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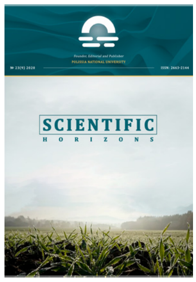

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Spread and Harmfulness of Infectious Diseases of the Main Forest-Forming Species in Zhytomyr Polissia of Ukraine

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Abstract. Given the multifunctional role of forests, there is an urgent need in forming biologically stable and productive tree stands to obtain the maximum ecological and economic effect for Ukraine in present-day conditions. Therefore, studies of the species composition, spread, pathogenic action, and harmful effects of pathogens of infectious diseases of the main forest-forming species in Zhytomyr Polissia of Ukraine allow designing a real phytosanitary situation that will take place in the forests in the coming years and developing timely measures to limit the spread of pathological phenomena, which is the relevant research vector. The purpose of this study is to assess the current phytosanitary state of the forests of the surveyed region and identify abiotic and biotic factors that most contribute to weakening and degradation of forest tree species. This paper uses classical forest inventory and phytopathological methods to establish the general phytosanitary condition of the surveyed forests. Special mycological and microbiological methods were also involved to investigate the aetiology and pathogenesis of infectious diseases pathogens. Currently, the comprehensive sanitary condition of the forests of Zhytomyr Oblast can be described as satisfactory. However, every year there is a slow but steady increase in the dieback of forest areas, specifically the main forest-forming species – pine, oak, ash, and birch. During the examinations, the authors noted typical symptoms of bacteriosis (bacterial dropsy), necrosis (dieback), vascular (graphiosis, tracheomycosis) and other diseases of contradictory aetiology (transverse cancer, dieback), as well as fruit bodies of aphilophoroid macromycetes, which are the causes of stem (pine polypore, birch polypore, false oak polypore, etc.) and root (heterobasidion perennial, honey mushroom) rot were noted. Monitoring of the phytosanitary condition with the allocation of predictors of degradation of forest stands will further allow forming a "global map of plant resilience and sensitivity" for analysis of phytosanitary risk and rapid and rational decision-making on forest protection measures

Keywords: aetiology, pathogenesis, wood-destroying fungi, bacteriosis, common pine, common oak, phytosanitary condition

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INTRODUCTION

The general digression of weakened woodlands is an irreversible natural process that has recently been reinforced by the impact of human civilization on forests and dramatic global climate change. The main priority task for forestry workers is to form biologically stable tree stands while preserving healthy trees and simultaneously strengthening their natural immunity.

Various pests and pathogens of infectious pathologies are constantly recorded in the forests of many states. There is no doubt that the forest is a powerful "food resource" for pathogens (Andreieva *et al.*, 2018). Thus, it is known that forests around the world are critical habitats in terms of the biological diversity they contain and in terms of the ecological functions they perform. Environmental services of forests are also numerous. Forests regulate the local and global climate, mitigate weather events, regulate the hydrological cycle, protect watersheds and their vegetation, water flows and soils. The need to understand the values found in forests stems from the estimated rate of loss of forest area and, consequently, biological diversity. Currently, it is assumed that the rate of loss is thousands of species per year (Pearce & Pearce, 2001).

Presently, almost the entire Northern Hemisphere is affected by global warming, which results in the drainage of water bodies and subsequently the death of arboreal plants. On the territory of Ukraine (as of 01.01.2020), the total area of forest dieback exceeds 420 thousand hectares. Of them, stands of *Pinus sylvestris* L. – 222 thousand ha, *Quercus robur* L. – over 100 thousand ha, *Picea abies* (L.) Karst. – about 27 thousand hectares, other types of arboreal plants – 64 thousand hectares. There are alarming reports of new foci of forest dieback involving *P. sylvestris* on the territory of Ukraine by secondary pests, namely *Ips acuminatus* and *Ips sexdentatus* (Meshkova *et al.*, 2018).

Over the past decades, there have been waves of mass drying of most species of arboreal plants – common pine, common oak, European silver fir, European spruce, common ash, silver birch, etc. Certain assumptions have been made about the causes of this phenomenon, this specifically refers to climate change (Zhang *et al.*, 2018) and hydrothermal stress (Christopoulou *et al.*, 2022; Rodriguez-Vallejo *et al.*, 2021), invasive infectious agents and pests (Goychuk *et al.*, 2020), natural biotope changes (Kobal *et al.*, 2015), forestry activities (Meshkova *et al.*, 2018) and polyfactorial causes (Elling *et al.*, 2009).

