In ***the simple sine method***, daily temperature maxima and minima are used, which create a sine curve during a 24-hour period. Daily amounts are obtained by calculating the area above the lower temperature limit and inside the curve. The method assumes that the temperature curve is symmetrical around the temperature daily maximum (Murray, 2008).

The double sine method buckets the first curve from the daily temperature minimum to the daily temperature maximum, and the second curve forms the link between the daily temperature maximum and the daily temperature minimum. The daily amounts are calculated as the sum of the daily amounts for the two halves of the day (Murray, 2008).

The Huber method gives the same result as the simple sine method with a horizontal boundary, except that 0.3°C is subtracted from the daily degree cumulation if the minimum and maximum temperatures for that day are between the upper and lower limits. This method is used in the desert southwest for pest control in cotton (Agriculture and Natural Resources, 2016).

The horizontal limit method assumes that evolution continues at a constant rate at temperatures higher than the upper limit. Mathematically, the area above the upper threshold is subtracted from the area above the lower threshold. The intermediate limit method assumes that development slows but does not stop at temperatures above the upper limit. Mathematically, the area above the upper threshold is twice subtracted from the area above the lower threshold. The vertical threshold method assumes that there will be no development at a higher threshold value (Moore, 2014).

THE ROLE OF ENTOMOPATHOGENIC INSECTS IN THE IPO SYSTEM

Entomopathogenic insects have an irreplaceable place in integrated production systems. It significantly regulates pests that cause significant damage to fruit crops. We generally call them a group of natural enemies, and they can be characterized in a broader sense as organisms that adversely affect the life of other organisms, living at their expense. They can be animal enemies, or the causative agents of diseases, which include microorganisms, viruses, bacteria and fungi.

Animal enemies include e.g. **parasites**, which are animals that obtain nutrition from one individual, the host, harm it but do not kill it. However, they are of little importance for biological protection. Among the best known are parasitic nematodes, especially *Trichoderma spp., Pythium, Fusarium, Botrytis, Sclerotinia*. The fungus *Trichoderma harzianum* wraps and outgrows other fungi with its mycelium, while some strains produce antibiotics, thereby suppressing the development and spread of the attacked fungi in a nutrient-competent way. Parasitic nematodes (*Steinernema carpocapsae*) move in the soil and seek out the host insect by smell, enter its body, where they expel bacteria that multiply and kill the host.

Another group are **parasitoids**, which are animals that also obtain nutrition from the host, carry out their development in it, and finally the host is killed. This includes species of the genus *Hymenoptera, Diptera*, but also bacteria, such as *Bacillus thuringiensis, Beauveria bassiana*, but also viruses. The bacterium *Bacillus thuringiensis* uses an endotoxin crystal that activates the breakdown of the intestinal wall, while the target organism dies as a result of bacterial sepsis. The fungus *Beauveria bassiana* grows its hyphae into the tissues of the host and disrupts their hemolymphatic circulation, while the host dies in 2 – 8 days. It is also effective against the larvae of butterflies (bud moth – *Spilotana ocellana*, bud moth – *Argyroploce variegana*, codling moth – *Cydia pomonella*, brown-tail moth – *Euproctis chryssorhoea*, gypsy moth – *Lymantria dispar*, lackey moth – *Malacosoma neustrium*, fall webworm moth- *Hyphantria cunea* , winter moth – *Operophtera brumata*) and not only on fruit trees.
Cydia pomonella granulovirus (CpGV) is often used. After ingestion, the viruses are activated by the low pH in the digestive tract, where they continue to travel through the hemolymph to the fat bodies, where they multiply. Subsequently, the caterpillars die due to the proliferation of vortices. They are highly effective against first instar larvae and are especially effective against first generations, but their preparation is relatively expensive compared to bacterial and fungal preparations. Viruses reproduce only in living organisms and therefore it is necessary to breed a host for their reproduction.
The most important parasitoid in field conditions is the egg parasite *Trichograma* (especially the species *Trichogramma evanescens, T. cacoeciae, T. dendrolini*), which lays its eggs in the eggs of the pest, and the eggs of the pest do not hatch into larvae of the pest, but the egg parasitoid image. It is used against the codling moth (*Cydia pomonella*). In orchards, the parasitoid of *Aphelinus mali* was introduced to Europe against the woolly apple aphid (Eriosoma lanigerum) and the parasitoid *Prospaltella perniciosi* against the dangerous shieldworm.

Predators are the broadest group of natural enemies of pests. They are animals that feed on a higher number of pieces of prey that they kill. This includes representatives of the genera *Staphylinidae, Cantharidae, Coccinellidae, Carabidae, Syrphidae, Chrysopidae, Araneae*, and others.
Predatory mites (*Typhlodromus pyri*), which are placed on trees in felt bands, are already widely known, where they reproduce and expand in search of food. Larvae of the common green lacewing (*Chrysoperla carnea*) are used to eliminate many types of aphids, but also other insects. The predatory ladybird *Cryptolaemus montrouzieri* is used in biological protection mainly on ornamental trees against worms from the genera *Pseudococcus* and *Planococcus*, but it can be used with success when it occurs on fruit trees.

Preparations containing entomopathogenic nematodes are also used against harmful insects. There are well-known preparations effective against the codling moth (*C. pomonella)*, cabbage moth (*Mamestra brassicae*) and other pests. Nematodes from the genus *Heterorhabditis* are used against the lovage weevil (*Otiorhynchus ligustici*) and the vine weevil (*Otiorrhynchus sulcatus*) on ornamental plants, strawberries, vines and other crops.

Beneficial insects	**Target organism**	**Predatory activity**
predatory mites (*Acari* spp.)	mites	daily: 5 mites, 20 larvae, 20 (nymphs), total: 30-50 mites
stinkbugs (*Heteroptera*)	mites, aphids, pear psylla	daily: 30 mites, 150 spotted mites, total: 200 mites
ladybug (*Stethorus punctillum*)	mites	total: 250 mites, 600 mite eggs
ladybugs (*Coccinallidae*)	aphids, mites	daily: 10-15 aphids, total: 400 aphids
lacewings *(Chrysopidae)*	aphids, mites	daily: 30-50 mites, total: 200-500 mites
parasitic wasp (*Aphelinus mali)*	wooly apple aphid	overall: 90% parasitism in autumn
hoverflies (*Syrphidae*)	aphids	daily: 10-40 aphids, total: 150-600 aphids
parasitic wasp (*Prospatella perniciosi*)	San José scale	overall: 90% parasitism in autumn
Hymenoptera (*Ephedrus persicae, plagiator, Praon volucre*)	aphids	total: 200-1000 aphids
parasitic wasp (*Apanteles*)	leaf miners	overall: 60 – 90% parasitism in autumn
parasitic wasp (*Colpoclypeus florus)*	bud moths (*P. heparana, S. ocellana*)	overall: 70% parasitism in autumn

Natural enemies are usually found in forests, but in some cases it is necessary to deliberately bring them in from other geographical areas, the so-called introduction. Commercial, artificial propagation is also often done. In already existing orchards, it is necessary to protect them and possibly guide the movement of populations by creating suitable conditions for their development, e.g. by greening the rows with special herbal mixtures or by planting bio-corridors.

REGULATION OF WEEDS

Principles of herbicide use in IPM:

- each product can only be used once during the growing season (year),
- the same active substance must not be applied more than once during vegetation,
- herbicides can be used for pome fruits no later than 80 days before harvesting,
- for stone fruits, no later than 50 days before harvesting.

The fruit grower should, in principle, adapt soil cultivation to the different light, growth and competition conditions in young and fruiting orchards.

Recommendations for new and young orchards up to 3 years

Immediately after planting, a simazine preparation can be applied to the still bare soil: 2 kg per ha. The effect lasts until July. The manufacturer recommends not using a glyphosate product in the first year. In practice, however, it has already been used many times without adverse consequences. However, the condition is to hit a minimum part of the trunk and use only for two-year-old trees. From the end of August, even the belt under the trees can be left green in young orchards. By removing excess nitrogen, the maturation of wood is supported.
In the fall of the first year, a glyphosate preparation can be applied in half the dose to normally matured trees without any problems.

Alternatives to herbicide treatment in young orchards

For the mechanical cultivation of the soil of the belt under the trees, the disc plow has proven itself in particular. However, it can only be used in small and medium-sized enterprises (3 – 10 ha).

Recommendations for bearing orchards

From the 4th to the 5th year, as a result of increasing shading and multiple covering of the soil with mulch, the plant composition changes in the strips under the trees. Weakly competing perennial plants with cushion-like leaves, such as chickweed (*Stellaria media*), ground-ivy (*Glechoma hederacea)* and others. They gain the upper hand and suppress problem weeds.
As long-term experiments in Laimburg have clearly shown, the year-round covering of the strip under the trees with weeds even in fruiting orchards on the M9 rootstock with sufficient irrigation did not cause any yield losses.
Therefore, we do not recommend applying herbicides in fruiting orchards on strong and medium-growing rootstocks, but covering the tree belt under the trees with mulch. On the plains, this is also possible with trees on the M9. In certain cases, such sets require 10-20% more nitrogen and water.
In apple orchards with weak growth, without the possibility of irrigation and located on a slope, the use of herbicides may be more advantageous.

Autumn treatment

Autumn treatment is recommended in young orchards. By applying a half dose of a glyphosate-based preparation in the period after harvest, the strip under the trees can be kept weed-free until the next year's flowering. At the end of May, the strip under the trees will grow again. Further use of herbicides may save work in the short term, but it will facilitate the growth of some problematic weeds. The amount of water consumed at glyphosate should be 3 – 5 hectoliters for each hectare of treated area.
According to the tree spacing, the ideal driving speed is around 5 km/h. Nozzles with a long spray (Tee – Jet) are the most suitable. The OC 06 nozzle is suitable for a belt width of up to 80 cm, the OC 10 nozzle for a belt 1 – 2 m wide in multi-row systems. Tee Jet OC 03 is a suitable type of nozzle for the reverse syringe.

THE MOST IMPORTANT PESTS AND DISEASES OF APPLE TREES

Codling moth (*Cydia pomonella*)

Bionomics and harmfulness

The apple peeler originated in Eurasia (Backman, 1999), but followed the cultivation of apples and pears all over the world, such as East and South Africa, Pakistan, China, America, South Australia, New Zealand, Belarus, Ukraine, Moldova, and Asia. (Razowski, 2003). Of all the pests of apple trees, it has the greatest potential for fruit damage (Backman, 1999).

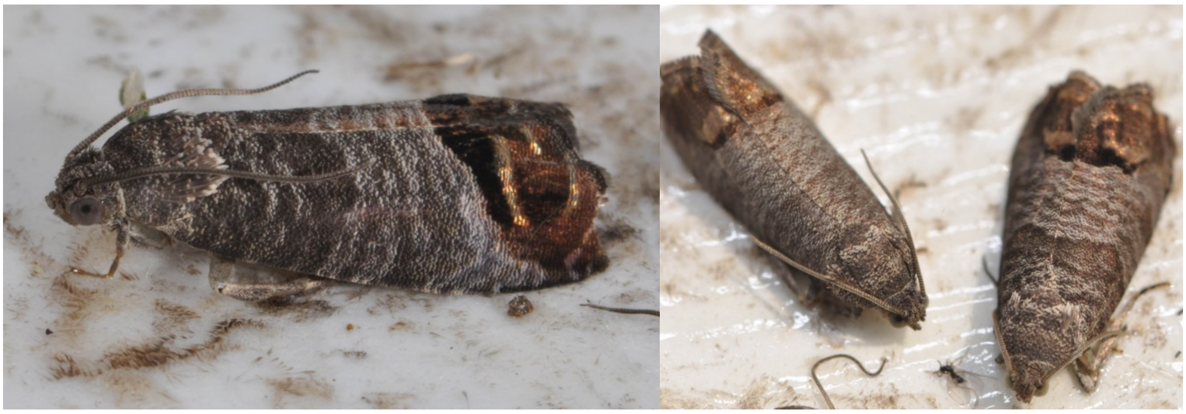


Fig. 1. A male codling moth (*Cydia pomonella*) caught in a pheromone trap. (photo: Mezey)

The codling moth is a tiny, about 10 mm butterfly. It measures approximately 20 mm in wingspan. The front wings are slate-gray, transversely brown-striped and with a large reddish-brown spot on the outer edge. The hind wings are brownish gray (Mejierman, 2000). Some types of apple trees are considered sensitive to damage caused by the codling moth (e.g. Golden Delicious) (Vétek – Nagy, 2011). Vétek states that, in addition to apple fruits, it also damages pears, quinces and walnuts, and Hluchý (2008) also mentions apricots and peaches, but also other types of fruit trees (Mikolayjski, 2010). The exception is plums, which are not attacked. The caterpillar damages the fruit and seed (Tamašek, Tancík, 2009).

The codling moth has a size of 14 mm – 21 mm. The front wings are dark gray with a transverse wavy line. At the top is a brown spot with a bronze tinge. The united wings of a butterfly at rest resemble a folded roof. (Grichanov, 2011).

The 5^{th}-6^{th} instar overwinters in a cocoon in cracks in the bark on the trunk. In intensive plantings, it also overwinters in the soil, under tufts of grass or in fruit chambers and warehouses. (Hluchý et al., 2008) The caterpillars pupate only in spring, usually in April, and hatching of butterflies begins around mid-May (depending on altitude) after reaching SET_{10}(d)=80 °C. The sitting butterfly has roof-like folded wings and is conspicuous by its bright wing tips. Butterflies fly only in the early evening and in the first part of the night at temperatures above 12 °C. During the day, they rest in shaded places in the crowns of trees. Butterflies mate if the temperature at 9:00 p.m. reaches 15 °C. After copulation, females begin to lay eggs individually on leaves or young fruits. Mass laying of eggs occurs if the temperature at 9:00 p.m. reaches 17 °C. Females usually lay eggs singly. The egg is milky, about 1 mm in size, almost round, flat, resembles a lentil grain, stuck to a leaf or fruit. (Razowski, 2002).

Fig. 2. Fruit damage by the caterpillar of the first generation of the codling moth (*Cydia pomonella*). (photo: Mezey)

Egg development takes 5 – 14 days. The hatched caterpillar is looking for a suitable place to enter the apple fruit. (Razowski, 2002). After a short surface feeding, the hatched larvae burrow into the fruit and bite through the passage towards the testicle. (Hluchý et al., 2008). A caterpillar can damage two to three apples during its lifetime (Hudec – Gutten, 2007). Hluchý et al. (2008) states that individual fruits of fruit trees are usually attacked by only one caterpillar. The entrance to the fruit is filled with dry caterpillar droppings, which are also found along the entire length of the corridor. (Mikolayski, 2010). First it is on the surface of the skin and later after the first instar penetrates into the flesh of the fruit. Further shedding occurs in the seminal chamber of the fruit. The 3rd instar caterpillar lives on seeds, but for development it needs to consume pulp, which contains, among other substances, sugar as an energy substance. The 4th instar caterpillar makes a return hole on the fruit surface. Subsequently, she is able to settle another fruit. After the 4th instar, the caterpillar stops eating. It leaves the fruit and creates a cocoon (silk cocoons). The pupa develops for 14 – 21 days. Part of the population of the first generation of caterpillars enters diapause after completion of development, part completes development and gives rise to the second generation. (Razowski, 2002).
Fruits attacked by the first generation of codling moth drop. (Hluchý et al. 2008). When attacked by the second generation of the codling moth, the fruits ripen, but on cross-section they are wormy and the caterpillar of the pest can be found in them. Infested apples are eaten inside and filled with droppings. Corridors caused by the eating of caterpillars lead to the nucleus. Fruits damaged in this way are very often attacked by moniliosis and other diseases (Hudec, Gutten, 2007).
In warmer regions, these caterpillars pupate from late June to early July. In the second half of July, hatching of butterflies begins, and at the end of the month, eggs appear again and the second generation of caterpillars hatches. In cooler areas at an altitude of about 500 m and above, only one generation develops. Only a partial second generation may appear in transitional areas. In the warmest regions of Slovakia, there are up to three generations of codling moth. The last generation of caterpillars creates cocoons in which it hibernates (Razowski, 2002).

Preventive measures

Preventive measures include shallow cultivation of the soil in early spring to a depth of 50 mm, if protection against apple sawfly is also done, then to a depth of 100 mm. It is important to take care of the surroundings of the orchard in the form of eliminating the possibility of the pest overwintering, which is very often old sheds, neglected gardens, accompanying vegetation, but also wooden boxes used in the past, or the workers' dormitories themselves. We recommend the installation of birdhouses, especially for titmice, which dispose of a large number of larvae when feeding their young. Correct pruning and training of the trees is also important, we ensure that the crown is not overcrowded, which makes it impossible for the moths to hide. Fruit thinning is a very important operation. During the June thinnings, it is necessary to do the thinning so that there are no clusters of fruits within the tree, or so that the two fruits do not touch, because it very often happens that the eggs are laid precisely in such overcrowded places.

Direct protection
In direct protection systems, we use either separately or in combination three options, namely signaling and subsequent chemical protection, protection with the granulovirus and the method of confusing males.

Signaling and chemical protection
The optimal dates for the necessary visual inspections of pest infestation can be determined in two ways:
1) By monitoring the flight waves of butterflies with a pheromone trap in combination with the detection of evening temperatures at 9 p.m.
2) Cumulatively above 10 °C since the beginning of the year detected by SET monitoring. (Hluchý et al. 2008). Placement of pheromone traps when SET 100°C degree days is reached, we expect the first butterflies at 150 – 200 °C SET (Alston, 2006).

Threshold of economic damage: 2 eggs per 100 randomly selected fruits and adjacent leaves.
There are 2 options for determining the optimal dates of use of larvicides:
1) Temperature sums – when meeting SET 2.100 degree hours from the time of detection of the peak of the individual flight waves of the apple wrapper by the pheromone trap;
2) Monitoring the development of the collected eggs – when the "red ring" to "black head" stage is detected (Hluchý et al. 2008).
The first sprays are applied at a daily SET of 50-75°C after reaching the biofix, 100-200°C in the early egg-laying stage and at 220-250°C when the caterpillars first hatch from the eggs (Alston, 2006).
If the method of confusing males is implemented in the orchard, vaporizers are hung immediately after reaching the biofix (if the biofix in this case is the capture of the first butterflies in the traps), as a prevention against egg laying. Chemical sprays are also recommended in the case of the method of confusing males. The first spray is usually the most important because it suppresses the first generation and thus the next generations. It is important to repeat the spraying after the protection period has expired. It is important to keep the fruits under a chemical screen for the entire duration of all generations (Alston, 2006).

Management of arrangements for the codling moth based on DDays SET.

SET_{10} °C	% of adults	% egg hatching	Measure
40	0	0	pheromone traps placement
65 – 90	First moths	0	trpas controll till biofix
first generation			
0 (biofix)	continuous catch	0	reset of summators
10 – 25	5 – 9	0	first eggs layed
			application of insecticides suitable before egg laying
40 – 90	15 – 40	0	early egg laying stage
			application of insecticides suitable for this time period
100 – 120	45 – 50	1 – 3	beggining of egg hatching
			application of insecticides effective for newly hatched larvas
170 – 340	67 – 98	12 – 80	critical control period
			high percentage of egg hatching

			important to protect the fruits in this time period
490	100	99	end of hatching for the first generation
second generation			
540 – 570	5 – 8	0	first eggs of second generation
			application of insecticides suitable for this time period
590	13	1	beggining of egg hatching
			application of insecticides effective for newly hatched larvas
710 – 940	46 – 93	11 – 71	critical control period
			high percentage of egg hatching
1150	100	99	end of hatching for the second generation
third generation			
1180	1	15	beggining of egg hatching
			important to protect fruits until september the 15th.
			withholding period control

Mating disruption

It comes from Japan. This is the principle of a strong concentration of the female pheromone, which confuses the males and they are unable to locate the female, fertilization will not occur, or only very sporadically, which significantly reduces the number of eggs and larvae. At the same time, it is not necessary to apply as many insecticide sprays, which also reduces the risk of developing resistance to the used insecticide. Evaporators are installed before the start of the flight of the overwintering generation by hanging them on the edge rows directly on the branches, approx. 0.5 m from the top of the tree. Evaporators should not be hung on the wires of the supporting structure. At the same time, it is recommended to apply parasitic nematodes (*Steinernema feltiae*) from mid-September to mid-October, which will help reduce the overwintering stages of the cocoons in the soil. The application is effective only on larger areas (5ha and more), accurate identification of the pest is important, it does not work against other moths on apple trees. If classic chemical protection is used at the same time, the use of selective insecticides and those that do not have an adverse effect on beneficial insects is strongly recommended.

Cydia pomonella granulovirus (CpGv).

This method uses a virus that is able to kill the larvae of the codling moth within a few days. The condition is the consumption of viruses by the larva. If this happens, the inner coating is dissolved in the intestine due to the high pH. After breaking down the lipophilic envelope, the virion is released. Virions pass through the intestinal wall and are transported by hemolymph to fat cells, where the virus multiplies. After multiplication, the virus particles are contained in the entire body of the larva and it is killed. They are then re-entered into the environment.

It is treated on the basis of signaling from pheromone traps, or SET. The first treatment before the end of egg development (before the caterpillars hatch), the next treatment at an interval of 6 – 14 days, or 8 days of sunny weather. Against the first generation, we apply a full dose of the product, against the second generation, half. A maximum of 3 treatments per one generation of the pest is recommended. Larvae die after 5 – 8 days. 1 – 2 virus particles are sufficient to achieve 50% larval mortality. If the number of viruses in the larva is higher, mortality occurs already in the first larval instar. At lower viral doses and more advanced instars, a longer period is required to achieve mortality because the virus needs to multiply sufficiently. The method is more effective against the first generation of the pest, because the eggs are laid on the leaves, from where, after hatching, the

larvae crawl towards the small fruit, and traveling through the leaf, virus particles also get inside them. In the case of the second generation, the eggs are laid directly on the fruit, thus the larva burrows into the fruit immediately after hatching and there is less chance of infection.
It is advisable to combine this method with the method of confusing males, and it is also effective to combine it with classical permitted, especially selective insecticides.

Apple sawfly (*Hoplocampa testudinea*)

Bionomics and harmfulness
Pest larvae overwinter in the soil at a depth of 2 – 25 cm. Images begin to appear sometimes already at the end of April, but most often at the beginning of May, when the apple trees are blooming. Shortly after hatching, the females lay their eggs in the sepals of the apple flowers. Eggs hatch into larvae after 6 – 20 days. The youngest larvae harm only shallowly under the skin of the developing fruit. It causes early worming of fruits with typical eating, the so-called gallery. The older larvae eat the inside of the fruit, which falls during June one to two weeks before the fruit drop caused by the codling moth. One larva can damage 3 – 4 fruits during its life. The adult larvae leave the fallen fruits, or they descend from the unfallen ones to the ground, where they overwinter. Some larvae can survive the entire following vegetation in diapause, and hatching of imagos does not take place until the next year.

Preventive measures
Part of the overwintering larvae is destroyed by cultivating the soil to a depth of 100 mm under the tree crowns in eraly spring. In addition to entomopathogenic fungi, the sawfly population is also affected by a parasitic wasp *Lathrolestes sensator* from the *Ichneumonidae* family. We recommend the installation of birdhouses, especially for titmice, which dispose of a large number of larvae when feeding their young.

Direct protection
In protection against the sawfly, white glue traps are primarily used to signal the presence of adults. For signaling, 3 pieces per set or individual block set. The boards should be at least 25 m apart. They should be installed at a height of approx. 1.5 m, on well-lit parts of trees with a non-thickened crown, in sufficient time for the hatching of images, approximately 10-14 days before flowering. The subtraction of images captured by white glue traps should be carried out 2-3 times a week. Spraying is necessary if at least 2 eggs per 100 flowers are found (with BBCH 67-69 the end of flowering), or if the first pests are found on white traps.
An innovative method is to catch sawflies with white sticky tape to decrease the population. Fixing the white sticky tape before the first flowers are open with Rimpro / Fruitweb models that predict the start of the flight. Hang 150 – 250 sticky tapes per hectare, depending on infection pressure. Fix the sticky tapes with staplers between the horizontal wires of the trellis system between the trees. In orchards without a trellis system, research about an effective method of fixing the tapes is needed. No branches should cover or move against the sticky tapes. One person on the working platform for the top wire and two persons for the lower wires are needed. Two rows can be done at once. The distance between the wires can vary from 1 to 2 m. Start at the high wire and go down to the lower wire. Remove the bands soon after flowering to prevent the bycatching of bees and natural enemies (Brouwer 2022).
For biological protection against sawflies, preparations based on extracts of *Azadiracha indica* (NeemAzal) at the end of flowering are suitable, or: water extract from the tropical *Quassia amara*. The ideal date is the time of mass hatching of larvae. However, this term can only be determined in a relatively complicated way, either by monitoring the development of the eggs, or based on monitoring the sum of active temperatures calculated since the start of the image raid.
Controlling sawflies in organic orchards is challenging because the most effective plant protection products are not available to organic production. Adult sawflies emerge before blossom and once the

larvae have excited the apples in May, the rest of the lifecycle is spent belowground in a prepupal or pupal form (Vincent 2019). Nematodes once applied to a substrate (Divya 2009), locate a host by following CO_2 trails (Labaude 2018). Nematodes can also be applied to plant foliage. In field trials, where four foliar applications of *Steinernema carpocapsae* were applied to apple trees, secondary sawfly damage was reduced by 19% compared to an untreated control (Vincent 1992). When applying nematodes as a foliar application, growers should be aware that in-field conditions, such as low humidity or high temperature, can make control variable (Wright 2005).

Apple sawfly is parasitized by the *Ichneumonid*, *Lathrolestes ensator*. This wasp lays eggs during a two-week period, targeting the first and second larval instars (Vincent 2019). This short window of opportunity can be disrupted by poor weather conditions. In addition, due to variation in flowering and fruit development time, varying rates of parasitism occur on different cultivars (Cross 2001), depending on whether cultivar phenology is synchronized with that of the parasitoid. Rates of parasitism by *L. ensator* are affected by individual orchard and the management strategy used. Generally, parasitoid species richness is higher in organic orchards compared to conventional or IPM orchards (Mates 2012) due to the detrimental impact of chemical applications (Cross 1999). However, the occurrence of *L. enactor* can also be impacted in organic orchards by sulphur applications during parasitoid flight, and *L. enactor* is found more commonly in orchards with sandy soils (Zijp 1993, Zijp 2002).

The average emergence of sawflies occurred at 169 degree days (SD = 20) counted from March 15 (threshold temperature 4 °C). The difference in emergence from existing first flight model of average and maximum 9 and 39 degree days (1 and 9 calendar days) was found acceptable. Accumulated oviposition of 85% at full bloom (BBCH 65) suggests that mass trapping and monitoring could stop at this time. This is supported by a tendency of decreased trap catches during that period (Sjoberg 2014).

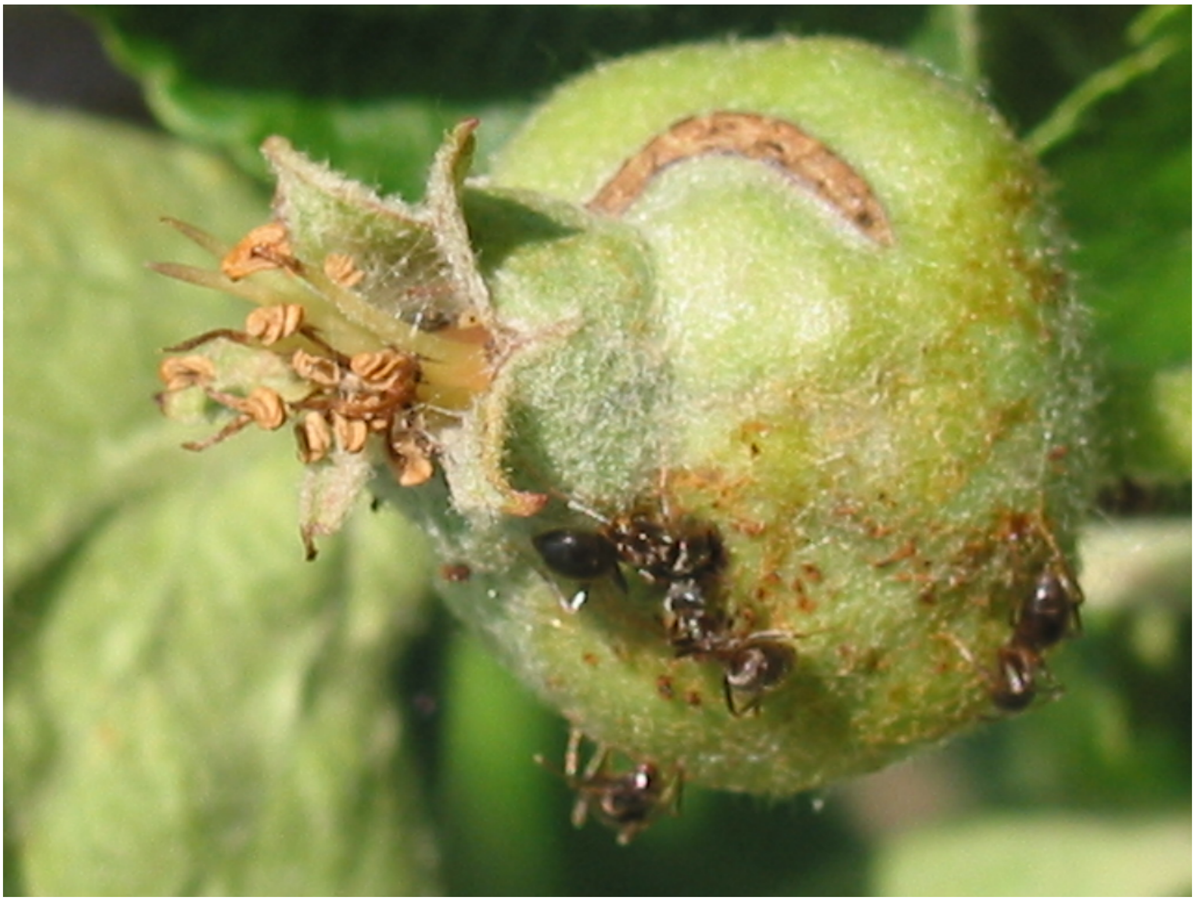


Fig. 3. Young fruit damage by the caterpillar of the apple sawfly (*Hoplocampa testudinea*). (photo: Mezey)

Pear leaf blister moth (*Leucoptera scitella*)

Bionomics and harmfulness

Pear leaf blister moth belongs to the so-called mining pests and among the under-diggers it causes the most damage. It is widespread in Europe, Asia and North Africa. The greatest damage was observed in areas of southern Europe. The front wings of the pest are pale gray with a metallic sheen. At their end, they have a yellow box in which there are three white spots on the front edge of the wing. There are four black stripes on the tip of the wing. The hindwings are also pale gray and fringed with algae. The head and thorax are pale gray, the abdomen is dark gray, the antennae are filiform and about as long as the forewings. The color of the egg changes from pale gray to yellow during development.

It is a feared pest especially in fruit tree nurseries. If it occurs in large numbers (more than 10 pieces on one apple leaf), the damaged leaves dry up and fall prematurely. Over time, it weakens, and the fruits from such trees are of lower quality and are less storable. We also include the apple leaf miner (*Lyonetia clerkella*) and the spotted tentiform leafminer (*Phyllonorycter blancardella*) in the category of destructive pests. Fruit borer larvae create tunnel-like mines with a strip of droppings in the middle. Trees that are attacked look burnt from a distance. Brown elliptical or round mines on the back of the leaves are a characteristic sign of the presence of pear leaf blister moth caterpillars. The finished mine is slightly contracted from the inside by the fibers spun by the caterpillar, which causes deformation of the leaves. Round mines, on the other hand, are typical for the larvae of the spiral weevil, while inside there is dung that is arranged in circles or in the shape of a spiral. As a polyphagous species, the spiral weevil lays its eggs mainly on the leaves of the domestic apple tree, cherry, common pear, as well as on other deciduous trees.

In the conditions of the Slovak Republic, we meet with two to three generations per year. Mines of the first generation of the pear leaf blister moth usually occur en masse after the apple trees bloom. After growing up, the larvae climb out of the mine and pupate in a white cocoon on the underside of the leaves or in cracks in the bark. Generally, only pupae that are in white cocoons under the bark of trees or in other shelters overwinter. The development of the larvae of the next generation takes place from mid-July to the beginning of September. We can consider birds as natural enemies for the larvae of the spiral weevil. The harmfulness of the spiral weevil is significant mainly in the warmest areas.

Preventive measures

We recommend the installation of birdhouses, especially for titmice, which dispose of a large number of larvae when feeding their young.

Promotion of natural antagonists by implementing flower strips in the tree alleys and/or along the plantation. Flower strips can help to enhance the parasitation rate and reduce the needed usage of NeemAzal®-T/S. They can also positively affect the control of other pests, such as green or woolly apple aphids (Adolphi 2022).

Direct protection

Spraying with approved insecticides is necessary if we observe the appearance of at least 100 eggs or incipient mines per 100 leaves (i.e. 1 mine per leaf). Spraying efficiency is best if the mines are up to 1 mm in size, which is especially true for the second and third generation. For signalling, we use pheromone traps, which we hang in mid-April. Protection is necessary if an attack of butterflies is caught in pheromone traps.

In bioprotection systems, it is possible to apply a preparation, NeemAzal, based on extracts from the tropical tree *Azadirachta indica.* Apply NeemAzal®-T/S shortly before the peak of hatching of L. malifoliella. Eggs are laid on the undersides of leaves; mass hatching takes place from early to mid-June (northern Germany). To choose the correct application date, use flight monitoring with pheromone traps, visual control of larval hatching (Binocular) and the temperature sum model according to Gottwald. The active ingredient of NeemAzal®-T/S is absorbed via the sucking activity of the larvae before it enters the leaf. It is very important to apply shortly before the larvae hatch, as the adults and eggs are not affected. Larvae development is inhibited, as well as in their feeding activity. The damages on the leaves, also known as mines, remain small, and the next generation is reduced (Adolphi 2022).

A natural insecticide with the active substance spinosad can be also used, in identical terms. Even with this protection system, it is necessary to choose such a term of the measure as to reach the maximum number of young caterpillars, for which pheromone traps can be used.

The main predators of pear leaf bliister moths are parasitoids of the family *Chalcidoidea*. Most of them attack larval and pupal stages. Also, earwigs are important in the control of this pest. Thus, it is crucial to apply control measures which do not harm these predators. The parasitoids may benefit from flowering strips. Do not use broad spectrum insecticides during the flight period of the parasitoids (Adolphi 2022).

