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Ulcerative tumour-like disease of white fir in the Pokuttia Carpathians

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Abstract. The current state of dark coniferous forests on Earth is a bio-indicator of global environmental change, in particular, the process of gradual degradation of tree species of the genera Pine, Spruce and Fir, due to the negative impact of anthropogenic activities, abiotic and

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biotic factors. The purpose of the study is to establish the symptoms, prevalence and harmfulness of the causative agent of ulcerative tumour-like disease on the shoots and trunks of white fir. The research was conducted on the territory of the forest fund of the Pokuttia Carpathians, in particular, within the branch Kutske forestry of the State Specialised Economic Enterprise “Forests of Ukraine” in the Kosivske forest enterprise. The study uses classical phytopathological and mycological methods, which are used to investigate the aetiology of the disease, analyse typical symptoms (starting from the early stages), and perform microscopy of the affected parts of fir. The symptoms, aetiology, and pathogenesis of white fir ulcer-like disease, which tends to spread, were investigated. A new name for the disease is substantiated, in particular, it is proposed to use the name “ulcerative tumour-like disease” of fir instead of the current name “cancer”. It is shown that a typical sign of infection is the development of tumours, which eventually transform into ulcers. It was found that the tumour-like type of lesion prevails on the undergrowth of fir, and on plants of the upper tiers – ulcerative. It is noted that a typical sign of ulcerative tumour-like disease of white fir is also the presence of pathologies such as “witches’ broom”. It is proposed to remove affected trees with typical signs of infection with ulcerative tumour-like disease to reduce the infectious background, especially during lighting and cleaning, since affected trees are not released from infection. Therefore, assessing the risk of infection of white fir trees with ulcerative tumour-like disease at the level of specific stands and ensuring an appropriate response to potential infection risks is an important part of sustainable forest management

Keywords: *Abies alba*; rusty fungi; biotic factors; symptoms; aetiology; pathogenesis

Introduction

The problem of dieback of dark coniferous forests with the participation of woody species of genera *Pinus* L., *Picea* A. Dieter and *Abies* Mill. in the world is gaining more and more scale, as their sanitary condition acts as a global biological indicator of environmental changes. Among the main hypotheses of this phenomenon, there are three main factors: abiotic, biotic, and anthropic, which are the foundation of the polyfactorial concept. The impact of abiotic factors, such as climate change and excessive soil moisture, is significant in the process of forest dieback: Biotic aspects, in particular, the spread of diseases and pests, also proved to be important factors leading to a decrease in the hardiness of dark coniferous forests. Measures to regulate the impact of anthropic factors, such as unstable forest management and insufficient environmental protection, are becoming

extremely important for preserving biodiversity and ensuring the stability of dark coniferous forest ecosystems.

Predictors or factors of “primary” influence include abiotic abnormalities (climate aridisation, exposure to ultraviolet radiation and stratospheric ozone, and anthropic pressure (anthropogenic air pollution and forestry activities that lead to changes in the species composition of stands (Meshkova *et al.*, 2018; Hůnová *et al.*, 2019). Phytocenotic prerequisites for the dieback of *Abies alba* Mill. in Forest cenoses, which were considered in the paper by M.I. Soroka *et al.* (2019), involve complex interactions between different plant species and environmental factors. Propensity of *Abies alba* Mill. to drying time is determined by the composition and structure of the surrounding vegetation, soil characteristics and climatic

conditions in specific cenoses of Kutske forestry. Understanding these phytocenotic dynamics is essential for implementing effective conservation and management strategies to overcome the challenges of *Abies alba* Mill. drying out in this forest enterprise.

