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SANITARY STATE OF WATER-PROTECTION PINE PLANTATIONS IN THE INTERFLUVE OF DNIEPER AND DESNA

The purpose of the study was to establish the sanitary state of pine plantations, identify the causes of the development and spread of diseases and pathogens, develop recommendations for improving the condition and increase the biological stability of pine plantations between the Dnieper and Desna rivers.

The studies were carried out in middle-aged, mature and over-mature pine plantations of the Ukrainian interfluve of Dnieper and Desna. The sanitary state of the stands was determined on 52 circular trial plots laid in the forest growing conditions of fresh poor site and fresh rich site. On each trial plot, the index of the sanitary state was calculated according to the generally methodology accepted in forestry.

Calculations of the sanitary state index showed that middle-aged plantations are more resistant to biotic and abiotic factors, the dominant number of trees is classified as weakened. In general, the sanitary state index of middle-aged pine forests of fresh poor site and fresh rich site is 2.04 and 1.79, respectively. The mature plantings of fresh poor site with sanitary state index 2.86 are highly weakened, and fresh rich site are weakened, due to the more fertile rich site soil conditions enriched by the biodiversity of the living ground cover. Pine plantations of IX and XI age classes, in which the sanitary state index varies between 2.30–2.33, and the percentage of drying and dead trees reaches 10 %, are weakened.

It has been established that the most influential factors of a significant deterioration in the sanitary state of mature and over-mature water-protection pine plantations are changes in the hydrological regime of floodplain territories, which leads to tree damage by the mistletoe Austrian and root sponge. In order to prevent the development of these pathogens, it is recommended to create mixed plantations of Scots pine with the introduction of 20–40 % deciduous species, which will simultaneously serve as a fire barrier to the spread of ground fires.

Key words: biological stability, state categories, indicator of sanitary state, Austrian mistletoe, roots sponge, dry wood.

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Formulation of the problem. The current negative state of the environment is closely related to the anthropocentric type of development. As a result of its intensification, the area of forest stands affected by pests and diseases of the forest has increased, which has led to their weakening and drying up. According to the State Agency of Forest Resources of Ukraine, the total area of drying up stands in the enterprises of the industry for 2018 is about 440 thousand hectares, of which Scotch pine – 243 thousand hectares [4].

Growth and ecological properties of plantations depend to a large extent on the state of forests. Recently, the sanitary state of forests in different regions of Ukraine has worsened, which is related to climate change and anthropogenic impact [6]. The tendency to decrease the planting stability is especially clear in the pure pine stands growing in poor pine sites and rich pine sites.

According to scientists, in case of an increase in air temperature by 1 ^{o}C, the latitude limits of climate zones within Ukraine will be shifted by 160 km. Modern forestry science lacks sufficient data on the behavior of forest ecosystems and their adaptive capacity in the face of such climate change. It is expected that there will be an increase in the recurrence of years during which forests will experience significant water stress. In addition to directly affecting the productivity and viability of forests, climate change provokes abiotic and biotic disturbances. Among the latter is expected to increase the mass reproduction of dangerous pests and diseases.

In the interfluve Dnieper and Desna, the dominant positions belong to protective forests under the category of water protection plantations. The main forest-forming species is Scotch pine, which accounts for 68 % of the forest fund [2]. The past two decades have seen significant climate change in the study area, which has affected the hydrological regime of floodplain lands. The aridity of the climate and the decrease in groundwater contributed to the appearance of pests and pathogens that migrated outside their natural habitat and had not previously developed in the pine stands of the region [15].

The viability of artificial stands and their good condition are maintained through the implementation of scientifically sound forest management measures that regulate the processes of natural self-regeneration, eliminating the effects of negative effects of natural and anthropogenic factors [14].

The purpose of the study is to determine the sanitary state of water protection plantations in different forest plant sites and age groups, to determine the causes of development and dangerous spread of the Austrian mistletoe semi-parasite plant, to provide recommendations for improvement of the biological stability of pine plantations in the interfluve Dnieper and Desna.

Material and methods of research. The object of the study was the pine plantations of the Ukrainian interfluve Dnieper and Desna, which occupies the northern part of the Chernihiv Polissia and covers part of the Dnieper-Donetsk depression [7]. In orographic terms, the study region is characterized as a weakly undulating plain. The general flatness of the territory is broken by the valleys of the rivers Dnieper, Desna, and Snov. According to the forestry zoning, the studied territories belong to the East Pole District Forestry Forest Region [5, 10] or the Dnieper Forestry District of the Kyiv-Chernihiv Polissia Province [2].

