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POWDERY MILDEW OF HAZELNUTS IN THE NORTH-WEST PART OF AZERBAIJAN

The article presents the results of a study of the prevalence, intensity of development and harmfulness of powdery mildew, conducted by us in hazelnut orchards located in the northwestern part of Azerbaijan in 2021-2023. As a result of our research, it has been established that this disease is very widespread in most of the main northwestern regions of the country engaged in planting and growing hazelnuts.

Powdery mildew usually affects the leaves and fruits of hazelnuts. The fact that powdery mildew directly affects the generative organs of the plant and forms a white powdery coating on their surface significantly increases the danger of the disease. During years of widespread disease, the yield of hazelnut bushes drops by 80-100%.

In the course of our research, it was established that rainy and at the same time hot weather conditions in 2021-2023 led to an intensive spread of the disease. The hazelnut cultivars "Ata-Baba", "Ganja hazelnut" and "Oily hazelnut", which we considered as objects of study during field experiments, were heavily infected with powdery mildew. In 2021-2023, the causative agent of hazelnut powdery mildew was studied at the microscopic level, and the fungicides Topaz, EC (100 g/l penconazole), Raek, EC (250 g/l difenoconazole) and Tercel, VDG (120 g/l dithianon + 40 g/kg pyraclostrobin) were used against this disease. Fungicide Topaz with a biological effectiveness of 74.0-76.3% showed the highest result from the drugs used.

***Keywords*:** hazelnuts, powdery mildew, pathogen, fungus, cleistothecia, conidia, control measures.

Introduction. The group of nut crops includes fruit species of temperate and subtropical zones from different botanical families that form fruits - nuts and dry drupes. Nut fruits include: walnut (*Juglans regia* L.), hazelnut (*Corylus* L.), almond (*Amygdalus* L.), pecan (*Carya* Nutt.) and chestnut (*Castanea* Mill.).

Their fruits are distinguished by their high shelf life, transportability and high calorie content. Used fresh and in the confectionery industry, they have important medicinal value. Nut fruits are durable, life expectancy is 200-300 years or more [6].

Hazelnut (*Corylus* L.) belongs to the birch family (*Betulaceae* Gray.) (Fig. 1,2). Wild plants of this species are called hazel (hazel), and cultivated plants are called hazelnuts. This is a large bush, multi-stemmed, 7-9 m high, branched from the base, with shoots. It begins to bear fruit in the 3rd-5th year, the productive period is 25-40 years.

Hazelnuts (*Corylus* L.) are produced in commercial quantities in Turkey, Azerbaijan, Italy, Greece, Cyprus, Georgia, the Spanish region of Catalonia, the UK in Kent, and the US states of Oregon and Washington. About 67% is grown in Turkey [7].

Hazelnut (*Corylus* L.) is a very delicate plant and therefore it is severely affected and damaged by diseases and pests. The main diseases of hazelnuts are: powdery mildew (*Phyllactinia guttata* (Wallr. Fr.) Lev.; *Erysiphe corylacearum* U. Braun & S. Takam.), black leaf spot (*Mamianiella coryli* (Batsch.) Höhn.), ocher-brown leaf spot (*Phyllosticta coryli* West.), phyllosticta or yellow-brown leaf spot (*Phyllosticta corylaria* Sacc.), common or European canker (*Neonectria galligena* (Bres.) Rossman & Samuels.), Villeminia necrosis (*Vuilleminia coryli* Boidin Lanq. & Gilles.), cylindrosporiosis (*Cylindrosporium avellanum* (B. et Br.) İbr. et Ach.), leaf rust

(*Pucciniastrum coryli* Kot. et Jacz.), fire blight (*Xanthomonas corylina* Mill. & Burkholer.), apple mosaic virus (*Apple mosaic virus* – AMV), etc.