According to R.C. Cobb & M.R. Metz (2017) biotic factors are considered to be secondary, reinforcing the role of previous ones and leading to irreversible changes in forest ecosystems. They noted that the spread of pathogens in forest ecosystems not only causes diseases, but also contributes to interaction with various disorders, such as insect pests and extreme weather conditions. The relationship between tree diseases and forest disturbances creates feedback, where the presence of one element increases the likelihood and severity of the other, leading to a complex cycle for forest health and sustainability. I.N. Pavlov *et al.* (2020) found that the impact of invasive pest species is recognised as the most significant on the planet's dark coniferous forests – *Polygraphus proximus* Blandford and *Ips typographus* Linnaeus, which cause mass tree death and alter the composition, structure, and function of forests. J.L. Morris *et al.* (2018) described that bark beetles become influential agents of change in socio-ecological systems, significantly affecting forest ecosystems. Their attacks, often caused by environmental stressors, can lead to widespread tree mortality, altering the composition and structure of forests. The impact of bark beetle activities extends far beyond environmental changes, affecting forest-dependent economic activities and challenging established forest-related social dynamics. According to forecasts, prolonged warming during the 21st century will contribute to the mass development of bark beetle populations in ecosystems where they were previously limited by climatic conditions (Robbins *et al.*, 2020). Therefore, despite the high natural resistance of fir and fir-beech forests compared to pure spruce forests to

most adverse environmental factors (Zhang *et al.*, 2018; Lukashchuk *et al.*, 2023), a detailed study of pathologies of biotic origin is the basis for developing a strategy for forest conservation and biodiversity maintenance. I.M. Kulbanska *et al.* (2022) considered that increased resistance of fir and fir-beech stands may occur due to allelopathic effects, for example, *Fagus sylvatica*. At the same time, a decrease in the proportion of deciduous tree species in the fir forest stand that are not infected with the same types of diseases as fir can contribute to a general decrease in the resistance of the stand to the occurrence of infectious epiphytotics.

Thus, despite the fact that the species composition of potential predictors of the influence of biotic origin on the condition of white fir is more or less outlined, some issues, in particular, regarding the substantiation of the names of diseases, aetiology, features of symptoms with simultaneous exposure to different species, have not yet been considered. Therefore, the purpose of this study is to determine the signs, spread, and effect of ulcerative tumour-like disease factor on the branches and trunks of white fir.

Materials and Methods

Field studies of the symptoms and spread of ulcerative tumour-like disease on shoots and trunks of white fir were conducted during the growing season of 2023 on the territory of forest plantations of the Pokuttia Carpathians within the forest fund of the Kutske forestry branch of the State Specialised Enterprise “Forests of Ukraine”. Two trial plots were established, which differ in the main silvicultural and inventory indicators, but fully represent the typical conditions of the study area.

Trial area No. 1 was established in block 23, stratum 13 of the Kosivske forestry. The height above sea level is 540 m, the slope is 25°. The total area of the compartment – 0.3 hectares. Forest stand composition – 90% fir 10% spruce + beech. Age – 93 years. Average height – 28.0 m,

average diameter – 40.0 cm, density – 0.50, reserve – 460 m³×ha⁻¹. Quality index – I. The forest type – fresh fir mixed beech forest (-).

Trial area No. 2 is established in block 31, stratum 9 of the Kosiv forestry. The height above sea level is 790 m, the slope is 36°. The total area of the compartment – 11.5 hectares. Forest stand composition – 70% fir 20% spruce 10% beech. Age – 103 years. Average height – 25.0 m, average diameter – 36.0 cm, density – 0.40, reserve – 300 m³×ha⁻¹. Bonitet – II. The forest type is wet beech mixed fir forest (-). The silvicultural and taxation characteristics of the trial areas are given according to the taxation descriptions of the enterprises provided by the Ukrderzhlisproekt production association. In total, 214 specimens of white fir were registered within the test areas, classified as undergrowth. To assess the prevalence and harmfulness of the disease, the degree of thickness, not the age of woody plants, was taken into account. This is conditioned by the fact that the undergrowth (even within the same height) has a different (sometimes by decades) age, which is the norm for white fir and reflects its high shade tolerance, and the ability to wait for a long time for a free “window” in the stand.

Special macroscopic, microscopic, and mycological research methods were used to determine the species composition of infectious disease pathogens. Identification of the collected phytopathological material was carried out directly using light microscopy methods in the Educational and Scientific Laboratory of Biotechnology and Cellular Engineering of the National University of Life and Environmental Sciences of Ukraine.

