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Microsphaera viburni (Duby) S. Blumer: Ecological and biological features, methods of control in the system of ornamental and fruit horticulture

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Abstract. The research relevance is determined by the need for a comparative assessment of different viburnum species in terms of resistance to powdery mildew, a disease that inhibits physiological processes in plants, negatively affecting growth, development, and yield, as well as decorative effect. The research aims to study the bio-ecological characteristics of *Microsphaera viburni* (Duby) S. Blumer and to develop measures to control powdery mildew in viburnum orchards. During the experiment, methods and techniques were used to conduct phenology, create provocative backgrounds, assess

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the level of damage to the ground part, and determine the degree of damage and resistance of viburnum plants. Recommendations for avoiding or reducing the risks of powdery mildew in viburnum orchards are provided. Nitrogen fertilisers should be applied in early spring and avoided in late summer to limit the growth and development of annual shoots, the tissue of which is more sensitive to the powdery mildew pathogen. It has been shown that formative, regulatory, and sanitary pruning in early spring can improve lighting and air circulation in the basal part of viburnum plants, intensify the growth of permanent shoots and form the desired type of bush (tree) in the system of fruit or ornamental horticulture. It has been proved that in the conditions of the Northern Forest-Steppe of Ukraine, it is advisable to grow highly resistant (Anya, Osinnia, Elina, Omriana) and resistant (Kralechka, Plododekorna, Sonetta, Horikhova, Yaroslavna) varieties (forms) of European cranberrybush of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine against powdery mildew. It is recommended to use resistant and medium-resistant varieties of common dwarf viburnum 'Eskimo' and common 'Roseum' for ornamental gardening (*Viburnum opulus* Roseum). The practical value was in a determination that powdery mildew of European cranberrybush 'Roseum' does not affect other species of the genus *Viburnum* L. under artificial inoculation; it was confirmed that the susceptibility of viburnum plants to this disease can be significantly reduced by low-susceptible and resistant varieties and species of the genus *Viburnum* L. and timely agronomic measures

Keywords: species (varieties, forms) of the genus *Viburnum* L.; powdery mildew; fungal disease; species assessment; control measures

INTRODUCTION

Diseases constantly accompany biological objects, including plants. Up to 40% of direct losses are incurred by major crops as a result of biotic stress, and in some years, crops such as wheat, potatoes and others have been affected by pathogens and have fallen out of the crop structure by almost 100% (Backyard Garden Information Source, 2023). Often, the environmental factors that cause crop losses are incorrect strategies for managing and controlling phytopathogens, which include forecasting, cultural, biological and agrochemical management. Biological control is becoming increasingly important due to its environmental friendliness compared to chemical control. However, the poor quality and timeliness of the implementation of agricultural management elements in the phytocenosis management system led to the large-scale use of fungicides. Plant tolerance and resistance are of great importance, which is the best option for preventing disease damage and increasing their range. This is achieved through the development of genetics, plant breeding and biotechnology. Reduced genetic diversity promotes the emergence and spread of pathogens to the point where diseases become both local and widespread.

T. Moskalets *et al*. (2019) state that direct losses from pathogens amount to about 20-40%. Representatives of the multispecies genus *Viburnum* L. are no exception, and among the complex of unfavourable biotic environmental factors, they suffer significantly from several diseases, including fungal diseases, which inhibit the processes of increasing the number of viburnum orchards. One of the most dangerous fungal diseases of viburnum is powdery mildew, one of the most common diseases in Europe, North America and elsewhere. Powdery mildew is host-specific, meaning that a certain type of pathogen cannot survive without a proper host plant (Morini, 2020). N. Pinchuk *et al.* (2018) reported that the causative agent of powdery mildew of plants of the genus Adoxaceae is the monophage *Microsphaera viburni* (Duby) S. Blumer, 1933 (homotypic synonym of *Erysiphe viburni* Duby, 1830), which affects and reduces the productivity and decorative value of infected plants, inhibiting their growth and development, the number of inflorescences and fruits.

V.P. Heluta and I.M. Anishchenko (2021) reported that in Ukraine, the damage to common viburnum (*Viburnum opulus* L.) plants is mainly observed in the western and northern regions, which manifests itself locally or as an epiphytotic disease, in particular, the manifestation of which was noted in 1989. Wijayawardene *et al*. (2022) note that the powdery mildew pathogen is unique because, in the absence of free water on the leaf surface, which often inhibits spore germination, it is capable of rapid functional activity, usually in partial shade and strong thickening, in particular, germination and infection of a larger plant surface with spores.