Fig. 1 Hazelnut bush

Fig. 1 Hazelnut leaves and branches

Powdery mildew (*Phyllactinia guttata* (Wallr. Fr.) Lev.; *Erysiphe corylacearum* U. Braun & S. Takam.) is the most common disease of hazelnut orchards in the northwestern geographical zone of Azerbaijan and causes great damage to crop yields.

The disease is characterized by the appearance of a white cobweb or powdery coating on hazelnut leaves. This plaque soon disappears on the underside of the leaf blade. On the underside of the leaf blades, pointy yellow fruiting bodies are formed, which turn black over time. The affected leaf apparatus turns yellow prematurely and falls off. The pathogens overwinter in infected plant debris, often in the form of mycelium. Primary infection and spread of the fungus is accomplished by both ascospores and conidia. The disease is very common in the northwestern part of the country.

Purpose and task of research. The main goal of the study was to study the susceptibility to powdery mildew of hazelnut bushes (*Phyllactinia guttata* (Wallr. Fr.) Lev.; *Erysiphe corylacearum* U. Braun & S. Takam.) in the northwestern geographical zone of Azerbaijan in the period 2021-2023. and the development of comprehensive methods to combat it. During the implementation of the study, the following tasks were solved:

- In the conditions of the northwestern part of Azerbaijan, the distribution, intensity of development and susceptibility of hazelnut bushes to powdery mildew were studied;
- Phytopathogenic fungi that cause powdery mildew on hazelnut bushes have been scientifically studied at the microscopic level;
- The resistance of different hazelnut cultivars to powdery mildew has been studied;
- Comprehensive methods of combating the disease have been developed.

Materials and research methods. During 2021-2023, field and laboratory studies were carried out to study powdery mildew in hazelnut orchards of large industrial importance located in the northwestern part of Azerbaijan. During field experiments, such cultivars as “Ata-Baba”, “Oily Hazelnut” and “Ganja Hazelnut” were taken for the purpose of research. All these hazelnut varieties turned out to be unstable to this disease and easily affected.

During phytopathological examinations, the type of manifestation and type of causative agent of the disease, its prevalence, intensity of development and harmfulness were determined [1, 2, 3].

The distribution was determined after counting diseased and healthy plants in the sample using the formula [4, 5]:

$$P = \frac{Ax100}{N}$$

where, *N* – total number of plants in the sample, pcs.; *A* – number of diseased plants, pcs.; *P* – disease spread, %.

The development of the disease reflects the average degree of damage to one plant. The intensity of disease development was calculated using the formula [8]:

$$R = \frac{\sum abx100}{NK}$$

where, R – development of the disease, %; *Σab* – the sum of the products of the number of diseased plants *(a)* by the corresponding damage score *(b)*; *N* – number of counting plants; *K* – the highest point of the accounting scale.

Biological efficiency *(BE)*, expressed as a percentage, was calculated using the formula [8, 9, 11, 12, 13]:

$$БЭ = \frac{Мк - М0}{Мк100}$$

where Mk is the indicator of disease development in the control (protective measures were not carried out); Mo-indicator of disease development in the experiment (with protective measures).

Powdery mildew of hazelnuts (*Phyllactinia guttata* (Wallr. Fr.) Lev.; *Erysiphe corylacearum* U. Braun & S. Takam.) was recorded using the following scale:

0 – no lesion;
0.1 points – there are isolated lesions of the vegetative organs;
1 point – from 1 to 10% of vegetative organs are affected;
2 points – from 11 to 25% of vegetative organs are affected;
3 points – from 26 to 50% of leaves are affected;
4 points – over 50% of leaves and other vegetative organs are affected.

Statistical analysis of the results obtained was carried out in accordance with the recommendations of B.A. Dospehov [10].

Research results and discussion. The disease spreads widely and affects hazelnut bushes in conditions of moderate temperature and high relative humidity. Analysis of climate indicators for 2021-2023 suggests that these years were favorable for the spread and development of the disease (Fig. 3). For example, as can be seen from the diagram, the air temperature in 2021 was 12 ^{0}C and humidity 72%; while in 2023 the temperature was respectively 19 ^{0}C and the relative humidity was 85%.