Researchers name the following infectious agents as the main causes of oak dieback: *Phytophthora ramorum* (Grünwald *et al.*, 2008), *Ceratocystis fagacearum* (Bretz.) Hunt. (Juzwik *et al.*, 2008), *Ophiostoma roboris* Georgescu et Teodoru (Selochnik *et al.*, 2000), *Lelliottia nimipressuralis* (Carter 1945) Brady *et al.* 2013 (Kulbanska *et al.*, 2021).

The dieback of common pine trees in the world is mainly associated with diseases of infectious aetiology (Wyka *et al.*, 2018), usually caused by *Heterobasidion annosum* ((Fries) Bref.) (Zhezhkun & Porohnyach, 2020), *Fusarium circinatum* (Elvira-Recuenco *et al.*, 2020) and *Dothistroma needle* (Bulman *et al.*, 2008), as well as xylotrophic insects – *Ips acuminatus* Gyll. (Porohnyach, 2018) and phytopathogenic nematodes – *Bursaphelenchus xylophilus* (Vicente *et al.*, 2012; Yusuf *et al.*, 2021; Zhen *et al.*, 2010; Roques *et al.*, 2015).

Degradation of European silver fir is associated with harmful activity of phytopathogenic fungi – *Heterobasidion annosum* (Fr.) Bref. s.l. and plants of the genus *Viscum* L. (Oliva & Colinas, 2010), *Phytophthora citricola* Sawada (Orlikowski *et al.*, 2004); phytopathogenic bacteria – *Lelliottia nimipressuralis* (Carter 1945) Brady *et al.* 2013) (Kulbanska *et al.*, 2022); insects – *Polygraphus proximus* Blandford (Kharuk, 2017) and high sensitivity to SO_2 emissions (Elling *et al.*, 2009).

The weakening and death of silver birch is caused by the mass spread within the range of a dangerous disease of bacterial origin – bacterial dropsy (causing agent – *Lelliottia nimipressuralis* (Carter 1945) Brenner *et al.*, 1988) (Goychuk *et al.*, 2020). There is also information about mushroom (Pasonen *et al.*, 2004; Nguyen *et al.*, 2017) and viral (Rumbou *et al.*, 2018) diseases that considerably affect the phytosanitary condition of birch.

Pathology of common ash is closely related to various causes of parasitic and non-parasitic origin. The main infectious agents that lead to ash dieback are fungi (Chandelier *et al.*, 2016; Lygis *et al.*, 2005; Langer, 2017) (*Hymenoscyphus fraxineus*, which is present in Ukraine) (Davydenko *et al.*, 2013), bacteria (*Pseudomonas syringae* pv. *savastanoi*, which causes ash tuberculosis and is registered in the forests of Ukraine) (Goychuk *et al.*, 2020), nematodes (Ryss & Polyanina, 2018), mycoplasmosis (Bricker & Stutz, 2004), representatives of harmful entomofauna (Davydenko & Meshkova, 2017; Korda *et al.*, 2019), as well as the influence of climatic and soil-hydrological factors (Goberville *et al.*, 2016).

Currently, there is a great need for a global map of arboreal plant resistance for phytosanitary risk analysis (Magarey *et al.*, 2008). The creation of a dieback forecast based on the FORKOME simulation computer model allowed estimating the bioclimatic effects on the growth, stability, survival, and death of spruce and other arboreal plant species (Kozak & Parpan, 2019).

Thus, given the catastrophic extent of degradation that occurs with almost all types of arboreal plants, the disappearance of forests is a complex socio-economic, cultural, and political event. It is a mistake to attribute forest decline to a simple causal relationship, or to assume that the relationship will stay unchanged over time (Contreras-Hermosilla, 2000).

The purpose of this study is to investigate the aetiology and features of symptoms of infectious diseases of the main forest-forming species in the forest coenoses of Zhytomyr Polessia of Ukraine, which will allow for high-quality early diagnosis of pathologies and prompt and rational implementation of forest protection measures.