J. Kubina (2017) states that the pathogen mainly affects young leaves of viburnum (old leaves are almost not damaged) and affects the distribution of carbohydrates and other nutrients in the plant, creating a powerful local sink in places where leaves are affected by fungal infections. S. Martin (2019) reports that powdery mildew reduces the radial growth of tree species with a cumulative and delayed effect over many years. The significant impact of powdery mildew on plants is associated with altered growth patterns, either environmental factors (pests, critically low and high air temperatures, etc.) or elements of agronomic practices (e.g., the formation of a viburnum plant by a tree or bush). According to J. Williamson (2021), in many cases, powdery mildew progresses, and the affected areas may increase, often covering the entire leaf, branch or stem (in particular those closest to the soil surface), and chlorosis

or necrosis of the affected leaf tissue is observed. Pane *et al.* (2021) argue that downy mildew fungal infections can often reduce the overall cold tolerance of plants.

As noted by R. Panstruga and H. Kuhn (2019), powdery mildew fungal colonisation of plants can disrupt local microbial community structures associated with the root/rhizosphere, and other (foliar) phytopathogens can interact with powdery mildew and mycoparasites can influence the outcome of plant-powdery mildew interactions. Successful colonisation by powdery mildew will affect pre-existing foliar and possibly even microbial communities. A. Gross *et al.* (2021) believe that in any case, powdery mildew will have a significant impact on plants in both cultivated and natural coenoses and will determine the duration of vegetation existence, in particular under global climate change, which will determine the severity of the disease, mainly by changing the phenological synchrony of the pathogen-host plant.

Therefore, the epidemiological detection and management of phytopathogenic foci to reduce the risks and scale of their manifestation in the context of global food and environmental security is relevant. The research aims to investigate the ecological and bioecological features of powdery mildew on viburnum plants and develop measures for its control.

MATERIALS AND METHODS

Viburnum powdery mildew damage was monitored at the experimental plots of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (NAAS) and its research network during 2018-2021. Varieties/breeding forms of common viburnum (*Viburnum opulus* L.) of Ukrainian selection were involved in the study of the degree of plant damage: Anya, Ulyana, Yaroslavna, Elina, Horikhova, Omriana, Sonetta, Kralechka, Osinnia, Plododekorna and viburnum species: *V. hordovina*; *V. carthyphyllum*; *V. rhytidophylloides* (*Viburnum* × *rhytidophylloides*); *V. Burkwood*; *V. wrinkled viburnum* (*Viburnum rhytidophyllum* Hemsl.); *V. opulus Roseum*; *V. sargentii* Koehne Onondaga; *V. opulus* L., variety Eskimo (Fig. 1).

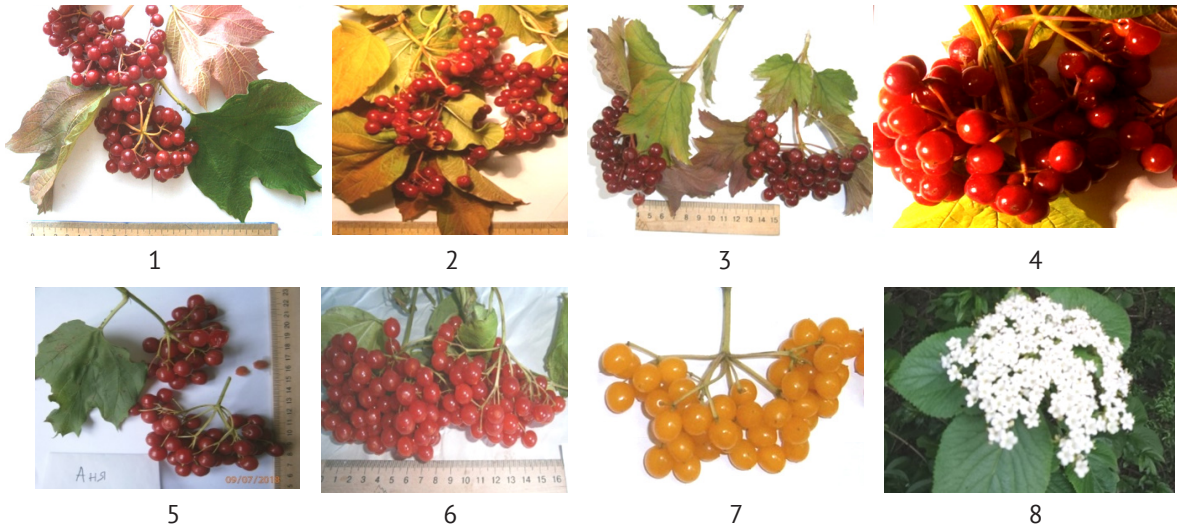

Figure 1. *Photos of individual samples of Viburnum officinale and Viburnum hirsuteum were used in the study*
Note: *1 – Kralechka; 2 – Plododekorna; 3 – Horikhova; 4 – Soneta; 5 – Anya; 6 – Elina; 7 – Yaroslavna; 8 – Viburnum lantana*
Source*: photographed by the authors*

Observations and records of plants were carried out during May and September (Methods of qualification..., 2023). Leaves of the studied varieties were collected twice during the growing season. During the vegetation of viburnum plants, 10-15 leaves were taken from 3 trees (bushes) of each variety/species (5 leaves × 3 replications) to determine the area affected by powdery mildew.

