PHYSICAL AND CHEMICAL PROPERTIES OF SOILS IN POTENTIAL APPROACHES OF VOLYNIC POLISSE, VIOLATED BY ROOT SPONGE

Volodymyr LUKYANETS [A], Anatoliy LISNYAK [B*], Oksana TARNOPILSKA [C], Sergey MUSIENKO [D], Alla GARBUZ [E], Alexey KRAYNUKOV [F]

Received: January 17, 2019 | Revised: February 28, 2019 | Accepted: March 3, 2019
Paper No. 19-61/1-524

Abstract

Peculiarities of growth, productivity and health condition of pine stands affected by annosum root rot were investigated in conditions of Volyn Polissya of Ukraine. The research was conducted in the forests of the State Enterprise «Gorodotsky FH» and SE «Manevitsky LH», which are subordinated to the State Agency of Ukraine for Natural Resources of Ukraine and located in the Manevytsky-Volodymyrets Physical-Geographic District of the Volyn Polissya of Ukraine. The purpose of the research is to detect differences in physical and chemical properties of soils in the center of drying out of the plumage and in the interfacial space (control) affected by the root sponge of pine plantations. It was revealed that the soil in the root of the root spider's lesion is poorer than organic soil (humus) compared with the soil of the interfacial space. At the same time, these soils are richer in the content of nutrients (NPK). The granulometric composition and specific gravity in soils in the center of drying out of the crumbling and in the interfacial space practically do not change. Humidity in all experimental soils in the center of drying out of the drooping to a depth of 50 cm is higher on average by 28%, and in deeper horizons - by 6% less than in the intercostal space. The hardness of the soil in the foaming areas throughout the depth of the profile is greater (especially at the depth of the arable layer) than in the interfacial space. It was discovered that the damage by the root sponge of pine stands established on the ancient lands depends on a complex of factors limiting the toppling of the soil layer due to its consolidation, especially at a depth of 50 cm. This contributed to the

A Ukrainian Research Institute of Forestry & Forest Melioration G.N. Vysotsky, Kharkiv, Ukraine
lukyanetc@uriffm.org.ua

B* Ukrainian Research Institute of Forestry & Forest Melioration G.N. Vysotsky, Ukrajine; V. N. Karazin Kharkiv National University, Ukraine
anlisnyak@gmail.com (corresponding author)

C Ukrainian Research Institute of Forestry & Forest Melioration G.N. Vysotsky, Kharkiv, Ukraine O. M. Beketov National University of Urban Economy, Kharkiv, Ukrajine
tarnopilskaya@gmail.com

D O. M. Beketov National University of Urban Economy, Kharkiv, Ukrajine
ispg@ukr.net

E V. N. Karazin Kharkiv National University, Kharkiv, Ukraine
eco-life@i.ua

F V. N. Karazin Kharkiv National University, Kharkiv, Ukraine
alkraynukov@gmail.com

concentration of root systems in the upper layers of the soil, which in conditions abrupt changes in the hydrological regime can lead to a decrease in the stability of plantings, in particular to the root sponge.

Key words
Root sponge, center of drying out, interfacial space, soils, humidity, hardness, site between disease centers

INTRODUCTION

Scots pine (Pinus sylvestris L.) is the main forest forming species in Polissya; it occupies about 60 % of the areas covered with forest vegetation. One of the strategic issues of the forestry sector with regard to the cultivation of high-yielding pine plantations is the problem of root rot, which does not lose its relevance in the world, since there are no radical methods of combating disease in any of the countries. The greatest damage to the pine (Polus sylvestris L.) is caused by root rot, the causative agent of which is the fungus - root sponge (Heterobasidion annosum (Fr.) Bref.).

The root sponge affects the productivity of the stands, causes their premature decay, provokes the massive proliferation of endoscopes, increases the fire danger, causes continuous sanitary cutting, worsens the soil protection, water protection and sanitary and hygienic functions of the forest. In addition, they are affected by root rot of the tree, susceptible to damage to the winds (Vollbrecht 1994, Brandtberg 1996, Bendz-Hellgren 1999, Volchenkova 2012, Lyamtsev 2015, Hronec et al. 2012).

The geography of the spread of the disease has gained in recent decades of global character and encompasses all parts of Europe (Vasiliauskas et al. 2002, Wang 2012, Mead 2013), North America(Harrington et al. 1989), Central America (Lewis 2002; Mead 2013) some areas of Australia (Mead 2013), Asia (Parmasto 1986; Dai et al. 2003; Koco et al. 2014) and Africa (Morocco) (Mead 2013).

The problem of the emergence and spread of the disease in Ukraine arose in the middle of the twentieth century after large plots began to create forest crops of pine forests in interfacial space, pastures, wildernesss, where the soils lost their forest properties. The study of the confinement of the centers of the disease to the plantings in the old lands (Sirota 1996, Kuznetsov 2005, Bilous 2009, Ustsky 2011). The emergence and spread of this disease in these lands, most researchers associate with the presence of the upper arable layer of soil, the depth of which is limited to a densified layer, often called the "umbrella sole".

The presence of such a layer prevents the roots from going deep into the lower horizons of the ground, which causes the growth of the above-ground part of the tree to decrease and significantly weakens it (Vasilyuskas 1989, Negrozky 1986). The risk of defeat of crops by the root sponge is substantially increased when they are created in areas where continuous sanitary felling of plantations affected by this disease has been carried out. (Negrutsky 1986, Kuznetsov 2005, Bilous 2009, Volchenkova 2012).

A number of researchers (Artyukhovsky 1998, Vorontsov 1978) play an important role in spreading the root sponge to the stem pests that are carriers of fungal infection. The high density of pure crops of young pine trees created in the ancient lands leads to a decrease in their resistance to defeat of the root sponge and curtin erosion (Vasiliauskas 1989, Volchenkova 2012). Scientists of URIFFM who conducted research in Eastern Polissya on sod-podzolic soils of the ancient lands, the appearance and distribution of root sponge associated with the water-physical properties of soils (Ladeyshchikova 1974, Tkachuk 2002, Ustsky 2011). Studies carried out in the Chernihiv Polissya indicate that turf-podzolic soils in plantations in the old lands are characterized by low fertility, densified horizons and layers, as well as unstable water regime (Ladeyshchikova 1974). The spread of the disease in pine forests of Kazakhstan's «belt» forests in indigenous forest soils is also explained by the unstable water regime of soils (Shatyayev 1987**)**. In the Byelorussian Polissya, the disease became widespread in pine plantations, created on fresh sod-podzolic soils, amplified by loose sands and moraine loams, starting at a depth of 1 m (Raptunovich 1981). At present, the causes of the origin of the center of drying out of the root sponge have not been sufficiently studied and there are no effective measures to limit the mass distribution of the disease (Alekseev 1974, Negrutsky 1986, Vasiliauskas 1989, Zvyagintsev, 2013).

Therefore, the study of physical and chemical properties of soils will make it possible to determine the directions of economic intervention in the course of the pathological process reduction in the size of the fall.

To increase the stability of the planting to the root sponge in the ancient lands should create mixed forest cultures with the participation of hardwoods. For mixing with pine in a fresh sub-tree, you can use the following tree species: birch hanging (Betula pendula Roth.), Northern oak (Quercus borealis Michx.), Oak (Quercus robur L.), alder (Alnus incana (L.) Moench) Their share in these conditions should be at least 30% (Alekseev 1974, Negrutsky 1986, Bilous 2009).

When restoring infected root sponge of pine plantations the best way to avoid losses in the next generation of the forest is to use resistant to root sponge rocks. According to the data (Alekseev 1974, Ladeyshchikova et al. 2001, Lygis et al. 2004), on structures affected by the root sponge plantings, it is proposed to create in fresh and wet sub-cultures birch cedar cultures as predecessors of pine cultures in order to reduce the infectious background of the root sponge and to promote the formation of the natural composition soil microcenosis. However, this provision needs to be confirmed, as there is not enough data on the growth, condition, productivity and product-assortment structure of birch cultures in the old land. Usually, in Ukraine, on planks affected by the root sponge, newly created mostly pure pine plantations.

The purpose of the work is to detect differences in the physical and chemical properties of soils in the center of drying out and in the interfacial spaces in the pine plantations affected by the root sponge.