Based on a detailed analysis of the ulcerative tumour-like disease of white fir, certain features in the symptoms of the pathological process were determined, in particular, two types of lesions were identified. Type 1 (usually characteristic of fir undergrowth) is characterised by the development of more or less extensive

(sometimes up to 15-20 cm) muff-like tumours encircling the trunk (shoot). Such tumours from the moment of development have a surface with longitudinal and transverse cracks, which is generally uncharacteristic for fir of any age.

Over time, some tumours of this type develop stepped ulcers, most often near knots on the trunks. Type 2 (typical for plants of older age groups and trees of the upper tiers) is characterised by the development of muff-like tumours, the edges of which are not clearly defined, often without changing the structure of the bark (longitudinal and transverse cracks, characteristic of type 1 lesions, do not develop). However, a characteristic transverse ulcer (deep crack) is formed, which in symptoms resembles an open form of transverse oak cancer with a similar effect on the physiological state of the plant. That is why even in the reporting materials of forestry enterprises, this disease is called “transverse cancer” of fir.

To establish the morphometric parameters of witches’ brooms, the length of shoots and needles was measured, and the number of needles, lateral buds of regular branching and lateral axillary buds was calculated. Latin names of higher plant species are given based on: World Flora Online (n.d.), mycobiotes – based on: Index Fungorum (n.d.). The degree of damage to trees was determined by condition categories (Resolution of the Cabinet of Ministers of Ukraine No. 756, 2016). Calculations and statistical processing of data were carried out using Microsoft Excel software suite. The research was conducted in compliance with the standards specified in the Convention on Biological Diversity (1992) and the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973).

Results

The causative agent of ulcerative tumour-like disease of white fir is a diverse fungus with a complete development cycle *Melampsorella*

caryophyllacearum J. Schröt. (outdated name – *Melampsorella cerastii*, synonym – *Melampsorella elatina* (Alb. & Schwein.) Arthur 1907) (Scholler *et al.*, 2022). Spermogonia on the upper surface of the needles between the epidermis and cuticle, yellow to honey-yellow, dotted, 100-120×30-50 µm in size, clearly protruding from the epidermis. Aecium on the lower surface of needles in the form of yellowish stripes located along the central vein. Aeciospores are ellipsoid or angular, with pink-orange contents, 15-20×18-20 µm; the shell is colourless, warty, 1-2 µm thick. Uredinium mainly on the underside of the needles, small, rounded, 0.1–0.5 mm in diameter, yellow, formed directly in the stomata. Uredospores are ellipsoid or almost spherical, 15-30×14-24 µm, with yellow-orange contents; the shell is colourless, bristly. Telium on the underside of the leaves develops more or less whitish or ochreous-yellow spots. Teleospores are grouped in the cells of the epidermis, spherical, ellipsoid or angular, irregular, 15-25 µm in diameter, with colourless or yellowish contents; the shell is colourless, smooth, 1 µm thick. Spermogonial (0) and aecial (I) stages of pathogen development occur on needles of *Abies alba* Mill., and urediniostadia (II) and teliostadia (III) develop on plants from the Clove family (*Caryophyllaceae*), in particular, on common starwort (*Stellaria graminea* L.) and greater starwort (*S. holostea* L.), water chickweed (*S. aquatica* Scop.), species of the genus *Cerastium* (*Cerastium* L.) and others. Currently, it is known that the endemic Turkish fir species *Abies nordmanniana* subsp. *equi-trojani* (Asch. & Sint. ex. Boiss.) Coode & Cullen is also sensitive to this pathogen (Keleş *et al.*, 2021).