Plant material was collected in parchment bags. Each sample of a particular viburnum plant variety/species was labelled with the sample number, place, and time of collection. Visual examinations were carried out in the basal part and on the periphery along the entire vertical crown of the plants. The assessment of viburnum plant resistance was performed in three periods: the first one – 10 days after the first diseased plants were detected in the experiment, the second one – 2-3 weeks after the first one, i.e., during the period of the greatest development of the disease, the third one – at the end of harvesting.

The degree of powdery mildew damage to viburnum leaves was determined on a scale of points. Processing the data obtained, the percentage of disease development or damage to plant organs (P) was calculated using the formula:

$$P = \frac{a}{b \times 9} \quad (1)$$

where: a – sum of damage scores of all plants in the replication; b – number of plants in the replication; 9 – maximum damage score. The lower the degree of damage, the higher the resistance of plants of a particular variety (Table 1).

***Table 1**. Methods for assessing the level of damage and resistance of viburnum plants to the disease caused by Microsphaera viburni (Duby) S. Blumer*

Damage scale	Damage stage	Damage to the surface of plant organs, %	Resistance scale	Resistance score
0-1	Absent or exceptionally weak	<5	High	9
2-3	Weak	5-25	Resistant	7
4-5	Average	26-50	Average	5
6-7	High	51-75	Weak	3
8-9	Highly resistant	>75	Exceptionally weak	1

***Source**: Methods of qualification... (2016)*

The average damage score of viburnum plants was determined by the formula:

$$B = \frac{\sum(a \times b)}{N}$$

where B is the average plant damage score; ∑(a×b) is the sum of the products of the number of affected plants and the corresponding damage score; N is the total number of plants under study.

The plant damage coefficient was determined by the formula:

$$K = \frac{A \times B}{100}$$

where K is the damage coefficient (in our conditions, it ranges from 1.07 to 2.41, with an average of 1.5); A – percentage of affected plants; B – average lesion score.

To facilitate the work on accounting for foliar diseases on viburnum plants (Methods of qualification..., 2023), a corresponding calendar for phytopathological accounting was developed, part of which is presented in the methodological part of the article (Table 2).

***Table 2**. Calendar of phytopathological inspections of viburnum plants*

Time of monitoring	Disease	Damage type	Indicator of monitoring
At noticeable damage	Powdery mildew	It affects leaves and shoots. The affected organs have a greyish-whitish, spidery, or powdery coating, which later becomes red or brown, and in late summer with dotted black cleistothecia. Affected leaves curl, harden, and fall off prematurely. Annual shoots do not grow, or have weak growth, often bend, and gradually die.	Stage of damage of leaves and shoots, %

***Source**: Methods of conducting phytopathological studies for artificial infection of plants (2016)*

In parallel with the diagnostics of viburnum plants, an experiment was set up that included variants of foliar inoculation of two-year-old viburnum plants with a suspension of conidia or particles of powdery mildew mycelium according to the accepted methodology (Methods of conducting phytopathological studies for artificial infection of plants, 2016). The experimental design included two variants: 1 – without inoculation (control), and 2 – with inoculation. Among the experimental plants, samples of viburnum *Viburnum opulus* L. varieties Yaroslavna, Elina, Omriyana, Autumn, Kralechka, Plododekorna, Horikhova and Anya; *V. opulus* Roseum; *V. opulus* L. Eskimo variety; *V. rhytidophyllum* Hemsl.; *Viburnum* × *carlcephalum*; *V. lantana*; *V. lantana* var. *variegatum*; *Viburnum* × *rhytidophylloides*; *Viburnum* × *burkwoodii*; *V. sargentii* Koehne. The number of plants of the studied species (variety) of viburnum was 3 copies, which was perceived as a 3-fold replication of the experiment. The extent and score of damage were determined based on the data in Table 1.

