Lesn. Cas. For. J. 60 (2014) 168–176 DE GRUYTER OPEN DOI: 10.2478/forj-2014-0018

PÔVODNÁ PRÁCA – ORIGINAL PAPER

Lesnícky časopis - Forestry Journal
http://www.nlcsk.sk/fj/

Co-adaptive system of tree vegetation and wood-destroying (xylotrophic) fungi in artificial phytocoenoses, Ukraine

Systém prispôsobenia sa stromovej vegetácie a drevokazných (xylotrofných) húb v antropogénnej fytocenóze, Ukrajina

Olena Blinkova, Oleksandra Ivanenko

Institute for Evolutionary Ecology NAS of Ukraine, 03143, Kiev, 37 Lebedeva str. Ukraine

Abstract

The co-adaptive system of tree vegetation and wood-destroying (xylotrophic) fungi in artificial phytocoenoses (in an old-aged, and middle-aged ash-hornbeam oakery and monocultures of *Pinus* L.) of Forest-Steppe zone of Ukraine was analysed from the point of selected forestry parameters. We investigated the vitality, age, phytosanitary structures of pure acerous (*Pinus strobus* L., *P. sylvestris* L.) and mixed broad-leaved stands (*Carpinus betulus* L., *Fraxinus excelsior* L., *Quercus robur* L., *Tilia cordata* Mill.) and species, systematic, trophic structures of xylotrophic fungi (39 species of macromycetes representing 32 genera, 22 families, 9 orders of 2 divisions: Ascomycota (classes Leotiomycetes and Sordariomycetes) and Basidiomycota (class Agaricomycetes)). The results showed that the species composition and the structure (vitality, phytosanitary) of artificial phytocoenoses altered both the composition of xylotrophs and the levels of the damage of tree stands caused by them.

Keywords: consortial links; experimental plots; xylotrophic fungi; woody plants

Abstrakt

Analyzoval sa systém adaptácie stromovej vegetácie a drevokazných (xylotrofných) húb v antropogénnej fytocenóze (staré a strednoveké jaseňovo-hrabové dubiny a boriny) v leso-stepnej zóne Ukrajiny vo vzťahu k lesníckym parametrom. Sledovali sa: vitalita, vek, fytosanitárna štruktúra borových monokultúr (*Pinus strobus* a *P. sylvestris* L.) a zmiešaných listnatých porastov (*Carpinus betulus* L., *Fraxinus excelsior* L., *Quercus robur* L., *Tilia cordata* Mill.) ako aj druhová, systematická a trofická štruktúra xylotrofných húb (39 druhov v rámci makromycétov, ktoré sa týkali 32 druhov, 22 rodov a 9 radov divízie Ascomycota (triedy Leotiomycetes a Sordariomycetes) a Basidiomycetes (trieda Agaricomycetes). Výsledky ukázali, že druhové zloženie a štruktúra (vývojové štádiá a fytosanitárne aspekty) antropogénnej fytocenózy boli pozmenené v závislosti od skladby drevokazných húb a intenzity poškodenia lesných porastov.

Kľúčové slová: konzorčné prepojenia; modelové plochy; drevokazné huby; lesné dreviny

1. Introduction

Nowadays a common knowledge is the scientific provision that when studying biota one should start from the concept of systematic biosphere organisation, since structural and functional unity of components, integrity of biotic and abiotic components are its characteristics. It is natural that each level of hierarchical organisation of biota has its own functional peculiarities, which are stipulated by its origin, structure, inter-relations with the environment and development. This complicates the process of educing the consequences of ecological factors' impacts upon ecosystems, in particular – the changes in their impact on structural and functional components of ecosystem (Arefyev 2010). Co-adaptive systems with their tight ecological links play a significant role in this issue. The study of such ecological objects is important for deeper noesis of not only their biological variety, but also of the issues of phylogeny, regularities of historical transformation of communities, the solving of which is in the initial stage.