MATERIALS AND METHODS

The spread and harmfulness of infectious diseases of the main forest-forming species of arboreal plants was investigated in the forests of Zhytomyr Regional Department of Forestry and Hunting (Zhytomyr RDFH). Statistical materials of the State Specialized Forest Protection Enterprise "Vinnytsialisozahyst" (SSFPE "Vinnytsialisozakhyst") and the Department of Forestry, Forest Security and Protection of Zhytomyr RDFH were used to figure out the volume of dieback in tree stands. Reconnaissance and detailed surveys were performed in forest stands with signs of weakening and drying of arboreal plants. In the surveyed forest areas, forest pathological routes were laid, covering tree stands involving common pine, common oak, silver birch, and common ash of different age classes. Detailed studies were performed on permanent and temporary trial areas in SE "Yemilchynske Forestry", SE "Korostenske Forest Hunting Range", SE "Horodnytske Forestry", SE "Zhytomyrske Forestry", SE "Korostyshyvske Forestry", SE "Malynske Forestry", SE "Ovrutske Forestry" and SE "Slovechanske Forestry" according to generally accepted methods and requirements of SOU 02.02-37-476:2006 "Experimental plots of forest management. Method of laying" SOU 02.02-37-476, 2006 (Forest inventory, 2007). 9 model trees were cut down for research. More than 123 samples (individual tissues and organs) of arboreal plants with visual signs of infectious diseases (trees of the II and III categories of sanitary condition) were selected for mycological and microbiological studies, which were performed per standard protocols and according to Patyka *et al.* (2017). The category of sanitary condition of trees was figured out according to the current requirements (Sanitary rules in the forests of Ukraine, 2020). Based on the results of accounting, the average category (index) of the sanitary condition of the tree stand was calculated. The sanitary condition of coenoses was estimated using the weighted average index of the sanitary condition of the tree stand (I.s.), calculated according to the following the formula:

$$I_s = \frac{\sum k_i n_i}{N}; \qquad (1)$$

where: I_s is the phytosanitary index; $k_1 - k_6$ is the category of phytosanitary condition of woody plants; n_i is the total number of arboreal plants in the context of a certain category of tree stand; N is the total number of all trees. Special macroscopic, microscopic, and mycological research methods were used to figure out the species composition of infectious disease pathogens. The collected phytopathological material was identified directly using light microscopy methods in the laboratory. To identify phytopathogenic macromycetes, measures were taken to promote abundant sporulation. For this purpose, the affected parts of arboreal plants were placed in wet chambers of Petri dishes and cultivated for 7-10 days at 25°C.

Specimens of tree destroyers were identified and examined in laboratories using an MBS-9 binocular magnifier and an MBI-3 microscope. Macroscopic structures were studied at microscope magnifications from ×8 to ×100, while microstructure studies were performed on temporary micro-preparations (microscope eyepiece ×15, lenses ×8, ×20, ×40).

Latin names of higher plant species are given according to generally accepted methods (The Plant List, 2022; Index Fungorum, 2022; List of Prokaryotic names..., 2022). Calculation and statistical calculations of the obtained results were performed using *Microsoft Excel* software.

RESULTS AND DISCUSSION

According to the results obtained upon monitoring the sanitary condition of the region under study, it was found that the tree stands of Zhytomyr RDFH involving the main forest-forming species are weakened in phytosanitary condition and medium-damaged in the degree of degradation.

The total area of spread of infectious pathologies in the stands of Zhytomyr RDFH in 2021 covered 4961.7 ha and practically stayed unchanged compared to 2020 (4760.3 ha). The main reason for the mass weakening of the surveyed tree stands are pathogens of stem rot, namely pine polypore (affected area 658.7 ha in 2021 and 312.4 ha in 2020) and birch polypore (affected area 445.6 ha in 2021 and 226.0 ha in 2020), as well as pathogens of root rot, mainly Heterobasidion annosum (affected area 2233.5 ha in 2021 and 2146.6 ha in 2020) and honey fungus (affected area 672.6 ha in 2021 and 811.5 ha in 2020).

For this reason, the largest area of damage (for the last 5 years of observations) of the surveyed forests was recorded in 2019 and amounts to 5548.3 ha, which significantly exceeds the indicators of 2018 and 2017, when the foci of the spread of infectious diseases covered an area of 3913.9 ha and 2301.0 ha, respectively (Fig. 1).

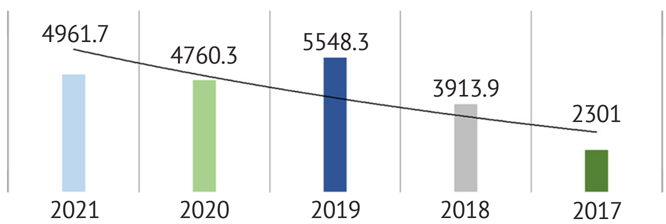

***Figure 1.** Area of distribution of infectious pathologies in the stands of Zhytomyr RDFH, ha*
***Source:** Statistical data of SSFPE "Vinnytsialisozakhyst" (2017-2021)*

Presently, the leading infectious agent that weakens and leads to the death of the surveyed forests is Heterobasidion annosum, the affected area of which stays almost unchanged from year to year (despite constant measures to limit its spread). Thus, the focus of *H. annosum* in 2019 was 2312.9 ha, in 2018 – 2094.1 ha, and in 2017 – 1338.5 ha. Other infectious agents (bacterial dropsy and dieback) that have now spread to smaller areas of the surveyed forests should also be identified, but by their nature, namely virulence and aggressiveness, as well as the ability to form mass epiphytotics, may soon become the main cause of forest degradation.