The first symptoms of the lesion appear on young branches and shoots, on which muff-like thickenings develop (Fig. 1). Next spring, a witches' broom sprouts vertically from the buds of infected shoots in the places where tumours form, which has the appearance of a cluster of dense shortened shoots with short yellow-green

needles (Fig. 2). Starting from mid-summer, the needles of witches' brooms develop aecial sporulation, which has the appearance of orange or yellowish cylindrical pustules filled with aeciospores. Aecias develop on the underside of needles, along the middle vein. The affected needles eventually completely fall off. In the following years of pathology development, new shoots appear on the witches' brooms, and new aecia develop on them. Usually, several bushes of witches' brooms with a diameter of up to 60 cm, and sometimes more, appear at the crown of the tree. The life cycle of witches' broom can last for 20 years or more. Very rarely (within the statistical margin of error), a witches' broom with perennial needles was found, which is not characteristic of the ulcerative tumour disease of white fir. Obviously, such witches' brooms have a different origin, which requires further study.



Figure 1. Muff-like thickenings – initial stage of pathogenesis of ulcerative tumour-like disease of white fir

Source: photo by the authors



Figure 2. The development of witches' brooms in the crown of white fir trees is a typical symptomatic sign of *Melampsorella caryophyllacearum* infection

Source: photo by the authors

On the affected trunks, a closed-type thickening with longitudinal surface cracks is formed. Over time, the crust cracks and falls off, partially exposing an open stepped ulcer (Fig. 3). Growths can appear along the entire length of the trunk, often several at once. From the affected shoots, the mycelium of the pathogen penetrates directly into the tree trunk, where it causes the process of necrotisation of the cambial layer, as a result of which atypical thickenings form on the trunk, usually covered with a crust with longitudinal and transverse cracks. On the affected shoots, yellowish needles appear locally, intensively crumbling. Over time, the crust cracks, partially falls off, exposing an open step wound, cracks on the surface of which begin to deepen. Growths are formed along the entire length of the tree trunk. Affected white

fir trees can show signs of weakening for several decades. The condition of infected woody plants significantly depends on the location of ulcerative tumour lesions on the trunk. The most dangerous lesions are those that develop in the sub-crown part of the trunk, leading to its dieback.



Figure 3. Cancerous and ulcerative wounds of various types of white fir

Note: a – on shoots; b, c – on trunks

Source: photo by the authors

The disease causes weakening and dieback of white fir, especially undergrowth, reduces the yield of commercial wood, contributes to the infection with rot pathogens, in particular, *Phellinus hartigii* (Allesch. & Schnabl.) Pat. and the development of foci of stem pests. As evidenced by the studies, quite often the fir undergrowth is significantly weakened and dieback if there are only closed tumours on the trunk without exposing the wood (without ulceration). Trees of older age groups mainly develop ulcers (common or stepped) located across the trunk.

Based on a detailed analysis of the ulcerative tumour-like disease of white fir, certain features in the symptoms of the pathological process were determined, in particular, two types of lesions were identified. Type 1 (usually characteristic of fir undergrowth) is characterised by the development of more or less extensive (sometimes up to 15-20 cm) muff-like tumours encircling the trunk (shoot). Such tumours from the moment of development have a surface with longitudinal and transverse cracks, which is generally uncharacteristic for fir of any age. Over time, some tumours of this

type develop stepped ulcers, most often near knots on the trunks. Type 2 (typical for plants of older age groups and trees of the upper tiers) is characterised by the development of muff-like tumours, the edges of which are not clearly defined, often without changing the structure of the bark (longitudinal and transverse cracks, characteristic of type 1 lesions, do not develop). However, a characteristic transverse ulcer (deep crack) is formed, which in symptoms resembles an open form of transverse oak cancer with a similar effect on the physiological state of the plant. Perhaps that is why, even in the reporting materials of forestry enterprises, this disease is called "transverse fir cancer".

Accounting data on the spread of ulcerative tumour-like disease on the undergrowth and trees of white fir of the upper tiers of the stand with a division into degrees of thickness and types of lesions (1 and 2) indicate the superiority of type 1 of lesions in young white fir trees (Table 1). The table does not consider dead white fir trees of various degrees of thickness that did not have symptoms of ulcerative tumour-like damage.