In this context a co-adaptive system of tree vegetation and wood-destroying (xylotrophic) fungi is an essential element to study. The actuality of the ecological object is stipulated by the core role of forests in biosphere stability, preservation of landscape and especially biotic variety of land, including fungi, and its global influence upon the planet's climate in accordance with the Rio Declaration on Environment and Development (1992). Taking into account the ecosystematic, and biospheric role of tree vegetation in cycling of substances, energy and information on the Earth, and its role as the environment for the existence of multiple living organisms' species, studying and preservation of forests remains one of the most significant aspects of natural management in the world. The experience in characterising hierarchic, species, geographic, trophic, informational, spatial structure of communities of xylotrophic fungi has been accumulated and the mechanisms of their substrate specialisation has been described in details (Stepanova & Mykhin 1979, Boddy & Rayner 1983, Schmidt 2006, Küffer et al. 2008). Numerous studies of the stated issues refer mostly to systematics and phytopathology of fungi. They differ mostly in the methodological approaches and the depth of studies of certain structural and functional components of forest ecosystems. This leads to

Corresponding author. Olena Blinkova, e-mail: elena.blinkova@gmail.com, phone: +38–044–526–20–51

receiving incomplete information, especially under the terms of ecological objects being influenced by a complex of factors of different origin, intensity and unsafety.

The co-adaptive system of tree vegetation and xylotrophic fungi has not been sufficiently studied so far, although it is an important basis for correct indication and monitoring of the state of forest ecosystems. This concerns the necessity of a complex analysis of evolutionally formed consortial links between tree vegetation and xylotrophic fungi. Following business practices in the countries where silviculture is intensive, in Ukraine major transformation of natural forests into cultivated forests (over 50 %) has taken place. Such a transformation of forest ecosystems caused deprivation of species composition and, accordingly, of structural and functional organisation, certain breach of the consortial links "tree – xylotrophs". Due to this, the study of a co-adaptive system of these organisms in phytocoenoses of artificial origin is expedient.

The structure of xylotrophic fungi is a reflection of parameters of artificial phytocoenoses' development and state, which evidences the unity of components at all hierarchic levels of their inter-links. In the phytocoenoses, which are not durable for anthropogenic or natural reasons, the resistance of biota species to negative influence is significantly diminished and in general, the attrition of the weakest plants and the reformation of species composition and ecosystem structures increases (Arefyev 2010). The facultative species of xylotrophs which have a high degree of pathogenicity take an active part in the formation of the most durable forest ecosystems. The dispersal of xylotrophic fungi in such phytocoenoses is driven by the amount of available substrate and by crucially high evaporation that depends on the intensity of tree drying, canopy openness, stand closure, and protective cover of living on-surface cover (Zmitrovich & Vasilyev 2006, Safonov & Malenkova 2011).

Taking the above into account, the hypothesis of our study is that the spieces, trophic, systematic structure of xylotrophic fungi depicts the phytosanitary state, vitality and age structure of stands of artificial phytocoenoses.

2. Materials and methods

Study site. Artificial phytocoenoses were selected from the nature reserve fund of Ukraine since in these objects human intervention is minimised. Hence, inter-links between tree vegetation and xylotrophic fungi are not significantly influenced by human activities.. That is why the study was conducted in the State Dendrological Park of Ukrainian National Academy of Science (NAS) "Oleksandriya" (dendropark), which is also a monument of garden art of nation-wide significance of nature reserve fund of Ukraine, and is one of the largest (49° 48′ 44′′ N, 30° 04′ 02′′ E, area 297 ha) and the most valuable dendrological parks in the territory of Ukraine (Klymenko & Mordatenko 2001). The dendropark is located North-East from the Right-bank of the Forest-Steppe zone, at the outskirts of Bila Tserkva town of Kyiv Region (elevation 80–106 m above the sea level). Architectural edifices and aged oak planted vegetation are extremely valuable landscape components in Ukrainian territory and worldwide. Probably the most valuable feature in Alexandria dendropark is the so called "old-aged oak-forest" with up to 2.100 trees of *Quercus robur* L. aged 220–250, and some even 400–600 years old, covering a total area of 44.6 ha. In literature these plantations are called "old-aged oak-forests" (Deriy 1958; Dragan 2010, 2012). However it is worth noting that according to forestry typological classification basics an "oak-forest" is a type of forests, an ecotope, which originates from natural regeneration of oak (Anuchin 1982). In turn a tree stand from oak planting is customarily called "oakery". Ergo, this paper deals with an overmature oak stand – "old-aged oak-forest".