The most represented water protection plantations are pine tree stands of State Enterprice "Vyshche-Dubechnia Forestry", the territory of which occupies the second over-floodplain terrace of the river basin and with a small slope extends from north to south. According to the latest forest inventory, dominant positions belong to protective forests under the category of water protection plantations [11]. Their share is 72.7 % (20,939.1 hectares). Exploitation forests cover an area is only 2105.7 ha, which are 7.3 % of the forest fund [17]. The predominant types of forest conditions are fresh poor pine sites and fresh rich pine sites, which account for about 65 % of the territory. Forest site conditions on the territory of the forestry are favorable for the cultivation of the main forest-forming species of pine, the plantations of which occupies 18385 ha, or 68.6 % of the area [17].

The sanitary state of the plantations was determined on circular test plots, which were placed in the forest plant conditions of fresh poor pine sites (A_2) and fresh reach pine sites (B_2). Middle aged, mature and overmature pine stands were explored. A total of 52 circular trial plots were laid. The study covers six forests massive with a total area of 32.0 ha. Pine forests of the massive typically represent the specified age categories of forestry plantations. The forest-biometric characteristics of pine plantations are given in Table. 1.

Table 1 – **Forestry-biometric characteristics of pine plantations**

No	Block/ unit	Area, ha	Site type	Age, years	Composition	Diameter, sm	Height, m	Class productivity	Density	Stock, m^3/ha
1	795/2	2.0	A_2	40	10Сз+Бп	18	17	I	0,70	220
2	794/7	3.3	A_2	81	10Сз	26	22	II	0.75	340
3	579/4	3.7	A_2	111	10Сз	36	29	I	0.70	420
4	882/2	8.5	B_2	41	10Сз	20	16	I	0.80	240
5	782/7	2.5	B_2	73	10Сз	26	24	I	0.85	430
6	782/8	12.0	B_2	91	10Сз	32	26	I	0.80	450

Table 1 data show that in fresh rich pine sites the stands are more complete than fresh poor pine sites stands. This fact is explained, first of all, by the richer fresh rich pine sites vegetation conditions, the soil fertility of which is able to provide more plants per unit area. The productivity of such stands is usually higher than that of fresh poor pine sites, although here they also reach high classes of productivity.

On circular test plots, a list of trees by category of state was carried out using the prism of M. Anuchin [1]. During the study of the sanitary status of water-protective plantations, the methodology approved by the sanitary rules in the forests of Ukraine was used [13].

During the list of trees in the test plots, for each of them, the category of the state was determined according to the sum of biomorphological features, which included the density and color of the crown, the presence and nature of the needles distribution, the last infection of the infectious and non-infectious nature, the pests and pathogens, the relative growth of the sprouts, age of needles stored on shoots, presence of dry branches, condition of bark, phloem etc. [8, 9].

The trees were divided into six categories of sanitary status: healthy, weakened, very weakened, withered and drying (recent and past years) [13]. The integral index of the state of trees or the so-called index of sanitary status of plantations was calculated by the formula 1 [13, 17]:

$$I_s = \frac{n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5 + 6n_6}{n_1 + n_2 + n_3 + n_4 + n_5 + n_6}, \quad (1)$$

where I_s – is the index of sanitary state; n_1, n_2,… , n_6 – is the number of trees in the respective sanitary category.

The index of the state of living trees was calculated by the formula 2:

$$I_s = \frac{n_1 + 2n_2 + 3n_3 + 4n_4}{n_1 + n_2 + n_3 + n_4}. \quad (2)$$

The degree weakened or plantings state on the units was defined as the weighted average of the tree distribution estimates of the different status categories. The plantation states was set according to the following sanitary index values: up to 1.50 – healthy plantations; 1.51–2.50 – weakened; 2.51–3.50 – strongly weakened; 3.51–4.50 – dry plantations; more than 4.51 – dead.

During field work, all manifestations of negative impact on the status of forest phytocenoses of other biotic and abiotic factors (pests and tree damage by pathogens, forest fires, damage to shoots by late spring frosts, as well as wild and domestic animals) were recorded on the test areas.

The mathematical and statistical processing of the results was performed using Microsoft Excel software packages [2].

Results of the study and discussion. On each circular test plot on the studied objects is determined by the index of sanitary state according to the formula 1. A fragment of the calculation of the sanitary state of the overmature pine plantation of fresh poor pine site is given in Table. 2.