METHODOLOGY DESCRIPTION

The research was carried out in pine forests according to the basic principles of soil science (Arinushkina 1970, Zhigunov 1980, SSTU 4289: 2004, SSTU 4730: 2007, SSTU ISO 10390: 2007, Tikhonenko 2010, Berezhnyak 2012, Lisnyak 2015) on the old land of two forest enterprises: State Enterprise «Gorodotsky FH» and SE «Manevitsky FH», which are confined to Volyn Polissya. Pine common in these enterprises is the main forest species and occupies about 68% of the area of forest areas covered with forest vegetation.

The climate of the region is moderate continental with mild winters and warm summers. The average temperature in January is from -4,4 ° to -5,1 ° C, July -18,5 ° C. Absolute minimum temperature - 39 ° C, absolute maximum + 39 ° C. The period with a temperature of + 10 ° C is 150-160 days. The sum of these temperatures is 2495-2580 °. Precipitation is 550-640 mm per year, most of them fall in the summer, and the least - in winter.

Volyn Polissya is characterized by a significant flow of field and card forms of relief, valley landscapes, excessive moistening, the development of repossessed lands and swamps, numerous (more than 200) lakes, and large forested areas. Here, the present landscape zones of mixed forests (45%), meadow-bog landscapes (about 10%) and moraine-zandrovy plain, Volyn region predominate. Among the fourth percent is the distribution of breeds of Cretaceous age, which condition the development of map forms of relief - lake basins, reservoirs, formation of sod-carbonate soils (Marinich 1985).

Wet climate and washing type of water regime, the predominance of non-carbonate rocks of light granulometric composition (glacial and water-glacial genesis), as well as forest vegetation, which covered the territory of Volyn Polissya everywhere, contributed to the development of the podzolic soil formation process and caused the formation of sod soils of podzolic type.

The surface of the surveyed sections of the state enterprise «Gorodotsky FH» and the state enterprise «Manevitsky FH» is represented by the turf-weakly podzolic and soddy-medium podzolic soils orientation. Forest lands, on which the test sites were laid (P 2, P 6, P 9), are referred to the ancient lands. On most of the examined sites, the morphological signs of plowing have not been preserved, but sometimes, they are clearly expressed.

In order to study the physical and chemical properties of soils in pine plantations affected by the root sponge, 30 soil sections were laid: 15 in the center of drying out; 15 in interfacial spaces (controls). On these sections, every 10 cm hardness of the soil is determined by a Golubev gauge and the moisture content of the soil is wetted with Walcom PMC-710. The soil cover was described in 3 soil cuts in foam center of drying out and 3 in intercostal spaces, and analyzed 36 soil samples, which were analyzed in laboratory conditions. The specimens were determined: the granulometric composition by the pipette method (SSTU 4730: 2007); Humus content according to Tyurin (SSTU 4289: 2004); The content of the general forms of N, P, K (in concentrated sulfuric acid extraction by the Ginzburg method) (Tikhonenko 2010); The level of acidity is potentiometrically (SSTU ISO 10390: 2007). The research results were processed using Microsoft Excel software.

The study of water, physico-mechanical and physical and chemical properties of the soils of the old lands as a habitat and feeding medium of the root system of trees is very important for the identification of the causes of the origin of the center of drying out of the root sponge, the consequences of its influence on the growth, condition and formation of forest plantations, as well as the development measures to combat this disease.

RESULTS OF THE RESEARCH

The analysis of the given data of the granulometric composition of soils showed that the composition of the studied soils is dominated by the fraction of fine sand (0.25 - 0.05 mm). The total content of mechanical elements of large and medium sand is smaller than fine sand, but compared to other fractions, its share is quite substantial. The content of physical sand (> 0.01 mm) on average in all soils is 92.2%, the physical clay content (< 0.01 mm) is 7.8%, the amount of colloidal particles (<0.001 mm) is 5.9% , which is a very low indicator (Table 1).

There were no significant differences between the variants in the center of drying out (CDO) and in the interfacial space (IS), but only 9% in interdimensional spaces had less colloidal particles (< 0.001 mm) and physical clay (< 0.01 mm) and physical sand more than 1% (Fig. 1).

The fractional composition of the mechanical elements of the humus horizon reflects the quantitative parameters of the granulometric composition of the parent rock, but some of its features are noted. The main difference between the upper and lower parts of the profile of the studied sod-podzolic soils is the gradual reduction of the contents of the silt particles in the upper part of the profile and their accumulation in the lower horizons.

In general, the granulometric composition of individual soil horizons on the experimental sites varies from the late assembly and changes from the genesis and subtraction of elementary processors.

The specific gravity of the investigated soils depends on the amount of physical clay and organic matter in it and varies between 2.51 and 2.68 g / cm^3 (Table 2),

Table 1 Granulometric composition of the studied soils

№ planting	Horizon	Depth, cm	The content of particles of different sizes, %			The name of the granulometric composition of the soil
			< 0,01 мм	> 0,01 мм	< 0,001 мм	
P 2– center of drying out (CDO)	$He_{(1)}$	0-18см	6,38	93,62	5,12	Sand is bonded
	$He_{(2)}$	19-28	6,1	93,9	4,54	Sand is bonded
	Pe(h)	29-51	5,24	94,76	4,04	Sand is bonded
	Pei	52-84	3,6	96,4	3,58	The sand is loose
	Pi(gl)	85-118	43,15	56,85	31,93	Loam is heavy
	P	119-160	12,93	87,07	7,1	Sue
P 2– interfacial space (IS)	He	0-32	7,3	92,7	5,09	Sand is bonded
	Pe	33-59	7,75	92,25	4,8	Sand is bonded
	Pi(e)	60-102	27,06	72,94	19,21	Loam is light
	P(i)	103-140	4,92	95,08	3,75	The sand is loose
	P	140-160	7,54	92,46	6,78	Sand is bonded
P 6– center of drying out	HE(п)	0-22	4,69	95,31	3,7	
	Ep(h)	23-43	4,99	95,01	4,53	The sand is loose
	Pe(i)	44-68	4,09	95,91	3,94	The sand is loose
	Pi(e)	69-96	3,71	96,29	3,47	The sand is loose
	P(i)	97-135	4,18	95,82	3,56	The sand is loose
	P	136-160	3,17	96,83	2,85	The sand is loose
P 6– interfacial space	HE(п)	0-24см	4,5	95,5	3,64	The sand is loose
	Ep(h)	25-32	3,4	96,6	2,85	The sand is loose
	PI(e)	33-49	5,4	94,61	4,19	Sand is bonded
	Pi	50-82	3,28	96,72	3,01	The sand is loose
	P	83-140	2,88	97,12	2,28	The sand is loose
P 9– center of drying out	HE	0-24	8,95	91,05	4,88	Sand is bonded
	Ep	25-68	7	93,0	4,18	Sand is bonded
	Ip(e)	69-95	4,15	95,85	3,33	The sand is loose
	PI	96-135	7,5	92,5	7,3	Sand is bonded
	P(i)	136-160	6,2	93,8	6,33	Sand is bonded
	P	161-170	9,78	90,22	6,5	Sand is bonded
P 9– interfacial space	HE	0-32	5,28	94,72	5,23	Sand is bonded
	Eph	33-64	3,93	96,07	6,33	The sand is loose
	Pe	65-82	10,03	89,97	4,6	Sand is bonded
	PI	83-105	9,73	90,27	5,33	Sand is bonded
	P(i)	106-130	7,1	92,9	6,98	Sand is bonded

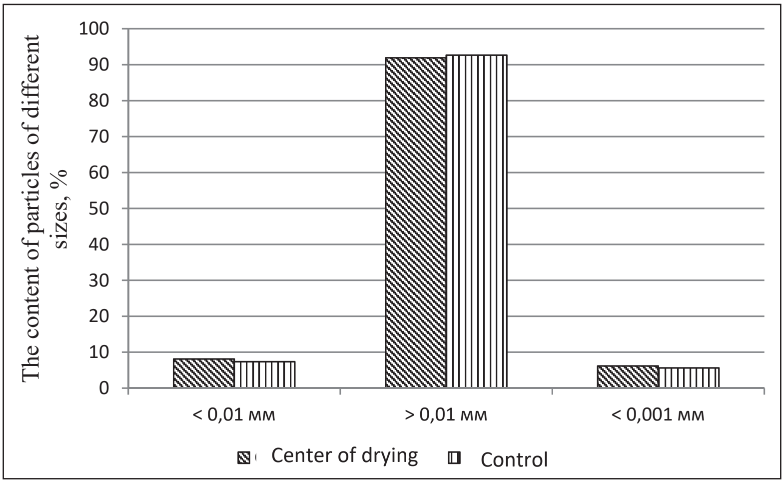

Figure 1
The content of particles of different sizes in the center of drying out and on the control

which is logical for this type of soil, since these soils are depleted with organic matter and more or less uniformly in profile provided with colloidal particles.