Considering the data from inventory documents, forest management plans and the primary survey performed in September 2013 (17 – 24), we distinguished three types of artificial phytocoenoses, which grow on grey forest soils. To analyse vitality, phytosanitary conditions, age structure of stands and the species, systematic, trophic structure of xylo-myco-complex, three experimental plots (EP) in phytocoenoses, which differ in forestry characteristics – type (or species composition), age and phytosanitary state of stands were established as ecological profiles: 1) EP1 (0.5 ha) – in an overmature (old-aged) mixed oak stand (the "old-aged oak-forest" according to inventory documents) called "The Dancing Oaks" (the 12th sector of the park); 2) EP2 (1 ha) – in a middle-aged ash-hornbeam planting (*Carpinus betulus* L. and *Fraxinus excelsior* L.) called "The Hornbeam Building" (the 15th sector); 3) EP3 (0.5 ha) – in a monoculture of *Pinus strobus* L. and *P. sylvestris* L. called "At the Great Glade" (the 28th sector of the park) (Fig. 1).

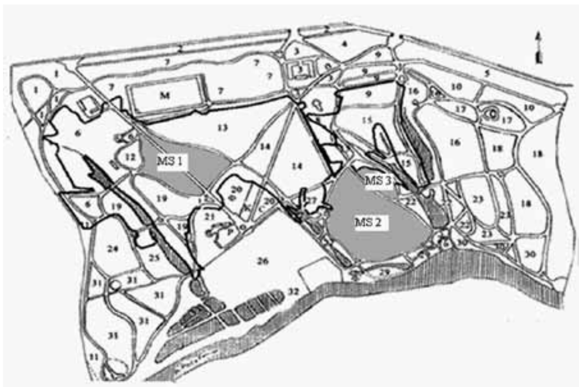

Fig. 1. State dendrological park of NAS of Ukraine "Alexandriia" and the position of the experimental plots.

Methods. In each experimental plot, ecological research was performed at different diagnostic levels of xylotrophic fungal infestation: organ, tree, population (species), bio-group (stratum) of phytocoenosis, phytocoenosis. The state of trees was evaluated according to common methods of forestry and landscape ecology (Vorobyov 1967, Anuchin 1982). The phytosanitary state of trees was appraised in accordance with the Sanitary Forest Regulation in Ukraine (1995). The stand state index was calculated as a sum of the values of the tree state index of the trees in a certain category, divided by the total number of examined trees. Stands with the index value from the interval 1 – 1.5 are considered healthy (I), the weakened ones (II) – 1.51 – 2.50, heavily weakened (III) – 2.51 – 3.50, the wilting ones (IV) – 3.51 – 4.50, recently dead (V) – 4.51 – 5.50, old dead stands (VI) – 5.51–6.50. In order to avoid the influence of the irregular intensity of silvicultural practice upon the index of stand state, for each category of states the weighted average of Kraft classes (WAKC) was calculated as the sum of the number of trees in each Kraft class was multiplied by stand state index (I–V), divided by the total number trees in a certain category of state. For this purpose the trees in each category were divided into 5 groups according to Kraft classes. Classes Va and Vb were united into class V, since the trees of these categories were rarely found in the experimental plots. The WAKC depicts the localisation of the damage zone in the tree stratum: the closer the WAKC is to Kraft class I, the higher is the degree of damage. Hence, this evidences that the most persistent trees are influenced by negative ecological factors. For each stand, forest mensuration parameters were determined: age (A); weighted average diameter (D_{ave}), height (H_{ave}), fluctuations range ($D_{min} - D_{max}$; $H_{min} - H_{max}$) and standard deviation (S.D.), stand density (N), mean tree basal area (G), stand basal area as a sum of tree areas (G_n).