Thus, in all three years of research, temperature and relative humidity as an environmental factor were favorable for the growth and development of fungi and, accordingly, pathological processes.

Considering that the disease affects young leaves of hazelnut bushes, observations in the garden were carried out in early spring.

Taking into account the widespread distribution of powdery mildew in the regions of our republic involved in planting and growing hazelnuts, we have determined the spread and intensity of development of the disease in the regions of the northwestern part of the country in 2021-2023.

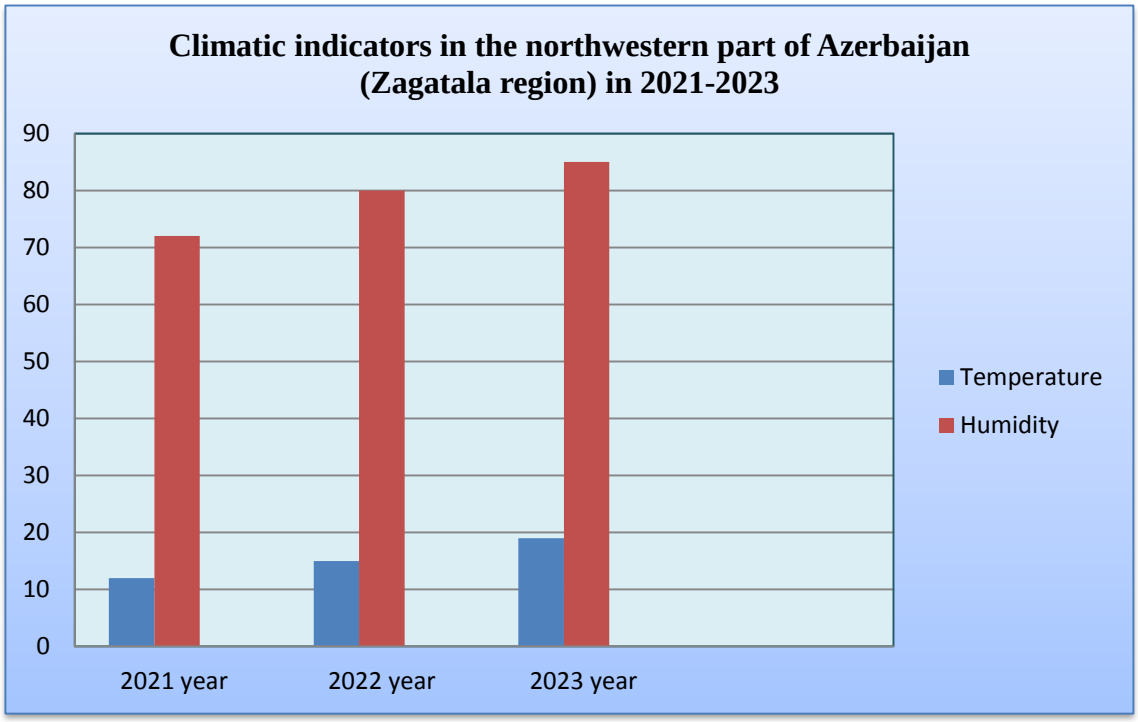

Fig. 3. Climatic indicators in the northwestern part of Azerbaijan (Zagatala region) in 2021-2023

The studies found that this disease is widespread in all northwestern regions of the country (Table 1).