To test the resistance of the new forms of Viburnum vulgare plants, an experiment was conducted that involved artificial infection of young plants (the average height of which did not exceed 1 m) with the powdery mildew pathogen by spraying a special inoculum from the affected leaves with spores of the fungus *Microsphaera viburni*. For this purpose, the most favourable conditions for infection were chosen, which are created at a temperature of +18-25°C and high air humidity of about 60-80% (third decade of May). Statistical data processing was carried out using Statistica-6.0 computer software. The study complied with the requirements of the Convention on Biological Diversity (1992).

RESULT

Regular inspections revealed that white powdery spots appear on the leaves and stems of affected viburnum plants. During 2018-2019, thorough examinations of viburnum plants in the collection nursery were carried out and it was found that the first visible symptoms of powdery mildew are raised bubbly areas on young leaves, which eventually cause them to curl, exposing the lower surface of the leaves. At the same time, the affected leaves are covered with a white (May-June), later (July-August) light grey or grey-white, like talcum powder, powdery coating (loose mycelium), mostly on the upper part of the leaf blade (Fig. 2).

A B

***Figure 2**. Part of viburnum leaf*
***Note:** not affected (A) and affected (B) by powdery mildew*
***Source**: photographed by the authors*

Young leaves of the lower tier were often noted to be the most affected, and as the disease progressed, leaf spots increased in size, accompanied by the formation of a large number of asexual spores, as a result, moulds could often appear on the leaves, which, in particular on plants with generative buds, made it impossible for them to open. In the second part of summer, the leaves of severely affected plants developed brown spots with purple or red colouration around the infection. The disease usually appears in the summer and reaches its peak at the end of the summer period. In 2018-2019 in the northern part of Ukraine, environmental factors contributed to the manifestation of powdery mildew on common viburnum plants, and according to Table 3, varieties and forms of common viburnum Anya, Elina, Omriana and Osinnia are highly resistant, the degree of damage was 1 point, fruit varieties and forms Yaroslavna, Sonetta, Horikhova, Kralechka, Plododekorna and decorative variety Eskimo were resistant (7 points), and *Viburnum opulus* Roseum was medium resistant (5 points) (Table 3).

***Table 3.** Results of the assessment of the degree of damage and resistance of viburnum plants to powdery mildew, average value for 2018-2019*

Name of the species/variety (breeding form)	Degree of damage, points	Resistance scale	Damage scale
V. opulus L. Anya variety *V. opulus* L. Elina variety *V. opulus* L. Omriana variety *V. opulus* L. Osinnia variety	1	Highly resistant	9
V. opulus L. Kralechka variety *V. opulus* L. Plododekorna variety *V. opulus* L. Eskimo variety *V. opulus* L. Sonetta variety *V. opulus* L. Horikhova clone *V. opulus* L. Yaroslavna variety	3	Resistant	7
V. opulus Roseum	5	Average	5
None of the species/varieties received this number of points	7	Weak	3
	9	Exceptionally weak	1

***Source**: compiled by the authors*

Plants of other species of the genus *Adoxa* L. *(Adoxaceae* Trautv.*)* (*V. rhytidophyllum* Hemsl.; *Viburnum* × *carlcephalum*; *V. lantana*; *V. lantana* var. *variegatum*; *Viburnum* × *rhytidophylloides*; *Viburnum* × *burkwoodii*; *V. sargentii* Koehne) hadnosigns of powdery mildew damage. It was noted that the incubation period largely depends on weather conditions and the resistance of the variety to the disease. At 5-10 days, a powdery white coating was observed on the plants of certain species (varieties), which is nothing more than the surface mycelium and conidial sporulation of the fungus. However, conidial sporulation became widespread after the visual presence of plant damage by the disease. The growth of new shoots of affected plants occurred, but less intensively than in the control variant. Spreading through the affected plant, conidia got on young leaves and caused a secondary infection, which manifested itself shortly before the end of the growing season.

It is worth noting that dry hot weather (up to +27-30°C) during the summer period caused a decrease in the resistance of a certain species (variety) of viburnum plants to the disease (wilting of plant shoots, which contributed to their damage, as the fungus penetrates more easily into the plant, which is close to plasmolysis), and, consequently, massive conidial sporulation of the fungus and an increase in the area of damage.

Thus, it can be assumed that the harmfulness of powdery mildew is due to increased transpiration of plants, disruption of the synthesis of organic compounds, the impaired outflow of plastic substances into the stems and roots, and rapid ageing of leaves.

A noticeable outbreak of secondary infection was observed during re-growth, with the affected leaves hardly drying out as compared to the primary infection. It should be noted that the secondary infection manifested itself mainly on the underside of the leaf, with the leaves becoming coarser, acquiring a felt-like appearance and in places of significant accumulation of mycelium, mainly on the surface of annual shoots, fruiting bodies of the fungal pouch stage – cleistothecia – were formed, in which one bag with eight sackspores was formed by the end of the growing season. At the same time, mature cleistothecia remain overwintering on the affected shoots.