Table 1. Spread of ulcerative tumour-like disease on the undergrowth and trees of white fir of the upper tiers

Degree of thickness, cm	Total recorded trees, units	Including infected trees, units	Number of ulcerative tumour-like lesions by type				Total lesions, units	Spread of the disease, %
			Type 1		Type 2			
			units	%	units	%		
Undergrowth								
2	62	43	84	81.6	19	18.4	103	69.4
4	49	24	46	88.5	6	11.5	52	49.0
6	43	10	20	71.4	8	28.6	28	23.3
8	31	12	7	63.6	4	36.4	11	38.7
10	18	3	4	66.7	2	33.3	6	16.7
12	11	1	2	66.7	1	33.3	3	9.1
Total	214	93	163	-	40	-	203	-
Upper tier trees								
28	26	1	0	0.0	1	100.0	1	3.8
32	71	3	0	0.0	3	100.0	3	4.2
36	119	4	1	20.0	4	80.0	5	3.4
40	186	15	3	15.8	16	84.2	19	8.1

Table 1, Continued

Degree of thickness, cm	Total recorded trees, units	Including infected trees, units	Number of ulcerative tumour-like lesions by type				Total lesions, units	Spread of the disease, %
			Type 1		Type 2			
			units	%	units	%		
Upper tier trees								
44	18	2	0	0.0	2	100.0	2	11.1
48	6	4	0	0.0	4	100.0	4	66.7
52	7	1	0	0.0	1	100.0	1	14.3
56	3	1	0	0.0	1	100.0	1	33.3
Total	436	31	4	-	32	-	36	-

Note: affected plants include undergrowth that had both symptoms of type 1 and 2 lesions, and witches' brooms. There were often plants whose only visual sign of infection was witches' broom; type 1 tumour-like growths (without ulcers) and type 2 – ulcerative tumour-like (stepped for undergrowth and young plants) and transverse (for trees of the upper tiers)

Source: compiled by the authors

Notably, there is no correlation between the height of the undergrowth and its age – to a greater extent, this depends on stressful (depressing) factors for plants. It is established that the average distribution rate of ulcerative tumour-like disease is equal to 43.5% on the undergrowth. The largest number of fir specimens with typical visible signs of infection is attributed to the smallest degrees of thickness. Accordingly, the total number of lesions (totaling type 1 and type 2) was also highest on trees with 2 and 4 cm thicknesses. Note that the type of ulcerative tumour disease lesion also prevailed in the undergrowth, that is, tumour-like formations on shoots and trunks without ulcers. At the same time, the disease is found not only on trunks, but also on shoots. The affected young undergrowth is usually depressed, and a significant percentage of plants are dead.

The report also covers 436 specimens of white fir of the upper tiers. The average spread of ulcerative tumour-like disease is 7.1%. The largest number of fir specimens with typical visible signs of infection is attributed to average (36–44 cm) degrees of thickness. The total number of lesions (total type 1 and type 2) was the highest on trees of 40 cm thickness (this

trend can be explained by the fact that in the studied plantings, the most common were trees that reached 40 cm in diameter). Note that on trees of older age groups, type 2 of ulcerative tumour-like disease prevailed, that is, there are ulcerative tumor-like and transverse growths (inflows). It is known that any ulcers (inflows, tumours) weaken the plant, but its death (due to the objective characteristics of obligate pathogens, in particular, the causative agent of ulcerative tumour-like disease of fir) is quite rare. This happens if more than 2/3 of the trunk is ringed and more than its perimeter. Such trees are mainly windbreak due to the defeat of their pathogens by stem rot, most often on fir it is Hartig's white trunk rot, which affects the tree with the core exposed and causes core corrosion rot.

In addition, a typical sign of ulcerative tumour-like disease of white fir is the presence of pathologies such as witches' broom, which occurs due to excessive bud formation. The needles on witches' brooms are shorter and wider compared to healthy needles and fall off annually during August and September. It is established that in the crown, the witches' broom is formed exclusively on the side branches, closer

to the top of the shoot. Visually, on the examined specimens of undergrowth, and on trees of older age groups, including model trees of 60-80 years of age, which were selected by us for

other studies (in particular, tracheid pathology of white fir), witches' brooms were registered in the crown, which differed in morphometric indicators (Table 2).

