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Mealy diseases on fruit species caused by pathogens of the genus *Podosphaera*

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Abstract

Powdery mildews on fruit crops, caused by species of the genus *Podosphaera*, represent a widespread and economically significant phytopathological problem in fruit growing. They affect both pome and stone fruit species and are characterized by high adaptability to various agro-ecological conditions. The management of these diseases is based on an integrated approach, combining agrotechnical measures, the use of resistant and low-susceptibility cultivars, appropriate control methods, as well as the application of predictive models for assessing infection risk. Economically significant representatives include apple powdery mildew, caused by *Podosphaera leucotricha* (Ellis and Everh.) E. S. Salmon, and peach powdery mildew, caused by *Podosphaera pannosa* (Wallroth) de Bary, which necessitates the implementation of environmentally sound control measures against the pathogens.



Apple powdery mildew

The genus *Podosphaera* encompasses fungal pathogens causing powdery mildews, which have been identified on a number of fruit crops, as well as on strawberry, currant, and hazelnut [1,12,15,18]. Economic damage is caused mainly on apple, with the primary pathogen *Podosphaera leucotricha* (Ellis et Everhart) E. S. Salmon, with conidial stage *Oidium farinosum* Cooke [1,9,20], and on peach - *Podosphaera pannosa* (7,15). According to data from the EPPO Global Database, the causal agents of

powdery mildew on fruit crops belong to the genus *Podosphaera*, family Erysiphaceae, order Erysiphales, class Ascomycetes. Both species are obligate biotrophic ascomycete pathogens, specialized for tissues of living hosts [11,12]. The causal agent of apple powdery mildew, *P. leucotricha*, has a polycyclic development and overwinters as mycelium, which attaches to the plant organ via appressoria (specialized branches), and obtains nutrition from the plant cell through haustoria. On the mycelium in infected leaf and mixed buds, conidiophores are formed, bearing 6-9 single-celled spores arranged in a chain. The fruiting bodies of the pathogen are cleistothecia, but they are rarely formed in our country [3]. Cleistothecia are dark, spherical in shape, and possess two types of appendages - simple and dichotomously branched. One ascus is formed within the fruiting body, containing single-celled ascospores [4]. In spring, a systemic form of the disease develops, while during the growing season, disease spread occurs via conidiospores. The pathogen develops over a wide temperature range (4-30° C) and a water droplet is not required for conidial germination, due to their ability to germinate at air humidity above 34%. Authors report that mycelium ceases development at temperatures above 33°C [3].



Apple powdery mildew

Symptoms on apple caused by *P. leucotricha* are observed on leaf and mixed buds infected during the preceding year (systemic form of the disease). Infected leaf buds give rise to weakly developed shoots covered with a dense white coating consisting of the fungal mycelium and spores. Infected mixed buds produce leaves and flowers entirely covered with a powdery coating, causing yellowing and premature dropping. Infected flower buds are small, deformed, do not set fruit, turn brown, and drop. In the case of infection during the same growing season (local form of the disease), a grayish-white coating is observed on the leaves, which ceases development at the site of damage, and deformation of the leaf blade is observed. Powdery spots are also observed on petioles, covered with mycelium, which reaches and encompasses healthy buds. The fungus has the potential to colonize the fruits of highly susceptible cultivars, showing signs of a russet network that covers the fruit in various forms and depths. Highly susceptible cultivars such as 'Golden Delicious', 'Jonathan' [14,19,4] have been described by numerous authors, whose yield can be significantly reduced if disease control is not implemented. Data from long-term field observations in the Dresden-Pillnitz breeding program show that apple cultivars 'Remo', 'Regia', 'Rewena', and 'Rebella' are characterized by a high degree of resistance to powdery mildew [10]. In a more recent field study under similar conditions of natural infection pressure, it was found that the cultivars 'Delicious', 'Demir', 'Dayton', and 'Burgundy' did not exhibit disease symptoms and demonstrated a high degree of field resistance over two consecutive growing seasons [8]. Cultivars 'Gala', 'Honeycrisp', 'Mutsu' [4,23] were found to have moderate susceptibility. Long-term studies at the Institute of Agriculture - Kyustendil show that control of the pathogen can be facilitated by the use of more resistant cultivars, reducing the infection pressure. Research conducted at the Institute has established varying degrees of susceptibility among apple cultivars, highlighting low-susceptibility 'Prima' and 'Erwin Baur' [1,20], moderately susceptible 'Mutsu' [21], and highly susceptible 'Moira' [1,9].