It is worth noting that the marsupial stage does not play a role in the maintenance and development of fungal infection. For example, in temperate climates, the pathogen overwinters in leaf and fruit buds with mycelium, which it penetrates in summer during their formation. It was found that after foliar inoculation, powdery mildew appears only on common viburnum in the period from the budding phenophase with damage to 5% of leaves and increases the level of its development by about 22% in the phase of growth and fruit filling after a decrease in the average daily air temperature of about 20°C and an increase in air humidity of more than 70% (III decade of August-I decade of September) (Table 4).

***Table 4**. Damage and resistance level of Viburnum vulgare plants depending on artificial inoculation with powdery mildew fungus*

Type (variety, form, cultivar) of viburnum	Damage to the surface of plant organs, %			Damage stage	Resistance level
	before inoculation	after inoculation			
	vegetative budding phase	budding phase	fruit growth and ripening phase		
Viburnum opulus L. Yaroslavna variety	0	9	18	weak	resistant
Viburnum opulus L. Anya variety	0	5	5	exceptionally weak	highly resistant
Viburnum opulus L. Elina variety	0	3	3	exceptionally weak	highly resistant
Viburnum opulus L. Omriana variety	0	10	23	weak	resistant
Viburnum opulus L. Sonetta variety	0	3	5	exceptionally weak	highly resistant
Viburnum opulus L. Horikhova clone	0	5	5	exceptionally weak	highly resistant
Viburnum opulus L. Osinnia variety	0	5	5	exceptionally weak	highly resistant
Viburnum opulus L. Kralechka variety	0	12	27	average	average
Viburnum opulus L. Plododekorna variety	0	3	4	exceptionally weak	highly resistant
Viburnum opulus Roseum	0	13	29	average	average
Viburnum opulus L. Eskimo variety	0	16	19	weak	resistant
Viburnum rhytidophyllum Hemsl.	0	0	0	none	-*
Viburnum × carlcephalum	0	0	0	none	-
Viburnum lantana var. Aureum	0	0	0	none	-
Viburnum lantana var. *Variegatum*	0	0	0	none	-
Viburnum × rhytidophylloides	0	0	0	none	-
Viburnum x burkwoodii	0	0	0	none	-
Viburnum sargentii Koehne Onondaga variety	0	0	0	none	-

***Note:** *The powdery mildew pathogen did not manifest itself as it is not specific to the host plant*
***Source**: compiled by the authors*

After inoculation, Viburnum vulgare varieties Anya, Elina, and forms Sonetta, Plododekorna, and Horikhova had a very low degree of damage (⩾5) and were noted as highly resistant. Cultivar Yaroslavna, from Omriana and *V. opulus* L. variety Eskimo, are characterised as resistant, and a form of common viburnum Kralechka *V. opulus* Roseum – as medium resistant. No signs of lesions after inoculation on viburnum plants of *V. rhytidophyllum* Hemsl, *V.* × *carlcephalum*, *V. lantana var. Aureum*, *V. lantana* var. *Variegatum, V.* × *rhytidophylloides*, *V.* × *burkwoodii* and *V. sargentii* Koehne of Onondaga cultivar were not found, which confirms the high species specificity of the pathogen to the host plant. Biometric studies carried out in the middle and at the end of the growing season revealed that shoot growth in viburnum plants affected by powdery mildew decreased by 1.3-1.6 times (Table 5).

***Table 5**. Comparative assessment of annual shoot growth of two-year-old viburnum plants on variants without inoculation and inoculation with powdery mildew fungus, average value for 2019-2020*

Type (variety, form) of viburnum	Variant	The average length of an annual shoot, cm		Deviation of data from the variant with an inoculation to the variant without inoculation (±, cm)
		middle of the vegetation period	vegetation period ending	
Viburnum opulus L. Elina variety	No inoculation	25.4	41.6	
	Inoculation	28.5	39.4	-2.2
Viburnum opulus L. Anya variety	No inoculation	49.7	63.5	
	Inoculation	48.6	58.5	-5
Viburnum opulus L. Sonetta variety	No inoculation	33.8	49.5	
	Inoculation	35.3	51.5	2
Viburnum opulus L. Horikhova clone	No inoculation	52.7	81.5	
	Inoculation	50.4	78.5	-3
Viburnum opulus L. Osinnia variety	No inoculation	21.6	42.8	
	Inoculation	23.5	39.5	-3.3
Viburnum opulus L. Plododekorna variety	No inoculation	18.4	63.5	
	Inoculation	17.5	68.9	5.4
Viburnum opulus L. Yaroslavna variety	No inoculation	49.9	61.8	
	Inoculation	35.5	52.6	-9.2
Viburnum opulus L. Omriana variety	No inoculation	30.4	63.3	
	Inoculation	27.7	60.2	-3.1
Viburnum opulus L. Eskimo variety	No inoculation	15.3	39.1	
	Inoculation	16.5	31.2	-7.9
Viburnum opulus L. Kralechka variety	No inoculation	39.5	54.7	
	Inoculation	32.5	49.0	-5.7
Viburnum opulus Roseum	No inoculation	23.7	58.5	
	Inoculation	18.5	31.7	-26.8