After analyzing our experimental data, we found that the differences between variants with root sponge and control were not detected, there are only very weak tendencies for increasing the specific gravity in the control variants (Figure 2).

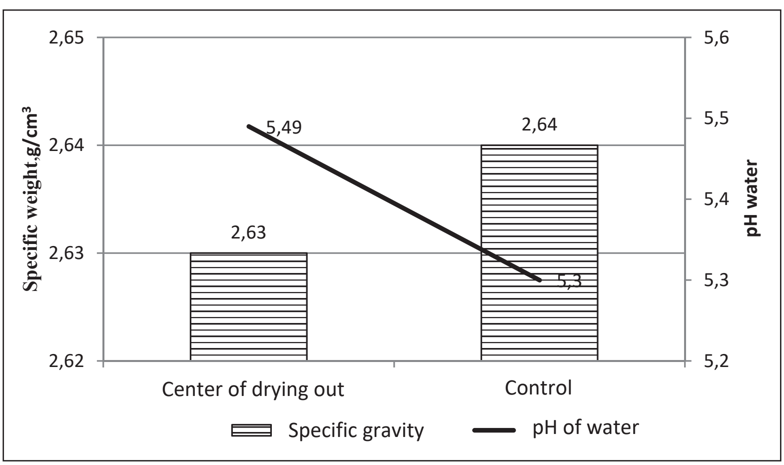

Figure 2
Specific gravity and pH of water in the root of the root sponge and control.

Table 2 Physico-chemical and agrochemical properties of investigated soils

№ planting	Horizon	Depth, cm	Specific weight, g/cm³	pH water	Humus content, %	N	P_2O_5	K_2O
P 2– center of drying out	$He_{(1)}$	0-18см	2,65	4,8	0,48	0,067	0,025	0,036
	$He_{(2)}$	19-28	2,68	4,76	0,42	0,597	0,021	0,041
	Pe(h)	29-51	2,66	5,1	0,24	0,065	0,022	0,037
	Pei	52-84	2,67	5,22	0,06	0,039	0,012	0,041
	Pi(gl)	85-118	2,51	4,97	0,24	0,054	0,045	0,341
	P	119-160	2,65	5,52	0,12	0,053	0,020	0,150
P 2– interfacial space	He	0-32	2,65	4,95	0,54	0,065	0,019	0,046
	Pe	33-59	2,63	4,95	0,72	0,053	0,016	0,060
	Pi(e)	60-102	2,61	4,9	0,54	0,067	0,025	0,264
	P(i)	103-140	2,62	5,4	0,24	0,038	0,004	0,040
	P	140-160	2,66	5,67	0,42	0,039	0,010	0,068
P 6– center of drying out	HE(п)	0-22	2,64	4,95	0,84	0,078	0,014	0,028
	Ep(h)	23-43	2,65	5,42	0,54	0,026	0,049	0,042
	Pe(i)	44-68	2,65	5,36	0,18	0,081	0,020	0,033
	Pi(e)	69-96	2,65	5,22	0,24	0,064	0,014	0,030
	P(i)	97-135	2,61	5,1	0,3	0,079	0,012	0,036
	P	136-160	2,60	5,8	0,36	0,078	0,005	0,032
P 6– interfacial space	HE(п)	0-24см	2,65	4,9	0,96	0,040	0,017	0,023
	Ep(h)	25-32	2,68	5,35	0,24	0,064	0,012	0,022
	PI(e)	33-49	2,65	4,98	0,54	0,013	0,067	0,044
	Pi	50-82	2,65	5,59	0,48	0,065	0,012	0,025
	P	83-140	2,65	5,52	0,30	0,080	0,005	0,029
P 9– center of drying out	HE	0-24	2,58	4,9	1,02	0,039	0,036	0,031
	Ep	25-68	2,64	5,69	0,39	0,052	0,015	0,034
	Ip(e)	69-95	2,62	6,14	0,18	0,025	0,011	0,031
	PI	96-135	2,62	6,85	0,08	0,053	0,012	0,045
	P(i)	136-160	2,63	6,4	0,18	0,025	0,011	0,034
	P	161-170	2,63	6,61	0,13	0,109	0,010	0,042
P 9– interfacial space	HE	0-32	2,62	4,55	1,12	0,013	0,029	0,036
	Eph	33-64	2,63	5,16	0,29	0,064	0,023	0,043
	Pe	65-82	2,65	5,89	0,13	0,064	0,007	0,027
	PI	83-105	2,62	5,8	0,08	0,013	0,010	0,030
	P(i)	106-130	2,62	5,95	0,18	0,026	0,010	0,034

Humidity of these or other layers of soil depends on many factors, in particular from forest conditions, tent closeness, as well as the limitation and precipitation intensity. The distribution of moisture in the thickness of the soil primarily affects the mechanical composition of certain layers and their density. Soil sections were laid by us in the absence of precipitation.

The relative humidity of the soil, both in the centers of drying and in interfacial space, varies with depth (Table 3). In the centers of drying, the maximum moisture content of 9.71% was observed in the soil layer at a depth of 30 cm and the minimum - 6.75% at a depth of 70 cm. In the interfacial space, the moisture content of the soil layers ranged from 6.18% (10 cm) to 8.10% (80 cm).

Table 3 Humidity of soil at different depths in the center of drying out and interfacial space of pine plantations in conditions of Volyn Polissya

Statistical Indicators	Depth of occurrence, cm										
	10	20	30	40	50	60	80	100	120	140	160
Center of drying out											
M – middle, %	9,31	9,49	9,71	9,19	7,79	7,19	7,41	7,08	7,05	7,18	7,63
± m – standard error	0,31	0,37	0,45	0,41	0,33	0,30	0,35	0,33	0,23	0,23	0,22
S – standard deviation	1,21	1,42	1,73	1,59	1,30	1,15	1,35	1,29	0,87	0,88	0,84
S^2 – sample variance	1,47	2,03	2,99	2,53	1,68	1,33	1,82	1,65	0,76	0,78	0,71
Excess	0,46	-0,40	-0,41	-0,67	-0,70	-0,82	1,25	0,07	0,01	-0,93	-0,58
Asymmetry	1,01	0,67	0,73	0,45	0,02	0,13	1,32	0,53	0,56	0,55	0,66
Minimum	7,8	7,5	7,6	7,2	5,6	5,5	5,8	5,2	5,7	6,2	6,6
Maximum	12,1	12,0	12,9	12,4	10,2	9,2	10,6	9,5	8,9	8,8	9,2
n – number of options	15	15	15	15	15	15	15	15	15	15	15
Interfacial space											
M – middle, %	6,18	6,41	6,53	6,65	7,16	7,62	8,10	7,99	7,25	7,28	7,61
± m – standard error	0,27	0,34	0,42	0,44	0,44	0,38	0,48	0,48	0,35	0,34	0,33
S – standard deviation	1,06	1,31	1,61	1,69	1,69	1,47	1,84	1,85	1,35	1,32	1,27
S^2 – sample variance	1,12	1,72	2,60	2,85	2,86	2,17	3,40	3,43	1,82	1,75	1,62
Excess	-0,73	-0,56	-0,19	-0,38	-0,98	-1,05	-1,11	-0,11	-1,19	-0,51	-0,25
Asymmetry	0,41	0,53	0,81	0,74	0,05	0,31	0,31	0,70	0,09	-0,02	0,26
Minimum	4,6	4,5	4,4	4,5	4,1	5,2	5,6	5,8	5,0	4,8	5,4
Maximum	8,2	8,6	9,7	9,8	9,8	10,1	11,2	11,7	9,2	9,3	9,7
n – number of options	15	15	15	15	15	15	15	15	15	15	15
$t_{fact,05}$	7,61	6,13	5,17	4,22	1,15	0,89	1,16	1,56	0,48	0,24	0,05

Note: $t_{the\ theor.}$ = 2,048; P = 0.05

The dynamics of the distribution of moisture in the soil of the centers of drying and interfacial spaces is described by polynomial equations of the 3rd degree (Fig. 3) with accuracy ($R^2 = 0.83$) in the cores and ($R^2 = 0.80$) in interfacial spaces. Relative humidity in the center of drying out of the root sponge gradually increases to 9.71% at a depth of 30 cm, then decreases to 6.75% at a depth of 70 cm, and then again increases unevenly to 7.63% at the end of the soil profile. In the interfacial space, relative humidity gradually increases unevenly from 6.18% (10 cm) to 8.10% at a depth of 80 cm and then decreases to 7.25% at a depth of 120 cm and gradually increases to 7.61% . Humidity in all experimental soils in the center of drying out to a depth of 50 cm is higher by 28%, and in deeper horizons, by 6% less than in the interfacial space. Significant difference in moisture content in the center of drying out and in the interfacial space was noted in the upper 40 cm layer of soil ($t_{\text{the theor.0,05}} = 7{,}61–4{,}22$, $t_{\text{the theor.}} = 2{,}048$).