Peach powdery mildew

The symptoms of peach powdery mildew, caused by *Podosphaera pannosa* (Wallroth) de Bary, with conidial stage *Oidium leucoconium* Desmazières, are similar to those on apple. The disease affects the green organs of the plant, including leaves, young shoots, and fruits. The pathogen manifests in two

forms - systemic (diffuse) and local, with the systemic form being of particular importance in the early stages of vegetation. In spring, upon the bursting of infected buds, shoots develop with a characteristic powdery coating, leading to stunted growth and development [4]. Under favorable conditions, the disease can also affect young fruits, resulting in deformations and a permanent deterioration of the commercial quality of the produce. The infection process of *Podosphaera pannosa* is typical for obligate biotrophs, with the pathogen penetrating plant tissues by directly crossing the cuticle and forming haustoria in epidermal cells [17].

Control Strategy

Agrotechnical Measures

The main agrotechnical measures against the causal agents of powdery mildew include:

- Selection of appropriate cultivars that are resistant or have low susceptibility to the pathogen, which will significantly reduce the infection pressure and the need for fungicide treatments [1,14].
- Selection of a suitable site and planting distances, along with a well-formed canopy, which improve aeration and limit the formation of a favorable microclimate for pathogen development [1,2].
- Balanced fertilization contributes to optimal vegetative growth and limits susceptibility to powdery mildew, while excessive nitrogen fertilization increases susceptibility [2,13].
- Pruning aimed at removing infected shoots and branches, reducing the amount of primary inoculum, is a key measure for limiting early infections in spring [2,23].

Chemical and Biological Control Approach

The application of fungicide sprays approved against the disease has a limiting effect, and control strategies should be aimed at effectively limiting primary and secondary infections. The most widely used group of active substances against *P. leucotricha* are ergosterol biosynthesis inhibitors (Demethylation inhibitors - DMI, FRAC group 3), including myclobutanil, penconazole, tetraconazole, difenoconazole, and flutriafol [23,25], and strobilurins (Quinone outside inhibitors - QoI, FRAC group 11) [25]. Rotation of active substances should be observed to prevent resistance to DMI and QoI fungicides. It is important that fungicide treatments be carried out in accordance with the plant protection products approved for the disease in the country.

Alongside chemical control, interest in biological agents for limiting the causal agent of apple powdery mildew has increased in recent years. Among the best-studied biological agents against powdery mildews are representatives of the genus *Bacillus*, which show effectiveness against various *Podosphaera* species, including on fruit crops, mainly by increasing chlorophyll content and improving photosynthetic activity, contributing to better physiological condition of plants and enhanced resistance to infection by *P. leucotricha* [16]. Studies are also available on the effectiveness of yeasts in reducing the degree of attack by *P. leucotricha* by 37.4% [5,6].

Last but not least is the use of predictive models for disease development as an important tool for optimizing the control of apple powdery mildew. Models such as RIMpro use meteorological data, the phenological development of the crop, and biological parameters of the pathogen to forecast periods of increased risk of primary and secondary infections, allowing for more precise and timely application of plant protection measures. Research in Europe and Bulgaria shows that the use of such models contributes to reducing the number of treatments without compromising control efficacy and supports the management of fungicide resistance by limiting unnecessary applications [13,20,22]. Although most predictive models were initially developed for apple scab, many of them, including RIMpro, successfully integrate modules for powdery mildew as well, making them a valuable element of modern Integrated Pest Management (IPM) against *P. leucotricha* under changing climate conditions.

Powdery mildews remain one of the key phytopathological challenges of economic importance, especially under conditions of intensive production and changing climatic conditions. Combining resistant or low-susceptibility cultivars with an integrated disease management approach, including agrotechnical and plant protection measures supplemented by predictive models, provides an opportunity for a long-term effective and promising control strategy [16,21,23,24].

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