The lower developmental threshold for *L. scitella* was 5.5 °C and the following temperature sums were estimated: egg stage, 155 – 172 degree-days; larval stage, 284 – 328 degree-days; pupal stage, 212 – 246 degree-days; from egg to imago, 651-746 degree-days; the beginning of flight of the overwintered generation, 122 – 177 degree-days; and beginning of egg laying of the overwintered generation, 153 – 185 degree-days (Andreev et al., 2001). A similar model based on degree-hours has been developed in the Czech Republic (Kneifl and Knourkova, 1999). The authors report that the appropriate time for ovicidal treatment against the pest is when the temperature sum is in the range of 3000 – 3300 hour-degrees (10 °C is the low temperature threshold). Sums of 5100 – 5400 hour-degrees indicate the best time for larvicidal treatment.

Fig. 4. Apple leaf with the damage after pear leaf blister moth (*Leucoptera scitella*). (photo: Mezey)

Green apple aphid (*Aphis pomi*) a rosy apple aphid (*Dysaphis plantaginea*)

Bionomics and harmfulness

The aphids overwinters in the egg stage and the nymphs hatch in April and develop into wingless female in two weeks. Already in the second generation, winged females appear and fly to other trees. It has 10 – 17 generations during the year. It is a monocyclic species, it does not migrate between the winter and summer host, it stays on the apple tree throughout the growing season. Larvae are born in August and September and develop into winged females (sexupare). These females give birth to a generation (sexuales) in which there are both females and males. After fertilization, the females lay eggs that overwinter.

In addition to apple trees, green apple aphid also damages pears, hawthorn, medlar and rowan. It attacks leaves and shoots. It sucks the juices from the underside of leaves and young shoots and creates dense colonies on them. Infested leaves and shoots are deformed but remain green, in the case of rosy apple aphid they turn yellow to crimson-red. In case of a larger attack, the deformed leaves dry up prematurely and the shoots do not mature enough and become not woody. In addition to direct damage, they are also harmful by transmitting viruses.

Preventive measures

Among the indirect measures against aphids, it is important to remove shoots from the orchard after winter prunning, on which eggs may already be laid. An important measure is also the support of the natural enemies of aphids, especially adults, but also larvae of various types of ladybugs, larvae of goldeneyes and moths, earwigs, predatory bugs and parasitoid nymphs and others. Many, especially gardeners, also take measures to destroy ants, which is harmful. Ants do spread aphids, but by destroying ants, we solve the consequences, not the cause. If we eliminate aphids, the ants will have nothing to spread and will disappear by themselves.

Direct protection

The key is, due to the number of generations and the subsequent occurrence of different developmental stages, to destroy the aphid population when only one developmental stage is present in the orchard. It is the egg stage, i.e. if we destroy immediately when laying eggs, aphids usually do not cause much damage. We call this measure a pre-spring population synchronization. However, this state is mostly achieved only in big orchards. This is often a problem in gardens, because it is not enough if only one gardener does this, everyone has to do it. If only one does it, neighboring aphids are guaranteed to fly from the others during the growing season. The average length of one aphid flight is about 100m.

We check the occurrence of eggs during the winter or in the pre-spring period on 20 randomly selected two- and three-year-old branches of min. lenght of 0.2 m. The result is converted to 1 regular meter. Later, in the phase of green and pink buds, treatment against apple aphid is carried out if we detect 10 aphids per 100 flowering roses and in the period after flowering, when we detect 10 colonies per 100 shoots. The harmfulness threshold of aphids in this period is almost zero, treatment must be done if there are 1 or more aphid per 100 buds.

We carry out direct measures against aphids in the pre-spring period with approved insecticides, preferably selective in combination with oil-based preparations if we detect 25 eggs per 1 m of branch length. From biological preparations against aphids, extracts from the tropical tree *Azadirachta indica* can be used in combination with oil preparations based on rapeseed oil methyl ester, or *Pongamia pinnata* oil extract in the bio version.

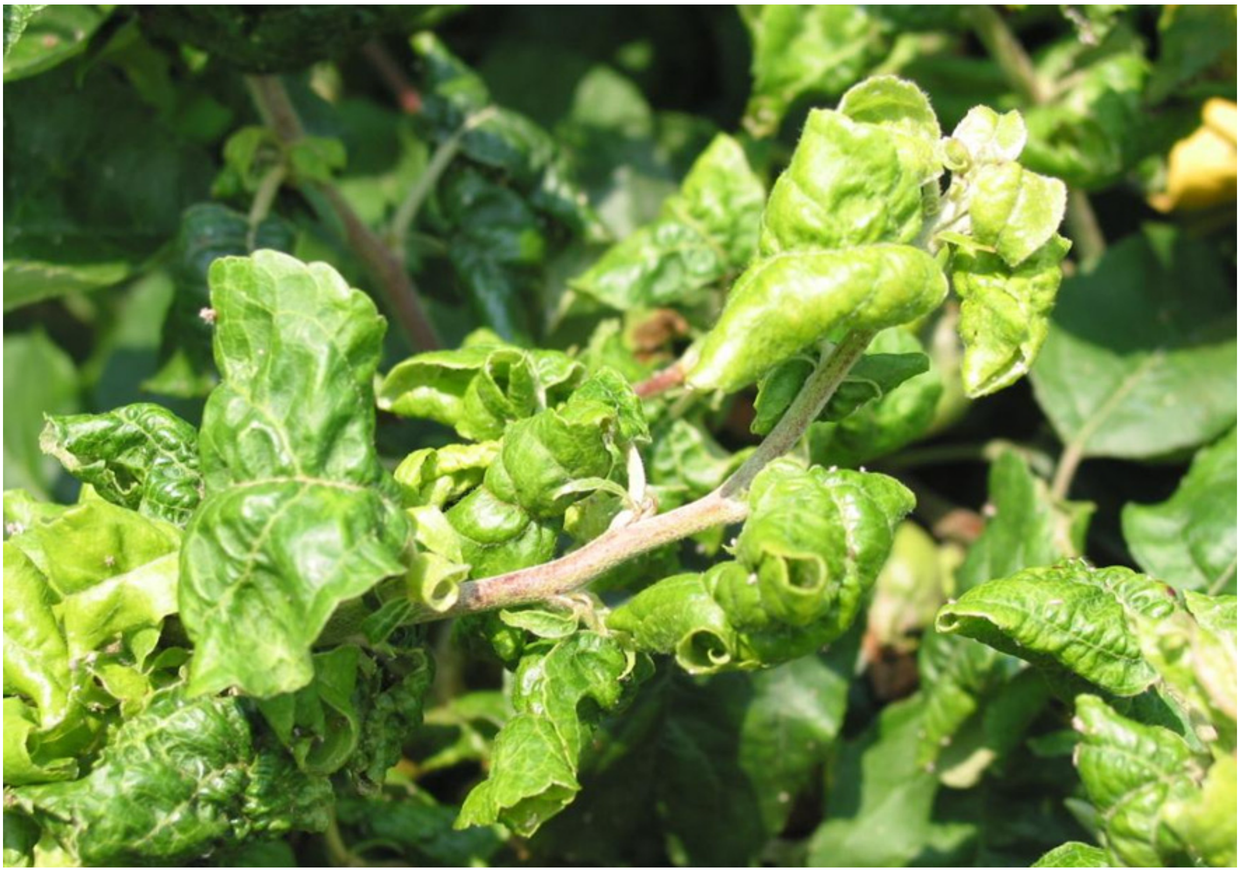


Fig. 5. Green apple aphid (*Aphis pomi*) causes curling leves without their discoloration. (photo: Mezey)

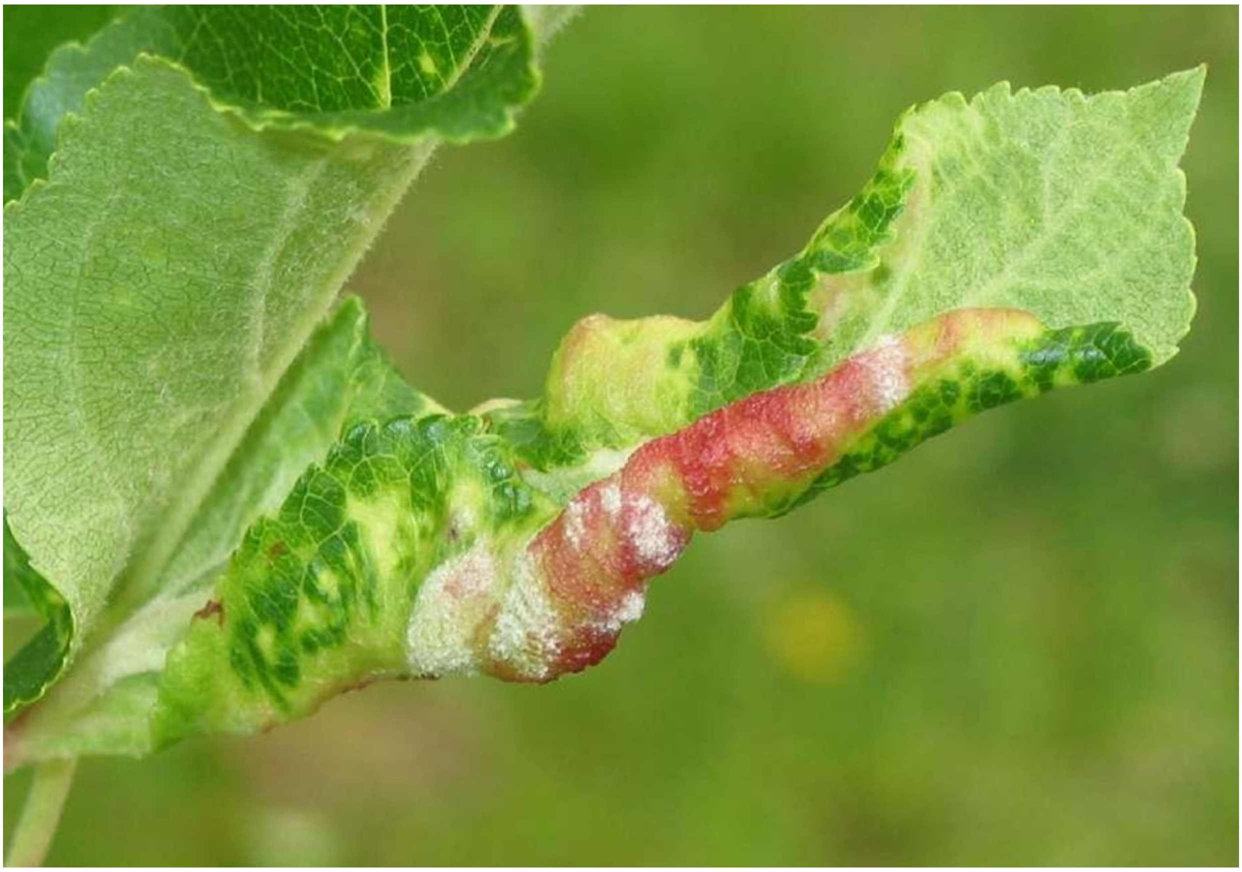


Fig. 6. Rosy apple aphid (*Disaphis plantaginea*) causes curling leves with their discoloration. (photo: Mezey)

Tortricid moths (*Adoxophyes orana, Pandemis heparana)*

Bionomics and harmfulness

This mainly includes the summer fruit tortrix and the apple brown tortrix. They are butterflies that damage the skin of the fruit and the upper layers of the pulp, especially in the second half of the vegetation. They hibernate as young caterpillars. After flowering, *Adoxophyes* larvae begin to pupate. *Pandemis* caterpillars develop more slowly and can damage young fruit after flowering before pupation. In June and July, larvae of the first generation can be observed, at the end of July, in August, larvae of the second generation. In warm years, a third generation may develop in September. Flight and egg-laying occurs when the temperature after dark is higher than 15 °C and subsequent hatching takes place 7 – 21 days later depending on the temperature, for a more accurate determination its recommended following the outputs from AMS, respectively, according to SET.

Preventive measures

We recommend the installation of birdhouses, especially for titmice, which dispose of a large number of larvae when feeding their young. Overwintering larvae can also be destroyed by shallow cultivation of adjacent strips.

Direct protection

The first spray with allowed insecticides or preparations based on *B. thuringiensis* should be applied at the beginning of the hatching of the larvae of the first generation from the eggs, which is usually determined by the capture of butterflies in pheromone traps over 5 pcs per week in one trap, or by a more precise method based on SET. Subsequently, repeat spraying every 7 – 10 days as long as hatching is in progress, which is usually in June. Sprays with preparations based on *B. thuringiensis* are not so effective, on the other hand, sprays with synthetic pyrethroids are effective, but very harmful to populations of predatory mites and other natural enemies.
Observations immediately after flowering – control of 100 rosettes of fruits or leaves for caterpillars. They are much more mobile than leech caterpillars and can easily be shaken to the ground. Chemical treatment is suitable if more than 5 caterpillars per 100 shoot tops are found, repeat the check in cold spring.
Observations in July/August – where overwintering caterpillars and caterpillars of the first generation have been dealt with in time, the second generation of caterpillars will cross the threshold of harmfulness in July or August only in exceptional cases. The limit of damage is 5 caterpillars per 250 fruits. It is also possible to use biological preparations based on granulovirus specific for this pest.

In orchards with biological protection, the occurrence and damage by tortricid moths is lower, because the natural balance of natural enemies, especially parasitic wasps, is preserved. If protection is still necessary, we do it with preparations based on *B. thuringiensis*, the active substance spinosad, or with the help of a specific granulovirus.

The first captures of *A. orana*, early in the season were observed at 362 DDs, (lower temperature thresholds: 7.2 °C and Biofix: 1st of January). The highest number of moth captures were observed at 428.7 DDs, while the start of the subsequent second flight was observed at 362 DDs. Moreover, the peak of the second moth flight was observed at 1 239.5 DDs (Damos 2022).

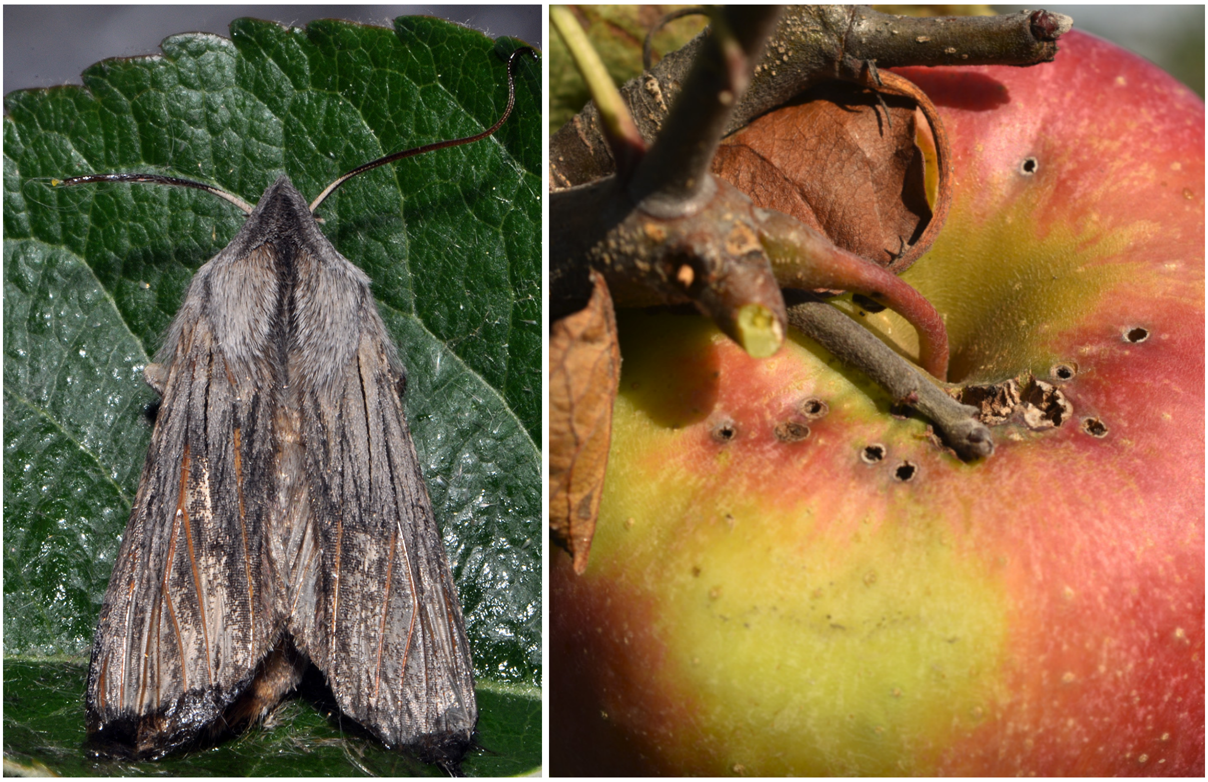


Fig. 7. Male of *Adoxophyes orana* on apple leaf and damage after larvae feeding. (photo: Mezey)

Apple scab (*Venturia inaequalis*)

Bionomics and harmfulness

The most economically important disease of apple trees. It affects all green parts of trees, including fruit. The fungus is most often found on the upper part of the leaves and causes round velvety brown-green spots (it is a sparse subfungus with conidia, grown in the skin of the leaves). The affected part of the leaves dies and acquires a gray-brown color. Similar spots appear on the affected fruits, which later turn into scabs. They remain in the skin and do not penetrate deeper into the pulp. The fruit growing in the place of the scab often cracks. Fruit cracking does not occur on developed apples, but spots on them deteriorate their quality and durability.

The pathogen overwinters on affected, fallen leaves. During the winter, perithecia (cell-shaped fruiting bodies) develop in them, in which pocket spores (ascospores) begin to mature from the beginning of April. The goal of protective measures is to reduce the source of infection in the spring, i.e. ascospores that develop on fallen leaves in early spring. Their physiological maturation usually occurs just before or at the beginning of budding. Ascospores enter the air and settle on leaves or fruits. Reducing the size of the infection is possible by removing fallen leaves in autumn or spring. Ascospores are the source of primary infections.

By overmoistening the mature fruiting bodies, ascospores fly out of them, which are spread through the air onto the plant. On a moist leaf, ascospores germinate (fastest at a temperature of around 20 °C) and penetrate the tissues of the host.

The maximum ascospore is released in the period from the pink bud phase to about 14 days after flowering (90 – 95%). During the growing season, the disease is spread by conidia from infected tree parts.

On the basis of monitoring the length of leaf wetness and temperature, it is possible to carry out targeted protection using the curative effectiveness of fungicides. Orchards in sheltered locations, where rain or dew only slowly dry out, are most at risk. Infections occur during rainy weather (moistening of the leaves is absolutely necessary for infections), optimal temperatures are in the range of 17 – 24 °C. The fulfillment of the conditions for infection (intensity of infection) can also be evaluated using the so-called Mills table based on the determined humidification time and the average air temperature during humidification. The method does not assess the intensity of the infection, but only whether the conditions for the infection have been met. The method is a fundamental part of all SW programs that are part of AMS and signaling programs.

Preventive measures

From the preventive measures, it is necessary to start with the selection of the location, when we plant apple trees in locations where moist air does not accumulate, or to locations where sufficient air flow is ensured. Next, the choice of growing shape is important, when we choose shapes that are airy with an adequate spacing. We also have to adapt the pruning to the shape, including the summer cut, which will air out and lighten the crowns. Another basic measure is the choice of varieties, when we try to plant resistant or tolerant varieties.

Direct protection

In modern systems of integrated protection, we mainly use AMS equipped with appropriate software (RimPro) for signaling, which, although they only show the fulfillment of the conditions for the emergence and spread of infection and do not show the actual occurrence of spores, but the occurrence of apple scab is so widespread in the Slovak Republic that protection based on signaling is justified and with we can say with certainty that when the conditions for the emergence of an infection are met, the infection will occur.

For preventive treatment, give preference to local systemic fungicides, and for curative treatment, preparations designed for this, knowing that under persistent suitable conditions, the effectiveness of curative sprays is about 3 days, i.e. after three days, if the conditions are suitable, repeat the curative spray. Systemic preparations have a longer half-life, so it is necessary to follow the label of the preparation. Combinations of systemic and curative preparations are also suitable, especially in periods of regular (repeated) infections, when the longer preventive action of these combinations is applied. However, we do all spraying only after signaling.

For some locally systemic fungicides from the group of strobilurins, a decrease in effectiveness against apple scab (onset of resistance) has been demonstrated when applied alone. It is very necessary to consistently apply a resistance management strategy, especially not to use these preparations more than 3 times per vegetation and 2 times in a row and to alternate them with fungicides with a different mechanism of action. Cross-resistance occurs with strobilurins, and alternating preparations from this group will not prevent the development of resistance.

The first treatment is usually signaled very early and sometimes already in the phenophase of the green tip of the leaves, so it is possible to apply preventive preparations after the detection of the first mature ascospores. More often it happens in the phenophase (mouse's ear) or in the case of curative protection after the detection of the first mature ascospores and the subsequent fulfillment of the conditions for infection based on signaling programs. Protection can be carried out preventively or curatively based on monitoring the course of the infection, or as a combination of both systems. It often happens that we treat 2 – 4 times before the flower, depending on the weather, and 4 – 6 times by the end of May. The interval between sprayings should take into account the infection pressure, the course of the weather, especially the period of permanent wetting of the leaves, the intensity of growth (in the period of maximum intensity of growth, the development of 2 – 3 leaves per week) and the possibilities of the fungicide used.

In cold and rainy weather (slow flowering), we also treat during flowering. Further, we treat as needed (course of weather, intensity of growth, used preparation) at intervals of 7 – 14 days until mid-June. We do not treat during a long-lasting drought, we only treat when the weather changes. If there is an unexpected rain during the period when the effectiveness of the preventive treatment is fading, it is possible to intervene immediately after the rain with a curative agent, the so-called stop spray. This measures must be done also after half of June, if the weather conditions are favourable for disease spreading.

The maximum intensity of protection must be in the period of greatest risk of infection (from the phenophase of the rose bud to approx. 1-2 weeks after flowering). Rational prevention consistently takes into account the course of the weather. In the middle to the end of June, we expect the end of spraying.

Summary

Preventive treatment (from BBCH 53-54 mouse ear – green bud) only until the end of May, further sprays only in cases of strong infection pressure (end of IV-beginning of V), contact+system can be combined.

Curative treatment (if there is no resistance) is done based on the signaling program (software output). Treat after infections that occurred on the 4th-6th. and other days after treatment, we recommend combining systemic and contact preparations.

The end of June – expected end of spraying, if the infestation is less than 0.5%, if it is higher, continue spraying.

Before harvesting – treatment for storage form.

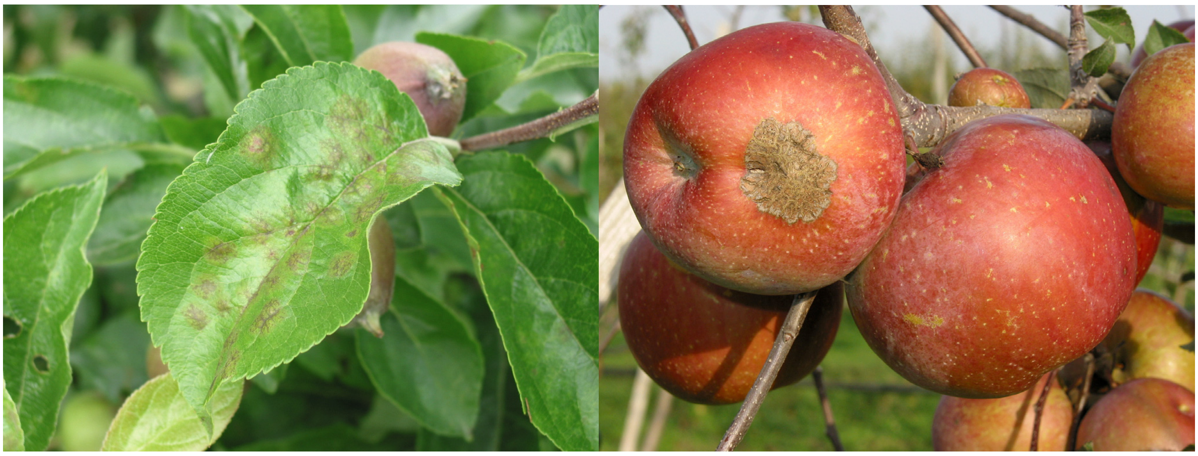


Fig. 8. Symptoms of apple scab (*Venturia inaequalis*) on leaf and fruit. (photo: Mezey)

Fire blight of apple and pear (*Erwinia amylovora*)

Bionomics and harmfulness

Bacterial disease. The bacterium enters the host plant through its natural openings (stomata) or wounds (secondary infestation), or is transferred by insects to the flowers (primary infestation). In the spring, fire blight deposits increase in size; elevated places (blisters) may appear on the surface of the lesions, from which mucus oozes after being punctured. Mucus droplets are the source of primary infection in the spring. The area between the cork mesh and the wood is watery, dark green, later a reddish-brown color appears. Later, when the multiplication and spread of bacteria stops, the surface of the lesion is rough and falls below the level of healthy tissue. Cracks appear at the edge between healthy and infected tissue. In the spring, the bacteria are transferred from the infecton sources to the flowers and from there they spread throughout the plant. They are spread to host plants by insects (especially bees), wind or rain. Flowers are the most susceptible organ of host plants. Individual flowers or entire inflorescences become watery, wither, turn light brown to dark brown or black, stick to the plant and eventually dry up.

Symptoms on annual shoots: the affected tissue has a watery appearance, in wet weather the infected tissue turns brown, later turns black and dries up. Droplets of slime appear on the surface of the stem. Shoots that have not yet completed their extension growth respond to infection by the bacterium *Erwinia amylovora* by connical bending of the top. The pathogen spreads to the leaves from the stem through vascular bundles or through injuries of the petiole and leaf blade. Eventually, the entire leaves turn brown and dry. Necrotic spots appear on the leaves, which start from the edge

of the leaf blade, or necrosis of the leaf blade and the main vein of the leaf appear in the shape of a triangle from the leaf petiole. Susceptible to infection are unripe fruits, into which the bacterium penetrates through stalks from infected brachyblasts, through natural openings or through wounds. Mucilage appears on the surface (and inside) of infected fruits under moist conditions in the form of droplets, fibrous formations or a continuous layer, which gives the fruit an oily appearance. Later, the surface of the fruit turns black and wrinkles due to the loss of firmness of the pulp. The shriveled fruits remain hanging on the tree. In the case of pears, the decomposition of the pulp progresses to the core; with apple trees, the damage is usually only superficial.
The hosts are all species of the genus *Rosa*, in particular: quince (*Cydonia*), cotoneaster (*Cotoneaster*), firethorn (*Pyracantha*), medlar (*Mespilus*), rowan (*Sorbus*), hawthorn (*Crataegus*).
Bacterial cells spread from the place of origin or survival to other host plants passively without expending their own energy. They are moved over shorter distances (up to 100 m) mainly by atmospheric water (mainly by wind and rain), insects, mites and spiders, over medium distances (100 – 5,000 m) by pollinating insects and over long distances (over 5,000 m) by birds, airborne currents and the activity of a person who is the mediator of the transfer of infected or contaminated reproductive material (grafts, cuttings, whole plants).
It is a quarantine disease. Natural and legal persons are required to immediately report all occurrences or suspected occurrences of harmful organisms to the ÚKSUP Department of Plant Protection, Hanulova 9/A, 844 29 Bratislava 42, email: ochrana@uksup.sk. The detection of symptoms similar to those of an attack is considered to be a suspicion of the occurrence. In the case of a large-scale attack on a comprehensive planting of intensive production fruit orchards, natural persons and legal entities are ordered to oblige the entire area of all host plants of fire blight on the entire area of the attacked orchard for the purpose of preventive eradication of fire blight determined by the decision of the inspection institute. The mentioned measure applies only to fruit orchards registered by the control institute.

Preventive measures

Healthy planting material, if it is possible to plant less susceptible or resistant varieties. Care of the planting area in the form of control and eventual disposal of host plants. Regular inspections of plantings.
It is possible to carry out preventive spraying with copper preparations. These will cause a change in the pH of the plant tissues, which is subsequently not suitable for the spread of spores. During the flowering period, attention should always be increased, especially when the conditions are suitable for the spread of fire blight, i.e. in humid and warm weather. Some AMS are equipped with software that can signal suitable conditions for the spread of this disease.
The use of bactericides with the use of the bacterium *Aureobasidum pullulans* has a selective effect against blight, it is a saprophytic, epiphytic and, in the case of *Erwinia amilovora* pests, an antagonistic microorganism. Due to the rapid growth of the tissue and the intake of nutrients, it competes with pathogens, taking nutrients from them, mainly sugars and important amino acids. The spore suspension is applied by spraying into open flowers, where it has an antagonistic effect. Spores promote cell division in the epidermis, they settle in the flower calyx, thereby preventing the penetration of *Erwinia amylovora* bacteria into the internal tissues of plants (flowers). The effectiveness of the preparation increases with the number of applications during full flowering and the number of pollinators in the plant. During the season, max. 2 – 4 applications, in the growth stage BBCH 61-69, in a few days (depending on the flowering of the tree): 1st application at the stage of 10% open flowers, 2nd application at the stage of 40% open flowers, 3rd application at the stage 70% open flowers, 4th application at the stage of 90% open flowers and possible 5th application at the stage of 90% open flowers in extremely infected orchards.

Direct protection

Direct protection is very limited.

Curative spraying with antibiotics only on the basis of an exception from the Ministry of Agriculture (streptomycin) for a specific orchard and a specific period, usually 90 days. Sprays with antibiotics such as streptomycin or terramycin can prevent new infections. The common use of these preparations is prohibited in the Slovak Republic, because they led to the emergence of bacteria resistant to streptomycin in some areas of the planet. Even after a long period of non-use, this condition did not lead to a reduction in resistance and the orchards were colonized by strains with a high degree of resistance to streptomycin. *Erwinia amylovora* does not show a significant difference in mutation rate compared to treatments with high or low streptomycin exposure. Previous studies have shown that streptomycin resistance in *Erwinia amylovora* is caused by a chromozonal mutation. Many new effective antibiotics have been used to treat anthrax with positive results and now show little or no resistance (oxytetracycline, kasugamycin).

A relatively effective measure is the removal of infected branches in a place approx. 0.35 m from the infected part as soon as possible, which reduces the amount of inoculum and is one of the most effective measures.

Fig. 9. Symptoms of fireblight (*Erwinia amylovora*) on young shoot. (photo: Mezey)

Powdery mildew (*Podosphaera leucotricha*)

Bionomics and harmfulness

Powdery mildew is a fungal disease endemic to apple production regions worldwide, caused by the obligate biotroph *Podosphaera leucotricha* in the order *Erysiphales*. The life history of this fungus is closely synced with the phenology of its perennial host, apple (*Malus* × *domestica*) Aside from apple, *P. leucotricha* may also infect almond, pear, quince, african cherry, the fruit of peach, and the ornamental evergreen shrub photinia (Garibaldi et al. 2005; Liang et al. 2012; Mwanza et al. 2001; Spotts 1984; Xu 1996).

P. leucotricha may overwinter as chasmothecia but is typically observed as mycelium developing from within buds produced by the apple host during the previous growing season. As infected buds break dormancy in the spring (typically 5 to 8 days after healthy buds), perennated mycelium resumes growth, spreading across the developing shoot and leaf tissue and forming haustoria within leaf cells in what are called primary infections, causing shoot malformation and stunting leaves (Turechek 2004). Conidiophores on the mycelial surface generate asexual conidia for dispersal via wind (Hickey and Yoder 2014; Jakab-Ilyefalvi 2016). Blossom infections are less common, yet all parts of the flower can become misshapen and discolored. Infected blossoms tend to fail to set fruit or produce fruit that are small, stunted, and/or have russet. Fruit russet occurs primarily from infections during the pink stage of floral development (Daines et al. 1984; Turechek 2004). Direct infection of apple fruit is rare (Blumer 1967).

Secondary infections are the result of infection by conidia and appear as mildew colonies on the lower surfaces of young leaves, with white felt-like patches resulting from hyphal outgrowth from germinated conidia. As disease symptoms spread, infected leaves curl longitudinally and may defoliate prematurely. Mycelium spreads until susceptible host tissue is no longer available, while continuing to generate conidia for release, ensuring multiple secondary disease cycles throughout the growing season (Hickey and Yoder 2014).

By season's end, fungal mycelium has infected the dormant flower and shoot buds, although this must occur before bud scales form (Woodward 1927). Terminal buds serve as overwintering sites more than lateral buds and may have a "striped" appearance from residual mycelium left on the shoot surface (Burchill 1958; Woodward 1927). Freezing winter temperatures pose a threat to successful perennation. Irrespective of cultivar, there is a reduction in survival potential of apple buds infected with P. leucotricha compared with healthy uninfected buds. Temperatures below -24 °C may kill bud tissue and reduce the pathogen's ability to survive the winter (Spotts et al. 1981).

The powdery mildew disease cycle can be interrupted at several specific stages with management practices: fungicides, selection of resistant hosts, and mechanical pruning (Braun et al. 2002). As such, considerable research effort has been expended identifying the factors that impact the development of powdery mildew colonies and dispersal of conidia.

Temperature is a key factor influencing conidia release and germination in *P. leucotricha*. Optimal temperatures for conidia release range between 15 and 28 °C, with germination optimal at 22 °C (Sutton and Jones 1979; Xu 1996; Xu and Butt 1998). Below 4 to 10 °C and above 30 °C, conidia cannot effectively germinate (Coyier 1968).

Preventive measures

Cultural control methods for apple powdery mildew focus on lessening or eradicating primary sources of inoculum, and in turn, the spread of the disease (Holb 2005). Because *P. leucotricha* is an obligate pathogen whose mycelium overwinters within host tissues, pruning has proven an effective sanitation practice by which to reduce inoculum, although the cost of labor for larger operations can make the effort impractical (Holb 2005; Yoder and Hickey 1983). Pruning benefits are greatly enhanced when used in combination with a fungicide program.

Additional pruning practices beyond those performed annually as part of regular orchard maintenance also assisted in reducing powdery mildew incidence when used in conjunction with either a calendar-based conventional fungicide management program or a program implementing integrated pest management practices (Holb et al. 2017). Removal of apparently infected shoots during the dormant season reduced primary powdery mildew disease incidence the following spring; however, this is difficult because no leaves are present to easily signal the disease's presence, and it instead relies on a "striped" visual effect left on shoot tissue by mycelium remaining from the previous growing season. Regular pruning also has the added benefit of opening the tree canopy, which leads to improved fungicide deposition and reduces the relative humidity found within the shoot-branch microclimate, further impeding foliar pathogen development (Cooley et al. 1997).

Direct protection

Elemental sulfur has been widely used to protect against powdery mildew in apple production (Ballard and Volck 1914; Fisher 1918; Reuveni 2000; Ruess and Blatter 1990) and continues to serve as a core broad spectrum fungicide in both conventional and organic powdery mildew disease management programs worldwide (Holb 2014; Tate et al. 2000). Sulfur is an economical fungicide choice that is effective at managing powdery mildew when used prophylactically and frequently, in intervals of approximately 5 to 7 days (Holb 2014). Sulfur may not effectively control the disease under conditions of high disease pressure and has phytotoxicity concerns when applied at temperatures above 28 °C. Both elemental and lime sulfur have found wide use in organic apple production (Holb et al. 2003).