The species composition of infectious pathologies in the stands of Zhytomyr RDFH and types of woody plants with symptoms of damage are presented in Table 1. In the composition of the mycobiota of the forest coenoses under study, a significant quantitative and qualitative composition is the fraction of aphilophoroid macromycetes (wood destroyers), namely basidiomycetes-xylotrophs. Therewith, the role of the latter in forest ecosystems is ambiguous. On the one hand, as pathogens of rot (root and stem), aphilophoroid macromycetes can have a harmful effect on the sanitary condition. On the other hand, saprotrophic species of basidiomycetes-xylotrophs are destructors of tree mortality; fruit bodies and mycelium of aphilophoroid representatives are an essential component in the trophic chains of many insect species, and certain types of such fungi can be used as indicators of forests unchanged by anthropogenic activity (Methodology, 2018).

***Table 1**. Species composition of infectious pathologies in tree stands of Zhytomyr RDFH*

Latin name (According to Index Fungorum and List of Prokaryotic names with Standing in Nomenclature)	**Type of arboreal plant on which the pathogen is detected (According to The Plant List)**
Pathogens of stem rot	
Phellinus pini (Brot.) Pilát 1941	*Pinus sylvestris L.*
Fomitopsis betulina (Bull.) B.K. Cui, M.L. Han & Y.C. Dai 2016	*Betula pendula Roth.*
Phellinus robustus (P. Karst.) Bourdot & Galzin 1928	*Quercus robur L.*
Phellinus igniarius (L.) Quél. 1886	*B. pendula*
Laetiporus sulphureus (Bull.) Murrill 1920	*Q. robur, Fraxinus excelsior L.*
Fomes fomentarius (L.) Fr. 1849	*Q. robur, B. pendula, F. excelsior*
Fomitopsis pinicola (Sw.) P. Karst. 1881	*P. sylvestris, Q. robur, B. pendula, F. excelsior*
Trichaptum fuscoviolaceum (Ehrenb.) Ryvarden 1972	*P. sylvestris*
Botryobasidium subcoronatum (Höhn. & Litsch.) Donk 1931	*P. sylvestris*
Stereum hirsutum (Willd.) Pers. 1800	*Q. robur*
Chondrostereum purpureum (Pers.) Pouzar 1959	*B. pendula*
Exidia nigricans (With.) P. Roberts 2009	*B. pendula*
Pathogens of root rot	
Heterobasidion annosum (Fr.) Bref. 1888	*P. sylvestris, F. excelsior*
Armillaria mellea (Vahl) P. Kumm. 1871	*Q. robur, P. sylvestris*
Ganoderma applanatum (Pers.) Pat. 1887	*F. excelsior*
Bacterioses	
Lelliottia nimipressuralis (Carter 1945) Brady et al. 2013	*B. pendula*, *Q. robur*
Necroses	
Hymenoscyphus pseudoalbidus Queloz, Grünig, Berndt, T. Kowalski, T.N. Sieber & Holdenr. 2011	*F. excelsior*
Vascular diseases	
Ophiostoma roboris Georgescu & Teodoru 1948	*Q. robur*
Ophiostoma ulmi (Buisman) Nannf. 1934	*Ulmus glabra* Huds.
Diseases of unknown aetiology	
No pathogen detected	*P. sylvestris*
No pathogen detected	*Q. robur*

Source: *Statistical data of SSFPE "Vinnytsialisozakhyst" (2017-2021)*

The total area of damage to forest stands of Zhytomyr RDFH by pathogens of stem and root rot in 2021 was 4961.7 ha, in 2020 – 4760.3 ha, in 2019 – 5548.3 ha (the highest for the surveyed period), in 2018 – 3913.9 ha, in 2017 – 2301.0 ha (the lowest for the surveyed period). Detailed information on the spread of particular types of pathogens is presented in Table 2.