Table 1

Distribution and intensity of development of powdery mildew of hazelnut bushes (*Phyllactinia guttata* (Wallr. Fr.) Lev.; *Erysiphe corylacearum* U. Braun & S. Takam.) in the northwestern part of Azerbaijan (2021-2023)

Northwestern regions of Azerbaijan	Local hazelnut cultivars	2021 year		2022 year		2023 year	
		P, %	R, %	P, %	R, %	P, %	R, %
Zagatala	«Ata-Baba»	88,1	45,2	88,5	45,2	88,7	45,3
	«Oily Hazelnut»	87,7	44,8	87,9	44,9	88,0	45,1
	«Ganja Hazelnut»	60,5	29,9	60,9	28,8	63,6	30,1
Gah	«Ata-Baba»	87,5	44,3	88,8	44,7	89,0	45,5
	«Oily Hazelnut»	70,1	42,5	75,2	42,7	77,7	43,0
	«Ganja Hazelnut»	55,5	40,4	56,1	40,8	57,0	41,0

Note: P – distribution, %; **R** – intensity of development, %

Analysis of laboratory studies indicates that the mycelium of *Phyllactinia guttata* (Wallr. Fr.) Lev. usually observed on the lower surface of host leaves, rarely on the upper surface. The conidia of this fungus are unicellular, rod-shaped, sometimes diamond-shaped. The cleistothecia of the fungus is round and wide (Fig. 4).

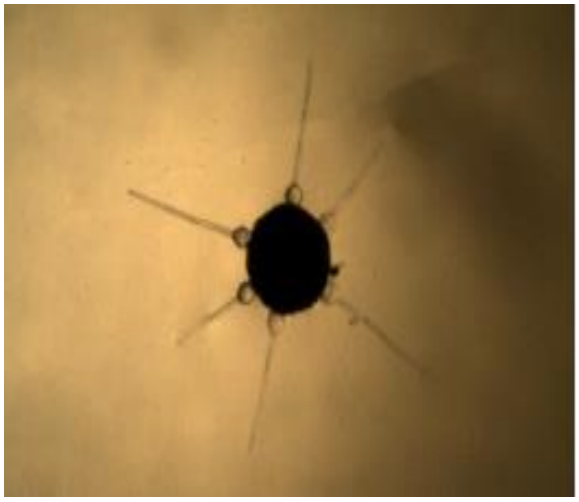

Fig. 4. Microscopic structure of the cleistothecia of the fungus *Phyllactinia guttata* (Wallr. Fr.) Lev.

Mycelium of the fungus *Erysiphe corylacearum* U. Braun & S. Takam. develops on both surfaces of hazelnut leaves. Conidia are unicellular, oval, ellipsoidal or barrel-shaped. Their cleistothecia are round in shape (Fig. 5).

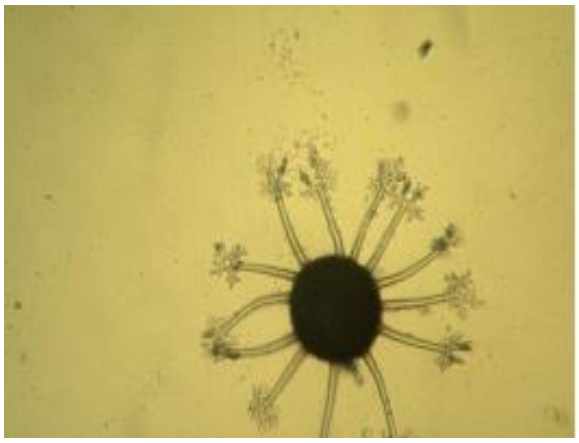

Fig. 5. Cleistothecia of the fungus *Erysiphe corylacearum* U. Braun & S. Takam

Phyllactinia guttata (Wallr. Fr.) Lev. overwinters as a cleistothecia in diseased leaves falling to the ground. Ascospores emerging from the cleistothecia in the spring infect hazelnut leaves that have reached normal size and initiate the disease. The suitable temperature range for ascospore germination is 10-20^{0}C. Conidia produced during the season are dispersed by the wind (anemochory) and form new infections.