Table 2 – **Sanitary state of plantation of fresh poor pine site** (block 579, unit 4)

Number of test area	Category of trees state						Number of trees in the test area, pc.	Index of sanitary status I_s
	I	II	III	IV	V	VI		
	Number of trees by state category, pc.							
1	12	20	8	2	0	0	42	2.00
2	8	12	5	0	0	1	26	2.04
3	9	15	8	3	1	1	37	2.32
4	13	13	7	1	0	0	34	1.88
5	8	14	10	0	0	0	32	2.06
6	10	20	8	3	1	1	43	2.26
7	5	9	11	6	1	0	32	2.66
8	5	22	10	1	2	1	41	2.41
9	2	14	11	4	2	1	34	2.79
10	2	14	14	2	1	0	33	2.58
Weighted average sanitary index								**2.30**

The analysis of the tabular data showed that in 10 circular test areas the index of sanitary state fluctuates within 1.88–2.79. That is, most of the studied sites belong to the category of weakened plantations and only the stands in circular test areas 7 and 9 belong to the category of severely weakened

with the indices of sanitary status 2.66 and 2.79 respectively. The weighted average index of the sanitary state of the investigated pine stands is 2.30, which allows it to be classified as weakened.

Summarized data for all objects is shown in Table 3, and the percentage distribution of the total number of trees by categories of sanitary state of mature pine stands in different forest plant conditions is illustrated in Fig. 1.

The data analysis of the table 3 indicates that the largest proportion of trees in pine stands of IV age class belongs to the first and second categories, that is, the percentage of weakened and healthy trees in fresh poor and rich pine sites is 33.2 and 59.6 %, respectively. At the same time, the index of the sanitary state of mature plantations of fresh poor and rich pine sites is 2.86 and 2.07, respectively. Thus, in the age of mature, pine plantations of fresh poor pine site belong to the high weakened, and the fresh rich pine site – to the weakened. The better sanitary state of the plantations of the fresh rich pine site is explained by the more fertile soil conditions, enriched with biodiversity of the living above ground cover.

Table 3 – **Sanitary state of pine plantations on units**

Block/ unit	Compo-sition*	Age, years	Number of trees by state category: numerator, pc, denominator,%						Number of trees in the test area, pc./%	I_s
			I	II	III	IV	V	VI		
Water protection plantations of fresh poor pine site										
795/2	10Ps+Bp	40	59	67	39	24	9	4	202	2.04
			29.2	33.2	19.3	11.9	4.5	2.0	100	
794/7	10 Ps	80	12	65	53	27	5	9	171	2.86
			7.0	38.0	31.0	15.8	2.9	5.3	100	
579/4	10 Ps	111	74	153	92	22	8	5	354	2.30
			20.9	43.2	26.0	6.2	2.3	1.4	100	
Water protection plantations of fresh rich pine site										
882/2	10 Ps	41	167	48	34	20	7	4	280	1.79
			59.6	17.1	12.1	7.1	2.5	1.4	100	
782/7	10 Ps	73	132	171	77	15	9	6	410	2.07
			32.2	41.7	18.7	3.7	2.2	1.5	100	
782/8	10 Ps	91	49	107	65	11	5	7	244	2.33
			20.1	43.9	26.6	4.5	2.0	2.9	100	

*) Ps – Pinus sylvestris L.; Bp – Betula pendula Ehrh.

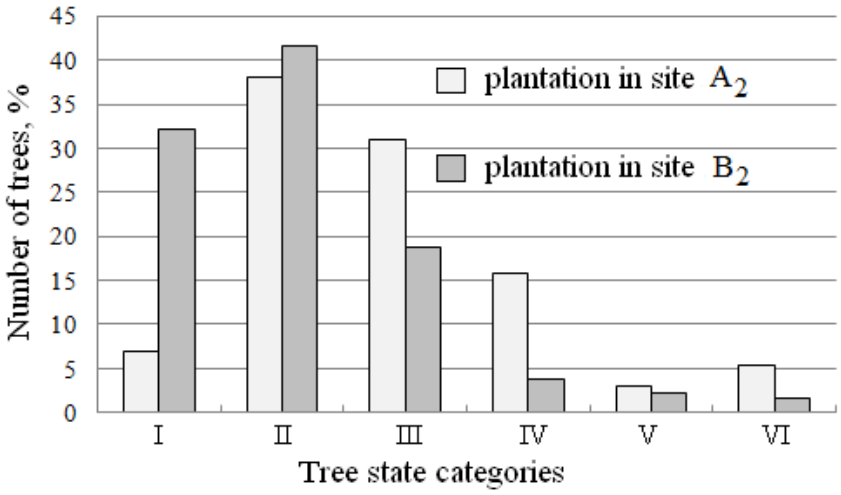

Fig. 1. **Distribution of trees in mature pine plantations growing in fresh poor and rich pine sites by category of sanitary state.**

Middle aged plantations in both forest plant sites are more resistant to biotic and abiotic factors; the dominant number of trees belongs to 1 and 2 categories of sanitary state. In general, the index of

sanitary state of fresh poor pine site and fresh rich pine site is 2.04 and 1.79, respectively, which characterizes them as weakened plantings. However, fresh rich pine site stands occupy a position close to healthy plantations, while plantations of fresh rich pine site are more closely aligned with heavily weakened stands.