Table 2. Morphometric parameters of shoots on the witches' broom of white fir

Shoot branching order	Indicator							
	Shoot length, mm		Buds of regular branching, units		Double shoot, units/ 10 mm shoot		Axillary buds, units	
	WBS	NS	WBS	NS	WBS	NS	WBS	NS
3	42.4±2.1	50.9±3.7	3.2±0.2	2.4±0.2	17.1±0.5	14.6±1.5	9.4±0.8	1.6±0.4
4	31.5±1.2	27.8±2.4	2.2±0.1	0.7±0.1	14.3±0.2	16.9±1.4	8.0±0.2	1.0±0.1
5	32.4±1.0	18.5±1.3	1.6±0.1	0.1±0.03	13.7±0.2	18.1±0.8	7.2±0.1	0.05
6	25.1±0.4	-	1.0±0.1	-	13.4±0.1	-	3.6±0.1	-
7	15.2±0.4	-	0	-	9.5±0.1	-	1.4±0.1	-

Note: WBS – witches' broom shoot, NS – normal shoot (control); 3-7 branching order, + sign means that this feature in shoots of the same branching order of the witches' broom and control has statistically significant errors (at $P < 0.05$)

Source: compiled by the authors

In 5 years, a system of branches consisting of five orders is developed from a lateral bud on the second order axis of branching of the witches' broom shoot, while a normally developed shoot forms only three orders of branching.

In length, the shoots of the witches' broom of the third order are smaller than normal, but they develop significantly more buds of regular branching and axillary buds, half of which will develop secondary shoots next year. Shoots of the fourth order of the witches' broom are longer than normal shoots, but they develop almost three times as many shoots of regular branching and 8 times as many axillary buds, about 30% of which will germinate next year. Shoots of the fourth order of branching developed from axillary buds are 20-25% shorter than shoots of regular branching, their growth characteristics depend on the location on the shoot: longer ones are formed from axillary buds developed in the upper half of the shoot, and short ones – in the lower part. On normal shoots of the fourth order, only 1-2 axillary buds develop, and they remain dormant. Witches'

broom shoots of the fifth order of branching are much longer and develop 16 times more lateral buds than normal shoots, approximately 90% of the shoots of which do not develop buds of regular branching at all. Axillary buds on normal shoots of the fifth order of branching are not developed, in the shoots of the witches' broom they continue to develop in large numbers. Shoots of the sixth and seventh orders of branching are not formed on normal shoots, and more than 60% of all axes are formed in the shoots of the witches' broom on these orders. Normal shoots and witches' broom have different orientation in space: normal ones are characterised by plagiotropic (perpendicular to the axis of the tree trunk and parallel to the plane of the Earth) arrangement of shoots, shoots of witches' broom grow orthotropically (parallel to the axis of the trunk or at an acute angle to it). The above results show that the shoots of the witches' broom differ from the shoots of the normal part of the crown. This information indicates significant differences in the morphometric parameters of normal fir shoots and

shoots on which the witches' broom was developed. The main difference is the abundant branching, due to which a denser fragment of the crown is formed, which is visually easily detected. There was also a dead white fir tree with no signs of ulcerative tumour disease (bacterial wetwood (causative agent – *Lelliottia nimipressuralis* (Carter 1945) and burn-type diseases).

A. Goychuk *et al.* (2022) described that the overall sanitary condition of dark coniferous forests forms a close correlation between biotic predictors and abiotic factors. Currently, the phytopathogenic bacterium *Lelliottia nimipressuralis* (Carter 1945) (Brady *et al.*, 2013) is a major contributor to the general pathology of white fir, characterised by its dynamic spread within the range of forests with white fir and causing massive mortality of trees of different age groups. I. Kulbanska *et al.* (2022) investigated that the main symptoms of infection of fir trees with bacterial droopy include the development of cracks and ulcers on shoots and trunks, detachment of the rhytidome, abundant exudate discharge, exposure of the primary bark and phloem, trees form a typical “hedgehog-like” appearance due to the mass development of water shoots. These results highlight the importance of studying and understanding the complex of symptoms for early diagnosis and effective control of this bacterial disease. According to A. Madmony *et al.* (2018), causes of weakening and death of trees of the genus *Picea* are fungi of the genus *Fusarium* sp. and the species *Heterobasidion parviporum* Niemelä & Korhonen, which cause root rot of varying intensity. Their study aimed to understand how these environmental factors affect the production of monoterpenes, which are important secondary metabolites in plant defence mechanisms. The revealed differences in monoterpene responses in the two clones reveal a complex interaction between drought stress and fungal infection in the formation of