***Source**: compiled by the authors*

As noted, the occurrence of powdery mildew was noted only on plants of the species *Viburnum opulus* L. It was found that for varieties Sonetta and Plododekorna on the variants of inoculation, the growth of annual shoots was not inhibited. For the varieties Elina, Anya, Horikhova, Osinnia, Omriana and Kralechka, the inoculation variant showed a decrease in the length of the annual shoot by 2.2-5.7 cm compared to the control (without inoculation). However, the greatest effect of powdery mildew on shoot growth was for common viburnum cultivars Yaroslavna and *Viburnum opulus* Roseum, 9.2 and 26.8 cm, respectively.

The types of fertilisers and methods of their application were determined to have a significant impact on the manifestation of the powdery mildew pathogen. In particular, nitrogen fertilisers (in the form of ammonium, potassium, or calcium nitrate) should be applied in early spring and avoided in late summer to limit the growth and development of annual shoots, whose tissue is more susceptible to fungal infection. It has been shown that pruning measures to remove excess and damaged shoots in the summer can improve lighting and air circulation in the basal part of viburnum plants, intensify the growth of permanent shoots and form the desired type of bush (tree).

During viburnum planting, it is necessary to ensure sufficient distance between plants and to thin out individual bushes (trees) every spring to ensure air circulation in the ground part. In the irrigation system of mother and cuttings nurseries, and hybrid nurseries, if necessary, it is advisable to use only drip irrigation, avoid water getting on the leaves, and prevent contact of the ground part of viburnum plants with wet soil. It is recommended to use cultural control: fruit change and selection of resistant varieties. It is recommended to alternate resistant varieties with those that are more or less susceptible to powdery mildew. Summarizing the above, we can say that measures for early diagnosis of viburnum plants for fungal diseases, timely preventive measures, selection of resistant varieties adapted to a particular area, compliance with the elements of agricultural technology, control in the nursery, etc. will

reduce the manifestation of powdery mildew in the orchards of the crop under study.

DISCUSSION

Powdery mildew, which is an obligate biotrophic phytopathogen, forms mycelium (fungal filaments), which, unlike the perinosporosis pathogen, which functions on the lower part of the leaf, grows only on the leaf surface, spreading haustoria, or root-like structures, into the epidermal (upper) cells of the plant without affecting the tissue. The downy mildew fungus overwinters on plant debris in the form of cleistothecia or mycelium and in spring the cleistothecia form spores that are transferred to the host plant by rain, wind or insects (Host and Disease Descriptions, 2023).

As noted by V. Heluta (2022), the obligate fungus of powdery mildew grows as thin layers of mycelium on the surface of infected plant organs, feeding on epidermal cell products using suckers. The formed asexual spores, known as conidia, are formed in chains on the affected surface of the plant. The presence of mycelium and conidia on the affected surface, such as a leaf, looks like a white or grey powdery mass. As noted by H.D. Shin *et al.* (2019), the spores are transported by abiotic environmental factors to healthy areas of the plant or other plants.

J. Drago (2023) notes that when the conidial stage season ends, the downy mildew produces spherical fruiting bodies (multicellular structure) in the form of small black or dark brown specks called cleistothecia, the overwintering stage of the pathogen that accumulates on infected plant parts or plant debris under the bush (tree). In May-June, under favourable weather conditions, sexual spores - ascospores of fruiting bodies – cause new infections and are the next cycle of the disease.

T. Moskalets *et al.* (2023) reported that if in autumn powdery mildew spores get on generative buds, new inflorescences form late and are often distorted, which further determines the decorative effect or productivity of viburnum plants, Since the development of powdery mildew has significant fluctuations, which is expressed in changes in the coverage of the pathogen's habitats and in the intensity of plant damage, which affects the condition of plants, it is appropriate to have information about the pathological process, which includes five phases: 1 – the phase of appearance on the plant, pathogen transmission, germination and growth of the infectious agent; 2 – the phase of rooting in plant tissue under certain environmental conditions; 3 – the phase of pathogen incubation, growth, and reproduction; 4 – the beginning of the disease development, accompanied by morphophysiological changes, symptoms, and sporulation; 5 – the phase of separation from the host plant and spread of the infectious agent in the area of diseased and still healthy plants.