Pine plantations of IX and XI classes of age is characterized by high weakened sanitary state, in which the index of sanitary state fluctuates within 2.30–2.33, and the percentage of drying and dry trees reaches 10 %.

The main reason for the weakening of pine plantations is the change in the hydrological regime of the floodplain lands. The past two decades have seen significant climate change in the study area. This usually affects the hydrological regime of forest areas. Investigation of the change of hydrological regime and dynamics of groundwater level, conducted by V. Yukhnovskyi and R. Prokopchuk within drainage system "Strashevo" in Rivne region showed a sharp decrease in the groundwater level since 2011. During this period, the water table decreased by 60–80 cm, reaching a stable value of 124–140 cm. Before that period the groundwater was lying at depth 60 cm [18]. Nowadays, there is a decrease in the level of groundwater in the whole territory of Polissia, which according to scientists is one of the reasons for the massive and partial drying up of forest plantations [18].

The aridity of the climate and the decrease in groundwater contributed to the affliction of pine plantations in the interfluve Dnieper and Desna by flowering semi-parasite mistletoe Austrian (*Viscum austriacum* W.). More recently, Austrian mistletoe has been singularly found in mature and overmature forest plantations in the green zone of Kyiv [15]. During investigations of the sanitary condition of water protection pine plantations, Austrian mistletoe foci were found in mature and overmature stands (Fig. 2).

а б

Fig. 2. **Infection of pine tree stands: a – the hearth of Austrian mistletoe in overmature plantation (block 578, unit 4); b – the development of Austrian mistletoe near hearth of root sponge (block 782, unit 8).**

Both the lesion of single trees (Fig. 2*a*) and the development of Austrian mistletoe in the places of root sponge (Fig. 2*b*) were revealed in the pine plantations. The foci of the latter are widespread in mature and overmature pine plantations in different forest pine sites. However, in fresh rich pine site, the phenomenon of plantings disease a root sponge is fragmentary.

In the floodplain lands of the Dnieper and the Desna rivers, it is advisable to grow pine in mixed plantations with deciduous tree species using all the possibilities of natural renewal of this species. The negative impact of local and extreme situations on the condition and growth of pine plantations should be minimized, principally, by a system of preventive measures aimed at preventing the defeat of pine stands in Austrian mistletoe, root sponge and forest fires. Timely carrying out of forestry measures in the young plantations provides for the reduction of natural waste, the excessive sampling

of trees according to the sanitary state, and, accordingly, the reduction of the density and number of trees per unit area. In order to prevent the development of Austrian mistletoe and root sponge, it is necessary to create mixed pine plantations with the introduction of up to 20-40 % of hardwood, which will simultaneously serve as a fire barrier for the spread of ground fires. In the zone of severe damage to pine stands for their healthy, elimination of root cells and Austrian mistletoe, increasing the biological stability of plantations, it is necessary to carry out continuous sanitary felling, followed by the introduction into the plantations of deciduous species.

Conclusions. In the interfluve of Dnieper and Desna the dominant positions belong to protective forests under the category of water protection plantations. The main forest-forming species is Scotch pine, which accounts for 68 % of the forest fund. The pine stands are grown in fresh poor and rich pine sites – the most prevalent types of forest plant conditions.

Analysis of the sanitary state index shows that the largest proportion of trees in pine stands of IV age class belongs to the first and second category, i.e. the percentage of weakened and healthy trees in fresh poor and rich pine sites 33.2 and 59.6 % respectively. In general, the index of sanitary state of middle aged pine plantations in fresh poor and rich pine sites is 2.04 and 1.79, respectively, which characterizes them as weakened plantations.

At the same time, mature plantations of fresh poor pine site belong to the heavily weakened, and the fresh rich pine site – to the weakened, which is explained by the more fertile soil conditions of the fresh rich pine site, enriched with the biodiversity of the alive above ground cover.

Pine plantations of IX and XI age classes is characterized by the weakened sanitary state in which the index of sanitary state fluctuates within 2.30–2.33, and the percentage of drying and dry trees reaches 10 %.

It is established that the most influential factors of significant deterioration of the sanitary state of mature and overgrown pine plantations are changes in the hydrological regime of floodplain territories, which leads to the infection of trees with Austrian mistletoe and root sponge.