Like sulfur, inorganic potassium carbonates are another important tool for powdery mildew control in organically managed orchards. Similarly, applications of inorganic kaolin-based particle film on the apple cultivar 'Delicious' were reported to reduce the incidence of apple powdery mildew considerably and is also approved for organic production (Sharma et al. 2020).

In the absence of durable host resistance, chemical management is the primary means of disease control. Demethylation inhibitor (DMI) fungicides (difenoconazole, fenbuconazole, flutriafol, myclobutanil, and mefentrifluconazole) are widely used to manage apple powdery mildew, but members within this fungicide class have been observed to differ in efficacy with respect to disease control. (Strickland, 2022). Demethylation inhibitors (DMIs; Fungicide Resistance Action Committee Group 3) are one such group commonly used to control apple powdery mildew because of their strong preinfection and postinfection activity, reported to be effective ≤4 days after an infection event (Beckerman et al. 2015; Hickey and Yoder 1981; Yoder 2000).

The recommended application timings for powdery mildew management are from the tight cluster bud stage (or as early as green tip) to terminal bud growth set (Agnello et al. 2019; Beckerman et al. 2021; Crassweller et al. 2020; Nottingham et al. 2019). Overwintering mycelia expands across emerging tissue after bud break and are thus exposed to fungicide applications (Holb 2014). Applications should continue until apple shoots undergo terminal bud growth set, at which point both the host and fungus have entered a dormant state, the latter now protected among host tissues in preparation for the onset of winter. (Strickland, 2022).

In areas where also scab is present, chemical management of apple powdery mildew is typically managed simultaneously with apple scab (*Venturia inaequalis*), as the two fungal pathogens often coinhabit orchards (Cooley 2009; Holb et al. 2017; Turechek 2004).

Treat sensitive varieties from BBCH 57 (pink bud) at 7 – 14 day intervals, use at appropriate times preparations also suitable against scab.

Fig. 10. Symptoms of powdery mildew (*Podosphaera leucotricha*) on young shoots. (photo: Mezey)

Brown rot *(Monilia fructigena)*

Bionomics and harmfulness

Brown rot is caused *by Monilinia spp*. and is one of the most destructive pre- and postharvest diseases of pome and stone fruits (Batra 1991; Byrde and Willetts 1977; Holb and Scherm 2007; van Leeuwen et al. 2000). Economic losses ranging from 7 to 25% and from 0.6 to 8% were found in orchards and storage facilities in Europe, respectively (Berrie and Holb 2014).

Symptoms begin as rounded brownish spots centered at the infection site. *M. fructigena* has a colony color ranging from white to light beige and large (1.5 mm on average) conidiospores tufts and disposition in concentric circles in the fruit. (De Oliveira 2016). Fruits can be infected by direct penetration of the cuticle, by the production of cutinase (Bostock 1999), stomata or trichomes and by cracks and wounds (Wade 1992). Conidia are produced along the growing season and can infect fruits at any stage of their development. Branch and stem cankers, in addition to mummified fruits, ensure the fungal pathogen survival over the year. However, brown rot disease observed during the storage mainly linked to the infection occurring just prior to harvest (De Oliveira 2016).

The life cycle of brown rot diseases comprises the following three phases (Byrde and Willetts, 1977): 1. blossom blight and twig canker in early spring, 2. brown rot in late spring and summer, and 3. mummified fruits on trees and soil (Rungjindamai et al., 2014). The pathogen overwinters in mummified fruits and twig cankers, and conidia from mummied fruits or ascospore from apothecia are blown on floral parts by wind, rain or insects. The infected tissues turn dark and new masses of conidia are produced. The infection advances rapidly into blossoms and fruit spurs. Rot of fruits develops in clustered fruits, in fruit contact spots, and in insect or wind damaged fruits, under moist environmental conditions. The infection can remain latent until the fruit ripening. The pathogen quiescence capability and the brown rot incidence were often related to the fruit development stage (Lee and Bostock, 2007). Latent infections present a typical pattern with the subcuticular infection of unripe fruit followed by the stop of the pathogen growth. As the fruit ripens, the fungal growth resumes resulting in post- harvest rot (Rungjindamai et al., 2014).

Preventive measures

Removing or turning under thinned fruit helps reduce fruit brown rot. Thinned fruit can be a source of inoculum for brown rot on ripening fruit, especially if they are left where they will come in contact with irrigation water. Unlike brown rot on peach and nectarine, control of brown rot blossom and twig blight (spring brown rot) of prune does not appear to have any effect on harvest levels of brown rot on fruit (Gubler 2009). Prompt removal and destruction of fruit mummies and diseased plant parts prevents the buildup of brown rot inoculum and helps keep rot below damaging levels. Prune trees to allow good ventilation. Furrow irrigate or use low-angle sprinklers to avoid wetting blossoms, foliage, and fruit. Plant varieties that are least susceptible (Farrar 2017).

Direct protection

Fungicides are preventive, not eradicative; they must be applied to uninjured fruit before infections occur. Injured fruit cannot be protected from rot caused by *Monilinia* with the use of preharvest sprays. Apply preharvest sprays as needed 4 to 6 weeks before harvest (Gubler 2009). If you have had problems in the past, applications of copper-containing fungicides or synthetic fungicides such as myclobutanil at pink bud stage can help avoid serious losses. Additional applications when fruit starts to color may be needed if rainy weather persists. Do not apply copper compounds after bloom (Farrar 2017).

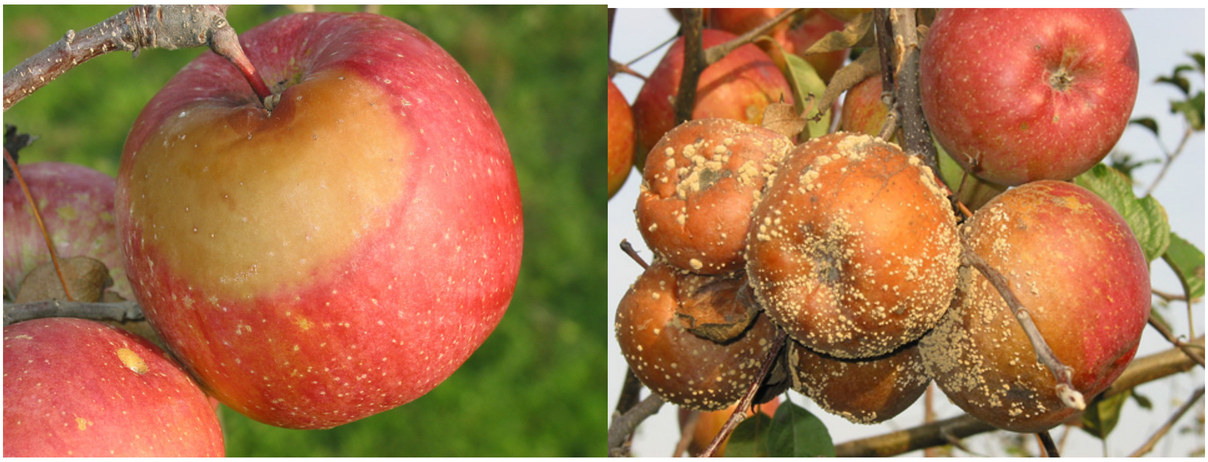


Fig. 11. Symptoms of brown rot (*Monilia fructigena*) on fruit. (photo: Mezey)

INTEGRATED PEAR MANAGEMENT

Pear psylla (*Cacopsylla pyri*)

Bionomics and harmfulness

Imago hibernates in cracks in the bark of trunks and branches. In early spring, females lay eggs on shoots near buds and larvae feed by sucking on flowers and young leaves. Development takes 35 – 40 days and at the end of May, the imagos of the second generation hatch. Females of this generation lay eggs in regular chains on the upper side of young leaves next to the main veins. They are much more fertile than females of the first generation, as they lay up to 500 eggs. Pear psylla has 3 – 4 generations per year. Very harmful are the larvae that suck on leaves and flowers in whole colonies and stick them with honeydew at the same time, infected leaves curl and develop unevenly. Honeydew, which covers the leaves by osmotic effect, causes "burns", which appear on the leaves as brown to black spots, the leaves dry up, tear, fall off en masse.

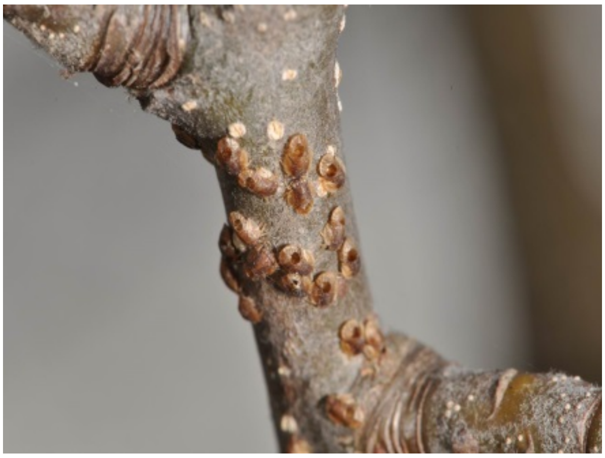
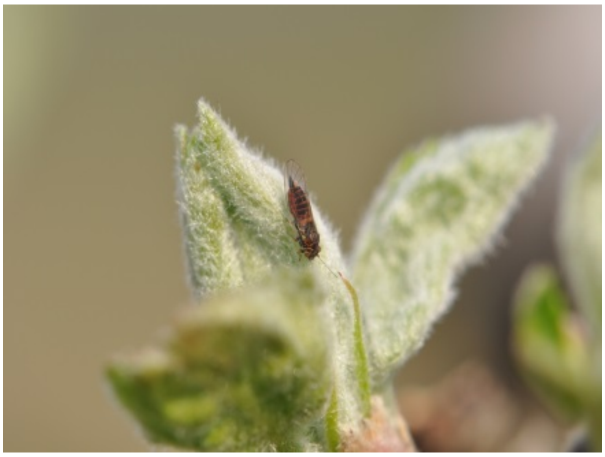


Fig. 12. After overwintering, adults leave their cocoons. (photo: Mezey)



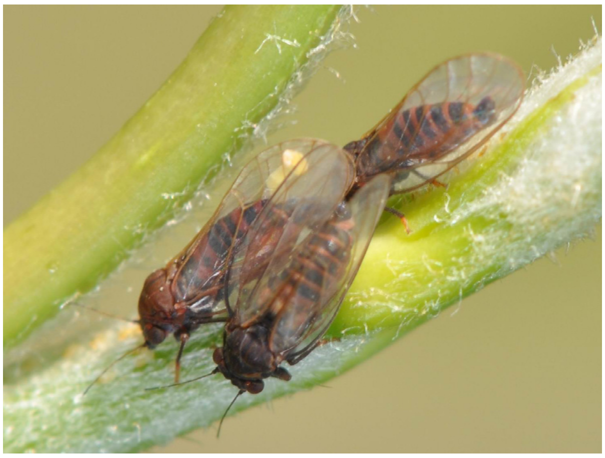


Fig. 13. After overwintering, adults are sucking cell saps on young shoots. (photo: Mezey)

Preventive measures

Summer Pruning

The removal of vegetative shoots from trees is an important cultural control. Summer pruning improves spray penetration and light in the canopy. If timed correctly, pruning can also reduce the pear psylla population and amount of honeydew in trees. Prune between SET_5= 1150 – 1300 °C to remove nymphs before they molt into third generation adults (Nottingham 2023).

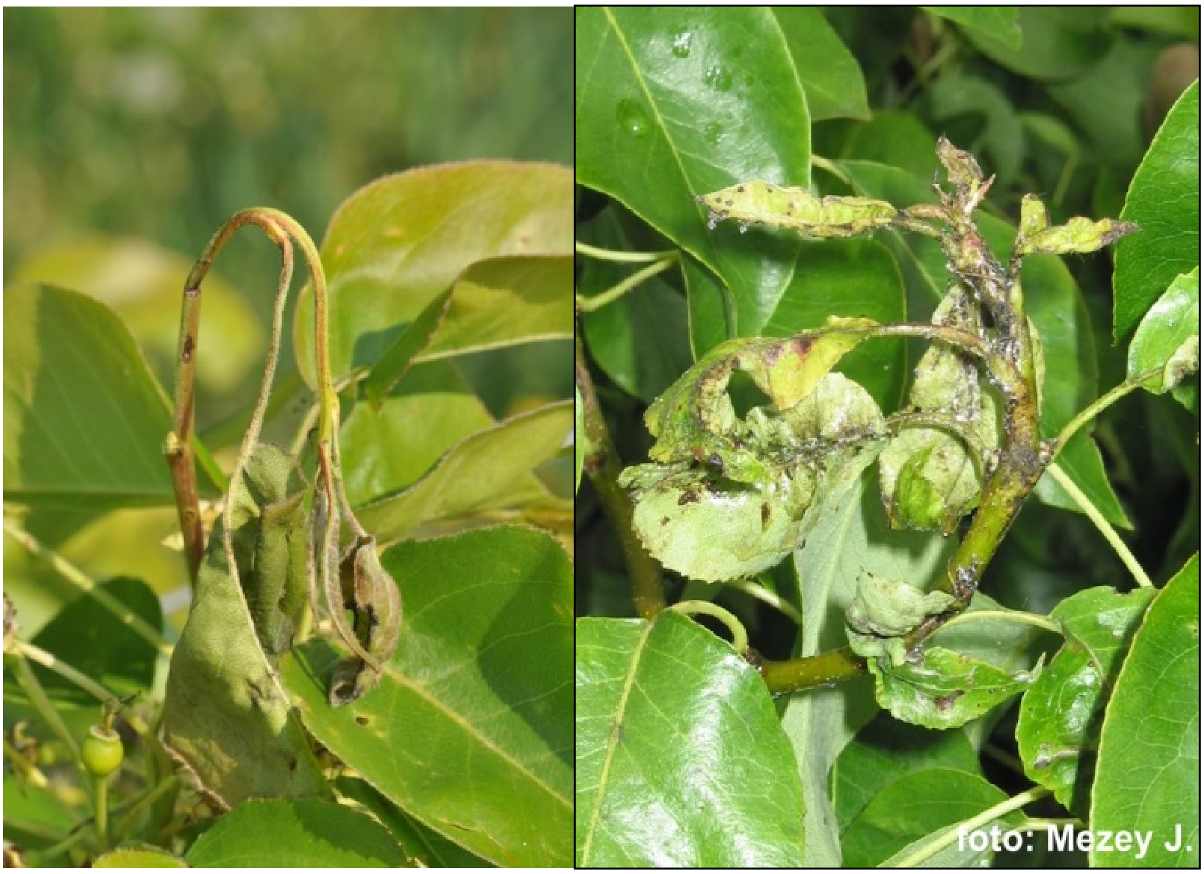


Fig. 14. Damage on young shoots. (photo: Mezey)

Washing honeydew off fruit trees with overhead sprinklers or airblast sprayers can significantly reduce fruit marking damage (Brunner and Burts 1981). Honeydew washing methods differ from overhead irrigation and are only used to remove honeydew. Under-tree sprinklers are recommended for general irrigation to reduce disease risk and increase irrigation efficiency. It is critical to limit honeydew washes, because washing too often and for too long can cause disease issues. Time washing to target honeydew from old nymphs of the second and third generations at SET_5=870 – 1300 °C and 1920 – 2200 °C, respectively. Washing is not necessary if visible honeydew is not apparent. In replicated on-farm trials, one to two washes with systems of 35 – 45m^3/h/ha for eight to twelve hours effectively reduces fruit marking (Strohm and DuPont, unpublished data). For airblast sprayer washes, use at least 120m^3/h/ha for smaller trees, and increase water amount with tree size (Nottingham 2023).

Direct protection

Protection against pear psylla is relatively complicated and need to be managed as a complex of various measures, which must be combined. The first assumption is the control of neighbouring plantings and surrounding. As next measures containing caoline and oil sprays with the use of alloved insectisides and biological predators should be applied. We must assure following steps:

- control and evidence of protective measures from the last year,
- strictly respect the principles of the anti-resistance strategy,
- monitor, conserve and support predators and parasitoids,
- ensure the passability of the orchard in the spring,
- do technically perfect treatments,

- pre-spring population synchronization,
- reduce the remains of overwintering imagos in stage of BBCH 10 -mouse's ear,
- larvicidal treatment on N1 before flowering,
- larvicidal treatment against N1-N2, if necessary.

By controlling, if there are found more than 20 adults for 100 shoots, or 0.4 eggs on 1m of shoots, protective measures should be done. Maximal egg laying period of the first generation is by $SET_{2.6}$=200 – 230 °C, for the second generation i tis $SET_{2.6}$=650 °C.
By the pre-spring population synchronization we do a set of three caoline sprays if the daily temperature for 2 consecutive days exceeds 10°C followed by one oil spray.
As next we must reduce the remains of overwintering imagos in stage of BBCH 10 (mouse's ear) by using an allowed adulticide spray. By phelogocical stage of BBCH 57 (pink bud), or BBCH 59 (white cluster) we do one larvicidal treatment against nymphs of first instar. If it is neccessary, we repeat this larvicide treatment against first and second instar.

Fig. 15. Despite some literature sources, we recorded damage of pear psylla also on fruits. (photo: Mezey)

Pear-grass aphid, brown pear aphid (*Longiunguis pyrarius, Melanphis pyrarius*)

Bionomics and harmfulness
In spring *Melanaphis pyraria* roll the leaves of its primary host, pear, transversely or diagonal to the mid-rib. This pseudogall may become yellowed or reddened. *Melanaphis pyraria* host alternates from its primary host pear (*Pyrus*) to its secondary hosts grasses (including *Arrhenatherum*, *Brachypodium*, *Holcus*, *Poa* and *Triticum*). On their primary host they may be attended by ants. On the secondary host the appearance of *Melanaphis pyraria* differs according to the particular genus of grass colonized – reddish purple on *Arrhenatherum*, and yellowish

on *Brachypodium*, *Poa* and *Triticum*. The pear-grass aphid is widely distributed in Europe, as well as the Mediterranean region, the Middle East and the Caucasus. *Melanaphis pyraria* overwinters on its primary host in the egg stage. Pear-grass aphids do not produce a true gall on pear (in other words there is no enlargement and/or proliferation of host cells), but they roll and crumple the leaves to form a pseudogall. These pseudogalls can be very conspicuous on pear trees in spring even without the typical red discolouration.
Aphid feeding causes pear foliage to curl and the growth of shoots to be stunted. This type of injury is of minor importance. Most of the damage is caused from aphids feeding directly on fruit and producing honeydew, which falls on the fruit. Honeydew causes fruit lenticels to darken, giving the pear a russeted appearance. The presence of honeydew also makes the fruit sticky, and a black fungus grows in this honeydew, giving the fruit a sooty appearance. This contamination and russetting will cause fruit to be culled from fresh shipping (Varela 2022).

Preventive measures
Begin observing shoots before budbreak, as management is best undertaken early while the aphid populations are small. Aphid populations tend to be higher in plants that are fertilized liberally with nitrogen. Avoid excessive watering which, together with nitrogen applications, produces flushes of succulent growth. Avoid broad-spectrum insecticide applications which disrupt biological controls (Thompson 2023).
Stary (1976) records three aphid parasitoids on *Melanaphis pyraria* – *Aphidius uzbeckistanicus*, *Ephedrus cerasicola* and *Trioxys angelicae*. INRA record *Ephedrus persicae* as a parasitoid of *Melanaphis pyraria*. Various aphid predators have been recorded as frequenting pear orchards. Youssif (2019) recorded the coccinellids Coccinella undecimpunctata, *Coccinella septempunctata, Coccinella 9-punctata, Scymnus syriacus, Scymnus interruptus, Cydonia vicina isis* & *Cydonia vicina nilotica* on pear trees in Egypt infested with *Aphis gossypii*.

Direct protection
The best results is achieved, when a pre-spring population synchronization is done by spraying in case of emerging of eggs. Later spray in case of appearance of eggs, or adults.
Aphids are infrequently encountered in pear orchards and seldom require special treatment unless the weather remains cool throughout spring and early summer. Aphids generally serve as a valuable early-season food source for insect predators. With the onset of warm weather, aphids leave pear trees for other hosts and do not reappear until the following spring. Use biological control and sprays of approved narrow range oils or neem oil to control aphids (Varela 2022).
The following active substances (not plant production product) are ranked with the pesticides having the greatest IPM value listed first-the most effective and least harmful to natural enemies, honey bees, and the environment are: thiamethoxam, imidacloprid, spirotetramat, clothianidin, diazinon, narrow range oil and neem oil (Varela 2022).

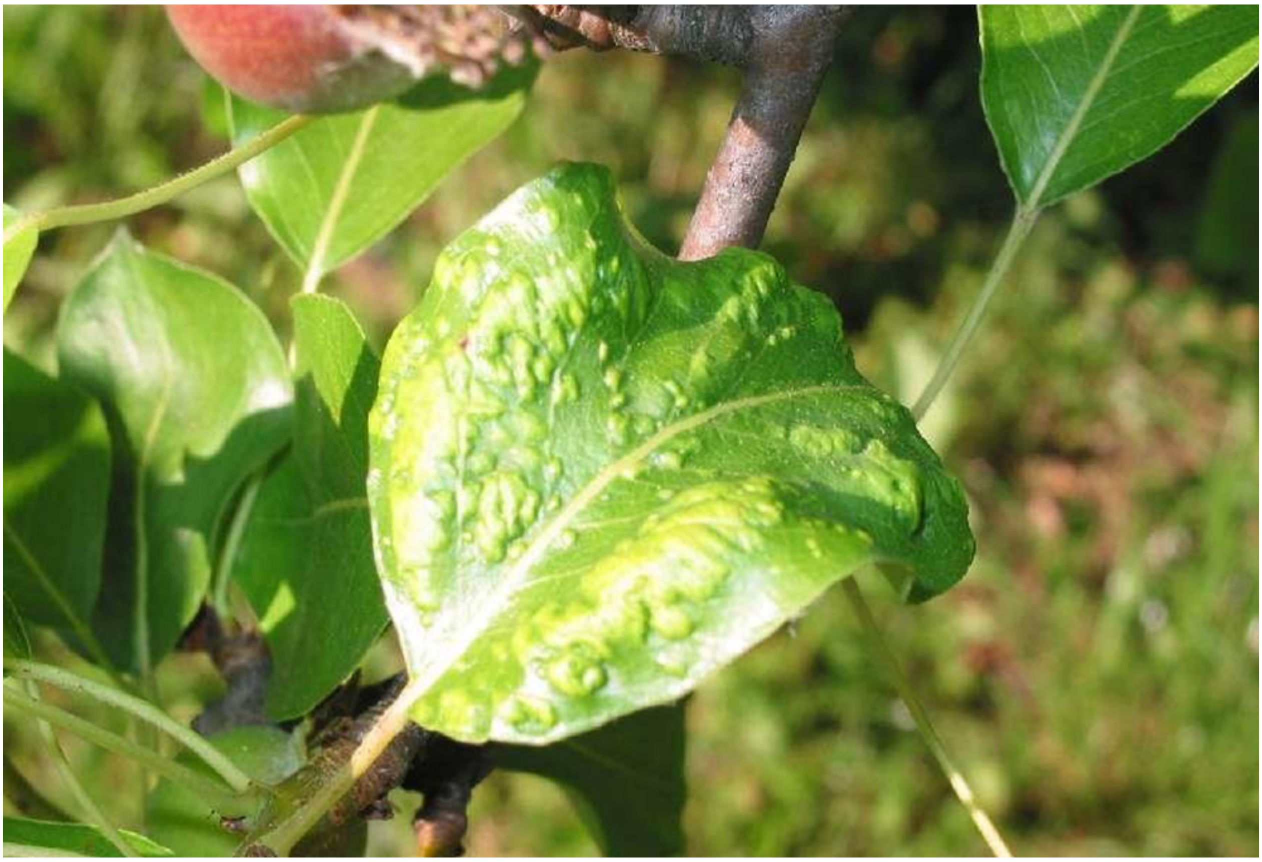


Fig. 16. Damage of pear-grass aphid on leaves. (photo: Mezey)

Pear leaf blister mite (*Eriophyes (Phytopthus) pyri*)

Bionomics and harmfulness

Mites of the superfamily *Eriophyoidea* are important pests in agriculture and forestry worldwide (Lindquist et al.1996; de Lillo et al.2018). The high economic significanceof four-legged mites is associated with their ability to carry phytopathogens and cause the formation of various damages on plants, such as galls, "witch brooms", bud overgrowth, etc. (Sukhareva1992). That is why many species of four-legged mites, along with spider mites, aphids and other plant pests, are included in the quarantine lists of phytosanitary control services around the world (Chetverikovet al. 2015).

Eriophyes pyri is a widespread and dangerous pest of pears in all localities of cultivatingthis plant species. In the spring, a rosette with 5 – 7 leaves is formed on the branches of the previous year. As soon as the leaves unfold, the mite gets settled and over time the first galls are formed here. During this period, damage to the young pedicel also occurs. Females lay eggs in galls, where the first generation of the pest develops. The formation of shoots of the current year occurs with some delay. On them, as a rule, the lower or first leaves remain intact. The mite and its larvae are found in the galls. The migration of the first generation of *Eriophyes pyri* from galls can be determined by the identification of newly formed galls on young leaves of the growing shoots. This corresponds in time to the formation of 7 – 9 leaves on the shoot. Leaves formed on the shoot up to the 7th ordinal leaf do not have galls. This indicates that at the time of the emergence of the first generation mites from the maternal galls, the leaves were physiologically unsuitable ("old") for feeding the mite and for the formation of galls. The process of colonizing newly formed leaves on the shoot with mites lasts until the formation of the middle section of a young shoot, up to about 7 – 9 ordinal leaves. Often, having populated these leaves, the mite stops there. That is, the transition of mites of the first generation to new leaves occurs with a delay, and it is not long in time. As a rule, on a young branch, the lower and upper leaves remain intact. In the first decade of June, the development of the first generation ends.

With the growth of the shoot, and the formation of young leaves, their gradual colonization by the second generation mites begins. In late June – early July, mites of the second generation form galls on the leaves of the upper part of the pear shoot. The development of the third generation of *Eriophyes pyri* is observed in late July – early August on the leaves of the shoot tip. The process of migration of winter females to the buds for wintering lasts until the end of August. The described course of pest migration on pear varieties of different ripeness of fruits and under different coenotic circumstances may vary, though insignificantly in terms of time (Bondareva 2021).

Preventive measures

First of all absolutely healthy and mite-free planting material must be secured for planting.

Leaf blister mites are relatively difficult to control because of their sheltered lifestyle. An important aspect in limiting their occurrence is to follow all agrotechnical principles and cultivation of cultivars resistant to phytophagous mites (Praslička 2011). Knowledge of the resistance of crop varieties to phytophagous mites can reduce the pesticide load in fruit plantations and the cost of carrying out protective measures. Due to the fact that phytophagous mites very quickly acquire resistance to acaricides applied in production, it is particularly important to evaluate pear varieties for susceptibility to them (Bondareva 2021). Treatments like trimming branches about the turn of winter and spring can contribute to reducing the number of pests like leaf blister mites. Secondly, the results from observations show that the biggest changes in leaf blister mites population occur in May when is noticeable a significant population growth and in September when the number of mites present on leaves strongly declines (Kolataj 2019).

Direct protection

In case of chemical methods very significant is to perform treatments only when leaf blister mites are present on a plant surface. Otherwise the treatment will not bring expected effects (Praslička et al. 2011). The treatment of pears with pesticides in the system of pest control is often scheduled in the spring, but it was not observed a high efficiency against *Eriophyes pyri*. Damage to foliage by the second and third generations of the pest is common, specifically in organic farming. Such a sequence of colonizing the leaves by *Eriophyes pyri* on a growing pear shoot is of practical importance for carrying out protective measures within the optimal period of time. The period of formation of 7 – 9 ordinal leaves on the growing shoot is the key moment when the first generation of mites leaves the old galls and colonizesthe newly formed leaves. During this period, the phytophagy moves from a hidden to an open way of life and is available to methods and means used in plant protection. Acaricides are highly effective and preparations of biological origin can be used. But this period is short-timed and requires careful monitoring. For this purpose, sticky tape such as scotch tape can be used. A similar moment is also observed during the migration of the second generation to the apical leaves and the third generation to the buds for wintering, but this process is greatly extended over time and is not so suitable for the use of acaricides (Bondareva 2021).

Relatively satisfying results brings introducing into orchards predatory mite *Typhlodromus pyri* as a biocontrol agent against leaf blister mites (Praslička et al. 2011). Introduction consists of placing special cloth strips containing specimens of this predatory mite on stems or branches (Sekrecka and Niemczyk 2006).

Timing during the season is best done prior to their movement into the leaf blisters after petal fall. A Degree Day model developed by Bergh and Judd showed 50% of the population emerge from overwintering sites by DD 44 (base 6 °C) (Bergh 1993).

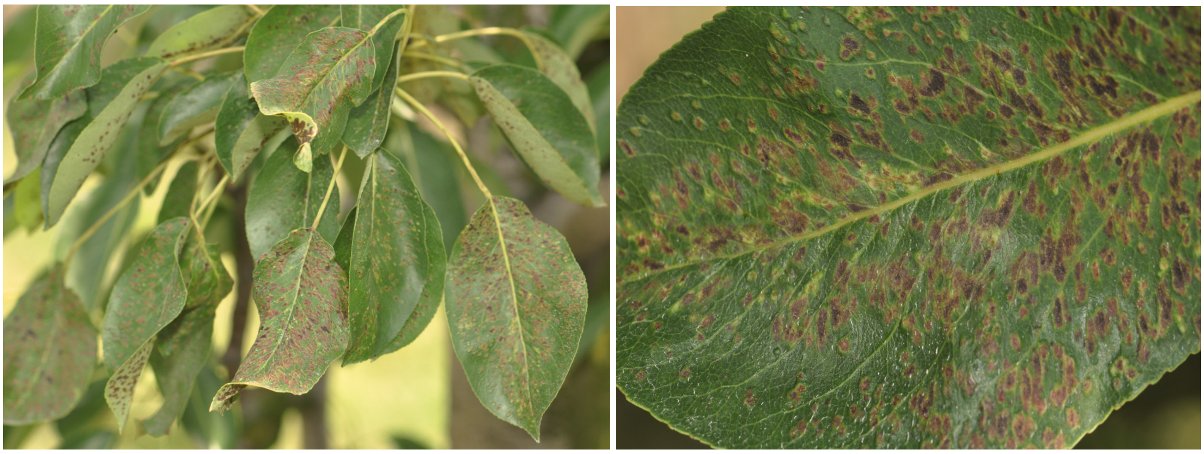


Fig. 17. Typical damage of pear leaf blister mite. (photo: Mezey)

Pear scab (*Venturia pyrina*)

Bionomics and harmfulness

Venturia pyrina, a fungus that overwinters in infected fallen leaves and, in some areas, on pear twigs. Fallen leaves produce ascospores in the spring. Spores are generally released during rainstorms over a 3- to 4-month period but primarily during bloom. Infection occurs when leaves are wet for 10 to 25 hours and symptoms are seen in 2 to 3 weeks. Conidia are produced in these new scab spots and can infect healthy foliage or fruit. In spring, sooty spots with a soft velvet look appear on young fruit, stems, calyx lobes, or flower petals. Young infected fruit frequently drop or are misshapen. Scab spots expand with growth until halted by dry weather or sprays. Old fruit infections often crack open. Cracks are surrounded by russeted, corky tissue and then an olive-color ring of active fungus growth. If fruit is infected late in the season, about 2 weeks before harvest, pinpoint-size scab spots often show up in storage a month or more later. On leaves, olive-black spots expand with leaf growth but often cause the leaf to twist abnormally. Infected twigs show small blister-like infections the size of a pinhead and develop a corky layer. Many twig infections are sloughed off during the summer season (Eikemo 2011).

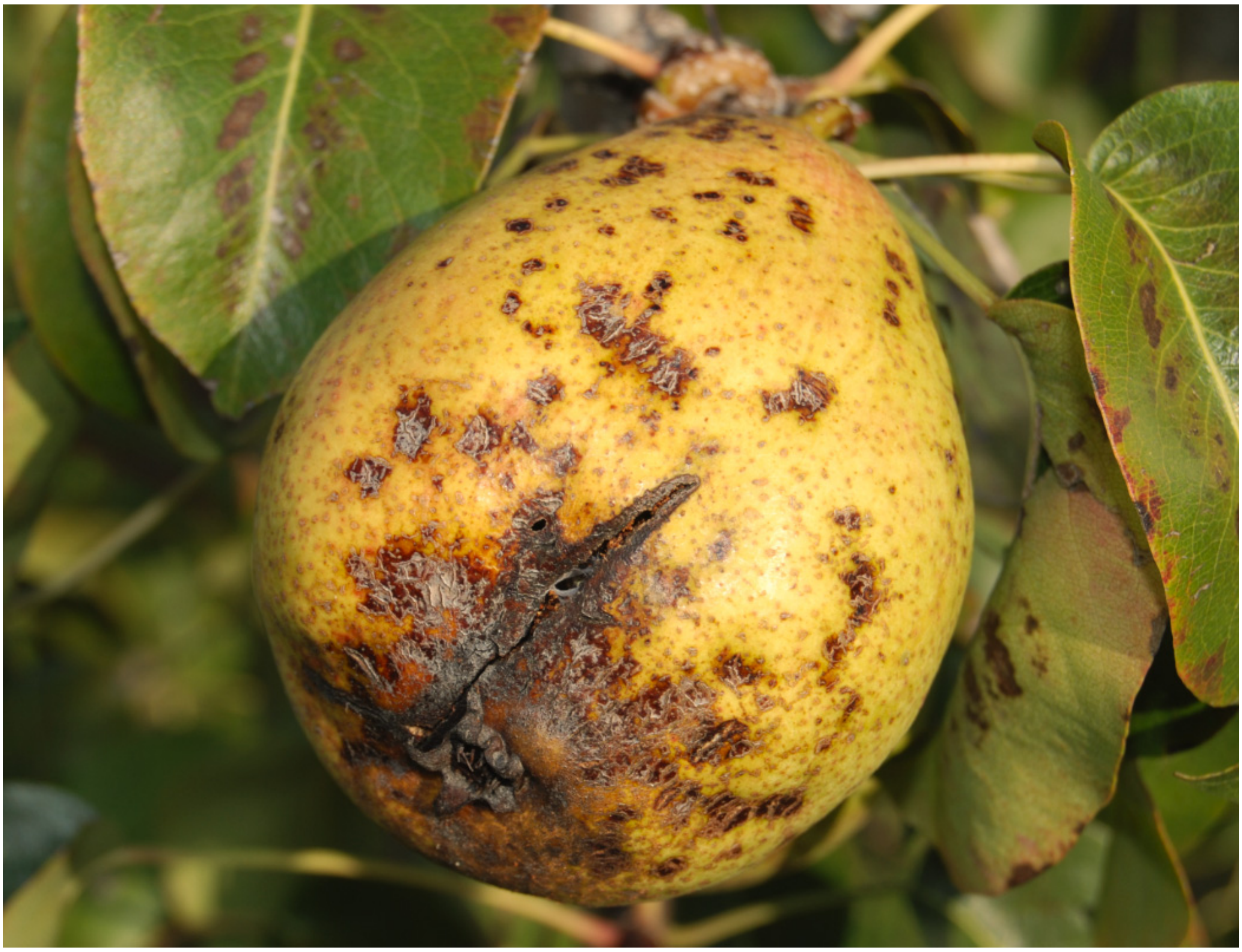


Fig. 18. Pear scab. (photo: Mezey)

Preventive measures
Apply nitrogen (urea) to leaves in fall to enhance decomposition of fallen leaves and make them more palatable to earthworms. Shred fallen leaves with a flail mower to help speed decomposition of infected leaves. Pruning out infected twigs also offers some benefit. Applying dolomitic lime after leaf drop in fall to increase soil pH also helps reduce inoculum the next spring. Reduce irrigation sets so leaves do not stay wet for extended periods of time. Use sprinkler heads that do not wet the foliage of the tree or use drip irrigation (Spotts 2000).