Table 2. *Areas of distribution of infectious pathologies in the tree stands of Zhytomyr RDFH*

Phytopathogen	Year and distribution area, ha				
	2021	2020	2019	2018	2017
Of which, pathogens of stem rot:	*1881.4*	*942.6*	*1499.3*	*924.5*	*355.4*
P. pini	658.7	312.4	488.3	185.3	118.5
F. betulina	445.6	226.0	309.6	162.6	44.8
P. robustus	200.1	315.5	196.1	309.3	0.0
P. tremulae	12.5	0.0	60.9	5.7	10.0
L. sulphureus	165.8	0.0	150.3	74.2	123.9
F. fomentarius	398.7	88.7	294.1	187.4	58.2
Of which, pathogens of root rot:	*2906.1*	*2981.2*	*3725.2*	*2427.0*	*1647.2*
H. annosum	2233.5	2146.6	2312.9	2094.1	1338.5
A. mellea	672.6	811.5	1412.3	332.9	299.0
G. applanatum	0.0	23.1	0.0	0.0	9.7
Bacterial dropsy	148.0	394.3	106.5	261.8	0.0
Transverse cancer	10.0	125.2	89.5	174.4	190.2
H. pseudoalbidus	16.2	0.0	0.0	0.0	0.0
Vascular mycosis (tracheomycosis)	0.0	262.7	62.9	0.6	108.2
Dutch elm disease	0.0	0.0	2.0	0.0	0.0
Dieback of unknown aetiology	0.0	54.3	62.9	125.6	0.0
Total	**4961.7**	**4760.3**	**5548.3**	**3913.9**	**2301.0**

Source: *Statistical data of SSFPE "Vinnytsialisozakhyst" (2017–2021)*

The structure of the species composition of pathologies in the areas under study in 2021 is presented in Figure 2. During the conducted studies, it was found that a larger number of species of aphilophoroid macromycetes, in relation to tree species, have an unequal degree of trophic specialization. Most of the identified aphilophoroid macromycetes belong to xylosaprotrophs that develop on dry and fallen wood. The largest number of species is registered on common pine, common oak, silver birch, and common ash. Thus, aphilophoroid macromycetes are characterized by specialization in substrate-forming tree species (so-called ecosystem engineers).

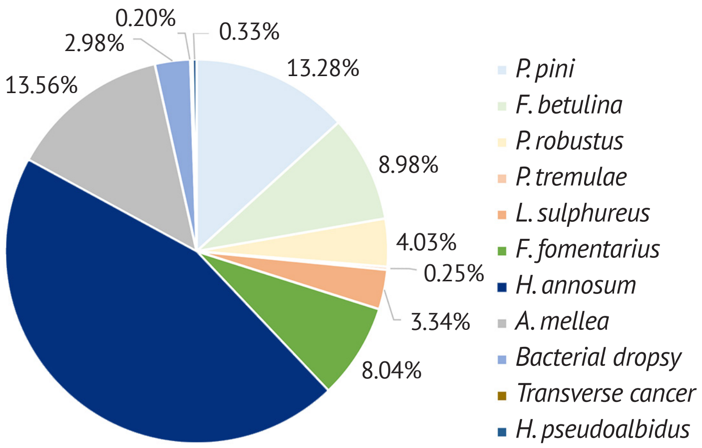

Figure 2. *Area of distribution of infectious pathologies in the stands of Zhytomyr RDFH, ha*
Source: *Statistical data of SSFPE "Vinnytsialisozakhyst" (2017-2021)*

6 species of aphilophoroid macromycetes were detected and identified on common pine. Thus, on the roots, on the lower parts of trunks, on the stumps and trunks of living trees, *Heterobasidion annosum* develops, which causes variegated central rot of wood and roots and is one of the most dangerous pathogens of mycotic diseases and mass dieback of coniferous forests (Fig. 3). H. annosum massively affects pine stands and leads to the loss of a considerable amount of wood, significantly weakens the protective properties of forests. It is established that this pathogen causes the gradual death of arboreal plants, where over time dense stands turn into woodlands. In weakened plants, resin pressure becomes less because it is a mechanical and physiological barrier against the harmful effects of stem pests. This phenomenon is usually typical for weakened trees that grow in a state of physiological stress.

Figure 3*. Destruction of the root system and common pine fallout from the tree stand due to the influence of wood-destroying fungi*

Source: *photographed by the authors*

On the growing trunks of common pine trees, the spread of *Phellinus pini* was recorded. On weakened, dead and fallen trunks, fruit bodies of *Fomitopsis pinicola*, *Trichaptum fuscoviolaceum* and *Botryobasidium subcoronatum* are common.