Therefore, understanding the disease life cycle is vital for the care and protection of cultivated plants, with conidial sporulation forming in spring on shoots affected from the previous year being the primary infection, and conidia forming on primary affected plant organs spreading throughout the garden, getting on young leaves and causing a secondary infection, the manifestation of which was noted after flowering (June) more than once during the growing season, which ends with the formation of bags and bags of spores as a baggy stage of the fungus to mature fruiting bodies – cleistothecia, which overwinter in a closed form on the shoots.

M. Bradshaw *et al.* (2021) believe that an improved understanding of the phylogeny and taxonomy of the powdery mildew pathogen is also of great ecological and applied importance. Identification of the powdery mildew pathogen allows for the analysis of the fungus morphology and also reveals the co-evolutionary relationship between powdery mildew species and host plants. M. Bradshaw *et al.* (2020), after studying the phylogeny and systematics of powdery mildew of viburnum species, noted that the fungus *Microsphaera hedwigii* or *Microsphaera viburni*, which affects common viburnum, should be reduced to synonyms, two new species, *Erysiphe viburniphila* and *Erysiphe pseudoviburni*, previously identified as *Erysiphe viburni* (including *Erysiphe hedwigii*), infect plants of *Viburnum edule*, *V. tinus*, *V. odoratissimum* var. *awabuki*, and *V. sieboldii* cultivated in North American, East Asian and European, areas.

T. Shirouzu*et al.* (2022) note that another species of powdery mildew *Erysiphe viburni-plicati Meeboon*& Takam affects plants of *V. plicatum* Thumb. in particular plants of *V. plicatum* Thumb. var. *plicatum* f. *glabrum* (Koidz. ex Nakai) Rehder and, according to molecular studies, significantly differs from other powdery mildew pathogens – *Erysiphe miranda*, *E. shinanoensis*, *E. hedwigii* and *E. viburni* – in the presence of one ascus per chasmothecia and fewer chasmothecial appendages (up to 5 per chasmothecia). The fungus *Erysiphe hedwigii* affects plants of *V. arrogantum*. The pathogen *Erysiphe pseudoviburni* affects plants of the *V. sieboldii* species, *Erysiphe viburni – V. edule*, *Erysiphe viburni* affects *V. opulus*. And the species of powdery mildew fungi *Erysiphe hedwigii* and *Erysiphe viburni*, infect the same host plant (Heiskanen & Valkonen, 2021).

However, as noted by M. Liu *et al.* (2021), genetic analysis is required to confirm the morphometry of powdery mildew. Since powdery mildew is difficult to detect at an early stage, as its signs and symptoms are often invisible. At the initial stages, the powdery mildew pathogen affects only a small percentage of the total leaf area of viburnum plants and creates a slight stress that does not affect the normal growth and development of the plants under study. In particular, as noted by R. Sanchez-Lucas *et al.* (2023), powdery mildew-affected plants have low photosynthetic productivity.

Laurel viburnum (*V. tinus* L.) plants are severely affected by powdery mildew (George, 2022). Canadian viburnum (*V. lentago*) is also susceptible to powdery

mildew, particularly when submerged, without pruning measures and in partial shade. *V. buldeneum* plants are also susceptible to powdery mildew (Backyard Garden Information Source, 2023). *V. farreri*, unlike plum viburnum and others, is known for its resistance to diseases, including powdery mildew (Sanchez, 2018).

On ornamental crops, powdery mildew spoils their appearance and destroys the marketability of flowers (VseRoste, 2023). Natural hybridisation, heterokaryosis and mutations lead to the emergence of new races of pathogens over time, which overcomes plant resistance and leads to epiphytoties. The large areas occupied by a particular variety contribute to the emergence of aggressive races, their infectious onset and spread increase rapidly, and there is a need to replace the variety with a more resistant one. Plant resistance is one of the best ways to combat plant diseases (Plant Disease Resistance, 2022). K. Wang *et al.* (2023) argue that the implementation of scientific programmes on the implementation of classical, marker-assisted breeding, biotechnology, and genetic engineering methodologies remains an alternative in the fight against diseases.

Therefore, as noted by Q. Li *et al.* (2020), the search for source material and the creation of new genotypes in the development of long-term resistance with a broad spectrum of action is an economical and environmentally friendly approach to the control of crop diseases for sustainable agricultural production. Thus, studying the signs of disease manifestation and implementing a strategy for the selection, creation, and introduction of new varieties (forms, cultivars) of viburnum will reduce the manifestation of phytopathogens in the orchards of the crop under study.