Direct protection
Spray delayed dormant compounds before bud scales drop. Apply in season sprays at preblossom (prepink), pink, calyx, and first cover. Forecasting systems are available to time sprays to control pear scab. Forecasting is especially useful in arid areas with few infection periods. A delayed dormant application is effective against twig infections in orchards that had a lot of disease the previous year(s). Apply foliar applications during the growing season. Alternate or tank-mix products from different groups that have different modes of action. Also, limit applications from any particular group to two (2) or fewer per year. Selection of products for rotation and/or mixing must consider fungicides when used through the irrigation as a nematicide (Spotts 2000).
Pear scab infection periods can be determined by measuring temperature and leaf wetness with weather monitoring equipment. The scab infection season starts when 160 degree-days (base 0 °C) have accumulated and ends after 880 degree-days (base 0 °C, starting when bud scales separate) have accumulated followed by at least 25mm of rain or dew. If the orchard is free of scab up to this date, no additional fungicide applications are necessary for the season, regardless of subsequent

infection periods. Additional degree days may be needed during extended periods of warm dry weather. In arid areas, if there are 5 or fewer leaves with scab in the fall after examination of all the leaves on 10 shoots from 10 trees in a 1ha area of the orchard with a history of scab then the first scab spray of the season can be skipped (Eikemo 2011).

Pear rust (*Gymnosporangium sabinae*)

Bionomics and harmfulness

European pear rust (EPR) is an important disease found on pears and junipers, widespread where the hosts are growing together (Helfer 2005, Lace 2017). It is caused by *Gymnosporangium sabinae*, a parasitic fungus commonly found in Europe, Asia, Africa, and North America (Li 2008). The main host of the rust pathogen is juniper (*Juniperus* sp.), the intermediate host is pear (*Pyrus* sp). (Cherniy 2019).

The peculiarity of the pathogen biology is an incomplete cycle of development, which consists of two stages: aecio-stage (pear) and telio-stage (juniper), which results in 4 types of spores. The disease cycle lasts almost two years and consists of two consecutive processes: 1 – formation of basidiospores on juniper and their distribution; 2 – germination of basidiospores and formation of aeciospores on pear. Basidiospores are dispersed by wind in the radius of 40 – 50 km and infects pear in the spring, aeciospores infects juniper in the autumn. The development of the fungus occurs in a wide temperature range from 3 to 30 °C (optimum 18 °C) and relative humidity of 85%. On pear rust develops over 4 – 5 months (April – September). The dynamics of disease development depends on the sporulatuion rate of basidiospores on the juniper and their spread to the pear; formation of aecia and ripening of aeciospores on pears. During the growing season, depending on the weather and climatic conditions, there are 4 – 5 periods of sporulation, which are the most threatening for pear infection (Cherniy 2019).

The infection on pear leaves is characterized by bright orange spots, where the spermagonium grows in the middle in small, dark dots (Juhasova 2002). These formations are harmful to the plant as they inhibit photosynthesis, increase respiration, and ultimately lead to the death of the infected organs (Dervis 2010), in plants, photosynthesis is getting worse and metabolism is impaired. The strong development of the disease leads to the loss of winter hardiness of trees and their death (Cherniy 2019).

Three factors are essential in the spread of rust infection: temperature, relative humidity, and precipitation (Hau 2006, Lace 2013).

Preventive measures

Protection and prevention measures include sanitary practices aimed at reducing the rust infection and use of disease-resistant varieties. Sanitary and organizational measures: in spring – cutting of severely affected shoots and skeletal branches, cleaning of wounds with subsequent disinfection; whitewashing of trunks and skeletal branches with a solution of fresh lime with the addition of copper-containing preparations. Treat the trees with a 7% urea solution, treat the soil surface with a 5% solution of copper sulfate. Juniper bushes, severely affected by the disease, dig in and remove. To reduce the risk of tree disease, it is advisable to plant resistant to rust pear cultivars (Cherniy 2019).

The organic fertilizer and microbial fertilizer can be increased in spring, and reasonable pruning will enhance the tree potential and improve the pear tree resistance. Drainage in rainy season should be paid attention, to reduce the humidity of pear orchard. The whole orchard bagging after fruit thinning can effectively prevent pear rust from harming pear fruit, reduce early fruit dropping, improve fruit appearance quality and reduce pesticide residues (Li 2022).

Direct protection

Control of alternate hosts. In spring, the galls of juniper and other alternative hosts near pear orchards should be manually cut off before germination and leafing of pear tree. In early March lime sulphur could be sprayed on alternate hosts to reduce the initial overwintering quantity of the pathogen and infection source. From July to August, allowed fungicide is sprayed on alternate hosts to eliminate the source of infection. The control of alternate hosts of pear rust can reduce the use of chemical agents in pear orchards, which is suitable for the production of green pollution-free fruits, and will save labor and chemical agents (Li 2022).

Spray with copper and sulfur-containing fungicides. Important is the timing and feasibility of chemical treatments in rust control, they are conditioned by periods of basidiospore formation and dispersion and the weather conditions. The application performs in the green cone stage, taking into account 3 – 4 hours of rainfall during this period and temperature not lower than 9 °C. At "white bud" stage and after the fall of 75% of the petals, a rain lasting at least two hours is required. The delay of rainfall shifts the application timing. The following two treatments are carried out during the period of fruit growth, taking into account that young leaves are the most susceptible to disease. The use of pesticides should be alternated to avoid the formation of resistance (Cherniy 2019).

Fig. 19. Pear rust on his primary host. (photo: Smutný)

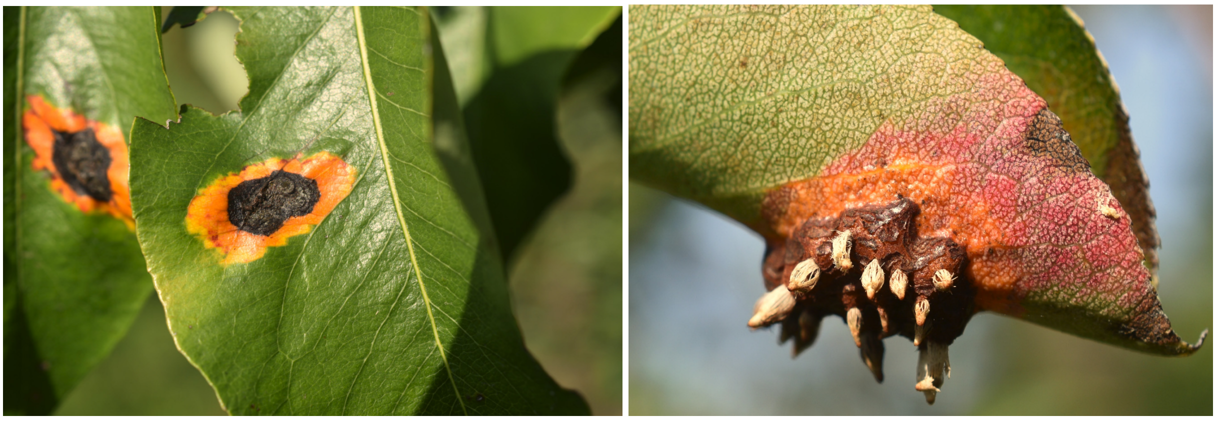


Fig. 20. Pear rust on upper and lower side of the leaf. (photo: Mezey)

Stony pear pit

Bionomics and harmfulness

Symptoms begin as early as 3 weeks after petal fall, when dark-green areas form on the fruit. Cell growth surrounding these areas is restricted and, as a result, fruit become pitted, gnarled, and deformed. Pits are produced by others causes such as plant bug injury, mechanical damage, boron deficiency, or cork spot. However, pits caused by such factors are more superficial. The virus is transmitted by vegetative propagation such as budding, grafting, and root cuttings. Spread by insect vectors or via infected seed has not been documented.

Heavily pitted fruit may become so gritty that it is difficult to cut the fruit with a knife. Some strains of the stony pit virus can cause a roughened bark or measles-like symptoms on the fruit. Pimpling and cracking of the bark, stunting of the trees and chlorotic vein banding or mottling have also been reported. Severely infected cultivars include Bosc, Comice, and Seckel. Obvious, but less severe, symptoms have been reported on Hardy, Conference, Forelle, Howell, Old Home, Packham's Triumph, Bartlett, Winter Nelis, and other cultivars. Symptoms on fruit vary from season to season as well as severity. Trees that show symptoms one year may have no pitted fruit the following year (Peter 2023).

Light or moderate fruit symptoms may be confused with pitting from tarnished-plant bug damage, stink bugs, boron deficiency, or corky spot. Stink bug feeding damage is a depressed blemish with a puncture site that is always visible in the center leading to a brown cork-like area in the flesh (Leone 1998).

Preventive measures

Remove and replace with a tree that has been tested and found free of all known viruses. Establish new plantings only with certified virus-tested trees (Leone 1998). It is important to disinfect tools after pruning the trees. With insecticidal protection, we prevent the spread of viruses by insects.

Direct protection

Doesnt exist, except removing of the tree.

Fig. 21. Symptoms of stony pear pit on fruits. (photo: R.S. Bither)

Fire blight (*Erwinia amylovora*)

Please refer to chapter in apples.

Brown rot *(Monilia fructigena)*

Please refer to chapter in apples.

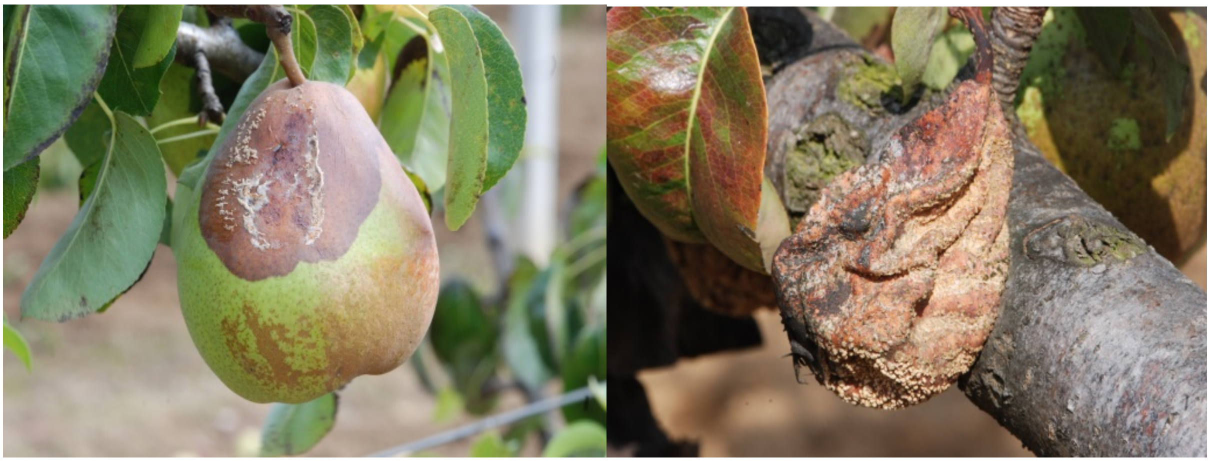


Fig. 22. Symptoms of brown rot on fruits. (photo: Mezey)

Fabraea **leaf and fruit spot (*****Fabraea maculata*****)**
Mycosphaerella **leaf spot (ashy leaf spot and fruit spot) (*****Septoria pyricola*****)**

Bionomics and harmfulness

Leaf blight and fruit spot is caused by the fungus *Fabraea maculata*, which infects the leaves, fruit, and shoots of pear and quince trees and the leaves of apple trees. This disease should not be confused with the fire blight or leaf spot diseases of pears. The disease can build up rapidly, even in orchards where it has not been a problem. If conditions favor the disease and it is not controlled, pear trees may become defoliated in a few weeks. Leaf spots first appear as small purple dots on the leaves nearest the ground. They grow to circular spots about ¼ inch in diameter, becoming purplish black or brown. A small black pimple appears in the center of the spot. When the leaf is wet, a gelatinous mass of spores oozes from the pimple and gives the spot a creamy, glistening appearance. Each lesion may have dozens of spots, resulting in extensive defoliation. Fruit lesions are much like those on leaves, but they are black and slightly sunken. They may be so numerous as to run together and make the fruit crack. Lesions on twigs occur on current-season growth. They are purple to black, with indefinite margins. The lesions may run together and form a superficial canker. Early defoliation leads to small fruit, weak bud formation, and fall blossoming. Infected fruit has no sale value and often is cracked and misshapen. The sexual spore stage develops on fallen, overwintered leaves. Conidia, asexual spores, may also develop in the spots on overwintered leaves, or they may be produced in the previous season's shoot infections. Often the first infections do not occur until mid-June to the first of July. Secondary infections begin about 1 month later and reoccur throughout the season during periods of rain (Peter 2023).

Preventive measures

Optimal tree-care managemet. Removing of old and fallen infected leaves. Keep the tree crown aery.

Direct protection

Routine fungicide sprays normally control this disease (Peter 2023). Use sulphur and/or copper-sprays by the end of blooming and repeat twice after 14 days if rainy period persists and in case, when last year the disese was present.

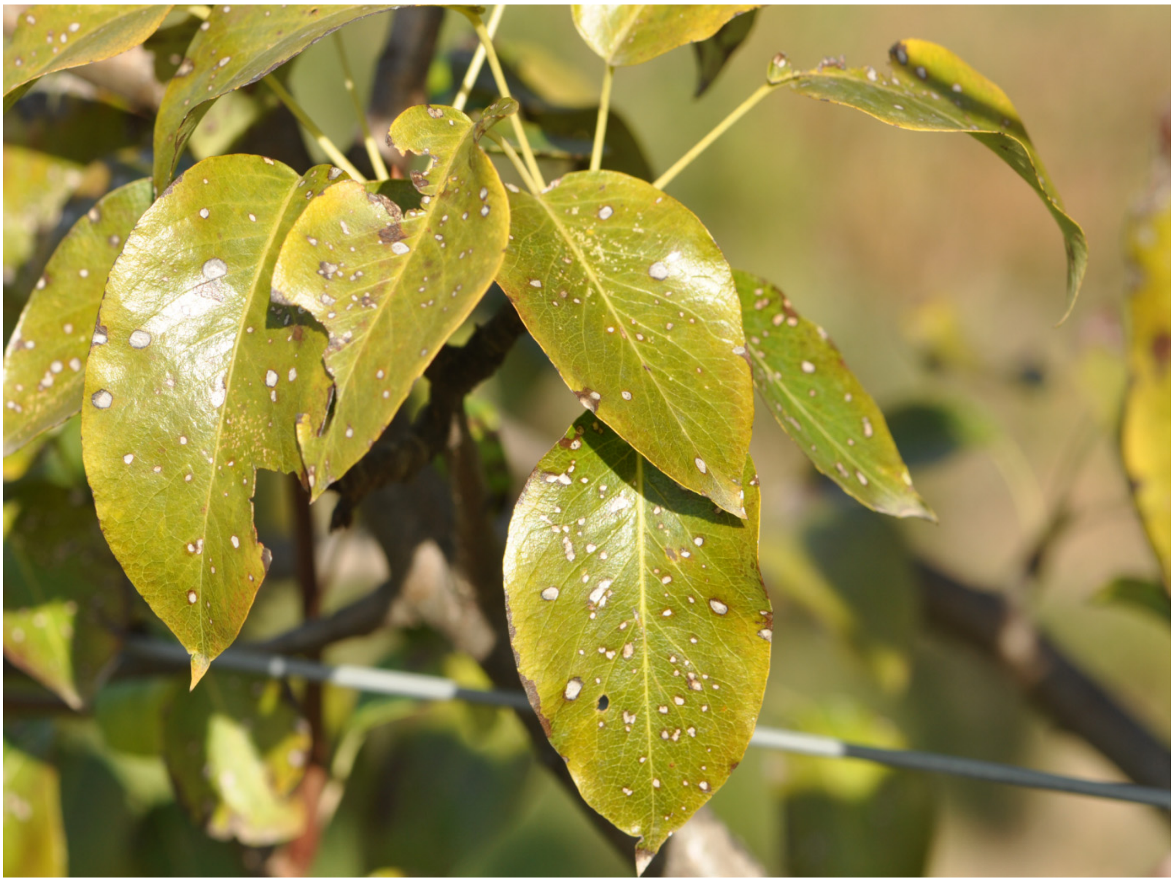


Fig. 23. Symptoms of ashy leaf spot on leaves. (photo: Mezey)

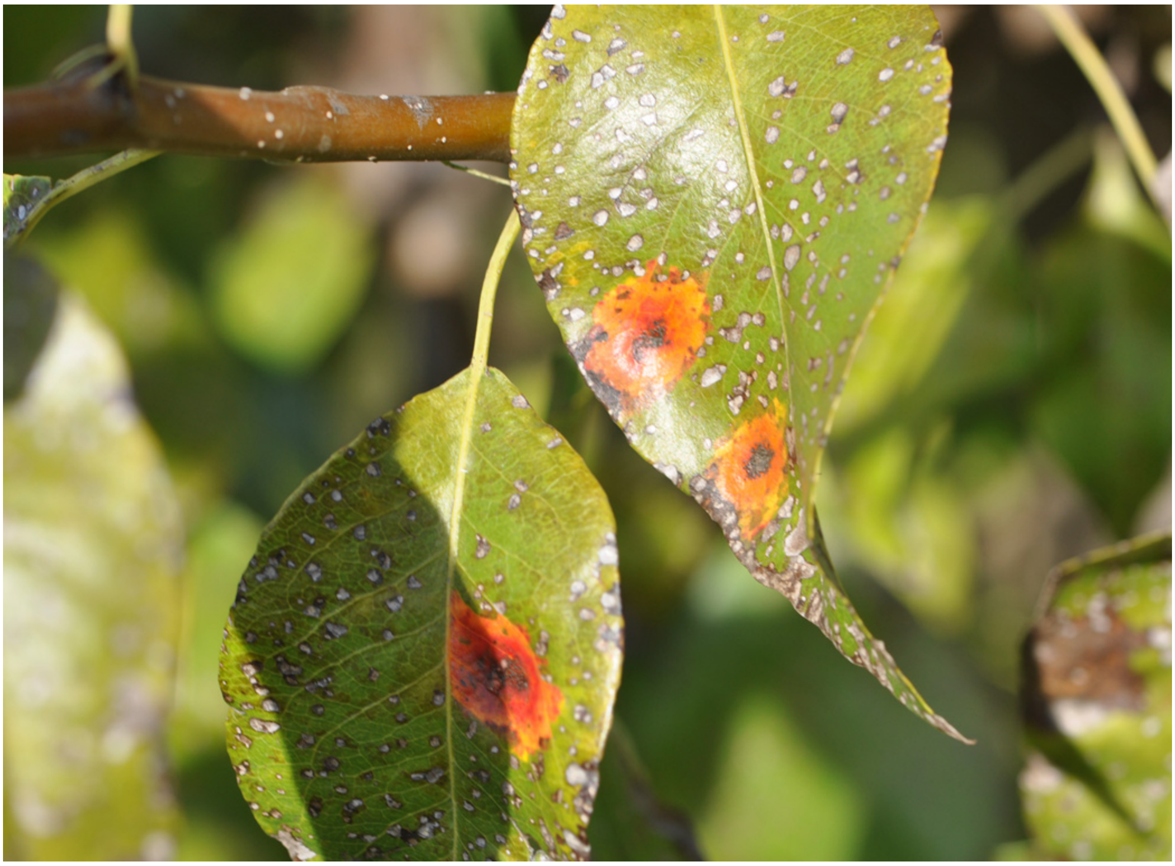


Fig. 24. Symptoms of ashy leaf spot and pear rust on leaves. (photo: Mezey)

INTEGRATED PLUM PROTECTION

Plum fruit moth *(Grapholitha funebrana)*

Bionomics and harmfulness

The plum fruit moth is an important pest of plums throughout northern Europe. Yield losses of 40 to 95% have been reported. Severe losses are more commonly related to the 2nd and 3rd generations, and in regions with warmer summers. (Whittle, 1984).

This pest feeds primarily on stone fruits and many potential wild hosts exist in the family *Rosaceae*. Adults begin to appear in April or May and can be seen through October. Depending upon the climate, this moth has one to 3 overlapping generations per year (Sáringer, 1967). In general, the first generation injures fruit at the end of May through June, and the second generation injures fruit in July and August. In areas where multiple generations per year develop, early season varieties are less susceptible to economic damage than later-maturing fruit (CABI, 2009). Females have a higher reproductive potential in the second and third generations (Bobîrnac, 1958).

Adult moths are most active at night (resting during the day high in the tree canopy) when temperatures reach (18 to 22 °C). Females live longer than males (11 days compared to 8 days, on average). Females are also much more abundant (proportionally) than males as the year progresses (Popova, 1971; Rauleder, 2002). Most mating occurs about two hours before dawn, and females prefer to mate about 10 feet above the ground (Charmillot and Blaser, 1982).

Beginning in May (when the temperature has reached at least 14 °C), eggs from the first generation are laid singly or in small groups (three to nine) on the sunny side and at the base of fruit stalks, on fruit surfaces, or on the underside of leaves in the afternoon and evening hours (Touzeau, 1972; Whittle, 1984). Eggs hatch in five to 10 days (mostly five to seven days) and the larvae chew into fruit, usually near the stem. Before feeding, the larvae seal up the entrance hole with deposits of chewed fruit skin bound with silk. In general, larval mortality is high in each generation, either through parasitism, competition, and/or failure to establish within the fruit. Larval feeding causes gummosis (fluid exuding from the entrance hole), a premature color change, and/or fruit drop. Larvae feed throughout the fruit, traveling from the outer part to the pit region, and have been seen feeding on multiple fruit, but usually do not. After 15 to 25 days, larvae complete their development, leaving a large exit hole and find a place to pupate under bark or other crevices, including on the ground and in the soil. In regions where two or three generations per year develop, these moths overwinter as larvae; where only one generation completes development, this moth overwinters as pupae (Raulder 2002).

Preventive measures

Shallow soil cultivating in early spring, which destroys the overwintering stages of plum fruit moth. Remowing of fallen fruit with the larvae of the first generation.

Direct protection

Chemical protection aginst first generation is not necessary. The protection is made against second generaton, when in general 10 adults on one pheromone trap in 3 – 4 days occurs. In early and mid varieties one treatment is necessary, in late varieties and by permanent flight activity the second treatment is adviced after 10 days.

Some orchard-wide pheromone releases for mating disruption have seen success, but not all. It seems tat some isolation from other wooded areas is necessary to control *G. funebrana* with pheromones (Charmillot et al., 1982). Male trapping over a period of years also seems to reduce fruit damage by up to 84% (Koltun and Yarchakovskaya, 2006).

Fenoxycarb (a juvenile hormone mimic) and diflubenzuron (a chitin formation inhibitor) have been used as a control for this moth. These chemicals are used most often at the beginning of the egg laying period. When a degree day value of 290 °C is reached, pheromone traps should be monitored. Once a marked flight wave is noticed, these ovicides should be sprayed. The chemicals have shown success controlling the summer (second) generation of *G. funebrana* with only one treatment (Kocourek et al., 1995). It is also been recommended that fenoxycarb should not be used without a chemical rotation. Organophosphorous insecticides and diflubenzuron (2 to 3 treatments per generation) have also been used to control *G. funebrana* (Andreev and Kutinkova, 2010). Dimethoate, fenthion and methyl parathion have also seen success in Europe on these larvae (Vernon, 1971).The pyrethrins cypermethrin, bensultap and λ-cyhalothrin were successful against this pest (Tălmaciu et al., 2006).

For plum fruit moths, the biofix is the first date of consistent, sustained adult moth catches using pheromone traps in the orchard or vineyard. Traps should be placed in early spring, or late winter, and checked on a regular basis. Once adult moths have been trapped for a few weeks in a row, the date of the first catch should be used as the biofix. After the biofix is set, growing degree day accumulation can begin, using a lower threshold of 10 °C. The first egg hatch will peak at approximately 7 DD (°C) after adult moth catch and the larval stage will be between 68 and 243 DD (°C). The optimum timing for a single insecticide treatment is approximately 149 °C after the adult moth catch. After 403 DD (°C) the next generations of adults will be seen in flight. For best results in second generation of Plum Fruit Moths in a given season, the biofix should be reset when new pheromone traps have successfully capture adult moths in late spring/ early summer. Approximately 177 DD(°C) following the readjusted biofix is, again, the optimum time for insecticide treatment (Charmillot 1979).

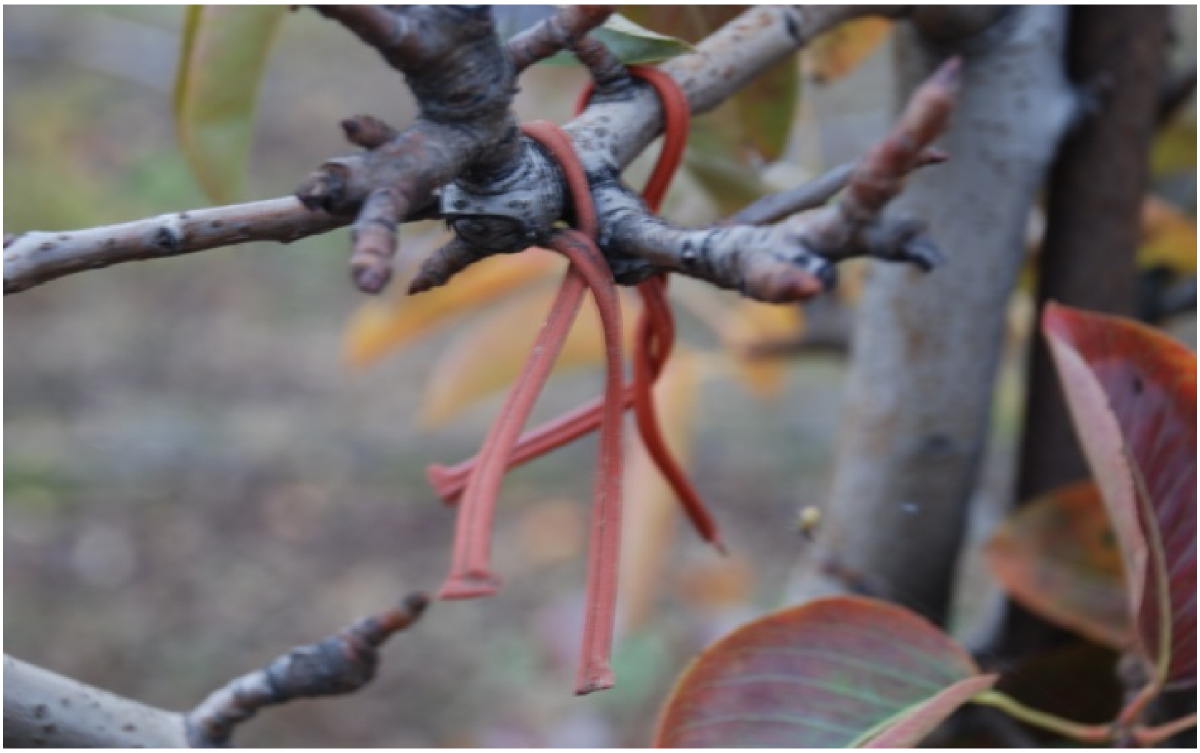


Fig. 25. Isomate pheromone dispenser for protection in form of mating. (photo: Mezey)

Fig. 26. Adult male, young larvae and damage in form of gumosis. (photo: Mezey)

Black plum sawfly *(Hoplocampa minuta)*

Bionomics and harmfulness

It produces only one generation per year and overwinters in the larval stage in a cocoon at a shallow depth in the soil (2 – 10 cm), under the crown of trees. In early spring, in March, the larvae turn into pupae, and the adults appear in April, in the lowland areas, and at the end of May, in the hilly areas of Slovakia.

3 – 4 days after hatching, mating takes place, and after another 2 – 3 days, the egg-laying. In a flower, 1 – 2 eggs are usually laid. Incubation lasts 5 – 12 days, the larvae hatch in the newly formed fruits and feed on the soft seeds. A single larva can destroy 3 – 6 fruits (Armuro Europe 2022).

Larvae of the last developmental stage fall to the ground with the fruits, leave them and burrow into the soil, where they overwinter. Causes the so-called "early fruit worm", which drops prematurely, about 10 days after physiological fruit drop. The inside of the fruit, like the larva of the last instar, smells like stink-bugs.

Preventive measures

It is recommended to perform deep plowing in autumn and spring, which destroys a large part of the cocoons that overwinter in the soil, and to gather and destroy the infested fruit before the larvae emerge (Armuro Europe 2022). It is also recommended to remove of the fallen fruit.

Direct protection

Black plum sawfly control strategies mostly are based on pesticide application. One of the key elements for successful pest control is to determine the optimal period for spray treatments as accurately as possible. Monitoring based on color traps is widespread in integrated protection systems (Shevchuk 2021, Tamosiunas 2013).

Management of plum sawflies is based on broad-spectrum insecticides, like pyrethroids and neonicotinoids, in countries where these products are still registered for sawflies control. As application of insecticides is in time of petal fall, some flowers are still found and insecticides can have harmful effects on bees but also on other beneficial insects and mites.

A biocontrol agent that was extensively studied against sawlfy is the parasitoid wasp *Lathrolestes ensator* but with limited success (Zijp & Blommers, 2002). Plant extracts of *Quassia amara* can reduce primary damage of fruits caused by the sawfly up to 66%, but not secondary damage (Sjöberg et al., 2014). Incorporating effective biological control agents in management of plum sawflies might lead to reduction of pesticide use. Entomopathogenic nematodes (EPN) of the genera *Steinernema* and *Heterorhabditis* are among the most successful biocontrol agents to manage soil pests. The infective third juvenile stages are free-living and harbour few cells of their symbiotic bacteria, Xenorhabdus and photorhabdus, respectively, in the intestine. They enter the insect host through natural openings (e.g. mouth, anus and spiracles) and release the bacteria into the haemocoel. The death of the insect is due to nematode activity inhibiting the insect´s immune defences and septicaemia due to reproduction of the symbiotic bacteria (Ehlers, 2001). The use of EPN can offer an interesting alternative to chemical control of sawflies (Vicent & Belair, 1992). Beside research advances in EPN production technology (Ehlers, 2001), their rapid expansion in biocontrol was supported by the exemption from or ease of registration based on reports of no negative effect on humans, mammals and plants or no or remote effects on non-targets (Ehlers, 2005). Their biocontrol success is based on a unique partnership of the host-seeking nematode and a lethal insect-pathogenic bacterium carried in the nematode´s intestine, presumed to have arisen through convergent evolution (Poinar, 1993).

Entomopathogenic nematodes are highly effective against numerous insect pests. Most of the pests are soil-dwelling organisms since EPN live in soil environment as well. Good efficacy was demonstrated against soil-dwelling pests such as the large pine weevil (*Hylobius abietis*) (Williams et al., 2013), the oriental fruit moth (*Grapholita molesta*), (Riga 2006), the small hive beetle (*Aethina tumida)* (Shapiro-Ilan 2010) or the western corn rootworm (*Diabrotica virgifera virgifera*) (Toepfer 2008). Some successful examples are against pests in cryptic habitats, like tree borers, that is the mediterranean flat-headed rootborer (*Capnodis tenebrionis*) (Garcia del Pino 2005) and peachtree borer (*Synanthedon exitiosa*) (Shapiro-Ilan 2009).

By precise timing, sufficient soil moisture and temperature above the nematode threshold for activity during and after applicationof the application of EPN against emerging adults approximately two to one week before start of adult emergence and against larvae just before construction of their cocoon can provide successful control of plum sawflies, by the application on the orchard floor. Nematodes should be applied in row space just before the first adult emergence. The application should be with enough water especially in orchards where tree row space is maintained by grass mulching. Priority should be given to *S. feltiae* since it is active at lower temperatures, which is necessary for application in time of plum blossom. The most important influencing factor for success of the EPN application is soil moisture. Humid weather conditions are more often recorded in early spring in time of adult emergence than in time of larval drop from the trees. During winter months, enough moisture has usually been accumulated in the soil providing environmental conditions well adapted for EPN performance. Spring application might not only have the potential to control plum sawflies adults but also provide side effects targeting overwintering stages of the plum fruit moth (*Grapholita funebrana*) (Njezič 2020).