5 species of aphilophoroid macromycetes were detected and identified on common oak: on the trunks and branches of living trees – *Phellinus robustus*, *Laetiporus sulphureus* and *Fomes fomentarius* (Fig. 4). A group of fruiting bodies of *Stereum hirsutum* and single fruiting bodies of *Fomitopsis pinicola* were also noted on dying and dead trunks.

Figure 4*. Basidiomas of Fomes fomentarius and Phellinus robustus*

Source: *photographed by the authors*

The most common was P. robustus (affected area in 2021 was 200.1 ha, in 2020 – 315.5 ha, in 2019 – 196.1 ha, in 2018 – 309.3 ha, in 2017 – not registered), which causes the destruction of the core part of the wood, subsequently penetrates into sapwood, cambium, and bast. As a result, dents form on the trunk, and later – cancer wounds.

The overall health of common oak is also substantially affected by the spread of transverse oak cancer (a disease of unknown aetiology). Pathology can affect trunks with thick branches, where it leads to the formation of cancerous growths. At the beginning of the disease, small tumourlike thickenings are formed, which later grow. An important sign is the presence of a transverse crack, which often exposes the wood. The trunk becomes noticeably deformed and the growth of the tree is delayed. It is customary to distinguish between 3 forms of transverse cancer: open, transient, and closed. This disease is moderate in severity, since it does not kill trees (i.e., it does not cause environmental damage), but only reduces the yield of commercial varieties (economic damage to the farm). In 2021, a significant reduction in the area affected by transverse cancer was found

(10.0 hectares were affected). Meanwhile, in 2020 this area reached 125.2 hectares, in 2019 – 89.5 hectares, in 2018 – 174.4 hectares, in 2017 – 190.2 hectares. It was found that the intensity of oak damage by transverse cancer mainly depends on several environmental and forestry factors. Thus, as a rule, in pure oak stands, the intensity of damage is higher than in mixed ones, which is confirmed during reconnaissance and detailed surveys. Various mechanical damages and excessive overgrowth of young stands contribute to the progression of pathology. During the examinations, typical symptoms of bacterial dropsy of oak were noted (Fig. 5). The primary symptoms of the lesion are formed on oak trunks and have the appearance of small (1-2 mm) purple, deep brown spots located under the secondary integumentary tissues. Under favourable conditions for the development of bacteria, the disease progresses, the tree bark becomes deep brown, and a depression is formed.

Figure 5. *Typical symptoms of the pathogenesis of transverse cancer (left) and bacterial dropsy (right) recorded on common oak*

Source: *photographed by the authors*

On young oak plants (up to 10 years old), black convex spots first appear. Often in early spring or late autumn, a brown exudate that turns black in the air appears. Under the experimental conditions, the release of bacterial fluid is most often observed in June and lasts for a short time. Diseased oaks have dry tops, fall behind in growth, bush profusely, many buds appear on them, and subsequently water shoots. If the disease develops for an extended period, then the resulting necrosis looks like a step cancer of deciduous plants. With the development of bacterial dropsy of oak, the growth of the focus of infection is not as intense as in cancer pathologies. Internal signs of bacteriosis are described by the presence of deep brown wet wood on the trunk and the presence of a sharp sour smell. On the cross-section, the wet wood area has a regular rounded shape, impregnated with a liquid of a viscous consistency that has an alkaline reaction. Within the surveyed forest stands, bacterial dropsy most intensively affects oaks of ripening and ripe age in various mixing schemes, as well as oaks in clean plantings. The highest percentage of damage is noted on low landforms.

According to the conducted observations in all age categories of stands (involving oak), the greatest danger is vascular mycosis, the spread of which was periodically noted within the surveyed forest stands (affected area: 2021 – 0 ha, 2020 – 262.7 ha, 2019 – 62.9 ha, 2018 – 0.6 ha, 2017 – 108.2 ha). Thus, in the conditions of forestry enterprises of Zhytomyr RDFH, the chronic form of the disease prevails. External signs of oak vascular mycosis damage on mature trees appeared in mid or late summer, while yellowing and leaf fall on individual branches of diseased trees were observed (as a result of the active development of the disease in the spring and summer period). The bark on such branches lost turgor, and the wood was dehydrated. In spring, partial or complete death of individual branches was noticed on the affected trees, buds on them bloomed late or did not develop at all. The leaves that formed on weakly affected branches were smaller. Subsequent stages of the disease were characterized by openness of crown, dryness, formation of water shoots on the trunk and gradual dieback of the tree. An internal sign of oak disease with vascular mycosis is browning of wood elements under the influence of a pathogen (branches, trunk, root system, growth). On the longitudinal section of the branches and the trunk, the water supply elements (large vessels) affected by the pathogen acquire a brown colour with different shades and have the appearance of intermittent lines-strands. Dark solid or fragmentary rings or semi-rings were recorded on a cross-section of the infected tree. This is the result of damage by fungal toxins that cause the death of living parenchymal cells, the formation of humic-like substances that clog the lumen of blood vessels. Often affected trees (to a weak and medium degree with drying branches from 10 to 50%) in subsequent years gradually restore the crown due to water shoots and can remain viable for many years.