In deeper layers, this difference is not significant, and at a depth of 110-160 cm, the moisture content of the soil in the center of drying out and control is almost unchanged (see Fig. 3).

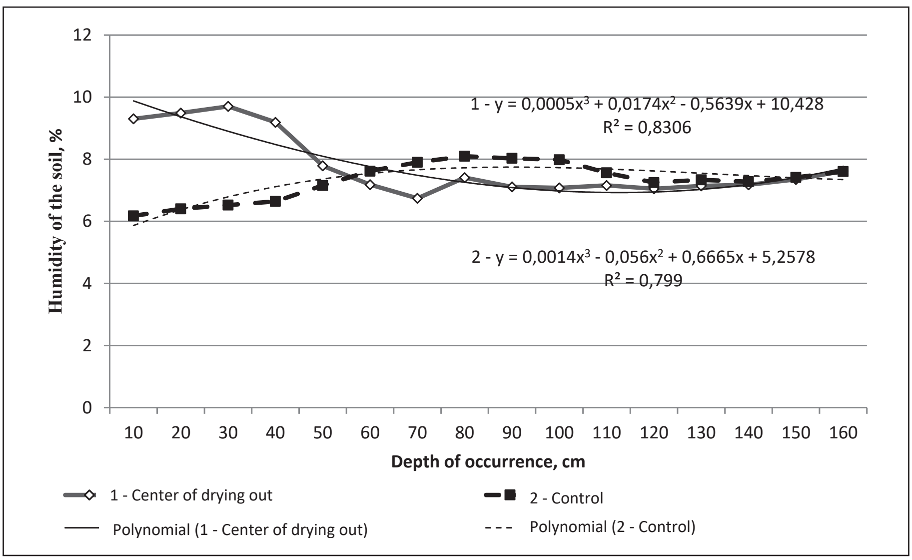

Figure 3

Humidity of the soil at different depths in sod-medium podzolic soils in medieval pine plantations affected by the root sponge.

The hardness of the soil layers depends on their moisture and mechanical composition, in particular, the contents of the muddy parts. The different hardness of the soil layers and the depth of the layers with the highest hardness values indicate, first of all, the water regime of one or another planting.

According to our research, the hardness of soil layers, both in the center of drying out of the crumbling, and in the interfacial spaces with depth increases. In the center of drying out of the root sponge, the hardness of the soil sharply increases to a depth of 50 cm in 2.4 times compared with the upper layer of soil (Table 4, Fig. 4). An increase in the hardness of the soil at this depth indicates the presence of a sealed layer. After a depth of 50 cm, the soil hardness gradually decreases from 12.5 kg / cm^2 to 11.5 kg / cm^2 at a depth of 80 cm, and then increases to 16.2 kg / cm^2 unevenly to the end of the profile. It should be noted that the hardness of the soil in the center of drying out of the root sponge throughout the profile is greater than that of the intermediate profile. Perhaps the reason for more hardness in the center of drying out of the root sponge in the conduct of selective sanitary felling, chipping sick and dry trees and their trailing from the area. In the interfacial space, the hardness of the soil increases uniformly from 3.4 kg / cm^2 (10 cm) to 16.0 kg / cm^2 (160 cm). At a depth of 140-160 cm, the hardness of the soil in the interocentric spaces is almost the same as the hardness in the center of drying out.

Significant difference in the hardness between the soil layers in the center of drying out of the damping and in the in interfacial spaces is noted in the upper 60 cm of the soil layer (tfact 0.05 = 6.70-2.25, $t_{theor.}$ = 2,048) and at a depth of 1 m (tfact 0 , 05 = 2.39, $t_{theor.}$ = 2.048) (see Table 4).

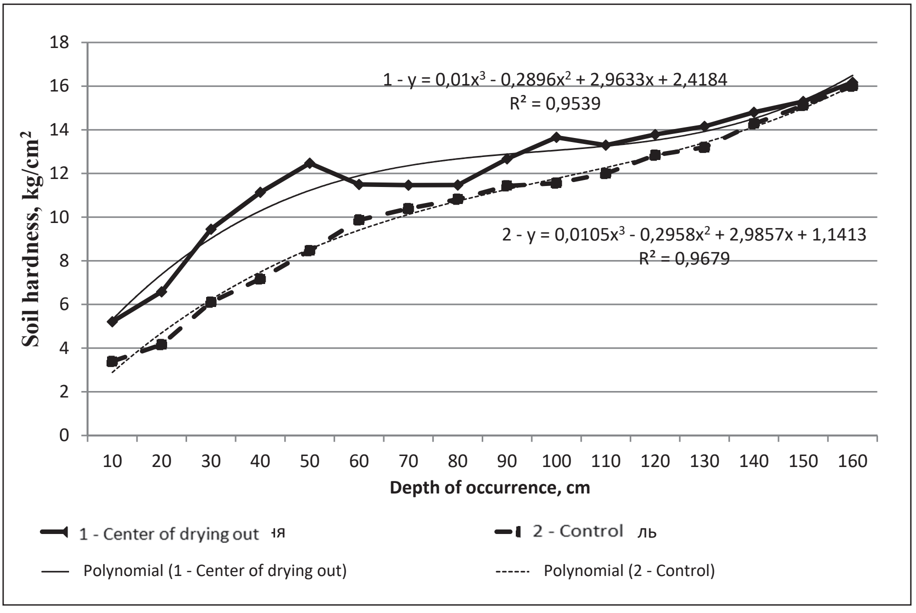

Figure 4
Hardness of soil at different depths in sod-medium podzolist soil in medieval pine plantations affected by root sponge.

Table 4 The soil hardness at different depths in the center of drying out and interfacial space of pine plantations in conditions of Volyn Polissya

Statistical Indicators	Depth of occurrence, cm										
	10	20	30	40	50	60	80	100	120	140	160
Center of drying out											
M –middle, %	5,2	6,6	9,5	11,1	12,5	11,5	11,5	13,7	13,8	14,8	16,2
± m – standard error	0,33	0,29	0,40	0,57	0,66	0,44	0,47	0,66	0,59	0,72	0,74
S – standard deviation	1,26	1,11	1,54	2,20	2,56	1,70	1,81	2,57	2,29	2,81	2,86
S^2 – sample variance	1,60	1,23	2,36	4,83	6,53	2,87	3,26	6,59	5,24	7,88	8,15
Excess	-1,24	-1,29	2,78	1,24	0,44	3,22	2,43	-0,38	-0,46	0,41	0,42
Asymmetry	0,40	-0,28	-1,73	-1,27	-0,69	-1,67	-1,68	-0,76	-0,79	-1,18	-1,06
Minimum	3,7	4,8	5,3	5,7	6,7	6,8	6,7	8,7	9,3	8,6	9,9
Maximum	7,3	8,1	10,9	13,3	16,0	13,2	13,1	17,4	16,5	17,6	19,3
n – number of options	15	15	15	15	15	15	15	15	15	15	15
Interfacial space											
M –middle , %	3,4	4,2	6,1	7,2	8,5	9,9	10,8	11,6	12,8	14,3	16,0
± m – standard error	0,18	0,21	0,36	0,39	0,58	0,56	0,54	0,58	0,51	0,64	0,59
S – standard deviation	0,69	0,81	1,41	1,50	2,25	2,16	2,08	2,26	1,98	2,46	2,29
S^2 – sample variance	0,48	0,65	1,98	2,26	5,06	4,65	4,34	5,13	3,94	6,07	5,24
Excess	-1,34	-0,34	0,53	1,46	-0,78	-0,70	-0,24	-0,37	-0,50	-0,39	-0,69
Asymmetry	0,43	0,04	-1,05	-1,23	0,18	-0,60	-0,52	-0,53	-0,61	-0,83	-0,63
Minimum	2,5	2,7	3,1	3,5	4,9	5,8	7,0	7,1	9,2	9,5	11,9
Maximum	4,5	5,5	7,8	9,1	12,5	12,9	14,1	14,9	15,7	17,1	18,8
n – number of options	15	15	15	15	15	15	15	15	15	15	15
$t_{fact\ 0,05}$	4,79	6,70	6,32	5,65	4,55	2,25	0,98	2,39	1,28	0,52	0,21

Note: $t_{the\ theor}$.. = 2.048; P = 0.05

A clearer idea of the possible influence of the water-physical properties of the soil on the condition of the plantations is given by the dynamics of the indexes of moisture and hardness, the magnitude of which is the proportion of these indices in the center of drying out of the loss of their size in the interfacial space (Fig. 5).