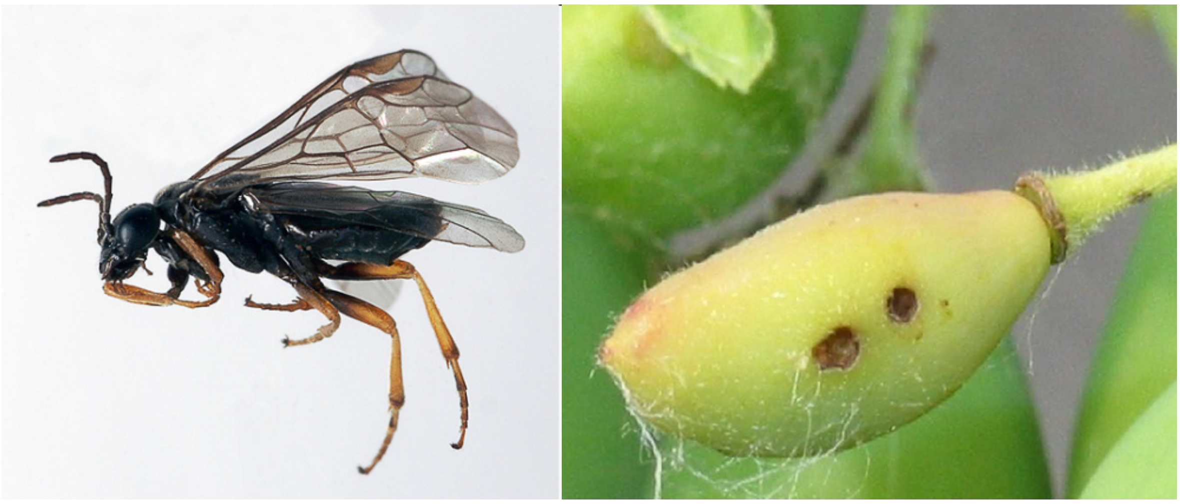


Fig. 27. Adult male and damage in form of entering holes. (photo: V.V.Neymorovets and Mezey)

Mealy plum aphid *(Hyalopterus pruni*)

Bionomics and harmfulness

The aphids concentrate on the leaves, fruits, and shoots, which causes severe deformation of the fruit and weakening of the fruit trees. The harmful nature of aphids also manifests in reduced yields and reduced frost resistance of the plantations and can also kill the trees (Matvievski 1987, Shevchuk 2021). *H. pruni* causes direct damage by sucking plant sap, which induces plant deformation and indirect damage by the development of over production of honeydew. Furthermore, it also reported as vector of the plum pox virus (Atlıhan and Kaydan, 2001; Daşcı and Güçlü, 2008).

Preventive measures

Maintain a sufficient amount of natural enemies by reducing chemical inputs.

Direct protection

The use of biological preparations for plant protection is only effective on plantings which are not heavily attacked by aphids. Various extracts and oils from plants are used. Additionally, chemical control remains the most effective strategy for aphid management, although it should be avoided owing to environmental contamination and the resulting health issues. Its important to rotate the used chemical substances to avois resistance. Chemical treatments should be done by early emergence of the pest.

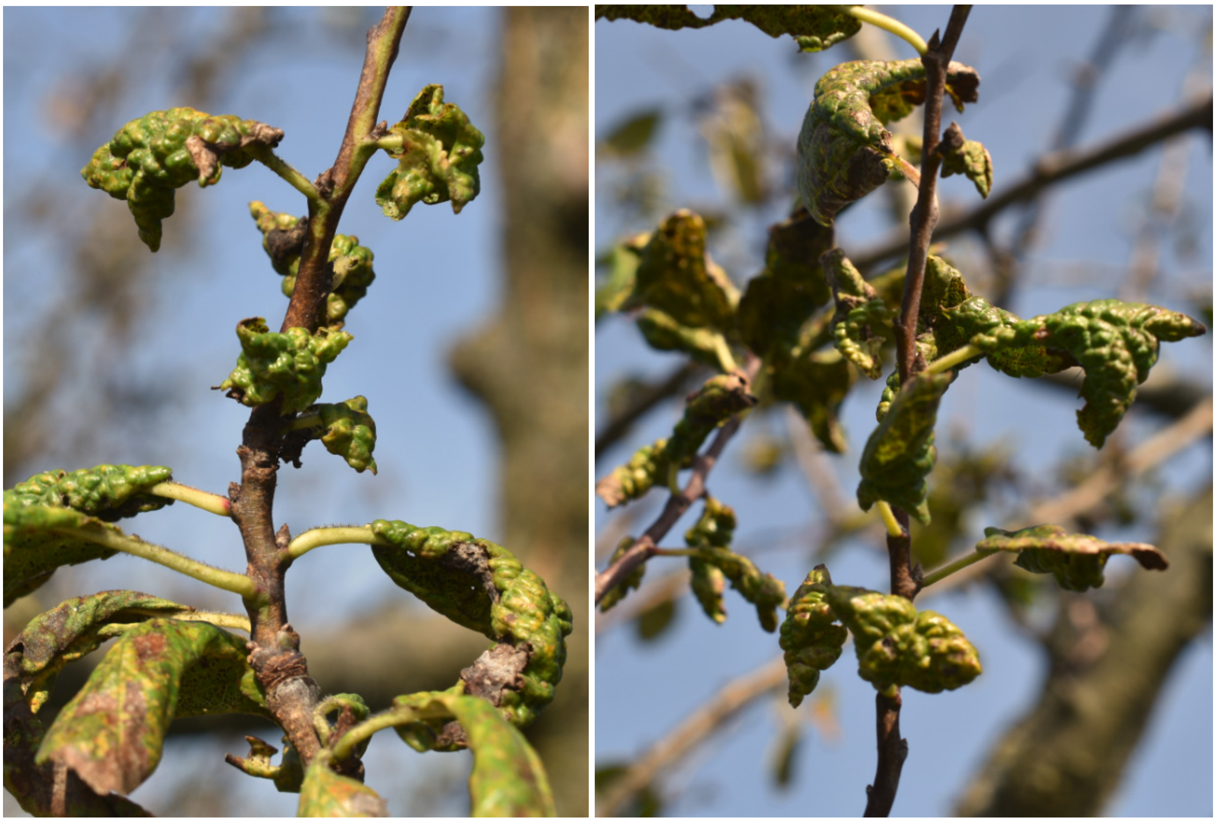


Fig. 28. Mealy plum aphid ob plum shoots. (photo: Mezey)

Plum pox virus

Bionomics and harmfulness

Plum pox virus (PPV) is the causative agent of sharka, one of the most important diseases of trees of the genus *Prunus*. Thanks to its high propagation potential, PPV has spread worldwide, causing great damage to many economically important crops. The impact of sharka disease in agriculture and the fact that the virus belongs to the relevant potyvirus group have placed PPV among the ten most important viruses in molecular plant pathology (Scholthof et al. 2011).

PPV has a very wide host range among *Prunus* species, including apricot (*Prunus armeniaca*), peach (*P. persica*), plums (*P. domestica* and *P. salicina*) and, for some isolates, sour cherry (*P. cerasus*) and sweet cherry (*P. avium*) (García et al., 2014). The virus is transmitted over short distances by many aphid species in a nonpersistent manner and by movement of plant materials over long distances (Damsteegt et al., 2007).

The variation of symptom expression on PPV infected plants is subject to virus strains, host plant species/cultivars, and environmental factors (Cambra et al. 2006). The disease caused by PPV reduces fruit yield and quality, often making the fruits unmarketable. The symptoms on susceptible *Prunus* leaves are vascular clearing, yellow rings, spots and stains, distortion and deformation. On fruits, deformation, chlorotic spots and necrotic areas are frequently observed, together with fruit drop in the most susceptible varieties (Gurcan 2020).

With low viral accumulation, response of the plant is mild and few symptoms are shown. When a high viral dosage is reached, increased oxidative stress activates chloroplast rearrangement and symptom development. Symptoms are also dependent on external elements and may vary seasonally and according to plant developmental factors (Rodamilans 2020).

There are five accepted and five tentative strains of PPV described so far: An (Ancestor), D (Dideron), C (Cherry), CR (Cherry Russian), EA (El Amar), M (Marcus), Rec (Recombinant), T (Turkey) and W (Winona) (García et al., 2014), and new cherry-adapted PPV strain for which the name PPV-CV

(Cherry Volga) has been proposed (Chirkov et al., 2018). PPV-M and PPV-D are the most prevalent strains, and both readily infect *Prunus armeniaca* and *Prunus domestica*, but they differ in their ability to infect *Prunus persica* cultivars (Candresse et al. 1998). M strains generally cause more severe symptoms and more rapid epidemics in *P. armeniaca, P. domestica, P. persica, and Prunus salicina* than do D strains.

Preventive measures

While most diseases caused by bacteria and fungi can be managed with appropriate cultural and chemical practices, this is not true of viruses and other graft-transmitted pathogens, including viroids and some systemic bacteria, spiroplasma, and phytoplasmas. For the virus and graft-transmitted pathogens, only preventive measures are effective. Once a tree in the field is infected, the virus- or graft-transmissible pathogens cannot be eliminated. In some cases, the losses may be relatively minor, while in others, the tree may ultimately be killed (Fuller 2013).

Certification and quarantine programs are the mainstay for protection against virus diseases and other graft-transmissible diseases (Lee 2020). So far, several measures have been used to manage epidemics of PPV, including the application and protection of virus-free planting materials, the surveillance and removal strategies on PPV-infected trees and nurseries, and the development of *Prunus* breeding strategies against PPV (Rimbaud et al. 2015). A few *Prunus* species sources have been identified to show natural resistance to PPV, which are useful in conventional breeding programs (García et al. 2014).

Advances in the knowledge of plant biology, viral life cycle, and the mechanisms underlying resistance allowed tackling alternative strategies to fight sharka disease, such as the generation of genetically modified plants resistant to PPV (Ilardi and Nicola-Negri 2011; Ilardi and Tavazza 2015).

The greatest success in the generation of a genetically engineered PPV-resistant tree was the *P. domestica* cultivar Honey Sweet, registered by the Environmental Protection Agency in 2011 (Scorza et al. 2013). This transgenic plum was originated by transformation with the full-length sequence of the PPV CP gene and has been tested in the field for more than 20 years, showing resistance against all major PPV strains, even in mixed infections with other pathogens (Callahan et al. 2019; Polák et al. 2018; Ravelonandro et al. 1997; Scorza et al. 2016).

The most reliable way to prevent this disease is to buy certified resistant or tolerant varieties. In the case of tolerant varieties, symptoms of the disease may appear, e.g. on the leaves, it will not affect the quality or quantity of the harvest. A lot also depends on the overall health and condition of the tree. If the tree is in good condition, it is more resistant to some less aggressive strains of the virus. Since one of the virus spreader is also the person performing the pruning and training, thorough disinfection and cleanliness of tools during and after work is necessary. Among the very important preventive measures is the consistent protection of the planting against the vectors of the virus, which are aphids and mites.

Direct protection

There are no curative protection possibilities. By heavy damaged orchard it is neccessary to dispose the whole orchard. Once the virus is present in the tissues, it cannot be removed, or healed.

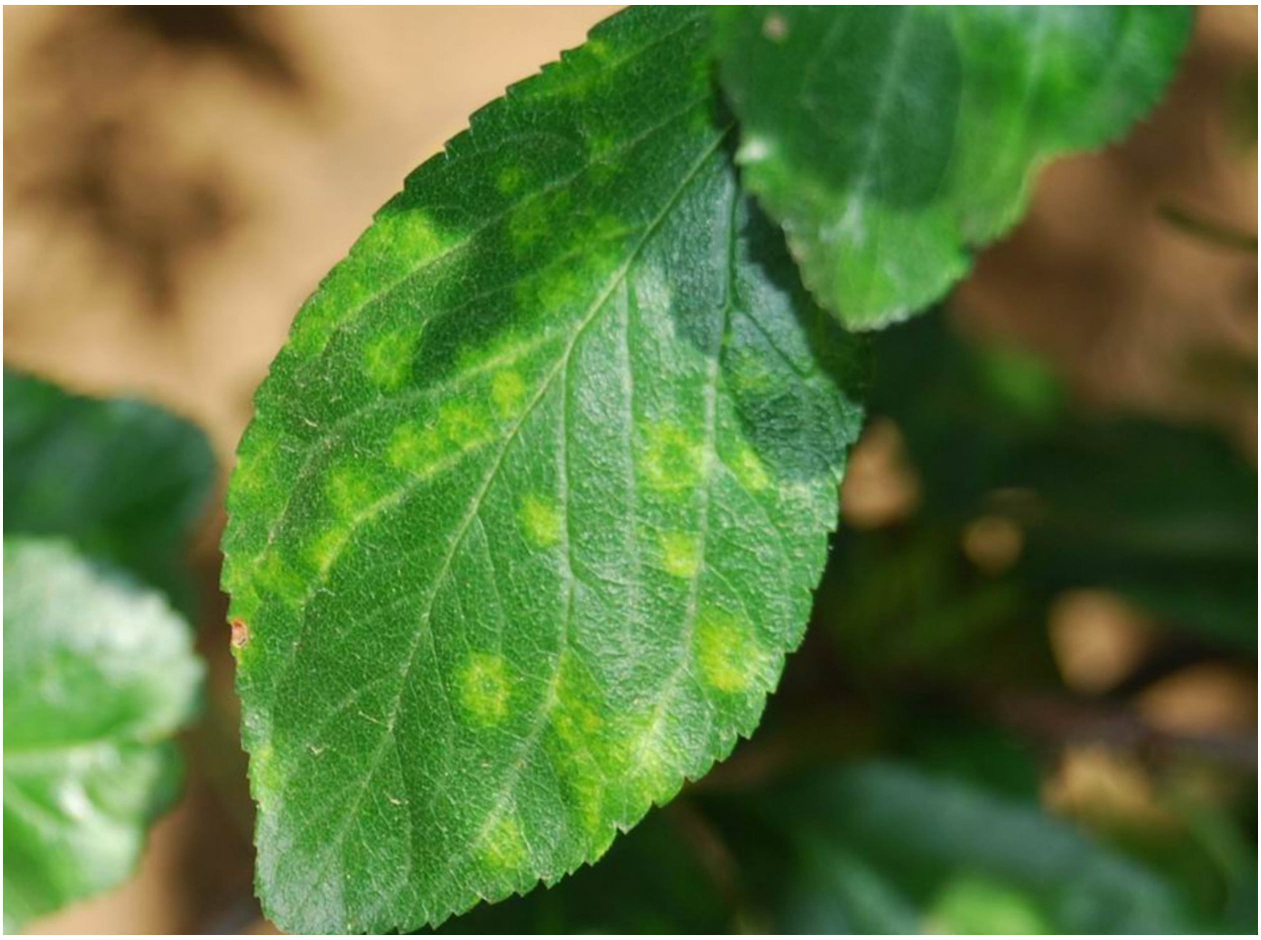


Fig. 29. Typical symptoms of sharka disease on leves. (photo: Mezey)

Fig. 30. By tolerant varieties the symptoms can be visible on leaves, but fruits are not affected. (photo: Mezey)

Plum brown rot (*Monilia laxa*)

Bionomics and harmfulness

The causal agent of brown rot (*Monilinia spp*.) is a polycyclic pathogen (Seem, 1984) involving infection sequence repeated several times throughout the annual growth cycle of the host. The fungus survives the winter in mummified fruits (Casals et al., 2015), in canopy or in the ground (Hrustić et al., 2013) and in fruit peduncles (Ritchie, 2000), in cankers on twigs, in spurs and in branches (Villarino et al., 2013; Kreidl et al., 2015). These propagules serve as sources of primary inoculum to infect blossoms, buds, and young shoots, establishing a source of secondary inoculum (Gell et al., 2009).

The opening blossoms of the host plant species provide the first susceptible tissue for infection in the spring. Spore production begins in the spring at temperatures of 12 – 25 °C. Blossom infection (via anthers and pistils) caused by *M. laxa* depends on the duration of wetness and temperature. For this, 5 to 18 hours of wetness are necessary at 24 and 10 – 12 °C, respectively, for the infection to occur. Very high relative humidity (>94%) is important for infection. The time required for the appearance of symptoms may be only a few days to 1 – 2 weeks, depending on the temperature. Secondary spore production begins almost immediately after primary spore infection symptoms occur on the blossoms and stems. Blossoms do not progress into fruit and remain on the tree, brown and wilted (Cannon et al., 2017). 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. Stem cankers can eventually girdle diseased stems being additional sources of inoculum. Few blighted blossoms may be enough to cause severe fruit rot if environmental conditions are optimal as fruits ripen. If spores are present during wet and warm conditions, infection of ripening fruits is highly susceptible (Cannon et al., 2017). Fruit lesions are brown and circular, and eventually the whole fruit decays and turns brown. Tufts of mycelium and conidia (ash-grey-brown in color) sprout from the skin of the infected fruit and are scattered on its surface; later, rotten fruits become "mummies" (Veteket et al., 2017; Dubois et al, 2018).

Preventive measures

Monitoring of the trees. At least 20 trees per block should be checked for fruit mummies and cankers during or after pruning early in the spring (before white bud stage). One to ten mummies and/or cankers per 20 trees is considered a moderate risk level for blossom infection. Greater than 10 mummies and/or cankers indicate a high risk level. During flowers shuck fall, scout ten shoots of 20 trees for blossom infections. A moderate risk level for fruit infection is reached when one to ten blossom infections per 20 trees is present. More than ten blossom infections indicate a high risk of fruit infection. As fruit ripens and becomes softer, the risk for infection increases. Two symptomatic fruit found per 4 ha during scouting before harvest is considered high risk for a brown rot outbreak (Cannon et al, 2017). Monitoring of weather conditions and key fruit pests (plum curculio, fruit moths, fruit flies, aphids, various bugs), direct into the orchard are important because preventive control measures can be properly applied, agrotechnical ones, the adequate control of pests as well as fungicides can be applied according to weather conditions, and that can cause injuries to fruits may reduce the risk of infection of fruits by *Monilinia spp*. (Veteket et al., 2017).

Very important preventive measure is the canopy of the tree. We should properly and regulary prune the trees to avoid dense and shaded parts of the tree. Crucial for this measure is also a summer pruning. During harwest we must collect all, even unripen fruits from the tree.

Direct protection

Currently, the use of synthetic fungicides in the field is crucial for containing plum brown rot close to the harvest, i.e., when the fruits are more susceptible to the disease, also for the presence of physiological cuticular cracks (Oliveira 2016, Gilbert 2009). However, chemical control is increasingly limited due to environmental and toxicological risks as well as for the onset of fungicide-resistant pathogen strains. Moreover, very few fungicides are allowed in preharvest and often none in postharvest. The European regulations in force establish lower residue limits of the active ingredients (EPPO Directive 2009).

In order to prevent and contain the damages produced by the brown rots on stone fruits species, intensive researches were carried out in Europe and USA, which conducted to the screening and release on the market of more efficient active ingredients and mixtures such as: new formulations of copper and captan), as well as molecules with systemic action like: boscalid; myclobutanil, propiconazol, tebuconazol, fenhexamid, penthiopyrad, pyrimethanil, pyraclostrobin, fluopyram + trifloxystrobin, fluxapyroxad + pyraclostrobin, cyprodinil + difenoconazole; tebuconazole + trifloxystrobin, etc.), biological or biotechnical products were tested and included in integrated phytoprotection programs (Cannon et al., 2017).

Sustainable alternative strategies are emerging, which also include the biocontrol based substances on the use of antagonistic microorganisms (bacteria, fungi, and yeasts) that is a promising tool to prevent pre- and postharvest fungal rots and to significantly decrease the use of synthetic fungicides (DeCurtis 2019, Lima 2008, Janisiewicz 2002, Ippolito 2004).

Under practical conditions, biological substances do not always reduce fungal decay when applied alone or when the number of treatments is insufficient and/or is not performed at critical stages for the disease development (DeCurtis 2019, Janisiewicz 2002, Droby 2009, Spadaro 2016). Therefore, for the control of an insidious disease such as plum brown rot, an appropriate preventive strategy based on the use of bioagents in combination/alternation with synthetic fungicides is suggested considering the times of application (DeCurtis 2019, Lima 2008, Droby 2009, Lima 2005).

The key treatments at crucial phenological stages (BBCH) for controll of plum brown rot are as follows: BBCH 69 – 71: End of Flowering-Ovary Growing, BBCH 75: Fruit About Half Final Size, BBCH 77 – 78: Fruit 70 – 80% of Final Size or 60 – 70 days before harwest, BBCH 81: Beginning of Fruit Coloring or 30-35 before harwest and BBCH 87: Fruit Ripe for Picking or 7 – 15 days utnil harwest (Palmieri 2022).

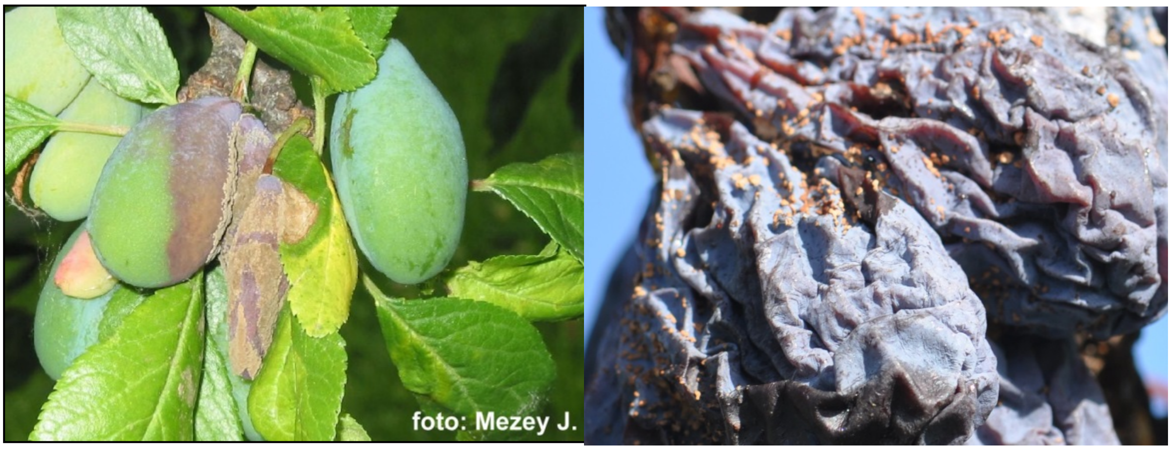


Fig. 31. Symptoms of brown rot on fruits in various development stages. (photo: Mezey)

Fig. 32. Fruits left on the trees will turn into spore-reservoirs for the next season. (photo: Mezey)

Shot hole disease (*Clasterosporium carpophilum)*

Bionomics and harmfulness

The fungus of *Stigmina carpophila* (syn. *Clasterosporium carpophilum, Wilsonomyces carpophilus*) causes shot hole disease in most stone fruit orchards, including plum (Molnár 2022). Symptoms of disease occur on the leaves, shoots and fruits of most cultivated stone fruit species. In the case of plum, the leaf symptom is the most common symptom type (Bubici 2010, Ahmadpour 2012, Ahmandpour 2018, Ahmadpour 2009). Leaf symptoms appear as tiny light spots that gradually turn brown. Later, a purple-brown border develops around the spots. The middle of the spots die and fall out and the 'shot hole' symptom appears (Adaskaveg 1995, Grove 2002, Ivanová 2012). Under favorable weather conditions, disease becomes severe and the leaves of the tree fall before harvest, resulting in an early defoliation of the tree (Shav 1990). Due to early leaf fall, the health of trees reduces year by year which is also reflected in yield reductions (Highberg 1986, Teviotdle 1997, Evans 2008).

Preventive measures:

Training system and cultivar susceptibility can significantly influence the temporal epidemics of shot hole disease in an integrated plum orchard. Plum cultivars with high or mid-high susceptibility to shot hole disease showed continuous disease development from May to November, while cultivars with low susceptibility to shot hole disease showed no symptoms until mid-summer and then progressed slowly until November. The annual disease incidences and accumulation of inoculum sources of disease on plum cultivars with high or mid-high susceptibility to shot hole disease showed more sensitivity to training systems, compared to cultivars with low susceptibility to this disease. Certain combinations of training system and cultivar can significantly reduce the temporal development of disease during the season and the accumulation of inoculum sources by the end of the season. This may be successfully used as a part of the integrated pest management approach during establishing new plantations (Molnár, 2022).

Very important preventive measure is the canopy of the tree. We should properly and regulary prune the trees to avoid dense and shaded parts of the tree. Crucial for this measure is also a summer pruning.

Direct protection:

Management of the disease usually requires 1 to 3 sprays during flowering then an additional spray after fruit set (Teviotdale 1997, Teviotdale 1989, Esitken 2002). In the case of severe infection, copper sprays are recommended at leaf fall in autumn (Holb 2005). Usually we spray in cases, when the time period after flowering is wet during three weeks.

Due to environmental concerns and chemical control compounds' detrimental effects on human health, interest has largely increased regarding environmentally friendly methods to control shot hole disease (Esitken 2002). Several biological fungicides based on different strains of the bacterium *Bacillus subtilis* the bacterium *Pseudomonas fluorescens* and the fungus *Trichoderma harzianum* can be used as biological protection. According to seasonal features of shot hole disease, the optimal timetable schedule for plum treatment with the fungicides should be in 3 treatments in May – June (Leonov 2020).

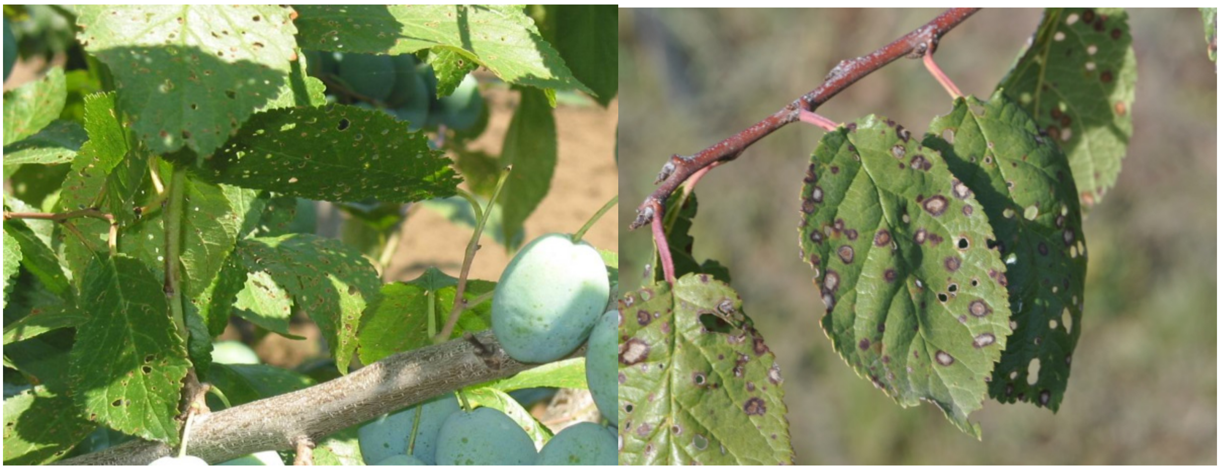


Fig. 33. Symptoms of shot-hole disease in early vegetaition and later in August (photo: Mezey)

Plum rust (*Tranzschelia discolor)*

Bionomics and harmfulness

Rust caused by *T. discolor* is an economically important diseases on plums and many other stone fruit, such as peaches and almonds. Plum rust results in the development of yellow speckling on the upper leaf surface, following a period of asymptomatic/latent development after initial spore infection. The length of time between initial spore infection, and development of symptoms is unknown, due to the lack of research in this area. The yellow speckling corresponds with pale brown raised dots on the underside of the leaf, which are spore-producing pustules. Young leaves often become puckered, distorted and heavily infected; older leaves are not as susceptible, but may become necrotic and shrivel. Leaf spotting and pustules tend to be much more visible on varieties with lighter coloured leaves, and do not affect twigs or fruit in plum (D’urban-Jackson 2018).

A critical feature of rusts is that they require a period when there is free water on the leaf surface in order for their spores to germinate (Scrace, 2000, O'Neill, 2002, Wedgwood and Robinson, 2016), with the length of time leaves are wet to be a major determinant of whether infection occurs (Kable et al., 1991). High relative humidity (>80%), rainfall and dew point also favour T. discolor rust development (Mancero-Castillo et al., 2015, Dicklow, 2013). Temperature is also important to germination, in the presence of free water, T. discolor urediospores in almond, germinate between 5 – 30 °C, with over 80% of spores germinating within 2 hours of incubation between 10 – 28 °C (Ellison et al., 1990).

Rust symptoms were predominantly on younger leaves, suggesting they may be more susceptible to infection, or that climatic conditions conducive to rust outbreaks occurred late in the season, when new young leaves were emerging (D’urban-Jackson 2018).

Preventive measures:

The use of resistant or ‘tolerant’ plum rootstocks may play a role in reducing levels of plum rust in commercial orchards. Cultural control methods such as leaf litter removal, and pruning to create an open canopy have been evaluated by some researchers, and are approaches worth exploring as part of an integrated management strategy. Pruning is considered important in reducing disease pressure, as it reduces humidity in the canopy that favours spore germination and infection. (D’urban-Jackson 2018).

A common management measure in apple orchards for reducing fungal inoculum (such as for apple scab) is to flail or use urea to break down leaf litter, a major site for over wintering spores. Regardless of the orchard cleanliness in autumn, missing the first fungicide application in spring always reduced yield. (Sundin and Irish-Brown, 2018).

Direct protection:

Management of plum rust has always been a challenge, relying on a limited number of plant protection product active ingredients. Where these actives have been withdrawn, growers are left in a vulnerable position with few plant protection product options. This occurred recently through the loss of Systhane 20 EW (myclobutanil), the only rust-specific fungicide available. Early season triazoles-based fungicide foliar sprays appear to be the most effective way of controlling plum rust. Approaches involving biological-based biopesticides PPP have been reported, so may be worth investigating further in experimental work (D'urban-Jackson 2018).

Control measures for plum rust must start as soon as first symptoms appear (Erincik et al., 2016) to ensure minimal disease progression. This is important as there are no curative products for plum rust, once leaves are infected. Once urediospores penetrate the leaf surface, rust pustules appear after 15 – 21 days (Erincik and Timur Döken, 2010), so fungicides should be targeted at this stage, to prevent further inoculum production, and further foliar infections.

There is potential for the use of biopesticides to control rust in plums, with existing approved products including Amylo X (*Bacillus amyloliquefaciens* subsp. *plantarum* strain D747), Prestop (*Gliocladium catenulatum* strain J1446) and Serenade ASO (*Bacillus subtilis* strain QST 713) (D'urban-Jackson 2018).

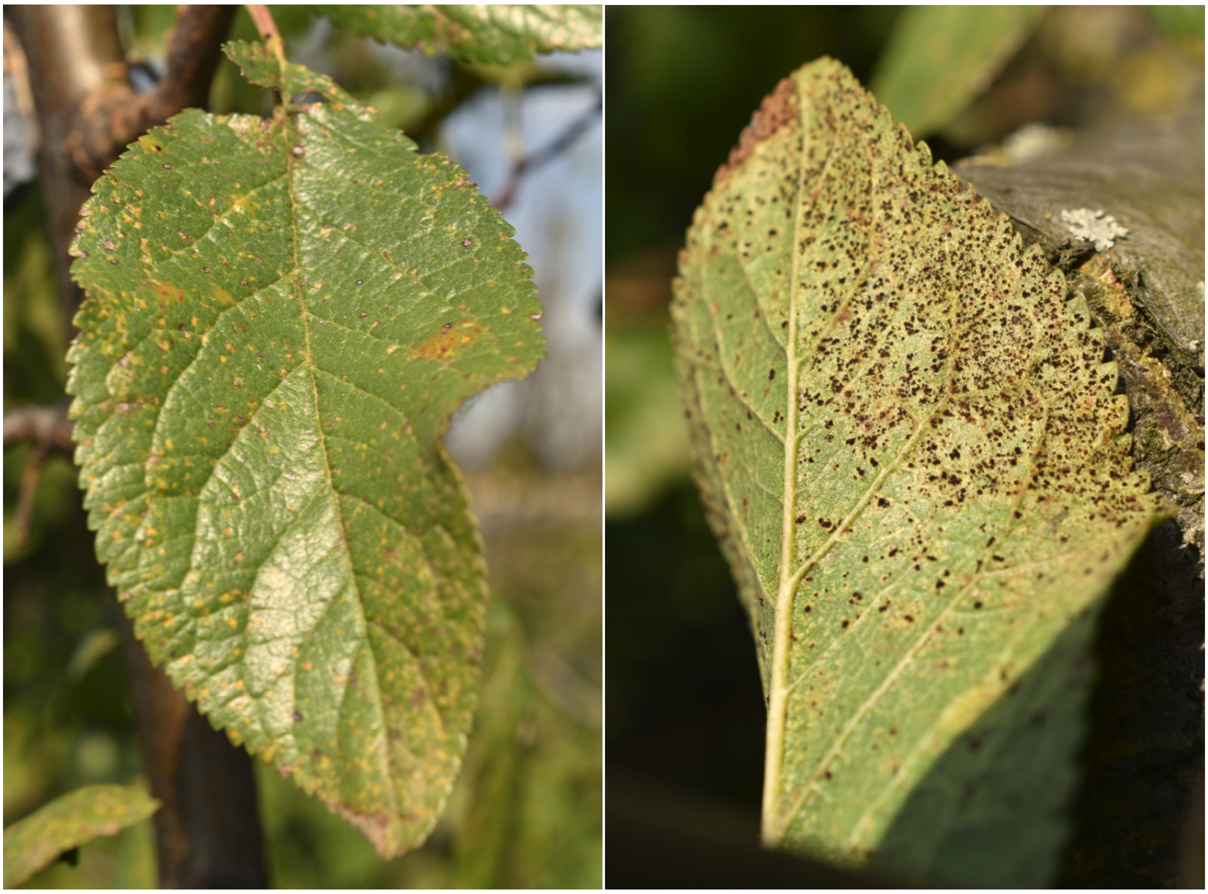


Fig. 34. Plum rust symptoms on upper and lower leaf side. (photo: Mezey)

INTEGRATED PEACH PROTECTION

Oriental fruith moth (*Cydia molesta*)

Bionomics and harmfulness

The oriental fruith moth is a long-term significant pest of peaches worldwide. In recent years, it has also become a significant pest of apple trees also (Rice a Kirch, 1990).

This pest damages trees both by eating the corridors in the tops of young shoots and by causing worminess of the fruit. Consequently, the fruits are often subject to monilium rot (Matlák, 2010). The host plants of this pest mainly include plants of the *Rosaceae* family: peaches, apricots, apples, plums and others. (Meijerman, 2000).

Unlike the peach twig borer, small caterpillars of the oriental fruith moth, that hatched from the eggs of the 1st generation imago, damage long shoots (longer than 8 – 15cm) in May. Caterpillars eat the pith of young shoots from the top down. As a result, the leaves and shoots wither and ooze appears at the site of injury. Dead shoots can be densely next to each other, because the larva is able to destroy 3 – 7 shoots during its development. (Meijerman, 2000).

The pest has 3 or 4 generations per year (Razowski, 2003). In Northern Europe, or in climatically colder regions, 2 generations (Germany) or 3 generations (Slovenia) are reported, as reported by Helmut (2007) and Tomse et al., (2004). A population mixed with fully developed caterpillars of the last two generations hibernates in bark cracks in densely woven cocoons. It pupates in the spring. The first butterflies appear at the end of April and the beginning of May. Females lay approximately 15-200 eggs (the number of eggs depends on the generations) and after 4 – 10 days of embryonic development, caterpillars hatch from them. They lay their eggs on the tops of shoots, leaves and fruits. 2nd generation butterflies fly in June, while 3rd generation butterflies fly from mid to late July. Females of the 3rd generation lay their eggs on or near the fruits. Part of the fully developed caterpillars then rest in the cocoon, while the other part pupates and undergoes further development. (Razowski, 2003).