CONCLUSIONS

As a result of phytopathological studies of plants of the genus *Viburnum* L. conducted during 2018-2021 in the collection nursery of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (northern part of the Forest-Steppe of Ukraine) for the manifestation of fungal pathogens, it was found that the powdery mildew pathogen with the highest degree of damage of 3 points was detected on plants of certain varieties of common viburnum (Plododekorna, Yaroslavna, Kralechka, Eskimo, etc.) only in 2018-2019, with the coefficient of powdery mildew damage ranging from 1.1 to 2.5. Viburnum variants *Viburnum rhytidophyllum* Hemsl., *Viburnum* × *carlcephalum* Cayuga variety), *Viburnum lantana var. Aureum*, *Viburnum lantana* var. *Variegatum*, *Viburnum* × *rhytidophylloides*, *Viburnum* × *burkwoodii* (Mohawk variety) × *Viburnum sargentii* Koehne (Onondaga variety) were not affected by powdery mildew.

By creating a stimulating infectious background, it was possible to distinguish varieties (forms) of Viburnum vulgare by the degree of damage and resistance and to formulate recommendations for production. According to the results of the evaluation, the following varieties (forms) of common viburnum were classified as highly resistant: Anya, Elina, Sonetta, Horikhova, Autumn and Plododekorna, resistant: Yaroslavna, Omriana and Eskimo, and medium resistant: *Viburnum opulus* Roseum, *Viburnum opulus* L., form Kralechka. It was found that under artificial inoculation with spores of the common viburnum powdery mildew fungus (*Microsphaera viburni* (Duby) S. Blumer), no damage to plants of other species of the genus *Viburnum* L. was observed, which confirms the data of other scientists on the species specificity of powdery mildew pathogens.

A promising area for further research is the involvement of non-susceptible or low-susceptible species and varieties of the genus *Viburnum* L. to powdery mildew in the breeding and production processes in the system of ornamental and fruit horticulture, which will prevent the occurrence of this disease.

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CONFLICT OF INTEREST

None.

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Microsphaera viburni (Duby) S. Blumer: еколого-біологічні особливості, способи контролю в системі декоративного та плодового садівництва

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Анотація. Актуальність даної теми полягає в необхідності порівняльного оцінювання різних видів калини в стійкості проти борошнистої роси, хвороби, яка гальмує фізіологічні процеси в рослин, негативно впливаючи на ріст, розвиток і врожайність та декоративність. Мета досліджень – вивчення біоекологічних особливостей прояву *Microsphaera viburni* (Duby) S. Blumer і розроблення заходів щодо контролю борошнистої роси у садах калини. Під час дослідження були використані методи та методики проведення фенології, створення провокаційних фонів, оцінювання рівня ураження наземної частини, встановлення ступеня ураження і стійкості рослин калини. Надано рекомендації щодо уникнення або зменшення ризиків появу борошнистої роси в садах калини, які передбачають. З'ясовано, що азотні добрива доречно вносити рано навесні і уникаючи їх внесенню наприкінці літа, з метою обмеженняросту і розвитку однорічних пагонів, тканина яких є більш чутливою до збудника борошнистої роси. Досліджено, що проведення формуючої, регулюючої і санітарної обрізки рано навесні дозволяє покращити освітлення і циркуляцію повітря в базальній частині рослин калини, інтенсифікувати ріст постійних пагонів та сформувати бажаний тип куща (деревця) в системі плодового чи декоративного садівництва. Доведено, що в умовах Північного Лісостепу України в системі плодового садівництва доцільно вирощувати високостійкі (Аня, Осіння, Еліна, Омріяна) і стійкі (Кралечка, Плододекорна, Сонетта, Горіхова, Ярославна) проти борошнистої росисорти (форми) калини звичайної Інституту садівництва Національної академії аграрних наук України. Рекомендовано для декоративного садівництва використовувати стійкі і середньостійкі сорти калини звичайної карликової (*Viburnum opulus* L.) Ескімо і калини звичайної Розеум (*Viburnum opulus* Roseum). Практична цінність полягала в доведенні, що борошниста роса калини звичайної при штучній інокуляції не уражує інші види роду *Viburnum* L.; підтверджено, що сприйнятливість рослин калини до *Microsphaera viburni* (Duby) S. Blumer можна істотно знижувати за рахунок малосприйнятливих і резистентних видів і сортів роду *Viburnum* L. та своєчасних *агротехнічних заходів*

Ключові слова: види (сорти, форми) роду *Viburnum* L.; борошниста роса; грибна хвороба; оцінка видів; заходи контролю