The dynamics of humidity indexes indicates a higher accumulation of moisture in the soil of the center of drying out, in layers of soil at a depth of 10-40 cm, in 1,4-1,5 times more than in the interfacial space.

The accumulation of moisture in the center of drying out in the upper layers of the soil (10-40 cm) is associated with a rarefied tent, where rainfall of any intensity enters the soil, is not retained by crowns and trunks of trees and is not used for physiological processes, and also by more hardness of soil layers at a depth of 40-50 cm.

These compacted layers of soil delay the infiltration of moisture in the lower layers of the soil and contribute to the accumulation of moisture and concentration of root systems in the upper layers of the soil, which, in the conditions of abrupt changes in the hydrological regime, can reduce the stability of plantations, in particular to the root sponge.

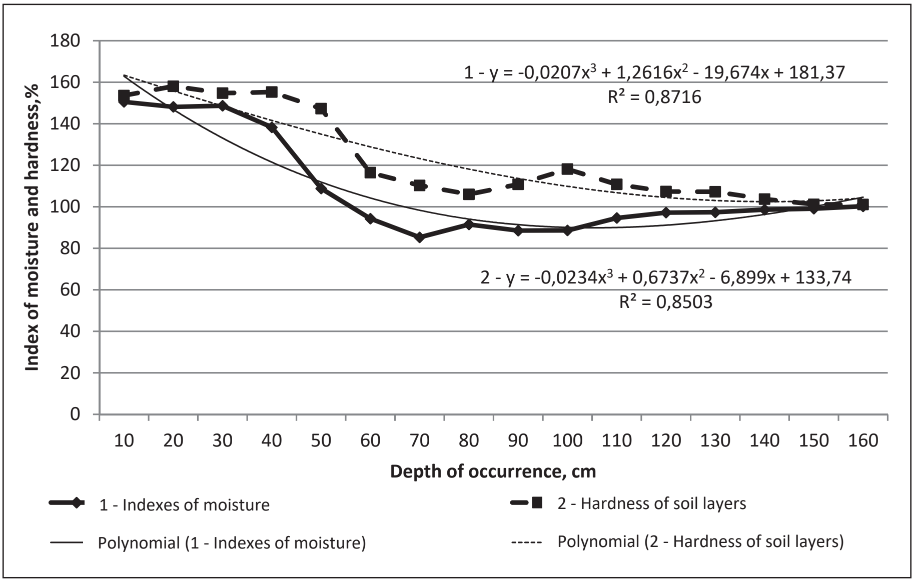

Figure 5

Dynamics of the indexes of moisture and hardness of soil layers (% in the center of drying out from the value in the interfacial space), depending on the depth of their occurrence

The dynamics of the indexes of hardness with depth indicates that in the centers of drying in comparison with the interfacial space in the upper layers of the soil (10-50 cm), the index of hardness is 1.5 and 1.6 times higher, which prevents the development of the roots in depth. Thus, the soils of the fouling centers differ significantly from the soils in the intercostal space with the increased accumulation of moisture in the upper layers of the soil (10-40 cm) and an elevated index of hardness, which undoubtedly affects the metabolism of trees that grow in these conditions. The increased hardness in the upper layers of the soil affects the migration of soil moisture to the ground and its distribution in the soil layers.

Analyzing the level of acid-base properties of the studied soils in the humus-eluvial horizons, it can be noted that in all investigated variants the acidic reaction prevails. However, in control variants, the degree of acidity is slightly higher than in variants with root sponge. Thus, in variations with the root sponge it was 4.8 - 4.95, whereas in the control variants it was 4.55 - 4.95 (see Table 1). The maximum acidity values for the studied sod-podzolic soils are recorded in the upper horizons of the soil, which gradually decrease with the approach to the parent rock. The average values of acidity throughout the profile for all soil cuts in the center of drying out are 5.49 and 5.30, respectively (see Figure 2).

The results of the analysis in the row of soils studied showed that the humus content is very low (see Table 2). Thus, the average content of humus in them is 0.40% at a variation of values from 1.12 to 0.06%. The content of humus in the upper humus-eluvial horizons is the highest and is 0.48 - 1.12%.Down the profile there is a decrease in its content and an increase in elements of inorganic nature (mineral), which is associated with a fairly high level of water availability of soils and the genesis of soil-forming rocks. The soils in the foci of the root spider lesion are poorer in organic matter (humus) compared to soils in the intercostal space in P2 by 47%, P6-18%, and P9 - 8% (Fig. 6). Thus, in the humus-eluvial horizon in the soils of the Horodoksky forestry, the state enterprise «Gorodots'ke FH» in the Typological forest-based conditions (TFC) B2 in the center of defeat of the root sponge (P2-CDO) humus content is 0.48%, and in the intercostal space (P2-IS) - 0,54%; on P6-CDO the content of humus is 0.84%, and on P6-IS - 0.96%. In the humus and eluvial horizon in the soils of the Okunsky forestry, «Manevitsky FH» in the Typological forest-based conditions (TFC) B2-C2 in the center of defeat of the root sponge (P9-CDO) the content of humus is 1,02%, and in the inter-medial space variant (P9-IS) - 1.12%.

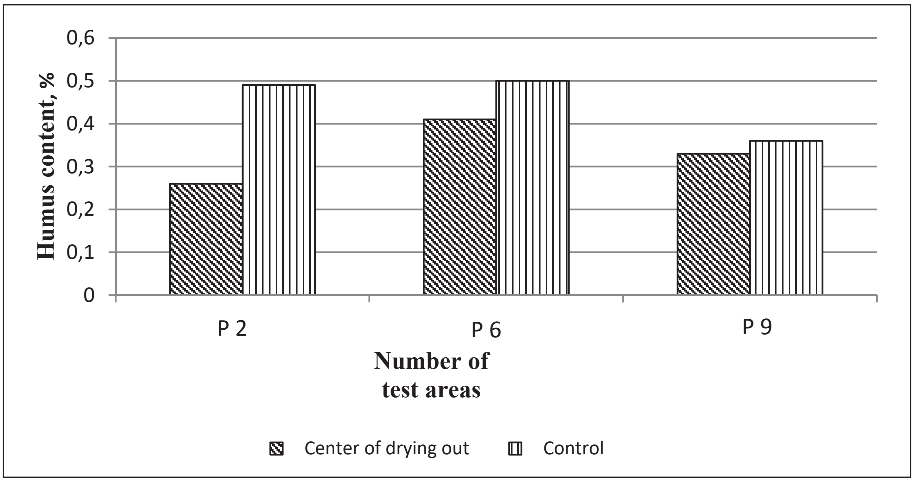

Figure 6
The content of humus in soils of pine plantations, affected and unaffected by the root sponge.

Comparing the soils with the index of the content of gross forms of the NPK, it can be stated that the content of nutrients in variants with root sponge is higher than in variants in the interfacial space, especially nitrogen (N) (Fig. 7). Thus, the content of total N on the average in Typological forest-based conditions (TFC) B2 in the center of drying out (P2-CDO) is 0.146%, P_2O_5 - 0.024%, K_2O - 0.108%, while the interfacial space (P2-IS) - N - 0.052%, P_2O_5 - 0.015%, K_2O - 0.096%.