Preventive measures:

The most important preventive measure is pre-spring shallow cultivation of the soil, when a significant amount of overwintering stages of the pest is destroyed. It is also important to remove overgrown trees, various bushes and dry branches around the orchard, which can serve as a wintering place.

Direct protection:

The most effective protection is chemical treatment of the overwintering generation. According to experience, it is recommended to do the intervention 6-8 days after the start of the flight. Treatments must be repeated in 10 – 14 days due to flight delays. We can follow the course of the flight using pheromone traps. The protection technology and chemical substances used are relatively similar to those we use against peach twig borer (*Anarsia lineatella*), but in the protection against oriental fruith moth (*Cydia molesta*) we do more treatments. (Matlák, 2010). The lower developmental limit for *C. molesta* was determined on the basis of laboratory experiments at 9.5 °C. (Damos et al., 2010). The phenology of *C. molesta* is unpredictable, especially during the harvest period, and for this reason defining individual generations, especially during the second generation, is very difficult. (Damos et al., 2010). Secondary factors, such as the host plant or microsite are also able to influence the flight activity, as well as the number of butterflies caught in traps (Hughes et al., 2004; Borchert et al., 2004; Myers et al., 2006; Myers et al., 2007), similar to relative humidity and diapause entry time (Graf et al., 1999). Inaccuracies in determining daily effective amounts are also due to differences between individual locations and the current air temperature (Kuhrt et al., 2006).

The first generation of *C. molesta* appears at 650 °C, the second at 780 °C and the third at 1250 °C, when March 1 is considered the biofix. (Damos et al., 2010). According to Rice et al. (1984), the peak of *C. molesta* attack of the first generation is in the interval of 200-600 daily degrees, while for the second generation it is 800 – 900 daily degrees at the lower development limit of 7.3 °C. The most individuals were caught during the months of August and September (Damos et al., 2010).
This moth seems especially susceptible to mating disruption, with a wide variety of formulation types (microdispersibles to aerosol puffers) of the pheromone providing excellent fruit protection (Cardé 2007; Evenden 2016).
The first captures of G. molesta early in the season were observed at 33 DDs, lower temperature threshold: 9.5 °C and Biofix: 1st of January. The highest number of moth captures were observed at 77.9 DDs, while the start of the subsequent second flight was observed at 133 DDs. Moreover, the peak of the second moth flight was observed at 204.8 (Damos 2022).

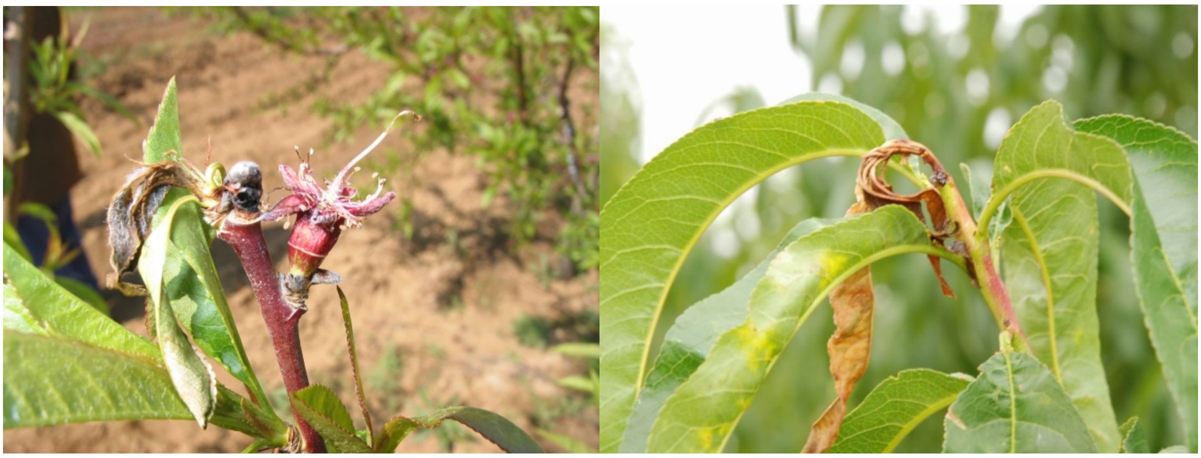


Fig. 35. Damage caused by oriental fruit moth in the beginning and during the vegetaton period. (photo: Mezey)

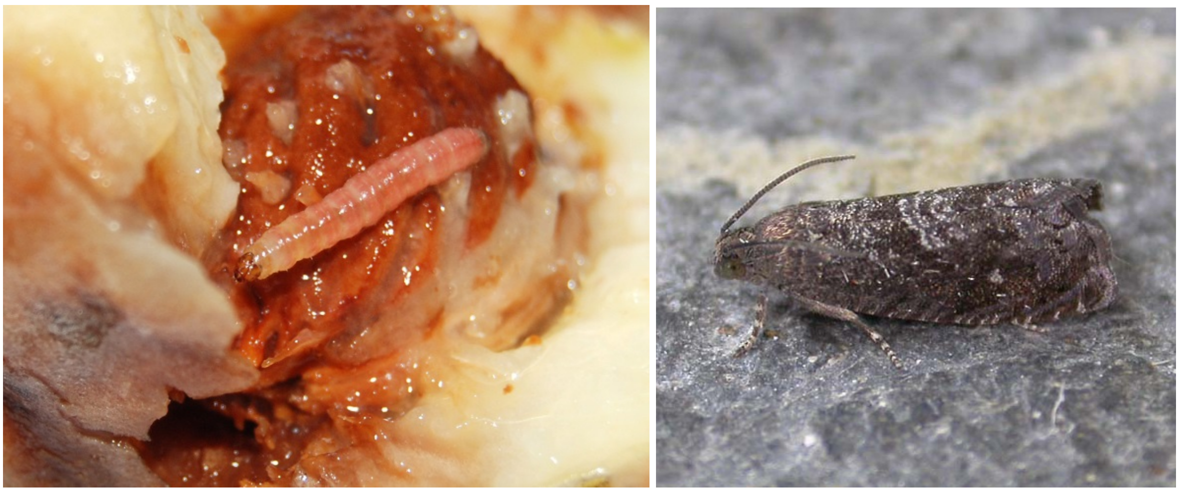


Fig. 36. Larvae and adult male of oriental fruit moth. (photo: Mezey, Mitchell)

Peach twig borer (*Anarsia lineatella*)

Bionomics and harmfulness

Peach twig borer is a major pest of apricot, peach, plum and almond. The adult is steel grey moth with white and dark scales. The full-grown larva is about 12 – 15mm long and has alternating bands of light brown and dark brown colour. The head is black, and six legs are clearly visible. The larvae push excrement from their tunnels onto the surface of the fruit where it is readily visible. The larvae of peach twig borer also tunnel the buds and terminal shoots in early summer, but later in the season,

the larvae bore into the shoots causing a characteristic flagging or wilting of new growth as the injured areas wilt and die. Flagging of fruit trees diagnoses infestation as it causes severe twig dieback and finally damage to fruits if not controlled. Actually, later generations of larvae infest the stem and may also bore into the peach and plum fruit and feed inside. The pupa is smooth and brown (Mir 2021). In subsequent generations, as twig tissue hardens, larvae attack the fruits, causing considerable losses in quantity and quality (Roshandel, 2019).

The wintering stage of peach twig borer is caterpillars of 1 – 4 ages (mostly 2 – 3) 1.1 – 3.3 mm long, which are concentrated in the bark of shoots, forks of branches, under the scales of apical, sometimes lateral buds (Naji 2013). Up to 78.3% of the caterpillars overwinter in cracked bark, up to 21.7% in buds and a small part is observed in mummified fruits. The best for wintering of the caterpillars of peach twig borer are the middle tiers of trees and sunlight sides of tree canopy (Lazarov 1971). After overwintering, caterpillars of peach twig borer damage the buds, then young annual shoots, which leads to their wilting. The nature of damage to shoots by caterpillars of peach twig borer is quite similar to the caterpillars of oriental fruit moth. This makes it difficult to identify the damage visually.

During its development, one caterpillar can damage 4 – 5 young shoots. In summer, the caterpillars damage green and ripening fruits, feeding under the skin near the petiole, or sideways, making moves to the stones (Naji 2013). Depending on the region, peach twig borer develops in 1 – 5 generations.

Preventive measures:

Cultural practices such as pruning the infected shoots (Alston and Murray, 2007) and protecting the natural enemies such as *Paralitomastix varicornis* (Roshandel, 2019) decrease the pest population.

Direct protection:

Insecticides according to flight activity from pheromone traps have been the primary method for controlling pest damage in peach orchards.

The pheromone dispensers Isomate A/OFM at a rate of 1000 pieces per ha provide excellent control for the oriental fruit moth (*G. molesta)*, plum fruit moth (*G. funebrana*) and peach twig borer (*A. lineatella*) (Palagacheva 2020).

The first captures of A. lineatella early in the season were observed at 70 DDs, respectively (lower temperature thresholds: 11.4 °C and Biofix: 1st of January. The highest number of moth captures of A. lineatella were observed at 150.6 DDs, while the start of the subsequent second flight was observed at 365 DDs. Moreover, the peak of the second moth flight was observed at 511.5 DDs. (Damos 2022).

Fig. 37. Adults, larvae and its damage on fruit. (photo: Murray)

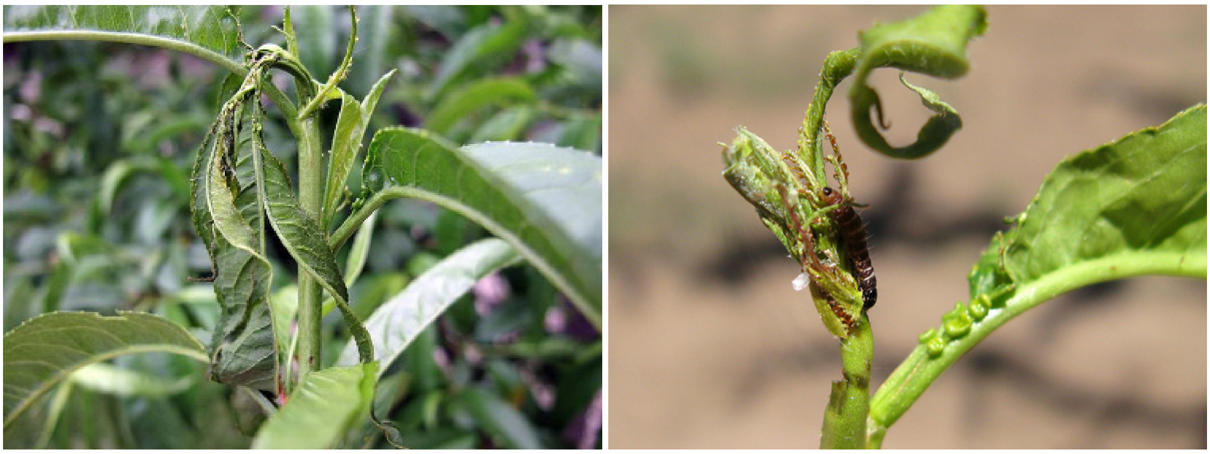


Fig. 38. Larvae of peach twig borer and its damage. (photo: Murray, Utah State University)

Green peach aphid *(Myzus persicae*)

Bionomics and harmfulness

The green peach aphid, *Myzus persicae*, is one of the most important pests of peach, one of its primary hosts. Although to our knowledge there has been no formal evaluation of yield loss in peach production due to this aphid species, it has been acknowledged as a very injurious pest (Dedryver et al. 2010). Damages to peach include leaf twisting, pitting and discolored fruits, and the vectoring of important viruses, such as plum pox, also known as sharka (Penvern et al. 2010, Barbagallo et al. 2017).

Preventive measures:

Maintain a sufficient amount of natural enemies by reducing chemical inputs.

Direct protection:

Aphids in peach crops have usually been managed with insecticide sprays (Barbagallo et al. 2017). Additionally, *M. persicae* resistance to numerous active substances, such as pyrethroids, neonicotinoids, organophosphates, and carbamates, often renders many insecticide treatments ineffective (Foster et al. 2011). In this scenario, biological control, more specifically conservation biological control, could be a good tool to reduce the use of insecticides in peach crops (Dedryver et al. 2010, Penvern et al. 2010). Conservation biological control relies on modifying the environment or existing practices to protect and enhance specific natural enemies or other organisms to reduce the effect of pests on crops (Eilenberg et al. 2001).

Another option is the use of essential oils, belonging to different families, on *M. persicae* (Albouchi et al. 2018; Kim et al. 2018; Pavela 2018; Lu et al. 2020).

Fig. 39. A peach shoot heavily damaged by green peach aphid. (photo: Nelson)

Peach leaf curl *(Taphrina deformans)*

Bionomics and harmfulness

Peach leaf curl is a common disease of peach and nectarine trees caused by the fungus *Taphrina deformans*. Severely affected trees reduce tree vigour, fruit quality and yield. Symptgoms on leaves appear about two weeks after leaves emerge from buds, deformations, blisters, thickened curling leaves, and white, yellow to red leave discolorations; affected leaves may dry up and fall off. Symptoms on fruits are blistered fruit tissue, later wrinkling. Infections on fruits make the surface corky and cracked, and affected fruits fall off. When trees are severely affected, the disease can strongly reduce yield and fruit quality. If significant premature leaf drop occurs, trees will be susceptible to drought stress and winter injury (Vávra 2023).

The fungus overwinters in bark and bud scales. The infection of buds happens in early spring during bud swelling. When temperatures reach above 10 °C, infections are possible as early as January. Humid weather promotes the growth and spread of the disease. Additional spores form on the surface of diseased tissue, and these spores cause new infections if the weather remains mild and wet (Vávra 2023).

Preventive measures:

Thin out and remove infested shoots by mid-May, thin fruit if the crop load is heavy, and apply copper in the fall after leaf drop. Grow tolerant varieties to leaf peach curl disease, however fully resistant varieties do not exist. Varieties described as the most tolerant: Bella di Roma, Catherine Sel.1, Golden Jubilee, Redhaven, Hardired, Filip, Frumoasa litoralului, Stark Saturn, Creola. Nowadays, the offer of peach varieties is large, but the lack of reliable data concerning their suitability to organic systems makes the choice difficult (Vávra 2023).

Direct protection:

Check records of growing degree hours +7 °C (sums of active temperatures about 7 °C (SAT+7)) from the beginning of the year (from January 1st) at meteo-stations in or near your orchards. The first movements of the bud scales are visible when the SAT+7 reaches the value of 800. Ordinarily, the first treatment by copper is recommended at the value of 1100-1200 SAT+7, but it is advisable to start mostly already at the value of 1000 SAT+7 (in central Europe). From bud swell to bud break during humid weather and temperatures above 10 – 12 °C treat with copper; in case of persistent humid weather, repeat the treatment 1 – 2 weeks later (Vávra 2023).

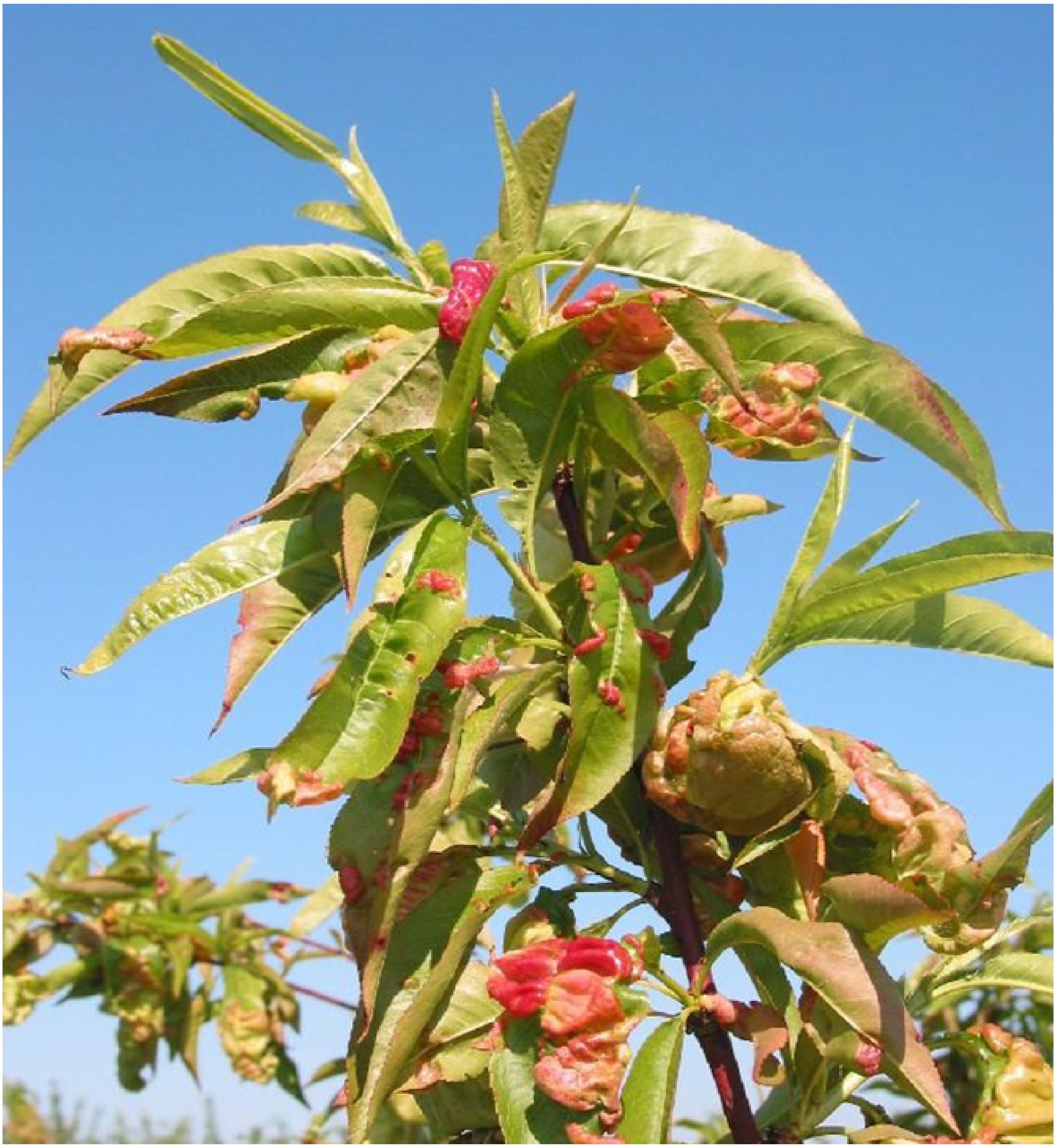


Fig. 40. A peach shoot heavily damaged by peach leaf curl. (photo: Mezey)

Brown rot (*Monilia laxa*)

Bionomics and harmfulness

Brown rot (BR) caused by *Monilinia* spp. is one of the most destructive diseases in commercial stone fruit orchards worldwide. *M. fructicola*, *M. laxa* and *M. fructigena* are the main species causing fruit infections (Byrde 1977). These fungi incite losses by infecting blossoms, flowers, and fruit during the preharvest, harvest, and postharvest periods (Larena 2005). Postharvest losses can be particularly severe, especially when conditions are favorable for disease development; in some cases, 80–85% of a crop may be lost (Larena 2005, Hong 1998). When weather conditions are unfavorable, infections may remain latent until conditions become favorable for disease expression, at which point fruit rot ensues (Gell 2008).

The critical life stages of *Monilinia* spp., such as primary inoculum availability, host infection and colonization, and secondary inoculum, are the essential prerequisites for the development of BR infection. Multiple factors influence the completion of these life stages, and their knowledge is critical to developing optimized phenotyping protocols.

Principally, the brown rot life cycle includes different stages (Byrde 1977): blossom blight and twig canker at early spring, brown rot at late spring and summer, latent infections, and overwintered inoculum in the form of mummified fruit on trees or orchard ground.

Monilinia spp. overwinters and produces primary inoculum from two sources: mycelia in the fruit mummies, fruit peduncles, cankers on twigs and branches, leaf scars, and buds that sporulate under favorable condition; and stromata that produce ascospores in the spring (Byrde 1977, Ogawa 1995, Jerome 1958, Holtz 1998, Biggs 1985, Gell 2009). However, mummies hanging on trees appeared to be a more viable and effective source of primary inoculum than ground mummies (Casals 2015).

Secondary inoculum can emerge from any infected tissue in which the moisture content is sufficient for sporulation (Byrde 1977); however, non-abscised (aborted) fruit on trees and thinned fruit on the orchard floor appeared to be critical sources in certain production regions (Landgraf 1981, Villarino 2010).

Environment plays an essential role in disease development (Agrios 2014). Variables such as temperature, photoperiod (light), humidity, and leaf wetness modulate canopy environment and influence fruit growth and quality (Lopresti 2014), as well as brown rot development. For *Monilinia* spp., the most critical environmental factors seem to be temperature and humidity. Under favorable conditions, the process of *Monilinia* infection starts with the conidium germination on the fruit surface, followed by elongation of the germ tube and formation of appressoria to penetrate the epidermis (Lee 2006) or to enter through natural openings and wounds (De Oliveiria 2016). Under adverse conditions, primary infections can remain latent in blossoms and immature fruits (Northover 1994), Cruickshank 1991).

Temperature and humidity are primary factors to be considered in the *Monilinia* spp. life cycle. The optimum temperature for mycelial development and sporulation was about 25 °C for all BR fungi (Byrde 1977). However, for most *Monilinia* spp., the optimum temperature for mycelial growth ranges from 15 to 20 °C, and only *M. laxa* requires 25 °C (Willetts 1984). Regarding *M. fructicola* germination, the best temperature range has been reported at 15 – 25 °C or 21 – 27 °C, depending on the study (Weaver 1950, McCallan 1930). More recently, analyzing the influence of temperature on fruit infection, Biggs and Northover (1988) suggested that optimum temperature for cherry and peach BR infection by *M. fructicola* ranged from 20 to 22.5 °C and 22.5 to 25 °C, respectively.

Preventive measures:

Commonly applied practices in a stone fruit orchard, including crop load management, irrigation, fertilization, pruning, and canopy architecture, have a major impact on *Monilinia spp*. development (Li 1989). Besides fungicide application, pruning blighted twigs and removal of mummified fruit are considered the most effective control measures against brown rot. Cultural practices can impact the inoculum source directly via microclimate modulation such as irrigation, pruning, fertilization, and indirectly via fruit thinning (Luo 2001).

Direct protection:

It is important to note that *Monilinia* spp. infect fruit in the field and losses can occur there, but disease symptoms mainly appear in postharvest in the packing house where losses can be as high as

80% (Larena et al., 2005). In this context, the control of *Monilinia* spp. must be undertaken, firstly, in the orchard. Currently, the control of *Monilinia* spp. on stone fruit is based on a program of chemical fungicide applications in the field, complemented, in some countries, with fungicide applications at postharvest. This conventional fruit production is unsustainable and could be greatly improved using tools such as: 1) a warning system to detect the most efficient moment to apply fungicides (Holb, 2013), 2) cultural practices applied in the field to reduce the inoculum pressure and 3), the use of alternative strategies to chemical fungicides both in the field and at postharvest (Casals et al., 2021; Usall et al., 2016).

At present, the most common strategy is based on the use of chemicals applied start from 45 days before harvest (Casals et al., 2021). Currently, there is a wide range of chemical active ingredients available worldwide which are applied in the field to control brown rot. These include boscalid, cyprodinil, diphenoconazole, fenbuconazole, fenparazamine, fhenexamide, fludioxonil, fluopyram, pyraclostrobine, tebuconazole, etc.

In recent years, social pressure has increased consumer demand for environmentally friendly fruit production that is more considerate of consumers' and growers' health. In addition, several other considerations have reduced the use of pesticides, such as stricter legislation on authorized active ingredients and their allowable presence on fruit, and the risk of pesticides for developing resistant strains (Droby 2016, Lahlali 2020, Casals 2010). Over the past few years, biocontrol research has also evolved towards more integrated approaches in production systems, with greater awareness of industry concerns (Droby 2009). However, biocontrol agents are not yet applied routinely under commercial conditions. Currently, only three biocontrol agents products based on *Bacillus subtilis* and *Bacillus liquefactions* or *Saccharomyces cerevisiae* are authorized in some countries for field control of brown rot.

Fig. 41. Peach brown rot. (photo: Mezey)

Peach powdery mildew *(Sphaerotheca pannosa)*

Bionomics and harmfulness

One of the most important peach disease is peach powdery mildew (PPM) (Pascal 2010, Pascal 2017), caused by the ascomycete *Podosphaera pannosa* (Dirlewanger 1996). Other powdery mildewspecies can be found on this fruit tree species, such as *P. clandestina*, *P. leucotricha*, and *P. tridactyla* (Farr and Rossman 2019), but *P. pannosa* is widely recognized as the main causal agent of the peach powdery mildew.

To our knowledge, all peach commercial cultivars are susceptible PPM to a variable degree. The pathogen infects the fruits, leaves, buds, and shoots, where mycelium develops as white-grayish spots on the surface, and heavy infections on fruit and leaves may induce their premature fall (Dirlewanger 1996, Foulogne 2003).

The pathogen overwinters as dormant mycelium in latent buds (Ogawa and English 1991), and inchasmothecia produced in the epiphytic mycelium of infected twigsand leaves (Butt 1978). Primary infections on the tree green parts occur in spring, when primary inoculum (ascospores) is available and favorable conditions are met. Infections from latent mycelium that overwintered in buds have also been reported (Weinhold 1961). Conidia released from these primary colonies disperse in air and initiate secondary infections throughout the season (Grove1995; Jarvis et al. 2002). Infection of fruit, if severe, makes the fruit commercially unacceptable (Weinhold 1961), thus causing important economic losses.

A similar symptom with rusty spots on fruit may be caused by *Podosphaera leucotricha*, which is the causal agent of apple powdery mildew, thus removing adjacent apple orchards can reduce rusty spot in peach orchards (Urbanietz and Dunemann 2005).

Preventive measures:

Clipping and proper destruction of diseased shoots and other diseased materials help in minimizing the disease inoculum (Huang et al. 1995).

It is necessary to avoid growing peaches near apple orchards, which are highly susceptible to powdery mildew. If there is such an orchard nearby, it is necessary to check the apple trees and apply fungicides to the peaches in the BBCH 71 phenophase – fruit drop after flowering.

Direct protection:

Peach posdery mildew can be controlled effectively through foliar fungicide applications, applied regularly every 7 – 14 days during the year (Grove 1995) from prebloom to the end of harvest (Pascal 2010). Recently, a predictive model for disease progress has been described (Marimon 2020), which included a threshold to initiate fungicide programs at early infection set.

The most used fungicides are sterol biosynthesis in-hibitors (SBI), quinone outside inhibitors (QoI), protein synthesis in-hibitors, and various inorganic multisite activity products including sulfur derivatives. Foliar fungicides, starting at petal fall or the beginning of fruit set, are sprayed routinely to protect peach fruit from infection (Grove 1995; Reuveni 2001), as fruit are susceptible from the early stages of fruit growth to the beginning of pit hardening (Ogawa and English 1991).

Fig. 42. Peach powdery mildew – symptoms on fruit and leaf. The brownish rusty stain on the left side of the fruit is apple powdery mildew. (photo: Utah State University, Steward)

Peach scab (*Cladosporium carpophylium*)

Bionomics and harmfulness

Peach scab is caused by the fungus *Venturia carpophila*. Symptoms on fruit start after pit hardening and consist of relatively small, velvety-brown spots on the fruit surface. They are irregular in shape and corky in appearance. Multiple spots may merge and form bigger lesions. Continuous expansion of the fruit can lead to massive skin cracking. The disease is particularly severe in temperate climate regions with humid and cool springs, and poor air circulation (González-Domínguez et al. 2017). Scab can result in fruit downgrading and/or rejection if the infection is severe because these blemishes reduce the value of fruit intended for the fresh market (Schnabel and Layne 2004). Much like bacterial spot, peach scab can cause early defoliation. Over time, the tree may become weaker and more susceptible to freezing injuries. The pathogen overwinters as mycelia in twig lesions or as chlamydospores on vegetative tissue or in the bark of 1-year-old shoots. Besides peach, it also afects black plum, apricot, and almond (Kim et al. 2017; González-Domínguez et al. 2017; Dar et al. 2019; Zhou et al. 2021). *V. carpophila* can cause severe damage to peach production in Asia, North America and Europe (EPPO 2021).

Mainly attacks fruits, but symptoms also appear on shoots and leaves, they appear mainly at the fruit stalk. Occurrence is rare in calyceal end. Possible brown rot infection through the resulting cracks in skin. Occurrence is especially in the second half of the vegetation, hibernates in the folds of the bark on the shoots. They inoculate in the spring and are washed away by the rain to the fruits and young shoots. The 4-week period after the flower petals fall is the most critical, but fruits remain susceptible to infection until harvest.

Preventive measures:

Pruning of the trees helps to allow good penetration of sunlight and also increases air circulation which helps in disease control. Low-lying areas should not be selected as planting sites. (Hendrix 1995).

Direct protection:

The disease is mainly controlled through the use of fungicidal sprays. Timely application of fungicides starts from calyx split and every 2 weeks thereafter for a total of four to five sprays. Various fungicides like chlorothalonil at 0.3%, wettable sulphur at 0.2%, carbendazim at 0.05%, bitertanol at 0.05% and captan at 0.3% have been found effective in checking the disease (Hendrix 1995).

Fig. 43. Peach scab – symptoms on fruit, leaves and twig. (photo: Missouri Botanical Garden)

Bacterial spot (*Xanthomonas arbicola pv. pruni)*

Bionomics and harmfulness

Bacterial spot is one of the most economically important diseases of stone fruits worldwide (Stefani 2010; Janse 2012). It not only causes damage to peach leaves but also to fruit and branches. The initial symptoms on leaves are the appearance of angular water-soaked lesions. As the lesions enlarge, the centers dry out and often detach from the leaves, giving the leaf a "shothole" appearance. Larger crater lesions on fruit are mainly caused by primary infection early in the season between shuck split and pit hardening. On maturing fruit, small and shallow lesions may appear with a mottled appearance. Tey are generally caused by secondary infections after pit hardening. On branches, cankers develop either as raised blisters or dark brown oval lesions. Bacterial spot is caused by *Xanthomonas arboricola pv. pruni* The bacterium mainly overwinters on cankers, also in buds, cracks in the bark, and leaf scars. Fruit infections are favored by frequent rainfalls, high humidity, and strong winds. Besides peach, it also infects many *Prunus* species including plum, apricot, cherry and almond, as well as ornamental plants such as *Prunus davidiana* and *Prunus laurocerasus* (Rosello et al. 2012; Tjou-Tam-Sin et al. 2014). This bacterium has been found to damage stone fruits in Asia, Europe, North America, South America, Australia, and Africa (EPPO 2021).

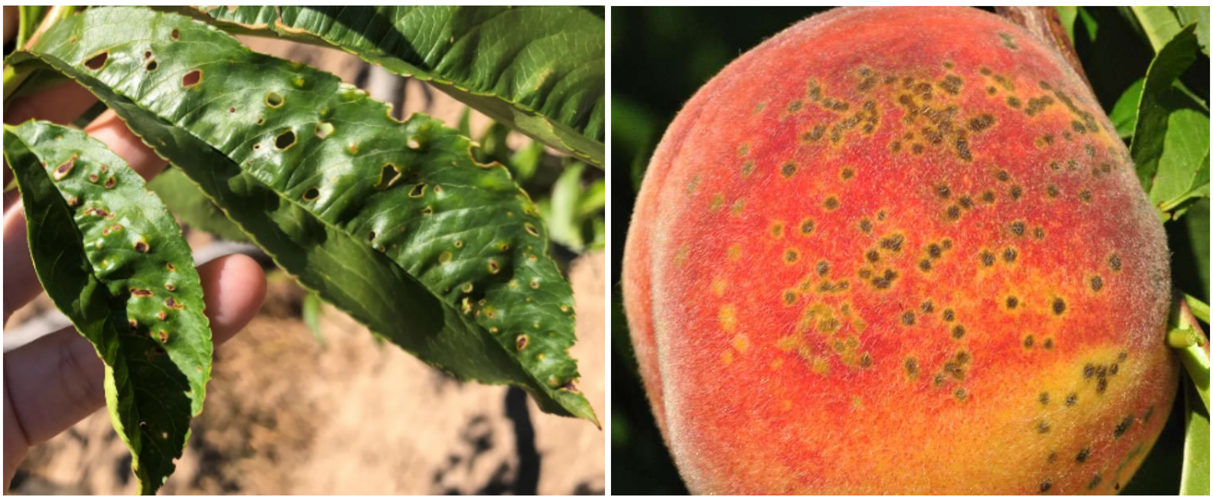


Fig. 44. Peach bacterial spot - symptoms on leaves and fruit. (photo: Caputo, Ontario Ministry of Agriculture, Food and Rural Affairs)

Preventive measures:
Chemical control of the disease is not feasible, so planting of highly susceptible cultivars should be avoided as the disease is more severe on some cultivars. Fertilization should be adequate to maintain good tree health (Khan 2021). Pruning of the trees helps to allow good penetration of sunlight and also increases air circulation which helps in disease control. Low-lying areas should not be selected as planting sites (Hendrix 1995).

Direct protection:
Dormant applications of fixed copper (copper oxychloride) may reduce bacterial populations. The antibiotic oxytetracycline at 500 – 700 ppm and fungicides like dodine and ziram have also been used with varying degrees of success (Khan 2021).

Shot hole disease *(Wilsonomyces carpophilus)*

Bionomics and harmfulness
The fungus produces olivaceous brown to black dot-like sporodochial conidiomata, on necrotic twig cankers and occasionally on fruit. Conidiophores are sub-hyaline to light brown in colour, simple to irregularly branch proliferating sympodially and bearing a solitary conidium and measure 17 – 45 × 5 – 11 µm in size. Conidia are sub-hyaline to golden brown in colour, thick walled, ellipsoidal or fusoid with apical cell ovate and basal cell truncate usually with three to five transverse double-walled septa, slightly constricted at each septum and measure 20 – 90 × 7 – 16 µm in size (Ellis 1959; Koul 1967).
The shot-hole fungus overwinters as conidia within infected buds and on twig lesions. In early spring, conidial germination proceeds disease development. Conidia are not easily detached from the conidiophores by moving air, but are readily removed by water. The incubation period ranges from 2 to 3 days at 20 – 28°C with 90 – 100% relative humidity (Gupta et al. 1972). Periodic showers, high relative humidity (70 – 80%) and optimum temperature (19 – 22 °C) favour disease development (Kosogrova 1976).

Preventive measures:
Pruning of the trees helps to allow good penetration of sunlight and also increases air circulation which helps in disease control. Low-lying areas should not be selected as planting sites. (Hendrix 1995).