chemical defence mechanisms of Norwegian spruce. Reports of massive outbreaks of these phytopathogens have been confirmed by researchers from different countries.

Researchers from Finland M.M. Müller *et al.* (2018) conducted extensive surveys to map the geographical distribution of infection *Heterobasidion*, identifying key factors that affect its distribution, such as climatic conditions, tree species composition, and forest management. These studies provide valuable information on the spatial patterns of *Heterobasidion* root rot, helping forest managers to implement targeted disease management strategies and sustainable forest practices in northern Finland. According to the data of Polish researchers P. Lech *et al.* (2020), damage to white fir and Scots pine trees in the forests of Central Europe caused by the massive spread of *Viscum album* L., which was monitored during 2008–2018. Systematic surveys were conducted to assess the prevalence and distribution of infestations on various tree species in Poland's forest ecosystems. The results of this study provide valuable information on time patterns and factors influencing the spread of European mistletoe, which is essential information for forest management practices and strategies aimed at reducing the impact of mistletoe on tree health and overall forest ecology in Poland. The pathogenic impact on white fir seedlings in forest nurseries by the fungus *Phytophthora abietivora* was considered by D.W. Li *et al.* (2019). The discovery of *Phytophthora abietivora* on fir trees in Connecticut highlights the need for vigilance in monitoring and managing emerging threats to tree health in the region. However, the least attention of researchers is paid to the disease, which is known as “fir cancer”, “fir broom rust”, etc. Only some results of studies of rust fungi of the order Pucciniales are known, in particular, *Melampsorella caryophyllacearum* J. Schröter (Keleş *et al.*, 2021), which cause the witches'

broom pathology on white fir trees. The findings revealed how the fungus, which causes powdery mildew, affects visual and internal features of *Abies nordmanniana* subsp. *equi-trojani*, providing valuable information about the ecological interactions between the pathogen and the host tree. To understand a particular plant pathology, well-established types of diseases are usually used, which are based solely on symptoms, that is, on anatomical and morphological features. When determining the types of diseases, the causes of their occurrence are usually not considered. In particular, there is a clear definition and understanding of “ulcers” as a type of disease – infectious or non-infectious, that is, depressions on plant organs (usually trunks) surrounded by living tissue (small ulcers are called anthracnose). Various thickenings, growths, in particular muff-like ones, have the common name “tumours” (this type of disease has a different nature of origin, in fact, and like other types of diseases). As for the term “cancer” (as a type of disease), it is usually not distinguished among plant diseases as a separate type of disease. Although now the term “cancer” defines diseases (types of diseases) that are characterised by the development of tumours (growths), ulcers, difficult-to-heal or non-healing wounds (often with the release of oleoresin, exudate, etc.). All these names (ulcer, tumour, growth, etc.) are different types of diseases that do not allow adequately understanding the symptoms of a particular pathology. In any case, if necessary and to preserve the established names of diseases, in terms such as “cancer ulcers” (these are different types of diseases), the word “cancer” should be put in quotation marks. In terms of symptoms, the disease under study most closely corresponds to the name “ulcerative tumour-like disease”, since in the initial stages of the disease, a tumour (growth) is developed first and over time, a common, but more often a stepped ulcer is formed.