At the P6-CDO the total N content is - 0,067%, P_2O_5 - 0,019%, K_2O - 0,034%, and the P6-IS – N - 0,052%, P_2O_5 - 0,023%, K_2O - 0,029%. In the Typological forest-based conditions (TFC) B2-C2 in the center of drying out of the root sponge (P9-CDO) the content of total N is - 0,051%, P_2O_5 - 0,016%, K_2O - 0,036%, whereas in the interfacial space (P9-IS) - N - 0.036%, P_2O_5 - 0.016%, K_2O - 0.034%.

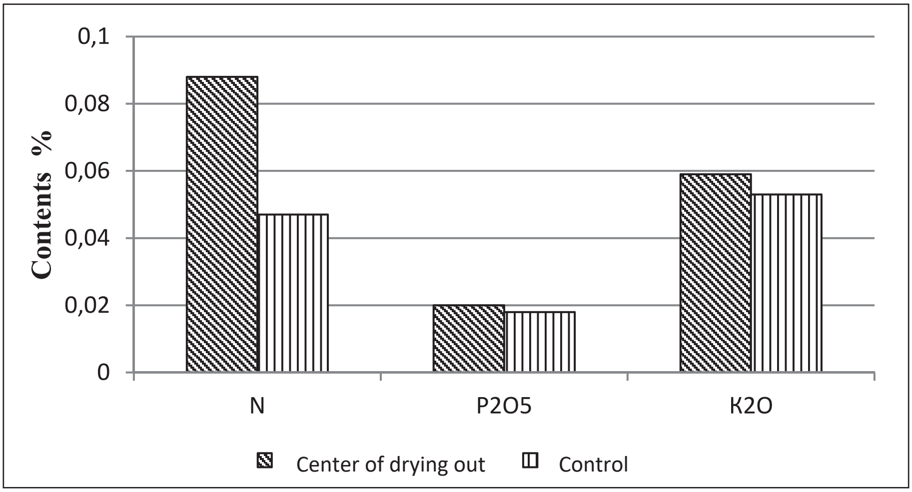

Figure 7
The content of common forms of NPK in soils of pine plantations, affected and unaffected by the root sponge.

DISCUSSION

The results of a number of authors suggest that in high-density pure plantations without timely tending felling, favorable conditions were created for the spread of the root rot due to the root splicing of closely-spaced trees (Ladeyschikova 2001, Vasiliauskas 2002, Ustsky 2011). Granulometric composition is an important genetic and agronomic characteristic of the soil, which is closely related to the properties of soil-forming rocks. The general physical and water-physical properties of soils depend on the granulometric composition: spatiality, moisture content, permeability, as well as air and thermal regimes, etc. Granulometric composition also determines the parameters of physical, chemical and agrochemical properties of soils. (Kovalev 1998). According to the results of our studies of granulometric composition, there were no significant differences between the variants in the center of drying out and in the interfacial space - only 9% of interfacial spaces had less colloidal particles (< 0.001 mm) and physical clay (< 0.01 mm), and the physical content The sand is more than 1% (see Figure 1). Researches conducted in East Polissya Raspadin and others (2013), there were also no significant differences in the granulometric composition in the center of drying out and in the intercostal space.

Specific gravity (solid phase density) of the soil - the ratio of soil volume to the weight of solid particles, dried at a temperature of 100-105 degrees Celsius. Depending on the specific gravity of the soil, the presence of organic matter and mineralogical composition. According to (Sheina 2007), the proportion for most sandy soils is close to the density of quartz (2.65 g / cm^3). In the upper soils of the soil, it decreases due to organic matter - up to 2.50 - 2.60 g / cm^3. In iron ileuvial horizons it rises to 2.70 g / cm^3. In general, in the lungs, with granulometric composition of soils, the density of the solid phase is relatively small, varies in profile from 2.50 to 2.70 g / cm^3. According to the results of our research, this indicator varies from 2.51 to 2.68 g / cm^3. There were no significant differences between variants with root sponge and control (see Figure 2)

Our studies of water-physical properties of the soil in Volyn Polissya revealed a significant difference in the hardness between the ground layers in the center of drying out of the crust and in the interfacial spaces in the upper 60 cm of the soil layer and at a depth of 1 m. The increase in the hardening of the c center of drying out at this depth contributed to a significant accumulation Moisture in the upper layers of the soil (10-40 cm). Also, the accumulation of moisture in the center of drying out of the crust in the upper layers of the soil is associated with a rarefied tent where rainfall of any intensity enters the soil, is not retained by crowns and trunks of trees and is not used for physiological processes.

Studies conducted in Novgorod-Seversky Polissya by Ustsky I. M. (2011) show that the soils of the fouling centers differ significantly from the soils in the interfacial space with the increased accumulation of moisture in the upper layers of the soil (10-40 cm) and the hardness of the soil at depths of 80 and 150 -180 cm. It was concluded that center of drying out occur in pure monolayer crops of pine, created on agricultural land. In places where layers of soil at depths up to 1 m, have a much higher density and delay more moisture, which, after abrupt changes in water regime (intensive felling, drought, drainage), can cause root canal disease.

Tkachuk (2002) in studies in Zhytomyr Polissya, an increase in moisture in the surface layers of the soil, also binds to the presence of layers with a greater volume mass and hardness. They also mark a significant link between humidity and the number of healthy trees. The higher the moisture content of the soil at a depth of 25-75 cm, the smaller the number of healthy trees in the planting.

The accumulation in the soil of organic matter in the form of humus is of great importance, since humus serves as a reserve of nutrients, the gradual release of which in its process of decomposition is considered as one of the important factors of soil fertility sustainability (Kovalets 2007).

According to our results, soddy podzolic soils of light granulometric composition are characterized by very low humus content, which is also reflected in its reserves, which, according to the system of indicators developed by S.D. Orlov and L.O. Grishina (1981) is rated as very low. Low values of humus can be explained by washing type water regime and low saturation with clay particles, which resulted in significant loss of humus. Thus, the average content of humus in them is 0.40%. Thus, in conditions of a sufficient level of humidification, which is a zone of the Volyn Polissya, the reduction of the stability of plantations to their defeat by the root sponge may be due to the extremely limited level of trophy of the location, especially the low content of organic matter (humus).

CONCLUSIONS

The soils in the centers of annosum root rot disease are deficient in organic matter (humus) compared to the soils of the sites between the centers. At the same time, these soils are richer in nutrients (NPK). The particle-size distribution and specific gravity are almost identical for soils in the disease centers and between the centers.

Humidity in all experimental soils in the center of drying out to a depth of 50 cm is higher by 28%, and in deeper horizons, by 6% less than in the intercostal space. The hardness of the soil in the foaming areas throughout the depth of the profile is greater (especially at a depth of 50 cm) than in the intercostal space. Compacted layers on 0,5 m thick soil contribute to the accumulation of moisture and concentration of root systems in the upper layers of the soil, which, in the conditions of abrupt changes in the hydrological regime, can reduce the stability of plantations, in particular to the root sponge.

REFERENCES

ARINUSHKINA V. (1970). Manual of chemical soil analysis / V. E. Arinushkina. - Moscow: Moscow State University Publishing House, 1970. - 120 p. / Аринушкина В. Е. Руководство по химическому анализу почв / В.Е. Аринушкина. – М.: Изд-во МГУ, 1970. – 120 с.

ARTYUKHOVSKY A. (1998). On the role of insects in the emergence and development of foci of the root sponge. / A. K. Artyukhovsky // News of higher educational institutions. Forest Journal. 1998, №5. - p. 33 - 37. / Артюховский, А.К. О роли насекомых в возникновении и развитии очагов корневой губки. / А.К. Артюховский // Известие высших учебных заведений. Лесной журнал. 1998, №5. – С. 33 – 37.

BELOUS M. (2009). Ecological-forestry features of reproduction of forest plantations in the old lands of Chernihiv Polissya. Author's abstract. dis Cand. s.c. Sciences: 06.03.01 / Belous Maxim Mikhailovich; National un-t biores. and naturedocor. Ukraine - K., 2009. - 20 p. / Білоус М. М. Еколого-лісівничі особливості відтворення лісових насаджень на староорних землях Чернігівського Полісся автореф. дис. канд. с.-х. наук: 06.03.01 / Білоус Максим Михайлович; Нац. ун–т біорес. і природокор. України – К., – 2009. – 20 с.