To increase the biological stability of the plantations, it is advisable to introduce in the pine plantations hardwood species up to 20-40 % of their participation in the stand. In the centers of strong defeat by the root sponge and Austrian mistletoe, it is necessary to improve the stands in the course of sanitary felling and thinning.

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Санітарний стан водоохоронних соснових насаджень межиріччя Дніпра і Десни

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Метою дослідження було встановлення санітарного стану соснових насаджень, виявлення причин розвитку і небезпечного поширення патогенів і збудників хвороб, розробка рекомендації з поліпшення стану і підвищення біологічної стійкості соснових насаджень межиріччя Дніпра і Десни.

Дослідження проводили в середньовікових, стиглих і перестиглих соснових насадженнях Українського межиріччя Дніпра і Десни. Санітарний стан насаджень визначали на 52 кругових пробних площах, які закладено в лісорослинних умовах свіжого бору і свіжого субору. На кожній пробній площі розраховували індекс санітарного стану за загальноприйнятою у лісівництві методикою.

Розрахунки індексу санітарного стану показали, що середньовікові насадження вирізняються більшою стійкістю до біотичних і абіотичних чинників, домінуюча кількість дерев відноситься до категорії ослаблених. Загалом індекс санітарного стану середньовікових сосняків свіжого бору і свіжого субору становить 2,04 і 1,79 відповідно. Стиглі насадження свіжого бору з індексом санітарного стану 2,86 відносяться до сильно ослаблених, а свіжого субору – до ослаблених, що пояснюється родючішими ґрунтовими умовами субору, збагаченим біорізноманіттям живого надґрунтового покриву. Ослабленими визначені соснові насадження IX і XI класів

віку, у яких індекс санітарного стану коливається в межах 2,30–2,33, а відсоток усихаючих і сухостійних дерев сягає 10 %.

Встановлено, що найвпливовішими чинниками істотного погіршення санітарного стану стиглих і перестиглих водоохоронних соснових насаджень є зміни гідрологічного режиму призаплавних територій, що призводить до ураження дерев омелою австрійською і кореневою губкою. З метою запобігання розвитку кореневої губки і омели австрійської рекомендовано створювати змішані культури сосни звичайної з уведенням до 20–40 % листяних видів, які водночас слугуватимуть протипожежним бар’єром поширення низових пожеж.

Ключові слова: біологічна стійкість, категорії стану, показник санітарного стану, омела австрійська, коренева губка, сухостій.

Санитарное состояние водоохранных сосновых насаждений междуречья Днепра и Десны

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Целью исследования было установление санитарного состояния сосновых насаждений, выявление причин развития и распространения патогенов и возбудителей болезней, разработка рекомендации по улучшению состояния и повышение биологической устойчивости сосновых насаждений междуречья Днепра и Десны.

Исследования проводили в средневозрастных, спелых и переспелых сосновых насаждениях Украинского междуречья Днепра и Десны. Санитарное состояние насаждений определяли на 52 круговых пробных площадях, заложенных в лесорастительных условиях свежего бора и свежей субори. На каждой пробной площади рассчитывали индекс санитарного состояния по общепринятой в лесоводстве методике.

Расчеты индекса санитарного состояния показали, что средневековые насаждения отличаются большей устойчивостью к биотическим и абиотическим факторам, доминирующее количество деревьев относится к категории ослабленных. В общем, индекс санитарного состояния средневозрастных сосняков свежего бора и свежей субори составляет 2,04 и 1,79 соответственно. Спелые насаждения свежего бора с индексом санитарного состояния 26 относятся к сильно ослабленным, а свежей субори – к ослабленным, что объясняется более плодородными грунтовыми условиями субори, обогащенным биоразнообразием живого напочвенного покрова. Ослабленными определены сосновые насаждения IX и XI классов возраста, у которых индекс санитарного состояния варьирует в пределах 2,30–2,33, а процент усыхающих и сухостойных деревьев достигает 10 %.

Установлено, что самыми влиятельными факторами существенного ухудшения санитарного состояния спелых и переспелых водоохранных сосновых насаждений являются изменения гидрологического режима припойменных территорий, что приводит к поражению деревьев омелой австрийской и корневой губкой. С целью предотвращения развития указанных патогенов рекомендуется создавать смешанные культуры сосны обыкновенной с введением в 20–40 % лиственных видов, которые одновременно будут служить противопожарным барьером распространения низовых пожаров.

Ключевые слова: биологическая устойчивость, категории состояния, показатель санитарного состояния, омела австрийская, корневая губка, сухостой.

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