Conclusions

Based on the study of the current sanitary condition of *Abies alba* Mill. trees growing in the Pokuttia Carpathians, typical symptomatic signs of the ulcerative tumour disease of plants of different age groups were recorded and identified. The causative agent is an obligate phytopathogen *Melampsorella cerastii* Wint. (= *Melampsorella caryophyllacearum* J. Schröt.). This pathology in the scientific and educational literature is associated with outdated names – “fir cancer”, “rusty fir cancer”, “transverse fir cancer”, “stepped fir cancer”, etc., which are based solely on anatomical and morphological features and do not consider the aetiology. The main symptoms of the pathogenesis of ulcerative tumour-like disease of white fir are the formation of typical muff-like growths on young branches and shoots, and witches’ brooms. There are two types of course of this disease, in particular, the type manifests itself in the form of muff-like thickenings and is characteristic mainly for the growth of fir. In Type 2 of the disease, deep transverse ulcers with cracks are formed. Ulcerative tumour-like disease of white fir is widespread in the forests of the Pokuttia Carpathians, the average spread rate is 43.5% on undergrowth and 7.1% on trees of older age groups. The development of this pathology leads to a general weakening of white fir trees, which makes them sensitive (susceptible) to other environmental factors.

Given the significant spread of ulcerative tumour-like disease of white fir, which tends to increase, further research should be aimed at reducing the infectious background in stands with the participation of white fir in the territory of the Pokuttia Carpathians. For this purpose, the disease should be detected first of all on the undergrowth in fir forests. Trees with signs of ulcerative tumour-like disease (development of tumours, witches’ brooms, ulcers) must be removed from the stand and

then disposed of. The same applies to white fir trees at the stage of lightening, thinning and clearing – trees with symptoms of damage should be removed. Special attention should be paid not only to the affected trunks, but also to the affected lateral branches of young trees, as the primary infection occurs through the needles and then spreads throughout the plant. It should also be borne in mind that the causative

agent, like other obligate pathogens, stimulates plant growth and development in the initial stages of pathology.

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Conflict of Interest

None.

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Виразково-пухлиноподібна хвороба ялиці білої в деревостанах Покутських Карпат

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Анотація. Сучасний стан темнохвойних лісів Землі є біоіндикатором глобальних змін навколишнього середовища, зокрема процесу поступової деградації деревних видів родів Сосна, Ялина та Ялиця, обумовленого негативним впливом антропогенної діяльності, абіотичних та біотичних чинників. Метою дослідження є встановлення симптоматики, поширеності та шкодочинності збудника виразково-пухлиноподібної хвороби на пагонах і стовбурах ялиці білої. Дослідження проводили на території лісового фонду Покутських Карпат, зокрема у межах філії «Кутське лісове господарство» Державного спеціалізованого господарського підприємства «Ліси України» у Косівському лісництві. У роботі використано класичні фітопатологічні та мікологічні методи, за допомогою яких досліджено етіологію захворювання, аналіз типової симптоматики (починаючи з ранніх етапів), проведено мікроскопію уражених частин ялиці. Досліджено симптоматику, етіологію та патогенез виразково-пухлиноподібної хвороби ялиці білої, яка має тенденцію до поширення. Обґрунтовано нову назву хвороби, зокрема пропонується використовувати замість вживаної назви «рак» ялиці – «виразково-пухлиноподібна хвороба» ялиці. Показано, що типовою ознакою інфікування є формування пухлин, які з часом трансформуються у виразки. Встановлено, що на підрослі ялиці переважає пухлиноподібний тип ураження, а на рослинах

верхніх ярусів – виразковий. Зазначається, що типовою ознакою виразково-пухлиноподібної хвороби ялиці білої також є наявність патологій типу «відьмина мітла». Пропонується для зменшення інфекційного фону видаляти уражені дерева із типовими ознаками інфікування виразково-пухлиновидної хвороби, особливо при освітленнях і прочистках, оскільки уражені дерева від інфекції не звільняються. Таким чином, оцінка ризику, спричиненого інфікуванням дерев ялиці білої виразково-пухлиновидною хворобою на рівні конкретних деревостанів, і забезпечення належної реакції на потенційні ризики зараження є важливою частиною сталого управління лісами

Ключові слова: *Abies alba*; іржасті гриби; біотичні чинники; симптоматика; етіологія; патогенез