BENDZ-HELLGREN M., BRANDTBERG P.-O., JOHANSSON M., SWEDJEMARK G., STENLID J. (1999). Growth rate of Heterobasidion annosum in Picea abies established on forest land and arable land. Scand. J. For. Res., 14(5). – pp. 402-407.

BEREZHNYAK M. (2012). Laboratory Workshop on Soil Science / MF Berezhnyak. - Kyiv, 2012. - 269 p. / Бережняк М. Ф. Лабораторний практикум з ґрунтознавства / М. Ф. Бережняк. – Київ, 2012. – 269 с.

BRANDTBERG P. O., JOHANSSON M., SEEGER P. (1996). Effects of season and urea treatment on infection of stumps of Picea abies by Heterobasidion annosum in stands on former arable land. Scandinavian Journal of Forest Research, 11. – pp. 261–268.

DAI Y. C., VAINIO E. J., HANTULA J., NIEMELÄ T., KORHONEN K. (2003). Investigations on Heterobasidion annosum s.lat. in central and eastern Asia with the aid of mating tests and DNA fingerprinting. Forest Pathology 33(5). – pp. 269–286. Available online at: https://doi.org/10.1046/j.1439-0329.2003.00328.x.

HARRINGTON T. C., WORRALL J. J., RIZZO D. M. (1989). Compatibility among host-specialized isolates of Heterobasidion annosum from western North America. Phytopathology 79(3). – pp. 290-296.

HARRINGTON T. C., WORRALL J. J., RIZZO D. M. (1989). Compatibility among host-specialized isolates of Heterobasidion annosum from western North America. Phytopathology 79(3). – pp. 290–296.

HRONEC O., VILCEK J., TORMA S., LISNYAK A. (2012). Environmental aspects of Phragmites Australis use at fertilization of contaminated soils // Man and the environment. Problems of neoecology. - Kharkiv: KNU named after V.N. Karazin, 2012, № 3-4. – pp. 113-119. - ISSN 1992-4224. / Hronec O., Vilcek J., Torma S., Lisnyak A. Environmental aspects of Phragmites Australis use at fertilization of contaminated soils // Людина та довкілля. Проблеми неоекології. - Харків: ХНУ імені В.Н. Каразіна, 2012, № 3-4. - с. 113-119. - ISSN 1992-4224.

KOCO S. et al. (2014). Analysis of the state of soil erosion and soil conservation measures in the loess plateau of China. / S. Torma, J. Vilček, G. Barančíková, Y. Tong, L. Liang, P. Ji, T. Hou. - Folia geographica 2014, 56/1. - pp. 57-68. Available online at: http://www.foliageographica.sk/unipo/journals/2014-56-1/4

KOVALETS Y. (2007). Transformation of the humus state of sod-podzolic soils of Western Polissya of Ukraine under the influence of long-term agricultural use

/ Y. M. Kovalets // Sb. sciences works of Podilsky agrar. un-th - 2007. - №15. – pp. 251-253. / Ковалець Ю.М. Трансформація гумусового стану дерново-підзолистих ґрунтів Західного Полісся України під впливом тривалого сільськогосподарського використання / Ю.М. Ковалець // Зб. наук. праць Подільського аграр.-тех. ун-ту. – 2007. – №15. – С. 251–253.

KOVALEV V. (1998). Patterns of the influence of granulometric composition on the content of humus in soils of the accumulative row / V. G. Kovalev // Agrochemistry and Soil Science: specialty. Issue of the V-rally of UTGA. - 1998. - V.2. - P. 55-56. / Ковальов В.Г. Закономірності впливу гранулометричного складу на вміст гумусу в ґрунтах акумулятивного ряду / В.Г. Ковальов // Агрохімія і ґрунтознавство: спец. випуск до V з'їзду УТГА. – 1998. – Ч.2. – С. 55–56.

KUZNETSOV I. (2005). Ecological features of the root sponge in pine plantations of the Middle Don River: Author. dis. Cand. biol. Sciences: 03.00.16 / Kuznetcov, Ivan Vasilevich; Voronezh. state forestry. Acad. - V., 2005. - 18 p. / Кузнецов И. В. Экологические особенности корневой губки в насаждениях сосны обыкновенной Среднего Подонья: автореф. дис. канд. биол. наук: 03.00.16 / Кузнецов, Иван Васильевич; Воронеж. гос. лесотехнич. акад. – В., 2005. – 18 с.

LADIESHCHIKOVA O. (2001). A guide to protecting pine plantations from the root sponge [Instruction. : O. I. Ladeyschikova, I. M. Ustsky, O. G. Chernykh, etc.]. - Kh.: URIFFM, 2001. - 28 p. / Ладейщікова О. І. Настанова по захисту соснових насаджень від кореневої губки / [Уклад. : О. І. Ладєйщікова, І. М. Усцький, О. Г. Черних та ін.]. – Х. : УкрНДІЛГА, 2001. – 28 с.

LEWIS J. W. (2002). Mapping risk from forest insects and diseases. USDA Forest Service, United States Department of Agriculture, 60 pp. Available at: https://www.fs.fed.us/foresthealth/technology/pdfs/riskmap_2002.pdf.

LISNYAK A. (2015). Methodical bases for estimating the ecological risk of soil degradation // Man and environment. Problems of neoecology. - Kharkiv: VN Karazin Kharkiv National University, 2015, No. 1-2. - P. 50-55. - ISSN 1992-4224. / Лисняк А. А. Методические основы оценивания экологического риска деградации почвенного покрова // Людина та довкілля. Проблеми неоекології. - Харків: ХНУ імені В. Н. Каразіна, 2015, № 1-2. - С. 50-55. - ISSN 1992-4224.

LYAMTSEV N. (2015). Results of the study of root sponge in Buzuluksky Bor / N. I. Lyamtsev // Problems of forest phytopathology and mycology: materials of the IX International Conference dedicated to the 90th anniversary of the birth of prof. NI Fedorova, [October 19-24, 2015] / Belarusian State Technological University; [Editorial: I. M. Zharsky and others]. - Minsk; Moscow; Petrozavodsk: BSTU, 2015. - p. 118-121. / Лямцев, Н. И. Результаты изучения корневой губки в Бузулукском бору / Н. И. Лямцев // Проблемы лесной фитопатологии и микологии: материалы IX Международной конференции, посвященной 90-летию со дня рождения проф. Н. И. Федорова, [19-24 октября 2015] / Белорусский государственный технологический университет; [редкол.: И. М. Жарский и др.]. - Минск; Москва; Петрозаводск: БГТУ, 2015. - С. 118-121.

LYGIS V., VASILIAUSKAS R., STENLID J. (2004). Planting Betula pendula on pine sites infested by Heterobasidion annosum: Disease transferred, silvicultural evaluation, and community of wood-inhabiting fungi // Can. J. Forest Res. 2004. 34(1). – pp. 120—130.

MARINICH A. M., PASHCHENKO V. M., SHISHCHENKO P.G. (1985). The nature of the Ukrainian SSR. Landscapes and physiographic mapping. Kyiv, Naukova Dumka, 224 p. [in Russian]

MEAD D. J. (2013). Sustainable management of Pinus radiata plantations. FAO Forestry Paper No. 170. FAO Rome, 246 pp. Available online at: http://www.fao.org/docrep/018/i3274e/i3274e.pdf.

NEGRUTSKY S. (1986). Root sponge / S.F. Negrutsky. - M .: Agropromizdat, 1986. - 196 p. / Негруцкий С.Ф. Корневая губка / С.Ф. Негруцкий. – М.: Агропромиздат, 1986. – 196 с.

ORLOV D. (1981). Workshop on Humus Chemistry: Teaching. allowance / D.S. Orlov, L.A. Grishina - Moscow: Izv. Mosk. Un-ta, 1981. - 272 pp. / Орлов Д.С. Практикум по химии гумуса: учебн. пособие / Д.С. Орлов, Л.А. Гришина. – М.: Изд-во Моск. ун-та, 1981. – 272 с.

PARMASTO E. (1986). Preliminary list of Vietnamese Aphyllophorales and Polyporaceae s. str. Tallin, 88 p.

PARMASTO E. (1986). Preliminary list of Vietnamese Aphyllophorales and Polyporaceae s. str. Valgus, Tallinn, 88 pp.