Direct protection:
The disease can be effectively managed by spraying the trees at leaf-fall in autumn and before bud burst and fruitlet in spring. Further, spray can be conducted 15 – 20 days after fruitlet depending upon disease severity. Fungicides like captan at 0.3%, copper oxychlorideat 0.3%, mancozebat 0.3%, carbendazim at 0.05% and thiophanate methyl at 0.05% have been found effective against the disease. Copper oxychloride should be sprayed immediately after leaf-fall to reduce the disease carry-over, but its application on apricot should be avoided beyond pink bud stage (Angelov 1980; Ogawa et al. 1995).

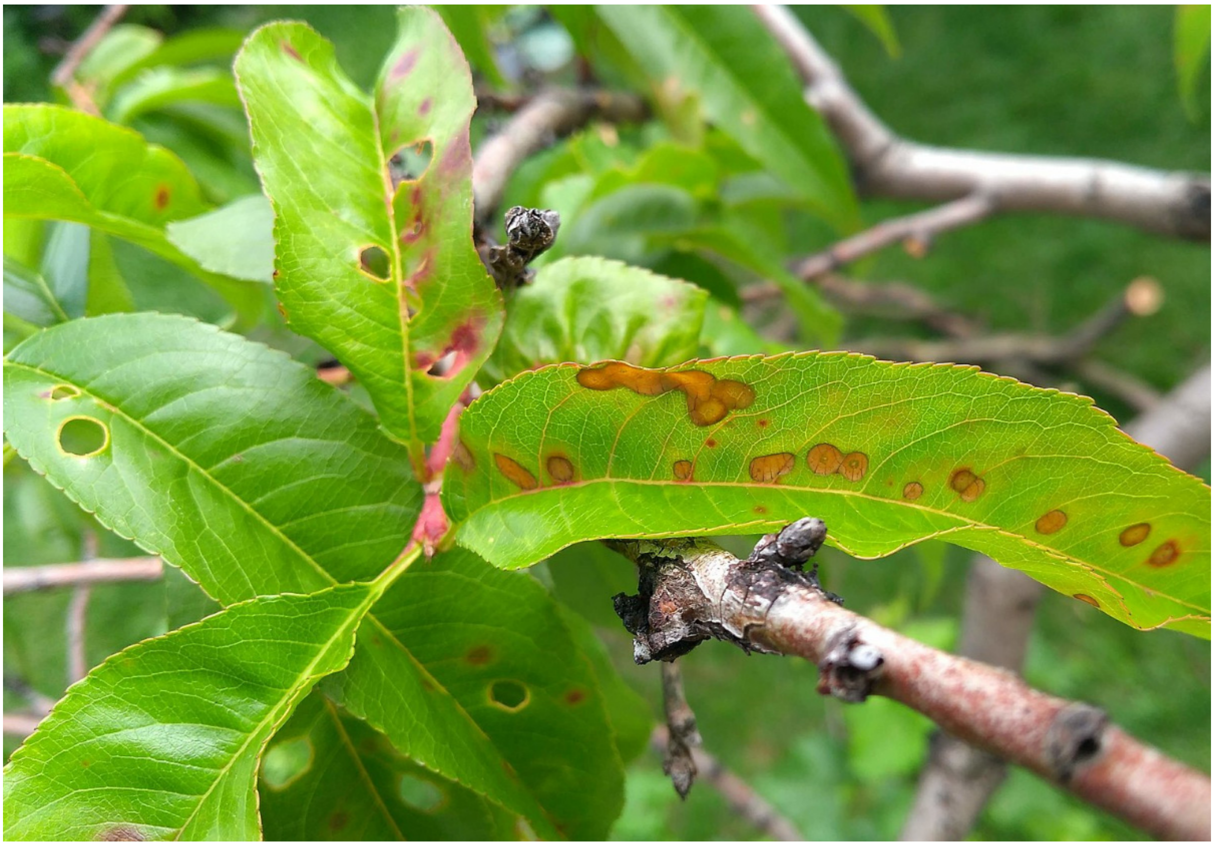


Fig. 45. Peach shot-hole disease. (photo: Arbor Vision)

INTEGATED APRICOT PROTECTION

Twig blight *(Monilia laxa)*

Bionomics and harmfulness

Among the many pathogens capable of attacking *Prunus* trees, brown rot caused by different species of *Monilinia* is one of the most important economic factors limiting the production of stone fruit around the world (Hrustic 2012, Oliveira 2016). In stone fruit, *Monilinia* spp. are able to infect various plant organs, causing blossom blight, twig blight and brown rot in immature and mature fruits. The two main species responsible for attacks on flowers and twigs in *Prunus* trees are *Monilinia laxa* (Aderhold and Ruhland) Honey and *Monilinia fructicola* (G. Winter). Apricot is the crop that is most susceptible to blossom and twig blight, followed in order by prune, sweet cherry, peach, sour cherry and plum trees (Holb 2008). *M. laxa* can cause infections in apricot blossom, twigs and fruit. The first two are of the greatest concern, especially in organic production, causing losses of up to 90% in southern France (Parveauzd 2011).

During winter, *M. laxa* and *M. fructicola* are preserved as mycelium in cankers on twigs infected the previous year and in mummified fruit which is hanging from branches or has fallen to the ground. For *M. fructicola*, there may also be the formation of apothecia in mummified fruit, which then produce ascospores. Conidia and ascospores constitute the primary inoculum and can be transported by wind, rain and insects (Hrustic 2012). When the conditions are humid, the flowers can be infected, with the mycelium progressing via the peduncle to reach the twigs and cause a canker there, which can lead to the apical section of the twig drying out (Oliveira 2016). All parts of the flower can serve as the first infection site. There is evidence that fully open flowers are the most susceptible to infection (Holb 2008). Luo et al. (2001) demonstrated that prune flowers have been shown to be the most sensitive to contamination by *M. fructicola* when wide open (BBCH Stage 65) (Meier 2009). In the orchard, the period of sensitivity of apricot flower buds to contamination by *M. laxa* begins at the ‘sepals open’ stage (BBCH stage 57), increases until the ‘full flowering’ stage (BBCH stage 65) and ends at the ‘flowers fading’ stage (BBCH stage 67) (Meier 2009, Tresson 2020, Brun 2021). The presence of humid conditions at the time of flower susceptibility is crucial in paving the way for contamination by *Monilinia spp*.

Preventive measures:

In some perennial crops, rain shelter systems have shown great effectiveness in reducing the incidence of many fungal diseases whose development requires a certain period of wetting in trees.

The efficiencies observed showed that rain shelters could be an effective solution to protect trees from moniliosis damage, thus reducing the use of fungicides. The wetness duration is the main microclimatic factor that is reduced by rain shelters. The rain covers did not significantly affect fruit production, however, the evaluation of these rain shelters on tree growth, productivity and fruit quality should be continued. The installation of rain shelters in apricot orchards can be expensive, and the profitability of such orchards will have to be evaluated in different situations according to input and labour costs and the selling price of apricots produced (Brun 2023).

The development of brown rot resistant cultivars could be an ideal strategy for brown rot disease control (Obi et al., 2019). No source of total resistance to brown rot blossom blight is currently known; nevertheless, some cultivars may have promising tolerance levels (Bassi 2006).

Mummified fruit and twig cankers should be removed from orchards. Given the importance of mummified fruits as an inoculum source, it may be possible to apply treatments onto mummified fruit in orchard during the dormant season to suppress inoculum production (Rungjindamai 2013).

Direct protection:

In IPM practice, predicting risk of disease development based on the relationship of flower and fruit infection with inoculum availability, host phenology and weather conditions is critically important; (Luo et al. 2001, b; Luo and Michailides 2003). Application of fungicides during the dormant season does not result in residues on fruit. Application of fenbuconazole in winter/early spring almost completely suppressed sporulation on mummified fruit and that application of two candidate BCA strains also led to a substantial reduction in sporulation (Rungjindamai 2013). Treatments in both winter and early spring led to an even greater reduction in sporulation than a single treatment. These results suggest that reducing primary inoculum in the dormant season is possible and should be part of an integrated management strategy.

When predicted risks are high, fungicides may be used during flowering and early fruit periods. When risks are low to moderate, or it is close to harvesting, alternative products can be used which are usually less effective than fungicides, e.g. copper hydroxide and lime sulphur (Holb and Schnabel 2005), and biopesticides.

To prevent *Monilinia* infection, apricot orchards are treated with chemical fungicides during bloom and harvest time to avoid the spread of the fungus into flowers and fruit (Frische et al., 2018). Application of fungicides to blossom (in early spring) and young fruit is still the main method for managing brown rot during the growing season. However fungicide-based methods are not sustainable in the longer term because of the emergence and subsequent spread of *M. fructicola* and *M. laxa* strains with reduced sensitivity to fungicides (Malandrakis et al. 2013; Weger et al. 2011; Zhu et al. 2010).

Biological control agents (BCAs) are an alternative to physical and chemical controls. Since this early work, other BCAs have been developed into commercial products, such as Serenade, the trade name of formulated *B. subtilis* QST713, recommended for use against many plant diseases, including brown rot on stone fruit, and marketed worldwide (AgraQuest 2009). Biocontrol strains of *B. subtilis* are usually bioactive through the production of lipopeptides such as iturins and fengycin which are inhibitory to the growth of many fungi. For example, *Bacillus sp.* OSU142 reduced infection of apricot blossoms by *M. laxa* in an artificial inoculation study (Altindag et al. 2006).

Fig. 46. Monilia twig blight on apricot branch. (photo: Mezey)

European stone fruit yellows phytoplasma (ESFY)

Bionomics and harmfulness

'Candidatus Phytoplasma prunorum' is one causative agent of disease for several host plants of the *Prunus* genus (Marcone 2010. These diseases are collectively called European Stone Fruit Yellows (ESFY) (Lorenz 1994). Apricot trees usually show yellowing, rolling and wilting of the leaves, and death of the woody parts or the whole tree as a result of the disease (Nečas 2015, Morvan 1977, Žežlina 2016). In addition to the destruction of trees, the economic loss is increased by the deterioration of fruit quantity and quality in the case of several varieties (Gazel 2009, Nečas 2018).

The currently known vector of the causative agent of ESFY is the plum psyllid, *Cacopsylla pruni* (Carraro 1998, Weintraub 2006)]. The wild plant species that could serve as reservoirs for this phytoplasma may be present either in the immediate surroundings of or far from orchards (Jarausch 2019, Labonne 2004). Based on the results of field tests*, C. pruni* generally acquires the pathogen from wild *Prunus* species (Marie-Jeanne 2020).

Diseased trees, especially apricots, peaches and Japanese plums on susceptible rootstocks may die few years after infection (Carraro and Osler, 2003). Symptoms do not always occur in the whole tree and only a part of the crown (e.g. a branch) might be symptomatic. Especially interesting is the distribution of phytoplasma within a tree during the winter season where some branches exhibit early leaf bud break while the rest of the tree remains dormant, asymptomatic. Also, during the vegetation period it often happens that only a part of the shoot is showing ESFY symptoms (Kiss 2022).

Preventive measures:

Crop protection measurements against phytoplasmas do not exist. Attempts to cultivate phytoplasmas in artificial media still fails, impeding the development of cures. In the European Union ESFY and further phytoplasma associated diseases are quarantine (Smith, 1997) and regulated in the Council Directive 2000/29/EC (Council of the European Union, 2000). Today the use of verified healthy rootstocks and cultivars as well as clearing of infected trees are the only possible phytosanitary measures to prevent the spread of ESFY. Alternatively, an effective strategy for vector control could help to reduce the pathogen spread (Gallinger 2020).

The control of *C. pruni* with insecticides cypertmethrin (pyretroid) and thiacloprid (neonicotinoid) was very effective, but came along with risks of those non-selective chemicals for pollinators and other beneficial insects (Paleskić et al., 2017). Therefore, the development of eco-friendly plant protection measurements should be the future aim. A selective and environmentally friendly control strategy could be based on semiochemicals (Gross 2019). Weed species can work as reservoirs of phytoplasmas and insect vectors can develop their life cycle on them in the absence of hosts (Hemmati 2021). The development of resistant plant varieties to phytoplasmas is a promising option. (Gabelman 1994).

Direct protection:

There are no registered plant protection products that are effective against this disease

Fig. 47. EFSY on young apricot trees – healthy tree, affected tree with visual symptoms, died tree. (photo: Mezey)

Dieback of trees, apoplexy

Bionomics and harmfulness
Part of apricot trees (*Prunus armeniaca*) suffer from dieback or as a consequence of sudden wilt may die unexpectedly. Apoplexy is the terminal syndrome of a complex of different diseases. It is especially important in central and northern European growing areas. In these countries, 20 – 60% of apricot trees are killed in 8 to 10 year old orchards (Vávra 2023). It is assumed that apricot tree dieback is caused by a complex of biotic and abiotic factors. Pathogenic bacteria, fungi and viruses are considered a biotic factor that plays a key role in apricot withering (Rejlová 2021).
Generally, bacteria, fungi and viruses infect trees that are stressed by extreme weather conditions (drought or freezing), and by invading wounds in the bark caused by insect damage and improper pruning. These fungi commonly overwinter in a form of pycnidia embedded in the bark of cankered branches (Adams 2005).

Preventive measures:
Using interstems can help improve apricot tree health and prolong the orchard's lifespan. Paint the stem white (or use white protection cover) to avoid too big temperature differences and thus fewer cracks in the stems. By this, there is a reduction in infections of, e.g., *Pseudomonas syringae* (Vávra 2023).
Recent studies revealed that multifactorial stress combinations cause a severe decline in plant growth as well as in the microbiome biodiversity that plants depend upon (Saleem et al. 2019; Zandalinas et al. 2021). The plant-associated microbiota could substantially influence crop health by stimulating plant growth through mobilization and transport of nutrients or by acting as antagonists in controlling phytopathogens and suppressing diseases. In recent years, it was demonstrated that the targeted application of plant growth-promoting rhizobacteria (PGPR) increases plant health via microbiome shifts in a site-specific manner (Kusstatscher et al. 2020). In fact, the contribution of microbes as biofertilizers is significant and this is due to its metabolic acclimatization within the plant host (Souza et al. 2015). PGPR can directly and indirectly improve plant growth and performance under stress via promoting nitrogen fixation, phosphate solubilization, increasing nutrient uptake, improving soil properties, inhibiting plant pathogens, and boosting up the potential of crops to cope with salinity, flood, drought and other stressful conditions (Shameer and Prasad 2018). Thus, exploiting the usefulness of microorganisms for improvement of soil quality, plant growth promotion, phytoremediation, and reclamation of problem soils provides the key for a future sustainable agriculture with reduced pesticide application (Bourguiba 2023).
It is also very important to keep the trees in perfect condition regarding planting site, suitable rootstock and spacing, ideal tree-shape associated with ideal pruning and training system, irrigation, soil management, fertilization and the tree-maintennance.

Direct protection:
There are no registered plant protection products that are effective against this disease.

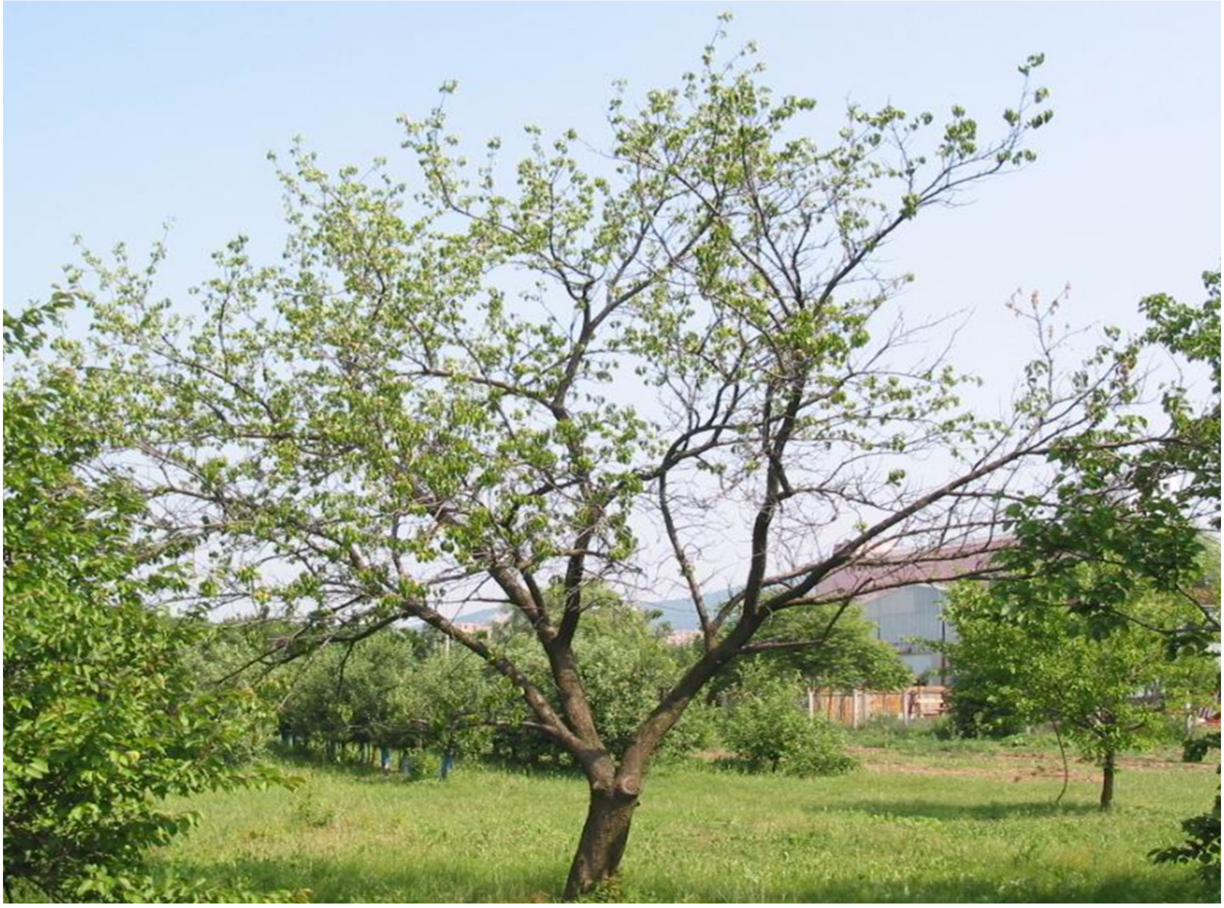


Fig. 48. Partial apoplexy on an older apricot tree. (photo: Mezey)

Brown rot (*Monilia laxa*)

Bionomics and harmfulness

There are three *Monilinia* species mainly responsible for the brown rot disease: *Monilinia fructicola* is mainly found in North America and Australasia, and *M. laxa* and *M. fructigena* mainly in Europe. Both *M. fructicola* and *M. laxa* can infect flowers, resulting in blossom blight, as well as both healthy and wounded fruit, resulting in brown rot (Rungjindamai 2014).

The life cycle of brown rot diseases comprises three stages (Byrde and Willetts 1977): (1) blossom blight and twig canker (early spring), (2) brown rot (late spring and summer), and (3) overwintered inoculum, primarily as mummified fruit (on trees and orchard ground). Initial inoculum of *M. laxa* in the spring in Europe most likely originates from conidia produced on overwintered sources, primarily mummified fruit on trees and orchard ground, such that the number of mummified peaches could be used to predict the incidence of post-harvest brown rot (Villarino et al. 2010). Mummified fruits can continue to produce conidia for 2 – 3 years after infection, and the number of conidia formed on overwintered mummified fruit is more than 10 times higher than that produced on newly infected blossoms (Holb 2008). Low temperatures seemed to favour production of *M. laxa* conidia: the highest number of conidiawere produced within 15 days at 10 °C (Tamm and Fluckiger 1993). These conidia infect blossom and twigs of susceptible plants during periods of moderate temperature and humid weather (Gell et al. 2009; Koball et al. 1997). Conidia produced from both blossom blight and twig canker may also infect developing fruits. Conidia of *M. laxa* can infect through cuticles on healthy blossom and fruits or via tiny injuries on the fruit surface caused by insects, natural splitting or fruit pickers during harvest. Recent work showed that conidia can also infect intact fruit (Xu et al. 2007).

Preventive measures:

Due to EU regulations, the number of fungicides available for controlling plant diseases has been steadily decreasing, particularly in the post-harvest environment. This has placed much more emphasis on alternative control methods. Promising physical control methods include removal of mummified fruit in orchards and post-harvest hot-water treatment. Many micro-organisms have been shown to have biocontrol potential against brown rot but only a few have been commercially formulated. It is generally agreed that the use of biocontrol agents needs to be integrated with other measures. Current research focuses on disease management from flowering to post-harvest period. Recent results have suggested that reducing overwintering inoculum should be considered as one of key aspects of integrated management of brown rot on stone fruit (Rungjindamai 2014).

Cultural methods such as the labour-intensive removal of mummified fruits and plant residues from trees and the orchard floor (van Leeuwen et al. 2000; 2002) have also proved successful when carried out in autumn or early spring.

Direct protection:

Application of fungicides to blossom (in early spring) and young fruit is still the main method for managing brown rot during the growing season. Fenhexamid, a hydroxyanilide fungicide, is highly effective against *M. laxa* (Malandrakis et al. 2013) and it is important to develop strategies for responsible use of this fungicide in order to delay the onset and subsequent spread of fungal strains resistant to this product.

Plant extracts from perennial Mediterranean weeds, Dittrichia viscose and Ferula communis, can reduce conidial germination and mycelium growth of many post-harvest fungi, including M. laxa and *M. fructigena* (Mamoci et al. 2011). Essential oils from laurel (*Laurus nobilis*) at low concentrations inhibited mycelium growth of *M. laxa* when applied onto fruit surface before and after inoculation, resulting in 91 % and 76 % reductions in fruit rot (De Corato et al. 2010). Essential oils from other plant species were also shown to be effective against *Monilinia spp*. (Lopez-Reyes et al. 2013). A variety of inducers of plant resistance (e.g. oligosachharides, chitosan, calcium plus organic acids, nettle extract, fir extract, laminarin or potassium bicarbonate) were used in field trials to reduce postharvest decay of sweet cherries, with chitosan being the most effective (Feliziani et al. 2013).

Most physical treatments have been targeted at the postharvest environment. Mechanisms underlying physical treatments include: (1) reducing fruit respiration, (2) killing pathogens on fruit surface, (3) suppressing/ eradicating latent infection, and (4) stimulating induced resistance.

Biological control agents (BCAs) are an alternative to physical and chemical controls. Their mode of action may involve: (1) competition for nutrients and space, (2) production of antibiotics, (3) direct parasitism, and (4) induced resistance (Sharma et al. 2009).

Microbes with inhibitory activity have been isolated from various sources and diverse environments, including soil (Hayakawa et al. 2004), inside plants (Guo et al. 2008) and from the sea (Bhatnagar and Kim 2010). Other BCAs have been developed into commercial products, such as Serenade, the trade name of formulated *B. subtilis* QST713, recommended for use against many plant diseases, including brown rot on stone fruit, and marketed worldwide (AgraQuest 2009). Biocontrol strains of *B. subtilis* are usually bioactive through the production of lipopeptides such as iturins and fengycin which are inhibitory to the growth of many fungi.

Yeasts or yeast-like fungi are also attractive candidates as BCAs, as fruit surfaces usually support the growth of large quantities of these organisms. (Janisiewicz et al. 2010). *Aureobasidium pullulans* has frequently been reported as an effective BCA (Mari et al. 2012; Robiglio et al. 2011) and occurs commonly in diverse environments.

Reducing the level of inoculum is a first step in disease management. Removing dropped (including thinned) fruits is practised in apple to reduce *M. fructigena* (Holb and Scherm 2007). Similarly, wherever possible, mummified fruit and twig cankers should be removed from orchards. Given the importance of mummified fruits as an inoculum source, it may be possible to apply treatments onto mummified fruit in orchard during the dormant season to suppress inoculum production. Application of fungicides during the dormant season does not result in residues on fruit. Treatments in both winter and early spring led to an even greater reduction in sporulation than a single treatment. These results suggest that reducing primary inoculum in the dormant season is possible and should be part of an integrated management strategy (Rungjindamai 2014).

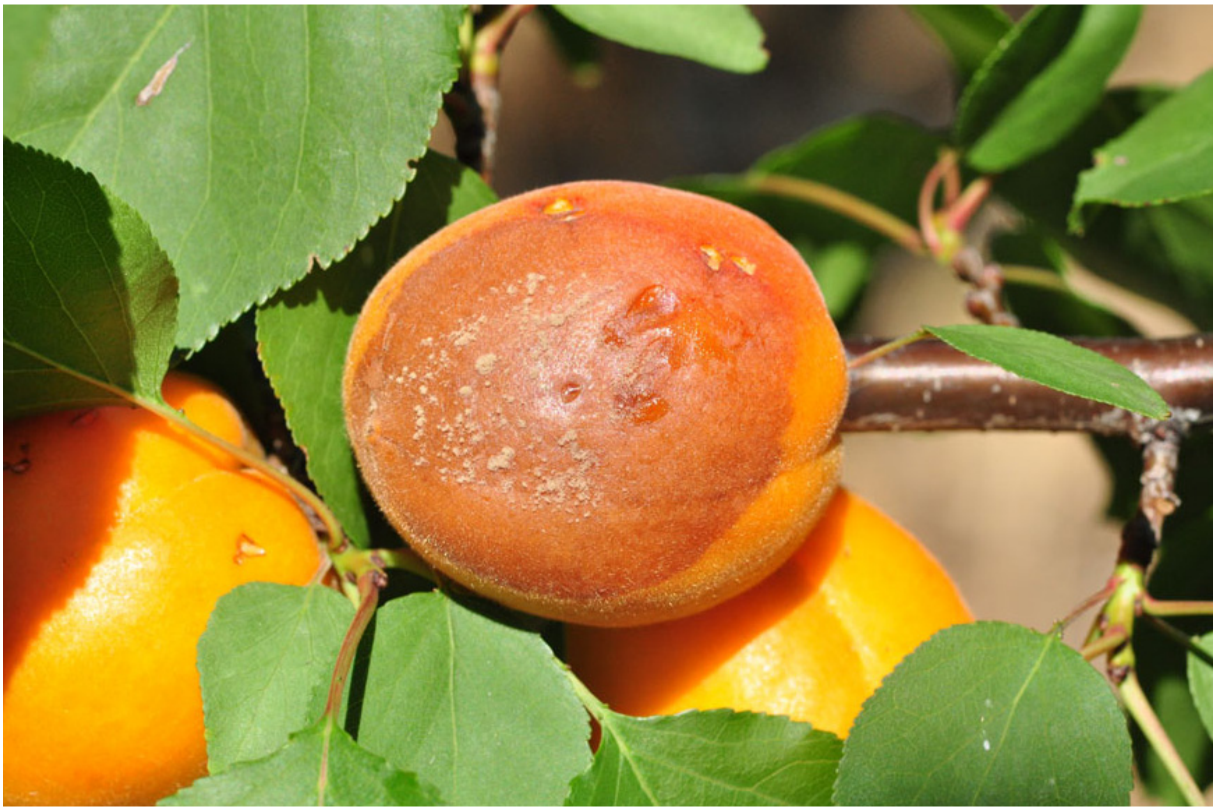


Fig. 49. Symptoms of brown rot on apricot fruit. (photo: Ontario Ministry of Agriculture, Food and Rural Affairs)

INTEGRATED SWEET AND SOUR CHERRY PROTECTION

Blossom/twig blight/brown rot *(Monilia laxa)*

Bionomics and harmfulness

Brown rot (*Monilinia* spp.) on sweet cherries causes blossom blight and fruit rot at pre- and post-harvest stages (Morca 2022).

Symptoms of cherry blossom blight are first observed on the anthers of flowers in spring and then on the reproductive structures of the flower. Under favorable conditions, not only flowers and twigs but also fruit can produce blighted symptoms similar to those of blossom and twig blight (Holb 2013). The fungus frequently spreads into shoots, twigs, and small branches from where cankers and the mass production of gums and abundant sporulation may originate (Byrde 1977). Fruit blight can occur in two ways: as a result of blossom and/or twig blight near the fruit, or at certain stages of green fruit in the absence of blossom or twig blight (Holb 2013). Fruit blight occurs between the periods of blossom blight and harvest fruit rot and often appears on the same shoots that have previously shown blossom and/or shoot blight, but also occurs separately from these symptoms (Holb 2013). Fruit-blight incidence was related to blossom blight in spring and fruit rot at harvest. The fruit can be infected by the pathogen at any stage of its development, but the disease only becomes more severe when the fruit begins to ripen (Xu 2007). The airborne density of *Monilinia* conidia increases continuously from the first appearance of infected fruit until their harvest (Corbin 1968, Holb 2008). Brown rot losses in cherries can be up to 33% at harvest, and after cold storage at 0 °C for one month, losses of up to 86% of rotted fruit have been reported (Xu 2007).

Brown rot is spread by the dispersal of *Monilinia* conidia, which can be caused by wind, water, insects, birds, and man (Byrde 1977). *Monilinia* airborne conidia are deposited on the fruit surface, where they can cause infection (Biggs 1988, Philips 1984). Survival, colonization, latency, reproduction, release, transport, and deposition of *Monilinia* conidia are related to the environmental temperature, the relative humidity, the amount of rainfall and the wind direction (Corbin 1968, Bannon 2009, Gell 2009). Since brown rot is a polycyclic disease, secondary inoculum is of great importance on its incidence and severity in each growing season (Byrde 1977). In addition, secondary inoculum can occur anywhere in the infected tissue where the moisture content is sufficient for the pathogen to sporulate (Landgraf 1982). Since brown-rot outbreaks in stone fruit depend on the prevailing environmental conditions, a highrelative humudity and a temperature range between 15 and 25 °C (Watson 2002) favor disease development, although infection can also occur under more extreme conditions (5 – 30 °C) (Tian 1999). The incidence of cherry-blossom infection by *M. fructicola* (Wlicox 1989) and *M. laxa* (Tamm 1995) was also shown to rise with increasing wetness duration.

Preventive measures:

During production season good management practices must be implemented such as ensuring tree canopies are well pruned to allow sufficient circulation of air to promote faster drying of foliage and penetration of light, which helps in optimizing plant health (Broembsen et al., 2005). Irrigation water must be supplied through drip systems such that water does not come into direct contact with flowers, leaves and fruits (Barrett et al., 2004). Sanitation practices such as removal of fallen fruits and twigs, particularly those with symptoms of infection, from orchard floor serve an important role reducing build-up of inoculum in the orchard (Ellis et al., 2008). Villarino et al. (2010) stressed that an important way to manage brown rot in orchards is to lower disease pressure by minimizing the spore load in the environment, especially in the spring, by reducing the number of sources of primary inoculum. According to Barkai-Golan (2001) farm apparatus can harbour spores that can later infect fruits, therefore cleaning and disinfection of all apparatus coming into direct contact with fruits either in the fields or at packinghouses is crucial. This includes cleaning pruning shears, harvesting shears and boxes, and disinfecting packing line. Chemicals such as formaldehyde, isopropyl alcohol, quadronic ammonium compounds, captan or other chemicals can used for disinfection of packinghouses and equipment.

Direct protection:

Preventive chemical treatments to reduce *Monilinia* were applied every 7 days in rainy periods or every 10 days in dry periods (Bolettin Fitosanitaro 2017). In Europe, two to three fungicide sprays around flowering, followed by one to two sprays between the beginning of ripening and preharvest are applied (EFSA, 2011; Sisquella et al., 2013). Moreover, application of insecticides during growing period to prevent wound damage on fruits caused by insect pests has been shown to lessen brown rot infection (Tate et al., 1975).

In some cases, significant differences were observed between treatments: fluopyram was more effective for inhibiting *Penicillium*, *Monilinia, Botrytis* mold development, while the biofungicide Serenade was more effective against *Alternaria, Rhizopus, Fusarium* and *Aspergillus*, and also reduced the cracking of sour cherries. Increases in the fruit firmness of fruits have been reported with the use of some *Bacillus subtilis* isolates (Mena-Violante et al., 2009; Wu et al., 2019). The *Bacillus subtilis* antagonist has been implicated successfully in a number of postharvest diseases, such as gray mold, green mold, brown rot, alternaria rot in the case of various fruits (Pusey and Wilson,1984; Demoz and Korsten., 2006; Utkhede and Sholberg, 1986).

Chitosan, a naturally occurring polysaccharide, has been used on fruits as preharvest and postharvest treatment. It is a suitable alternative to synthetic fungicides due to its nontoxic, biodegradable properties and antimicrobial activities (Jiao et al., 2019).

Biological control agents (BCA) are mostly used in conjunction with fungicides. Use of these agents originated from the need to reduce amounts of fungicides used in agriculture (Hrustić et al., 2012). The purpose of preharvest application of microbial antagonistic culture is to precolonize the fruit surface with an antagonist immediately before harvest so that wounds inflicted during harvesting can be colonized by the antagonist before colonization by a pathogen. Practically, postharvest application of antagonists has been proven to be a more useful and effective method of controlling postharvest diseases (Sharma et al., 2009). Antagonists possess the ability to rapidly increase their population after colonizing fruit surface such that they overcome pathogenic species population and produce toxins that inhibit their development. *Pseudomonas syringae* (strain 10LP and 110) is one of the few biofungicides active against *Monilinia* species. Another biofungicide, based on *Bacillus subtilis* has been commercialised in Europe for control of brown rot could serve as a good postharvest treatment of stone fruit (Di Francesco et al., 2017).

Fig. 50. Monilia blight on sour cherry. (photo:Mezey)

Brown rot (*Monilia laxa*)

Bionomics and harmfulness

The majority of infections are by the asexual conidia that can be produced at temperatures as low as −4 °C (Tian & Bertolini, 1999). These are usually spread by wind and water splash but can be spread by vectors (Byrde and Willetts, 1977). The lifecycle of *M. laxa* in the field means that there is a continuous supply of conidia throughout the entire fruiting season from overwintered mummified fruit, newly infected and blighted flowers, and spurs infected the previous season. The greatest source of inoculum usually comes from mummified fruit left in the orchard over the winter (Villarino et al., 2010). The number of conidia per unit area of infected tissue is 10 times higher on a mummified fruit than on an overwintered fruit spur or newly infected flower, and *M. laxa* may sporulate for up to three years on the same mummified fruit (Stensvand et al., 2001). These mummies, therefore, serve as the dominant source of inoculum infecting flowers in the spring. The incidence of post-harvest brown rot is positively correlated with the number of mummified fruit in the orchard (Villarino et al., 2010), so their removal could greatly reduce disease development in subsequent years.