Erysiphe corylacearum U. Braun & S. Takam overwinters. and in diseased plant debris. It infects leaves and newly formed seedlings at an earlier stage than *Phyllactinia guttata* (Wallr. Fr.) Lev., and its conidia are dispersed by the wind (anemochory).

In powdery mildew disease caused by *Phyllactinia guttata* (Wallr. Fr.) Lev., in the middle to end of the growing season, in hot and humid weather, a gray-white powdery fungal coating is formed, formed from the mycelium, conidiophores and conidia of the fungus, usually formed on the lower surface hazelnut leaves (Fig. 6). This plaque, initially in the form of small spots, eventually covers the entire leaf, and gradually the leaf loses its green color and shine and becomes dull. By the end of the season, visible small, round, brown, bright red and black cleistothecia of the pathogen form within the white fungal coating (Fig. 7). Then the leaves gradually begin to turn brown, becombrittle and curl.

Thus, disease-infected leaves fall off prematurely. Although the disease usually appears on the leaves and does not cause direct damage to the crop, it causes premature leaf drop, which

negatively affects the quality rather than the yield of hazelnuts. In addition, since diseased leaves cannot continue their physiological activities to the same extent as healthy ones, if this situation persists for many years and unchecked, trees may experience stunted growth.

Fig. 6. Powdery mildew on the bottom of the leaf

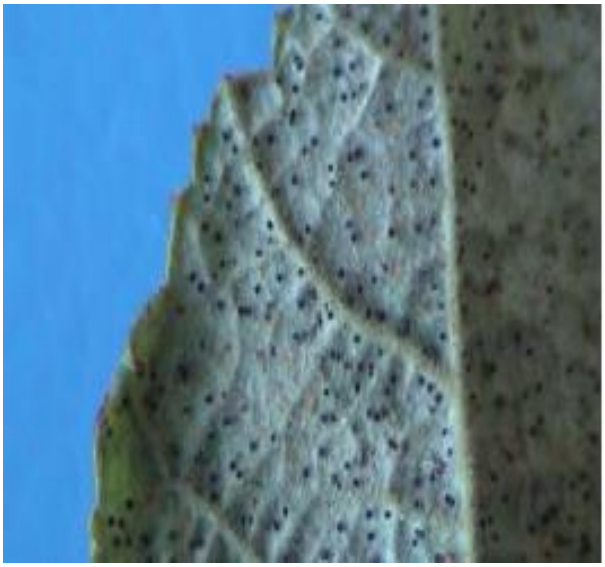

Fig. 7. Cleistothecia fungus on a hazelnut leaf

In powdery mildew disease caused by *Erysiphe corylacearum* U. Braun & S. Takam., symptoms appear on leaves and young shoots relatively early in the spring development period. Leaf symptoms can occur on both leaf surfaces. As fungal colonies develop on the lower parts of the leaves, the symptom of discoloration and yellowish spots initially appears on the upper parts of the leaves (Figure). Over time, the spots turn brown, the leaves begin to fade, and subsequently the brown-black cleistothecia of the pathogen can be easily observed on the spots (Fig.). Diseased leaves dry out, curl and fall off prematurely.

In young shoots and branches, the surface of the bark initially looks as if it had been sprinkled with flour, but in the subsequent period, dulling and browning of the color are observed, especially in those infected with the disease in the early period. Thus, the disease leads to both yield loss and quality loss. Powdery mildew causes economic damage in all hazelnut production areas.

In the 2021-2023 years of research, we developed comprehensive measures to combat powdery mildew of hazelnut bushes, with a predominance of the chemical control method. For this purpose, we used the fungicides Topaz, CE (100 g/l penconazole), Tercel, VDG (120 g/l dithianone + 40 g/kg pyraclostrobin) and Raek, CE (250 g/l difenoconazole). The drug Topaz showed the best result (Table 2).