RAPTUNOVICH Y. (1981). The influence of soil conditions on the spread of the root sponge in pine plantations / Y. S. Raptunovich, G. S. Snigiryov Tez. report scientific-pr. conf. Belarus and the Baltic republics (Minsk, September 9–10, 1981) Protection of coniferous plantations from root rot. - Minsk, 1981. - p. 60–61 / Раптунович Е. С. Влияние почвенных условий на распространение корневой губки в соснових насаждениях / Е. С. Раптунович, Г. С. Снигирёв Тез. докл. научн. - пр. конф. Белоруссии и Прибалтийских республик (Минск, 9–10 сент., 1981 г.) Защита хвойных насаждений от корневых гнилей. – Минск, 1981. – С. 60–61

SHATYAEV A. (1987). Root sponge Fomitopsis annosa (Fr.) Karst. in the ribbon forests of Kazakhstan and the biological justification of measures for the protection of pine crops: author. diss. cand. biol. sciences: 06.01.11 / A.V. Shatyaev - Sverdlovsk, 1987. - 22 p. / Шатяев А. В. Корневая губка Fomitopsis annosa (Fr.) Karst. в ленточных борах Казахстана и биологическое обоснование мероприятий по защите культур сосны: Автореф. дисс. канд. биол. наук: 06.01.11 / А. В. Шатяев – Свердловск, 1987. – 22 с.

SHEIN E. (2007). Theories and Methods of Soil Physics: Collective Monograph, ed. E.V. Sheina and L.O. Karpachevsky - M.: Grif and K, 2007. - 616 p. / Шеин Е. В.Теории и методы физики почв: коллективная монография / под ред. Е.В. Шеина и Л.О. Карпачевского. – М.: Гриф и К, 2007. – 616 с.

SIROTA Z. (1996). Evaluation of the Heterobasidion annosum (Fr.) Bref. Infection risk of 2-nd rotation Scots pine cultures in post-agricultural lands / Z. Sirota // Zakladu Instytutu Badawczego Lesnictwa. – 1996. – V. 3. – pp. 147 – 152.

SSTU 4289: 2004. Quality of soil. Methods of Determination of Organic Substances - Kyiv: Derzhspozhyvstandart of Ukraine, 2005. - 18 p. / ДСТУ 4289: 2004 Якість ґрунту. Методи визначання органічної речовини – Київ: Держспоживстандарт України, 2005. – 18 с.

SSTU 4730: 2007. Quality of soil. Determination of granulometric composition by the pipette method in the modification of NA Kachinsky - Kyiv: Derzhspozhyvstandart of Ukraine, 2005. - 24 p. / ДСТУ 4730: 2007 Якість ґрунту. Визначання гранулометричного складу методом піпетки в модифікації Н.А.Качинського – Київ: Держспоживстандарт України, 2005. – 24 с.

SSTU ISO 10390: 2007. Quality of soil. Determination of pH. - Kyiv: Derzhspozhyvstandart of Ukraine, 2012. - 14 p. / ДСТУ ISO 10390:2007 Якість ґрунту. Визначення pH. – Київ: Держспоживстандарт України, 2012. – 14 с.

TIKHONENKO D. (2010). Laboratory Workshop on Soil Science: Teacher. manual / D.G. Tikhonenko, V.V. Degtyarev, L.L. Velichko, etc. - Vinnitsa: New book, 2010. - 443 p. / Тихоненко Д. Г. Лабораторний практикум з ґрунтознавства: навч. посіб. / Д. Г. Тихоненко, В. В. Дегтярьов, Л. Л. Величко та ін. – Вінниця: Нова кн., 2010. – 443 с.

TKACHUK V. (2002). Grant conditions of pine plantations of the Zhytomyr region affected by root sponge / V.I. Tkachuk, I.M. Ustsky // Scientific herald of UkrDLTU. - Lviv, 2002. - Vip. 12.4 - P. 143-149. / Ткачук В.І. Грантові умови соснових насаджень Житомирської області, уражених кореневою губкою / В. І. Ткачук, І. М. Усцький // Науковий вісник УкрДЛТУ. – Львів, 2002. – Вип. 124. – С. 143–149.

USTSKY I. (2011). Soil features of pine plantations of Novgorod-Siversky Polissya affected by root sponge / I. M. Ustsky // Forest Journal. - No. 2 of the "Publishing House ECO-Inform" LLC and LLC: "New Printing" Ltd. - Kyiv, 2011 - P. 48-52 / Усцький, І. М. Ґрунтові особливості соснових насаджень Новгород-Сіверського Полісся уражених кореневою губкою / І. М. Усцький // Лісовий журнал. – № 2 ТОВ «Видавничий дім ЕКО-інформ» та ТОВ: «Новий друк» – Київ, 2011 р. – С. 48–52.

VASILIAUSKAS A. (1989). Root sponge and the stability of ecosystems of coniferous forests / A. P. Vasiliauskas. - Vilnius: Moxlas, 1989. - 175 p. / Василяускас А. П. Корневая губка и устойчивость екосистем хвойных лесов / А. П. Василяускас. - Вильнюс: Мокслас, 1989. – 175 с.

VASILIAUSKAS R., JUSKA E., VASILIAUSKAS A., STENLID J. (2002). Community of Aphyllophorales and root rot in stumps of Picea abies on clear-felled forest sites in Lithuania. Scandinavian Journal of Forest Research 17(5). – pp. 398–407. https://doi.org/10.1080/028275802320435414.

VASILIAUSKAS R., JUSKA E., VASILIAUSKAS A., STENLID J. (2002). Community of Aphyllophorales and root rot in stumps of Picea abies on clear-felled forest sites in Lithuania. Scandinavian Journal of Forest Research 17(5). – pp. 398–407.

VOLCHENKOVA G. (2012). Prevalence of root sponge foci in pine stands of Vitebsk, Minsk and Mogilev GPLHO / G. A. Volchenkova, V. B. Zvyagintsev, Z. I. Krivitskaya, S. A. Zhdanovich // Trudy BSTU. - Minsk: BSTU, 2012. - № 1. - p. 225-228. / Волченкова Г. А. Распространенность очагов корневой губки в сосновых насаждениях Витебского, Минского и Могилевского ГПЛХО / Г. А. Волченкова, В. Б. Звягинцев, З. И. Кривицкая, С. А. Жданович // Труды БГТУ. - Минск: БГТУ, 2012. - № 1. - С. 225-228.

VOLLBRECHT G., GEMMEL P., ELFVING B. (1994). Forest management with the purpose of reducing windthrow and infection by Heterobasidion annosum in Picea abies – preliminary results from a field experiment. In: G. Vollbrecht: Effects of silvicultural practices on the incidence of root and butt rot in Norway spruce with special emphasis on Heterobasidion annosum. Doctoral thesis, Swedish University of Agricultural Sciences, Alnarp, Sweden.

VORONTSOV A. (1978). Pathology of the forest. / A.I. Vorontsov. M., 1978. - 267 p. / Воронцов А. И. Патология леса. / А.И. Воронцов. М., 1978. – 267 с.

WANG L. Y. (2012). Impact of Heterobasidion spp. root rot in conifer trees and assessment of stump treatment. With emphasis on Picea abies, Pinus sylvestris and Larix × eurolepis. Doctoral Thesis (Summary). Swedish University of Agricultural Sciences, Alnarp, Acta Universitatis agriculturae Sueciae (1652-6880): 97, 66 pp. ISBN: 978-91-576-7744-0. Available online at: https://pub.epsilon.slu.se/9387/1/Wang_LY_130121.pdf.

ZHIGUNOV A. (1980). Study of the water regime of forest soils / A.V. Zhigunov, O.G. Solution, V.S. Zuev // Methodical instructions. - L.: Publishing house LTA, 1980. - 52 p. / Жигунов А. В. Изучение водного режима лесных почв / А.В. Жигунов, О.Г. Растворова, В.С. Зуев // Методические указания. – Л.: Изд-во ЛТА, 1980. – 52 с.

ZVYAGINTSEV V. (2013). Forestry and forest protection measures in pine plantations affected by root sponge / V. B. Zvyagintsev, G. A. Volchenkova, S. A. Zhdanovich // Trudy BSTU. - Minsk: BSTU, 2013. - № 1. - p. 223-226 / Звягинцев, В. Б. Лесоводственные и лесозащитные мероприятия в пораженных корневой губкой сосновых насаждений / В. Б. Звягинцев, Г. А. Волченкова, С. А. Жданович // Труды БГТУ. - Минск: БГТУ, 2013. - № 1. - С. 223-226.