M. laxa can infect intact fruit directly as well as through wounds and natural openings although wounds are still the major infection site. Intact cherry fruit becomes more susceptible with age, young fruitlets are resistant to infection by *M. laxa* conidia until they reached the stage when they began colouring (Xu et al., 2007). The severity of *M. laxa* can be influenced by climate with high humidity and high precipitation favouring infection. High humidity during blossom facilitates the disease because other floral parts become available as infection sites (in addition to stamens and stigma) (Weaver, 1950). The key factors influencing the development of cherry brown rot in the UK are fruit age and availability of inoculum; the latter is likely to be positively related to the amount of rainfall during the early season (Xu et al., 2007).

Preventive measures:

Pre-harvest physical controls such as the removal of mummies are an effective way of controlling *M. laxa* in the field when incorporated into a pest management programme (Rungjindamai et al., 2014). However, in order to be effective, all diseased parts of the plant must be removed before harvest – including mummies, branches and rotten fruit - and disposed of properly, such as burial (Usall et al., 2015). Pre-harvest physical controls also include plastic covers, which are now widely used within the UK to reduce fruit splitting from rain, reducing wounds easily infected by brown rot. However, *M. laxa* is able to infect intact fruit at almost the same rate as wounded fruit (Xu et al., 2007). Fruit bagging is another potential physical control that can also protect against pest damage and improve fruit quality (Sharma et al., 2015) however this practice is also very expansive and time consuming and may not protect against early blossom infections.

Commonly applied practices in a stone fruit orchard, including crop load management, irrigation, fertilization, pruning, and canopy architecture, have a major impact on *Monilinia spp*. development (Li 1989).

Direct protection:

Chemical control is still the main method of controlling brown rot within cherry orchards (Xu et al., 2007). However, the overuse of fungicide can lead to phytotoxicity for blossoms and resistant strains emerging (Egüen et al.,2016). This emergence of resistant strains, along with new legislation banning certain chemicals, has led to a reduction in the availability of chemical controls available to growers for use on cherry. (Malandrakis et al., 2013). There is also pressure from consumers to reduce fungicide use due to concerns about the environmental impact of chemical use and residues in fruit. With a lack of an alternative to control postharvest disease chemical fungicide use could be managed by reducing the number of application times and the doses used, throughout the season. To do this requires effective integrated pest management systems (IPM), which would utilise disease prediction models to indicate when sprays are needed and the optimum dose (Usall et al., 2015). Several antagonist microorganisms have been investigated and reported as effective against postharvest diseases on stone fruit. Despite these advances in research there is still no commercial product available that is specifically designed to treat brown rot in cherry (Janisiewicz et al., 2014). However, a few that have been taken forward for commercial use have been approved for the use on cherry to target brown rot. A strain of *B. subtilis* (QST713) has been approved by the European Union (Reg. (EC) No 839/2008) and is commercially available as Serenade (Serenade Max®, Bayer CropScience). It is currently the only *B. subtilis* product approved and available as a pre-harvest control for brown rot (Usall et al., 2015) though it is mainly used against *Botrytis cinerea* on outdoor grown lettuce and strawberries (Reiss & Jørgensen, 2017). Bio-ferm has produced two products 'BoniProtect' and 'Blossom Protect' to combat *Botrytis cinerea* and *Penicillium expansum*, both post-harvest rots on apple. These products use a strain of *Aureobasidium pullulans* that uses competition as its mode of action (Mounir et al., 2007).

Usually we aplly sprays according to the weather, in case of neccessity 2 – 4 weeks before harvest.

Fig. 51. Brown rot on cherry fruit. (photo: Petrželová)

Cherry leaf spot *(Blumeriella jaapii)*

Bionomics and harmfulness

The disease causes premature defoliation of leaves, the reduction of tree vigor and winter hardiness, and even tree death, leading to a bad quality of cherries (Wharton 2003). *Blumeriella jaapii* was regarded as the causal agent of cherry leaf spot disease in Europe and North America (Schuster 2004). In addition, several other associated fungi were reported. In Israel, the pathogen of cherry leaf spot was identified as *Cercospora circumscissa*, which caused a 40% yield loss in 1975 (Sztejnberg 1986). Additionally, *Alternaria alternata* and *Pseudocercospora pruni-persicicola* were reported as causing leaf spot in Greece and Korea, respectively (Thomidis 2006, Choi 2014). In China, *Alternaria cerasi* and *Passalora circumscissa* were identified to cause "black spot" and "brown spot" of sweet cherry according to their morphology in the early days, respectively (Zhu 2004, Liu 2012). In recent years, more pathogenic species have been reported based on morphological characterization coupled with phylogenetic analysis, including four *Alternaria* species, three *Colletotrichum* species and four *Didymellaceae* species (Chethana 2019, Yang 2020, Tang 2022). In study of Zhou (2022), *Fusarium spp*. were isolated from cherry leaf spots for the first time, which supplemented the pathogen variety of the disease.

The disease occurs during the hot and rainy conditions in summer and autumn and can reach a rate of 60–100%. The severely diseased leaves all fall off their trees from August to September, directly affecting the tree's vegetative growth post-harvest for that year, as well as flower bud differentiation and yield for the following year (Thomidis and Tsipouridis, 2006).

Infections caused by ascospores and winter conidia, followed by repeated secondary conidial cycles, cause leaf chlorosis and premature defoliation, resulting in low fruit quality and poor fruit size. In some instances, the summer development of the CLS can be severe even if the spring disease pressure from the primary infection is relatively low (Jones et al., 1993). When not properly managed these infections may lead to increased amount of overwintering inoculum in leaf litter (Holb, 2013), inner bud tissues or wood lesions (Joshua & Mmbaga, 2014). The long-term effects of the disease include reduction of fruit bud survival and fruit set during the following year, and in the case of severe defoliation the trees could die (Howell & Stackhouse, 1973). Jones et al. (1993) reported at least a two-season delay in fruit set when plants were infected with *B. jaapii*. Crop losses due to the CLS could be about 40 – 50% in sweet cherry and up to 100% in sour cherry if no control measures are undertaken (Dimova et al., 2014).

Preventive measures:
The reduction of the overwintering inoculum through sanitation and other control measures has the potential to postpone the disease onset after the ripening period when fungicides application could be hazardous for the fruit consumers (Marinov 2022).
An appealing alternative to the chemical control strategy is the identification of cherry cultivars that are resistant to foliar disease, thereby protecting cherry yields in a cost-effective and environmentally friendly manner (Santi et al., 2004).

Direct protection:
Currently, the measures for preventing and controlling cherry diseases mainly include chemical pesticide application. Although these pesticides can reduce the probability of disease occurrence, they are environmental pollutants. Moreover, the various types and dosages of pesticides can result in drug-resistant pathogens, thus increasing the difficulty of control (Li et al., 2022). Disease management is entirely dependent upon the use of fungicides, with six to eight full cover applications used in a typical season (Gleason 2021), from early spring until close to harvest (Gonzalez – Nunez 2022). Broad-spectrum fungicides including chlorothalonil, captan, and coppers are effective in CLS control; however, growers have historically favored single-site fungicides that are either systemic or translaminar because these fungicides can control other diseases including powdery mildew (*Podosphaera clandestina* and brown rot (*Monilinia fructicola)* and can be used with longer interval times between applications (Gleason 2021).
Consequently, biological control has been suggested as an alternative strategy or a supplementary method for controlling plant diseases, perhaps as a part of an integrated management system, thus reducing the use of chemical products and contributing to environmental preservation (Compant et al., 2005).
Antagonistic bacteria have received much attention as biological control agents (BCAs) because of their beneficial effects and potential applications in the suppression of plant diseases through different modes of action. Bacterial antagonists can produce hydrolytic enzymes, antimicrobial substances, and volatile organic compounds (VOCs) that can suppress or kill phytopathogenic microbes (Senthilkumar et al., 2009). Further, the competition between the antagonistic bacteria and the disease-causing agents for the available nutrients and living spaces deters pathogen growth (Elad and Baker, 1985). Finally, bacterial antagonists are capable of forming biofilms, which contribute to both bacterial survival and host plant colonization, thus protecting plants from pathogens (Bais et al., 2004). In addition to acting as inhibitors against pathogens, antagonistic bacteria are likely to stimulate the growth of host plants, either by synthesizing hormones, such as indole-3-acetic acid (IAA) (Idris et al., 2007), or by promoting an increase in nutrient concentrations by phosphate solubilization and nitrogen fixation (Senthilkumar et al., 2009). Among the most promising candidates for BCAs are several species of the genus *Bacillus*, such as *B. subtilis, B. velezensis*, and *B. licheniformis*. These species are regarded as safe microorganisms and possess several advantages that make them stand out from the members of other antagonistic bacterial genera. First, *Bacillus* spp. can produce endospores which are resistant to heat, UV light, and desiccation, which assure their prevalence in the environment and guarantee future suitable formulation strategies (Schallmey et al., 2004). Second, *Bacillus* spp. release a variety of active compounds with broad-spectrum antimicrobial activities (Cao et al., 2018; Chen et al., 2009; Xu et al., 2018).

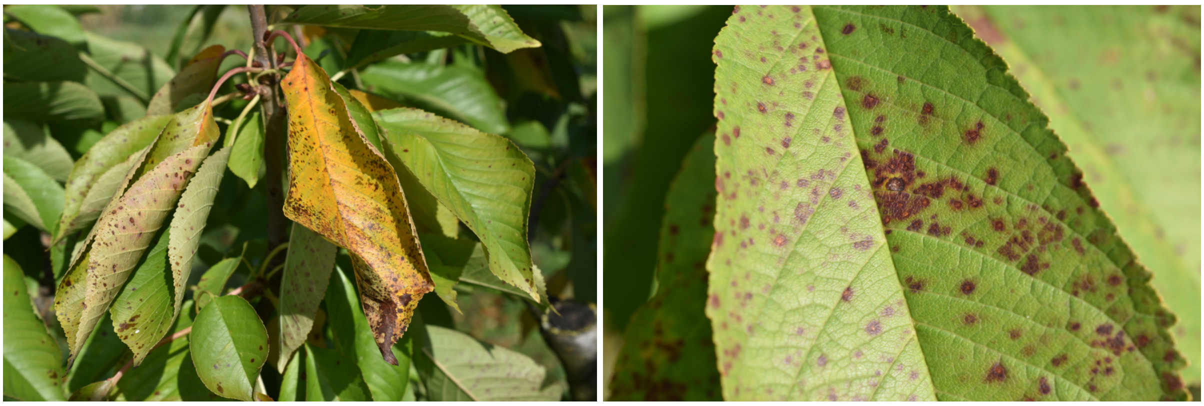


Fig. 52. Cherry leaf spot, symptoms on leaves. (photo: Mezey)

European cherry fruit fly (*Rhagoletis cerasi)*

Bionomics and harmfulness

European cherry fruit fly *Rhagoletis cerasi* (*Diptera: Tephritidae*), is an economically important frugivorous pest of sweet (*Prunus avium*) and sour (*Prunus cerasus*) cherries, common all over Europe, East Asia, and since 2016 – 2017 the pest has been recorded in North America (EPPO 2021, Barringer 2018). Females lay their eggs on the cherry fruit and larvae develop inside them (Daniel 2009). Larvae pupate into the soil where they undergo a marked diapause, adults emerge in spring and females are ready for oviposition when fruits are ripening. The female of this species lays the egg under the cherry cuticle and the larva feeds in the mesocarp and spoil the fruit (Daniel 2012, Boller 1976). Only 2% of attacked fruits in a lot is enough for it to be rejected for the market and, without adequate control, the whole production may be lost (Fimiani 1983).

Preventive measures:

To control the R*hagolethis cerasi* pest it is recommended to perform deep plowing in autumn and digging the soil under the crowns of trees to destroy the hibernating pupae. Also, in early spring, it is recommended to treat the soil around the trees with granular products, in order to destroy the adults (Pașol et al., 2007). Covering the ground with nets under the canopy to prevent hatching flies from reaching fruit is another effective management strategy. The net can reduce fruit infestation by 91%. This method could be an option for *Rhagoletis cerasi* control in extensively managed standard tree orchards (Beatrice 2021).

Direct protection:

R. cerasi is considered a key pest that requires insecticide sprays several times per season in commercial cherry orchards (Daniel 2009), when adult fruit flies start flying. In many countries insecticides are increasingly restricted and most of those used previously to control cherry fruit flies have been banned in Europe (Sarels 2015).

Chemical treatments will be applied at warning (Pașol et al., 2007), which it is 7-8 days after the start of the pest fly, if the temperature does not drop below 17 °C. If the temperature drops during this period, the treatment date will be delayed by the number of days with a lower temperature. If it is necessary to repeat the spraying, the most suitable date is 8 days after the first date. Protection is also possible during the hatching of the larvae, which occurs approximately 14 – 17 days after the hatching of the adults and again the assumption that the temperature does not drop below 17 °C.

Dimethoate spraying was the most common practice in Europe against this pest and since its recent prohibition other chemical insecticides, mainly the neonicotinoid acetamiprid and the pyrethroids lambda-cyhalothrin and deltamethrin, have replaced it (Daniel 2012). Bait sprays based on the naturally derived insecticides neem and spinosad showed promising results in field cages trials

(Koppler 2008). In some European countries as Italy, a spinosad-based adulticide bait [Spintor-Fly® (spinosad 0.024%)] that is authorized against *R. cerasi* has proved to be very effective in controlling the pest, although its large-scale use could be limited by its low persistence (Caruso 2013). On the contrary, in Spain and other European countries, spinosad bait formulations are not registered for *R. cerasi*, but conventional total sprays of spinosad [Spintor 480 SC (spinosad 48%)] are authorized against this pest, to a maximum of two applications per season (Registro de Productos Fitosanitarios 2022).

Environmentally-friendly pest control methods have been proposed such as application of nematodes to the soil (Kepenekci 2015), spraying cherry trees and fruit with entomopathogenic fungus *Beauveria bassiana* biopreparations (Daniel 2010, Daniel 2013), or applying a dense mesh on the undergrowth soil (Daniel 2009, Ozbek-Catal 2018) thus prevent emerging adults from getting to the host plants and fruit.

Another way of control is using traps with attractants for adult mass trapping (Ozdem 2009, Daniel 2012, Navaro-Llopis 2014). Yellow ball-shaped traps supplied with ammonium salts as attractants inside are the most effective. However, mass trapping of *R. cerasi* so far is too expensive and was estimated from $2500 to $3500/ha (Navaro-Llopis 2014). The efficacy of this method is often based on high trap density and therefore, mass trapping will only be applicable if the device used achieves high capture efficiency at a low cost. Despite its high cost, mass trapping is the most applied practice against this pest in organic cherry orchards due to the lack of other authorized alternatives. For the control of *R. cerasi*, some authors have recommended the hanging, in the southeast side of the canopy, from 1 to 8 traps per tree (Daniel 2012). Recently Bayer CropScience has developed the ready-to-use device Decis® Trap Cerasi for monitoring and mass trapping *R. cerasi*. In this trap, the transparent top part is internally impregnated with the insecticide deltamethrin as killing agent and the hemispherical, orange coloured lower part carries an attractant dispenser (filled in with ammonium carbonate). According to published results of large-scale field trials with this device, a density of 100 traps/ha reduced damage drastically even under high pest pressure (De Maeyer 2020).

Bacillus thuringiensis treatments should be applied when average temperatures are above 16 °C to ensure proper bacterial activity (Kutinkova and Andreev, 2004). Also, that Rebell trap + ammonium acetate combination against the *Rhagolethis cerasi* pest was the most effective. It was concluded that for a successful mass trapping, hanging four of these trap combination per tree was sufficient (Özdem and Kilinçer, 2009). Field experiments with foliar applications of *Beauveria bassiana* ATCC 74040 were conducted to control the European cherry fruit fly, it has been proven that the application is a suitable and economically feasible strategy for controlling *R. cerassii* in organic cherry production. The substance was applied at concentrations of 250 ml per 100 l in 7-day intervals. Fruit infestation was assessed at harvest. The number of infested fruits was significantly reduced by 65% with foliar applications of of *Beauveria bassiana* ATCC 74040 (Daniel and Wyss, 2010).

The cherry fruit fly model uses a lower threshold of 5°C. It can be calculated with daily high and low temperatures, using the sine model to estimate growing degree day units. For this model, the "biofix" date, or date from which to start accumulating growing degree days, should be set to March 1st for the Northern Hemisphere. First adult emergence occurs at approximately 444 DD (°C) after the biofix date. Egg-laying will begin at 523 DD(°C) after the biofix date, with the first egg-hatch/ larvae at 576 DD (°C) and pupation begins at 77 DD(°C) after the biofix date (AliNiazee 1979).

Fig. 53. Cherry fruit fly – adult and larvas. (photo: Hamers)

Black cherry aphid (*Myzus cerasi*)

Bionomics and harmfulness

Is a major pest in low-stem cherry orchards with rain protective covering and hail nets (Lang et al., 2011). Rain protective covering can alter the microclimate in the cherry orchard and thereby promote *M. cerasi*. Sucking sap from buds and foliage during spring and early summer leads to severely curled and damaged leaves (Kepenekcí et al., 2015). Furthermore, black sooty fungus grow on honeydew secreted by the aphids. *Myzus cerasi* is also considered to be the most important vector of plant viruses worldwide (Blackman and Eastop, 2000). In autumn, winged females (gynoparae) migrate from their secondary hosts Galium spp. or *Veronica spp*. (CABI, 2019) back to the cherry orchards and produce wingless oviparae. Winged males, which migrate later, mate with oviparae that lay eggs at the base of buds, in crevices of the bark and on young shoots. Fundatrices hatch in the following spring and reproduce asexually. Strong aphid populations can build up by favourable microclimate, less aphid antagonists (e.g. hover flies, lacewings or ladybirds).

Preventive measures:

A possible solution for black cherry aphid control is the selection of resistant hybrids and cultivars (Arnaudov and Kolev, 2007). In one study, Arnaudov and Kolev (2007) reported that none of the studied varieties showed complete resistance to M. cerasi. The cultivar "Bigarreau Burlat" on *Prunus mahaleb* was highly susceptible to *M. cerasi* infestation. In another study, Arnaudov (2006) established that the cultivars "Stella" and "Rivan" are slightly susceptible to *M. cerasi* infestation.
Indirect regulation of aphids in cherry orchards can be done with flower strips in cherry orchards, silting of the flower strips in the alley. Release of benefical insects with introducing rearings of beneficial insects. Need to apply a combination of different approaches always adapted to the present situation (age of trees, pressure of pests, existing beneficials, …) (Friedli 2020).

Direct protection:

Due to asexual reproduction, every fundatrix reproduces exponentially, which makes early control crucial. In organic production, fundatrices are controlled with paraffin oil after bud swelling (BBCH 51) and later Pyrethrum, Neem oil and insecticidal soap after flowering (Häseli and Daniel, 2009). As an alternative, aphid control in the preceding autumn with white kaolin (Surround ® WP) residue on the leaves could prevent immigrating aphids in autumn from establishing the next generation and thus reduce the number of fundatrices in the following spring. For the timing of the first application of kaolin, we suggest to start protecting the trees in mid or late September. To prevent the immigration and establishment of the next generation, two to three applications until leaves have fallen are necessary, depending on precipitation (Cahenzli 2022). Kaolin has different modes of

action on aphids. The white residue alters light reflection, which could affect host detection and selection (Cottrell et al., 2002; Döring, 2014), an accumulation of particle film on aphid body parts and especially on tarsi occurs, suggesting restricted aphid mobility (Cottrell et al., 2002) and repellency (Barker et al., 2007). The particle film can even increase mortality and reduce oviposition (Glenn et al., 1999; Cottrell et al., 2002; Burgel et al., 2005). The combination of kaolin applications in autumn with a paraffin oil application in spring had an efficacy of 86 – 99% and prolonged the effect of kaolin (Cahenzli 2022).
Looking at the biology of *M. cerasi*, there are different stages, where a regulation can be successful. A treatment with oil products before the hatching of the fundatrices in spring time is the first option. A successful regulation of the fundatrices is essential since each fundatrice and its following generation can produce up to about 200 nymphs (Karczewska, 1970). A second point in time for a regulation is a treatment with contact insecticides after the hatching but before curling of the leaves caused by the sucking activity of the aphids. The third opportunity for a regulation is during the return flight of the winged aphids from secondary hosts to the cherry trees but before laying of eggs in autumn (McLaren & Fraser, 2002).
Thus, for the direct control of M. cerasi in practice, only neem preparation can be used besides the paraffin oil treatments during sprouting. In the trials of the last few years and in practice, the following findings for an optimised effect were obtained with the NeemAzal-T/S neem preparation:
– Due to the lack of initial toxicity and the slow development of the effect by inhibiting the reproductive capacity, the effect is not sufficient in the case of rapid population development of aphids, particularly in fast-growing young trees. Therefore, a strong reduction of the initial population by the use of paraffin oil is crucial. – The duration of effect is limited. If the effect of the treatment is not sufficient to eliminate all aphids, the remaining colonies can recover from the temporary reproductive inhibition and build up huge colonies again until harvest or, in the case of fast-growing trees, beyond that, and cause damage to the fruit and shoots. Therefore, 2 to 3 treatments are necessary in case of a strong aphid pressure. Thanks to its translaminar mode of action, NeemAzal-T/S can still be used after the leaves have been rolled up. – For NeemAzal-T/S to be absorbed and develop its full effect, it is essential that sufficient leaf mass is existing during a treatment. This is usually the case shortly after flowering. At this stage, the first treatment should be carried out. Despite the translaminar effect, a good wetting of the entire tree is a prerequisite for a sufficient effect (Haseli 2020).

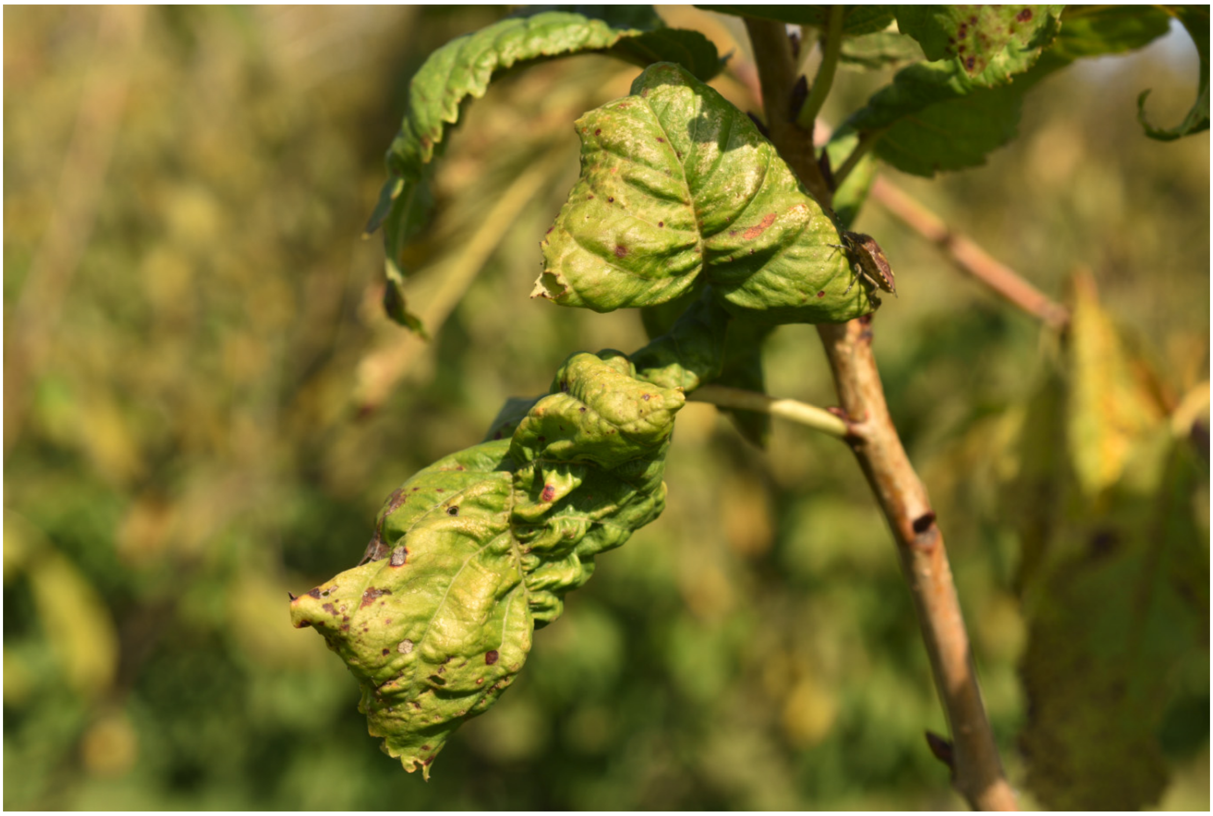


Fig. 54. Black cherry aphid – damage. (photo: Mezey)

Spotted wing drosophila (*Drosophila suzukii*)

Bionomics and harmfulness

Is a major pest of stone and soft fruit crops with global significance (Noble 2023), and in Europe, sweet cherry (Prunus avium L.) is reported as the most susceptible crop (Shawer et al. 2019).

SWD prefers soft, ripening and ripe fruits such as cherry, blueberry, raspberry and strawberry (Lee et al. 2011a; Ioriatti et al. 2015). The serrated ovipositor of the female causes physical damage to the host fruit, providing access to secondary infection by pathogens including fungi, yeasts, and bacteria (Walsh et al. 2011). Larvae develop within the fruits that become soft and rot rapidly, resulting in reduced crop yields and significant economic losses (Walsh et al. 2011, Farnsworth et al. 2017, Yeh et al. 2020).

Adult females attack ripening and ripe fruit by laying eggs within the outer 1 mm of the fruit surface (Lee et al. 2011), using a serrated ovipositor (Wiman et al. 2014). Larvae feed and burrow into the fruit flesh, rendering the crop unmarketable (Walsh et al. 2011). The egg and larval stages are presumably protected from direct contact with insecticide residues inside the fruit (Hamby et al. 2016; Plantamp et al. 2016; Andika et al. 2019).

Preventive measures:

Sanitary measures such as removal of dropped, infested fruits and managing ground cover vegetation can provide complementary strategies to chemical control on soft fruits (Lee et al. 2011b; Wiman et al. 2016; Leach et al. 2018). Furthermore, the landscape context can play an important role in SWD control. Indeed, cherry orchards located in forest-dominated landscapes may increase SWD population densities (Cahenzli et al. 2018; Santoiemma et al. 2018; Tonina et al. 2018a, 2018b).

Fruit management, i.e. harvest two-three days before fully ripe (e.g. Leach et al. 2018), removal of all tree fruit, and post-harvest removal of fallen/discarded fruit, appeared to be the most effective combinations of control strategies that reduced SWD damage in sweet cherry (Santoiemma 2020).

Prolonged harvest times allow SWD eggs to develop into new adults. When infested fruits are not removed in a timely manner, SWD population density increases inside cropping areas (Leach et al. 2018). Damaged fruit need to be contained or removed since flies continue to emerge and can potentially infest healthy fruit (Walsh et al. 2011). In addition, other SWD adults can be attracted from the surrounding landscape from plant volatiles associated with fruit ripening (Haviland et al. 2016) and rotting cherries, i.e. high food availability (Keesey et al. 2015). According to Haye et al. (2016), larvae inside removed fruits can be effectively killed by solarisation (i.e. the use of sun heat to kill insects) or fermentation (Noble et al. 2017). Infested fruits can either be placed on the ground in a sunny location and covered with clear plastic sheeting (Lee et al. 2011b) or can be contained within air tight containers, causing anoxic conditions and the death of SWD eggs and larvae. Beyond fruit management, the creation of an unfavourable environment inside the orchard can also limit SWD density. Frequent grass mowing regime can reduce SWD density through reducing ambient humidity, necessary for the survival of pupae and adults (Hamby et al. 2016; Tochen et al. 2016; Enriquez & Colinet 2017; Guédot et al. 2018). In contrast, the presence of unmowed grass during the ripening period may provide shelters and suitable humidity levels to promote SWD survival (Diepenbrock & Burrack 2017).

Direct protection:

To protect fruit effectively during the whole ripening period, the number of insecticidal applications ranges from one to eight, depending on crop and its susceptibility, pest intensity, and other environmental factors (Asplen et al. 2015; Shawer et al. 2018a; Dam et al. 2019; Shawer 2017). Current effective *Drosophila suzukii* control programs are mainly based on chemical methods although violations of maximum residue limits for specific pesticides, developing of insecticide resistance and negative impacts to beneficial arthropods. The current published data confirm the excellent activity of insecticides from four families, i.e., spinosyns (e.g., spinosad, spinetoram), pyrethroids (e.g., lambda-cyhalothrin deltamethrin bifenthrin, beta-cyfluthrin, permethrin, fenitrothion, and zeta-cypermethrin), organophosphates (e.g., dimethoate, phosmet, malathion, methidathion, and diazinon), and diamides (cyantraniliprole). The best result achieved by any of them regarding protecting fruits from damage was up to 14 days after application. While less effective insecticides provided shorter periods of fruit protection. Adding a feeding stimulant such as sugar, sugar-yeast bait, or erythritol to the insecticides, i.e., spinosad, spinetoram, acetamiprid, and cyantraniliprole, enhanced their biological performances against *D. suzukii* (Shawer 2020). Repeated applications of a limited number of effective pesticides can give control (Van Timmeren and Isaacs 2013; Rosensteel and Sial 2017), and fruit growers have become reliant on their use (Noble 2023). The most effective insecticides are principally conventional broad-spectrum products which are not always compatible with integrated pest management (IPM) programs (Haye et al. 2016).

Rainfall after application greatly reduced the level of control achieved by insecticides and impact the need for re-application to keep fruit protected (Van Timmeren & Isaacs 2013). Shaw et al. (2019) demonstrated that sprays of spinosad, cyantraniliprole, or lambda cyhalothrin gave up to two weeks' protection to cherry fruit under polythene covers. However, there are risks associated with reliance on pesticides. These include resistance to active ingredients such as spinosad (Gress and Zalom 2019). Targeting *D. suzukii* with sprays is difficult because juvenile stages are inside fruits, and the adults spend most time on the underside of leaves and in the middle of the crop canopy (Eaton 2014). The complex canopy structure of most fruit crops increases the difficulty in reaching these areas with sprays (Lewis and Hamby 2020). Mermer et al. (2021) found that certain insecticides, including spinosad and cyantraniliprole, were effective in increasing mortality of immature life stages of *D. suzukii*, and Wise et al. (2015) found that certain insecticides including spinetoram had curative effects on fruit post-infestation with *D. suzukii* larvae.

Baits have been added to sprays in 'attract and kill' strategies to improve the efficacy of existing and alternative insecticides for *D. suzukii* control by encouraging pest attraction to and ingestion of active ingredients (Cowles et al. 2015; Knight et al. 2016). Inclusion of sugar, corn steep liquor and/or brewer's yeast (*Saccharomyces cerevisiae*) into sprays had only a limited effect on the efficacy of

insecticides against *D. suzukii* (Diepenbrock and Burrack 2015; Fanning et al. 2021). Several proprietary products containing natural phagostimulants have been shown to increase the efficacy of insecticides and reduce the effective dose of insecticide needed. These include Combi-protec, a mixture of plant extracts, proteins and sugars (Dederichs, 2015), a protein bait based on spent brewery waste (Cai et al. 2018), and the unspecified formulations HOOK SWD (Klick et al. 2019) and ACTTRA SWD (Babu et al. 2021). However, the cost saving in pesticide may be negated by the price of the bait (Babu et al. 2021; Noble et al, 2021). The by-product, molasses, was shown to be equally effective to Combi-protec for *D. suzukii* control in a semi-field-scale raspberry (*Rubus idaeus*) trial (Noble et al. 2021).
Limited data are available regarding the effects of insecticides on immature life stages inside susceptible fruit (Wise et al. 2015; Shawer et al. 2018), but certain insecticides including malathion, methomyl, phosmet, spinetoram, and zeta-cypermethrin are effective for control of the immature stages of *D. suzukii* (Van Timmeren and Isaacs 2013; Wise et al. 2015).
The Spotted Wing Drosophila model uses a lower threshold of 10 °C. It can be calculated with daily high and low temperatures, using the sine model to estimate growing degree day units. The first egg laying by overwintered females begins at 127 DD(°C), using Jan. 1st as a starting point, (biofix) for beginning the model accumulation. After this the first new generation of adults will begin to emerge at 266 DD (°C) and peak at 402 DD (°C). This range is a good opportunity for setting up monitoring traps. First egg-laying by this generation will begin at 296 DD (°C) and peak at 535 DD (°C).

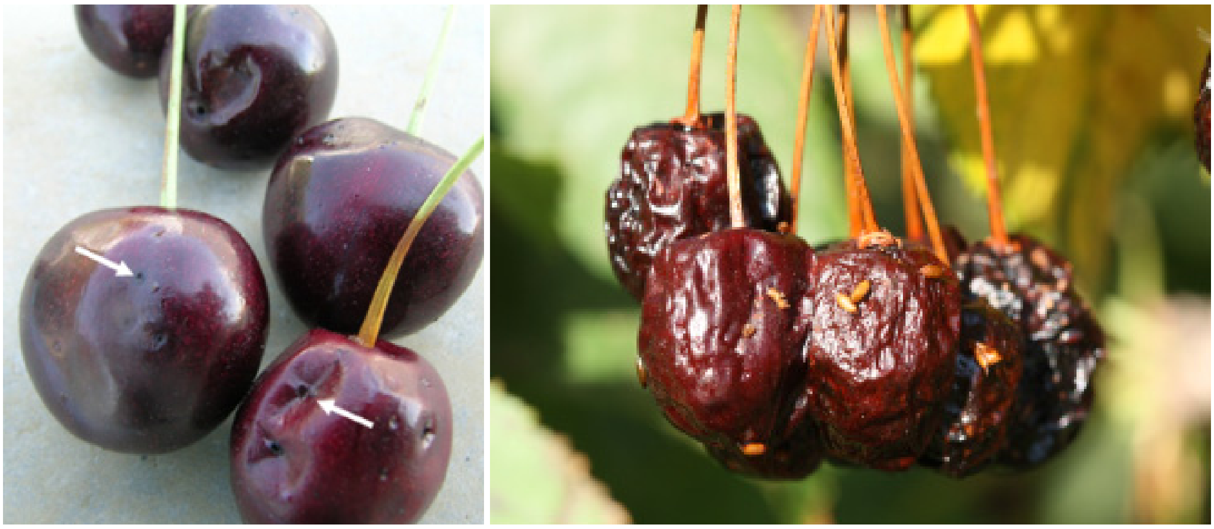


Fig. 55. Spotted wing drosophyla – egg laying scars and pupae on infested fruit (photo: B. C. Ministry of Agriculture.)

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Integrated systems of pome – and stone fruit production

Autor: doc. Ing. Ján Mezey, PhD.

Publisher: Slovak University of Agriculture in Nitra

Edition: First

Publishing: 2023

Form of pub: online

AQ – PQ: 13.90 – 14.13

Not reviewed at the Puglishing House of SUA in Nitra.

ISBN 978-80-552-2675-0