According to regular mycology methods (Arefyev 2010), the measuring unit is a host tree, on which carpophores of certain fungi species were detected. The collection of factual evidence was carried out during the period of visible growth and formation of carpophores of xylotrophic fungi in the vegetation period. Every detected species was photographed in vivo. The species that were easily identified "in oculo nudo" and did not require additional micro-morphological studies were not included in the exsiccates. If required, the colour, smell, and the structure of carpophores were noted including the reaction of carpophores to mechanical damage (change of colour, sap ooze) and the substrate. The determination of fungi species was effected by the methods of Ryvarden and Gilbertson (1993, 1994), Clémençon (2009), Bernicchia and Gorjón (2010). The dead substrate of the host tree of xylotrophic fungi was divided into two categories – fallen woody debris (branches and stems) and stump depending on the morpho-metric parameters. Xylotrophic fungi species were identified on the base of macrosystem and phylogeny of higher fungi (Zmitrovich 2001, Zmitrovich & Wasser 2004, Hibbett et al. 2007) using the nomenclature base MycoBank (Robert et al. 2005). The names of fungi species are cited according to Kirk and Ansell (1992).

3. Results and discussion

Due to the construction of the park alleys, parkways, introduction of alien crops and creation of new landscape components during the past decades, the dendrological park has undergone an intensive anthropomorphic transformation, which is manifested in the breach of structural and functional integrity of phytocoenoses' organisation. This in turn essentially affects the functioning of a co-adaptive system of *C. betulus, F. excelsior, P. strobus, P. sylvestris, Q. robur, T. cordata* and xylotrophic fungi. It is also notable that there is no data on mycobiota of tree vegetation from the territory of the dendrological park. Our mycological study detected altogether 39 species of macromycetes (30 species of xylotrophic fungi), 32 genera, 22 families, and 9 orders of 2 divisions: Ascomycota (classes Leotiomycetes and Sordariomycetes) and Basidiomycota (class Agaricomycetes) (Table 1) at all experimental plots of the dendropark's ecoprofile.

At the first EP, the stand consisted of two storeys, the canopy cover was 0.5 – 0.6; mean tree basal area G of *Q. robur* (A = 220 – 250) (the first storey) varied between 0.1808 m^2/ha and 0.6510 m^2/ha, S.D. – 0.1263, stand basal area G_n at the ecoprofile was 140.4 m^2/ha; N (stand density) = 401 pcs./ha; H_{ave} = 29.5 m, H_{min} = 21.5 m, H_{max} = 34.7 m, S.D. = 3.62 m; D_{ave} = 65.24 cm; D_{min} = 44.5 cm, D_{max} = 91.5 cm, S.D. – 12.16 cm.

The herbaceous storey is represented by oakery forbs only at plots with preserved forest structure (*Veronica chamaedrys* L., *Pulmonaria obscura* Dumort.). The dominating species at the EP were *Dactylis glomerata* L., *Trisetum flavescens* L., *Asarum europaeum* L., *Urtica dioica* L., etc. Altogether, 30 species of macromycetes were found at EP1, the fruiting of which occurs autumn. These fungi species represented 26 genera, 17 families, and 7 orders of 2 divisions: Ascomycota (class Leotiomycetes) and Basidiomycota (class Agaricomycetes). From the on-ground saprotrophs we detected *Chlorophyllum rhacodes* (Vittad.) Vellinga, *Stropharia aeruginosa* (Curtis) Quél., and dry carpophores of *Calvatia utriformis* (Bull.) Jaap, which grows mainly in July–August. From the fungi fruiting in spring and summer on small dry branches of *T. cordata* we found *Polyporus alveolaris* (DC.) Bondartsev et Singer, which is a xylotrophic fungus with broad substrate preference. On *Q. robur* 23 species of xylotrophic fungi were detected, while 3 were parasitic species, and their share in the artificial phytocoenosis comprised only 9%: *Fistulina hepatica* (Schaeff.) With., *Inocutis dryophila* (Berk.) Fiasson et Niemelä and *Phellinus robustus* (P. Karst.) Bourdot et Galzin. The latter 2 species were detected only on the trees of I–II phytosanitary stand categories. Their carpophores fruiting time coincides mainly with mechanically undamaged stem of *Q. robur* at a height of 4 – 10 m. On the contrary, *Phellinus robustus* preferred mechanical damages of stems (hollows, chaps, shear cuts of branches of the 1st and the 2nd order), which accelerate mechanical drain. Fruiting of *Fistulina hepatica*, on the contrary gravitate to dead substrata. The analysis of the vital structure of *Q. robur plantings* revealed that xylotrophic fungi were observed mainly on the trees in I Kraft class (45%), while their proportion on the trees of IV Kraft class was the lowest (7%) (Table 2).