Table 2

The influence of fungicides on the spread and intensity of development of powdery mildew of hazelnut bushes (*Phyllactinia guttata* (Wallr. Fr.) Lev.; *Erysiphe corylacearum* U. Braun & S. Takam.) in the northwestern part of Azerbaijan (2022-2023)

Experience options	2022 year			2023 year		
	P, %	R, %	БЭ, %	P, %	R, %	БЭ, %
Tercel, VDG 120 g/l dithianone + 40 g/kg puraclostrobin)	25,9	14,0	73,0	25,0	13,3	75,1
Raek, CE (250 g/l difenoconazole)	26,0	14,8	71,0	25,6	14,1	74,0
Topaz, CE (100 g/l penconazole)	24,4	13,5	74,0	23,9	12,7	76,3
Control (without chemical treatment)	88,9	50,9	0	89,0	53,5	0

Note: P – disease prevalence, %; **R** – intensity of disease development, %; **BE** – biological effectiveness of fungicides, %

Conclusion. Thus, in the conditions of the northwestern part of Azerbaijan, powdery mildew (*Phyllactinia guttata* (Wallr. Fr.) Lev.; *Erysiphe corylacearum* U. Braun & S. Takam.) is one of the most dangerous diseases that reduces the productivity of hazelnut bushes. In order to determine the spread, development and harmfulness caused by the disease in hazelnut orchards in the northwestern part of our country, in 2021-2023. Research has been carried out in this direction. In the course of the studies, it was established that the disease is most common in the Zagatala region. At the same time, among the tested cultivars, the cultivar "Ata-Baba" was most affected by the disease. In general, over all three years of the study, climatic factors also favored the widespread spread of the disease.

After identifying the causative agents of powdery mildew on hazelnut bushes (*Phyllactinia guttata* (Wallr. Fr.) Lev.; *Erysiphe corylacearum* U. Braun & S. Takam.), determining their biology, ability to cause pathological processes and the mechanism of infection of the plant, comprehensive methods for combating the disease were developed, including mainly chemical protection measures. For the purpose of chemical control of the disease, the greatest result from the applied fungicides was shown by the drug Topaz with a biological effectiveness of 74.0-76.3%.

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БОРОШНИСТА РОСА ФУНДУКА В ПІВНІЧНО-ЗАХІДНІЙ ЧАСТИНІ АЗЕРБАЙДЖАНУ

У статті представлені результати дослідження поширеності, інтенсивності розвитку та шкодочинності борошнистої роси, проведеного нами в фундукових садах, розташованих у північно-західній частині Азербайджану в 2021-2023 роках. В результаті наших досліджень було встановлено, що це захворювання дуже поширене в більшості основних північно-західних регіонах країни, які займаються садінням і вирощуванням фундука.

Борошниста роса зазвичай вражає листя і плоди фундука. Значно підвищує небезпеку захворювання той факт, що борошниста роса безпосередньо вражає генеративні органи рослини й утворює на їх поверхні білий борошнистий наліт. У роки масового поширення хвороби врожайність кущів фундука знижується на 80-100%.

У ході наших досліджень встановлено, що дощові та водночас спекотні погодні умови у 2021-2023 роках призвели до інтенсивного поширення захворювання. Сорти фундука «Ата-Баба», «Гянджинський фундук» та «Фундук олійний», які ми розглядали як об'єкти дослідження під час польових дослідів, були сильно уражені борошнистою росою. У 2021-2023 роках збудник борошнистої роси фундука вивчали на мікроскопічному рівні, а проти цієї хвороби застосовували фунгіциди Топаз, к.е. (100 г/л пенконазолу), Райок, к.е. (250 г/л діфеноконазолу) та Терцел, ВДГ (120 г /л дитіанону + 40 г/кг піраклостробіну). Топаз з біологічною ефективністю 74,0-76,3% показав найвищий результат із застосованих препаратів.

Ключові слова: фундук, борошниста роса, збудник, гриб, клейстотеції, конідії, заходи боротьби.