Vascular mycosis was detected in all examined middle-aged, maturing, mature, and over-mature tree stands of Zhytomyr RDFH. It was found that with increasing age, the area of oak stands with signs of vascular mycosis and the intensity of its development gradually increases. In mature forests, it makes up an average of 18.0% of the surveyed area. Most of the examined tree stands involving oak are affected by vascular mycosis in mild to moderate degrees. One of the reasons for the high incidence of oak vascular mycosis is stem pests, which are the main carriers of fungal infection.

Aphilophoroid macromycetes of silver burch consortia are represented by three species diagnosed on live trunks: *Fomitopsis betulina*, *Fomes fomentarius* and *Phellinus igniarius*. On stumps and fallen trunks, the spread of *Chondrostereum purpureum* and *Exidia nigricanswas* noted (Fig. 6).

Figure 6. *Fruit bodies of C. purpureum (left) and E. nigricans (right)*
Source: *photographed by the authors*

However, the main cause of phytosanitary deterioration and death of trees in the tree stands of Zhytomyr RDFH is the spread of bacterial dropsy (Fig. 7). At an early stage of the disease, its indirect signs are broken canopy, the presence of dry branches and watery shoots, and visual – small oval spots on the bark of a light rusty colour, followed by the leakage of liquid that has an unpleasant smell. The final stage of the disease is characterized by the appearance of large rusty-brown, almost black spots, which subsequently turn into one large wound up to several meters long. The bast part of the wood is destroyed, and the wood is infected with various types of bacteria and wood-destroying fungi.

Figure 6. *Symptoms of birch bacterial dropsy*
Source: *photographed by the authors*

Characteristic signs of ash weakening in the surveyed tree stands are the presence of dry branches and wet shoots (11.0%). In some stands, crown weakening, mechanical damage (3.0%) and frost damage (1.0%) are observed. Among the factors of infectious origin of ash tree damage, pathogens of Hymenoscyphus pseudoalbidus (5.7%) and stem and root rot (20.6%) are most often found.

Characteristic symptoms of ash damage by *Hymenoscyphus pseudoalbidus* are the dieback of individual branches in the crown and the formation of bushy "water" shoots. The infection spreads through the central vein to the leaf petiole and penetrates the shoots of the current year, which subsequently die off and turn brown. In place of the diseased shoot, two shoots are formed next year, which in turn can also become infected. This phenomenon then leads to the formation of bundles of shoots of different drying ages (such as those inherent in growth from stumps). Chronic late blight causes the death of individual large branches and reduces the overall resistance of arboreal plants. This disease is characterized by a chronic pathogenesis, i.e., it does not "kill" the tree, but makes it more vulnerable (e.g., to secondary pathogens – several types of stump disease). Weather anomalies increase the stress of trees and reduce their resistance to root pathogens. The wood of the root systems is rapidly destroyed, which leads to intense windbreaks. Fruit bodies of wood-destroying fungi *Trichoptera flatworm* and *Heterobasidium annosum* were diagnosed on weakened and dying ash trees.

In summary, the key factor in the forest dieback in Zhytomyr Oblast is the complex effect of ecological and climatic processes with the harmful effect of infectious pathogens. The research results are limited and have not been described by scientists for a thorough scientific comparison.

CONCLUSIONS

Due to the influence of persistent ecological and climatic factors, especially sharp changes in the hydrological regime with a significant lack of moisture in the forests of Zhytomyr Oblast, we observe a significant decrease in the biological stability of the main forest-forming species. On all the surveyed test areas, there is an accumulation of dead wood inhabited by stem pests.

The results of the study of the current phytosanitary condition of forest stands subordinate to Zhytomyr RDFH suggest that the process of deterioration of the phytosanitary condition of arboreal plants of common oak, common ash, common pine, and silver birch closely correlates with the influence of infectious pathogens. The most dangerous diseases are *L. nimipressuralis* and *H. pseudoalbidus* which have an acute nature of the pathological process, the ability to cause large areas of tree mortality, and lead to dieback of affected trees in several years. The total area of damage to forest stands of Zhytomyr RDFH by pathogens of bacteriosis in 2021 was 164.2 hectares. More common, but not so aggressive are pathogens of fungal diseases. Analysing the species composition of the phytopathogenic mycobiota of the forest coenoses under study, the quantitative and qualitative representation is dominated by the fraction of aphilophoroid macromycetes, namely xylotrophic basidiomycetes, which cause root and stem rot. The most dangerous and widespread wood-destroying fungus that causes root rot on common pine and common ash trees is *Heterobasidion annosum*. The largest number of species is registered on common pine (*Phellinus pini*, *Fomitopsis pinicola*, *Trichaptum fuscoviolaceum*, *Botryobasidium subcoronatum*, *Heterobasidion annosum*, *Armillaria mellea*) and common oak (*Phellinus robustus*, *Laetiporus sulphureus*, *Fomes fomentarius*, *Fomitopsis pinicola*, *Stereum hirsutum*, *Armillaria mellea*). Apart from the group of wood-destroying fungi, typical symptoms of tree damage by vascular mycosis (tracheomycosis) (*Ophiostoma roboris*) and graphiosis (*Ophiostoma ulmi*) are also registered, which considerably affect the sanitary condition of common oak and Scots elm. In addition, the general sanitary condition of common oak trees is significantly affected by the spread of a disease of unknown aetiology – transverse oak cancer, which does not cause drying of woody plants, but substantially reduces the marketability of wood.

The total area of distribution of foci of infectious diseases in the forests of Zhytomyr RDFH in 2021 was 4961.7 hectares. Therewith, the indicator of the weighted average phytosanitary index of the surveyed massifs, obtained from the results of dividing arboreal plants into six categories, is satisfactory. In general, the detected and identified diseases are mainly chronic and develop on trees over many years, gradually weakening them.

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Поширення та шкодочинність інфекційних хвороб основних лісотвірних видів у Житомирському Поліссі України

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Анотація. Зважаючи на багатофункціональну роль лісів, є нагальна необхідність у процесі формування біологічно стійких і продуктивних деревостанів для отримання максимального еколого-економічного ефекту для нашої країни в сучасних умовах. Тому дослідження видового складу, поширення, патогенної дії та шкодочинного впливу збудників інфекційних хвороб основних лісотвірних видів у Житомирському Поліссі України дозволяють спроєктувати реальну фітосанітарну ситуацію, що буде в лісах у найближчі роки і вчасно розробити заходи щодо обмеження поширення патологічних явищ, що наразі і є актуальним напрямком дослідження. Мета роботи полягає в оцінці сучасного фітосанітарного стану лісів обстежуваного регіону та виокремленні абіотичних і біотичних чинників, що найвагоміше впливають на ослаблення та деградацію лісових деревних видів. В роботі використано класичні лісівничо-таксаційні та фітопатологічні методи для встановлення загального фітосанітарного стану обстежуваних лісів. А також застосовано спеціальні мікологічні та мікробіологічні методи в частині дослідження етіології та особливостей патогенезу збудників інфекційних хвороб. На даний час комплексний санітарний стан лісових масивів Житомирщини можна охарактеризувати як задовільний. Проте щорічно фіксуєтьсся повільне, але стійке збільшення площ всихання лісових масивів, зокрема основних лісотвірних видів – сосни, дуба, ясена і берези. У ході обстежень відмічено типову симптоматику бактеріозів (бактеріальну водянку), некрозів (халаровий некроз), судинних (графіоз, трахеомікоз) та інших хвороб суперечливої етіології (поперечний рак, всихання), а також плодові тіла афілофороїдних макроміцетів, які є причинами стовбурових (соснова губка, березова губка, несправжній дубовий трутовик та ін.) та кореневих (гереробазидіон багаторічний, опеньок осінній) гнилей. Моніторинг фітосанітарного стану з виокремленням предикторів деградації лісових деревостанів у подальшому дозволить сформувати «глобальну карту стійкості та чутливості рослин» для аналізів фітосанітарного ризику та швидкого і раціонально прийняття рішень щодо проведення лісозахисних заходів

Ключові слова: етіологія, патогенез, дереворуйнівні гриби, бактеріози, сосна звичайна, дуб звичайний, фітосанітарний стан