Such a distribution of trees to individual Kraft classes is caused byover-maturity of *Q. robur*. Besides, the weighted average of Kraft classes (1.55) of healthy trees of *Q. robur* (I phytosanitary stand category) indicates that the closer the trees are to forest roads and open landscape elements , the more increasing is the number of trees in Kraft classes II–III. The proportion of co-dominant trees among the weakened trees is growing with the increasing proximity of forest roads. Although the total proportion of very weakened trees is not high (15%), the number of trees in the weakened Kraft class III is increasing, which further increases the probability of the pathological process in the old-aged oakery. In general, 51% of *Q. robur* trees at the EP1 were healthy, the rest were weakened to different extent, including 3% of dying ones (Table 3). The phytopathological state of *Q. robur* trees at this plot

Table 1. Taxonomic structure of macromycetes at the experimental plots.

order	family	genus
division ASCOMYCOTA (1;1;1;1;1;1;1)		
subdivision PEZIZOMYCOTINA (1;1;1;1;1;1)		
class LEOTIOMYCETES (1;1;1;1;1)		
subclass LEOTIOMYCETIDAE (1;1;1;1)		
order	family	genus
Helotiales (1;1;1)	Helotiaceae (1;1)	Ascocoryne (1)
class SORDARIOMYCETES (1;1;1;1;1)		
subclass XYLARIOMYCETIDAE (1;1;1;1)		
order	family	genus
Xylariales (1;1;1)	Xylariaceae (1;1)	Xylaria (1)
division BASIDIOMYCOTA (1;1;7;20;30;37)		
subdivision AGARICOMYCOTINA (1;7;20;30;37)		
class AGARICOMYCETES (7;20;30;37)		
order	family	genus
Corticiales (1;1;1)	Corticiaceae (1;1)	*Vuilleminia* (1)
Hymenochaetales (2;4;4)	Hymenochaetaceae (3;3)	*Hymenochaete* (1), *Inocutis* (1), *Phellinus* (1)
	Schizoporaceae (1;1)	*Schizopora* (1)
Polyporales (4;6;9)	Fomitopsidaceae (1;1)	*Laetiporus* (1)
	Ganodermataceae (1;2)	*Ganoderma* (2)
	Meruliaceae (1;1)	*Bjerkandera* (1)
	Polyporaceae (3;5)	*Fomes* (1), *Polyporus* (1), *Trametes* (3)
Russulales (3;3;4)	Auriscalpiaceae (1;1)	*Auriscalpium* (1)
	Peniophoraceae (1;1)	*Peniophora* (1)
	Stereaceae (1;2)	*Stereum* (2)
Thelephorales (1;1;1)	Thelephoraceae (1;1)	*Thelephora* (1)
subclass AGARICOMYCETIDAE (2;9;15;18)		
order	family	genus
Agaricales (7;11;13)	Agaricaceae (4;4)	*Calvatia* (1), *Chlorophyllum* (1), *Crucibulum* (1), *Cyathus* (1)
	Fistulinaceae (1;1)	*Fistulina* (1)
	Inocybaceae (1;2)	*Crepidotus* (2)
	Mycenaceae (1;1)	*Panellus* (1)
	Pterulaceae (1;1)	*Radulomyces* (1)
	Schizophyllaceae (1;1)	*Schizophyllum* (1)
	Strophariaceae (2;3)	*Hypholoma* (2), *Stropharia* (1)
Boletales (2;4;5)	Boletaceae (3;4)	*Boletus* (1), *Xerocomellus* (1), *Xerocomus* (2)
	Suillaceae (1;1)	*Suillus* (1)

Table 2. Vitality structure of *Quercus robur* L. and specific structure of xylotrophic fungi at the first experimental plot.

No.	Fungi-consorts	Kraft class* (pcs./%)			
		I	II	III	IV
1	*Ascocoryne sarcoides* (Jacq.) J.W. Groves et D.E. Wilson	—	1/6,3	—	—
2	*Bjerkandera adusta* (Willd.) P. Karst.	1/2,9	—	—	—
3	*Crepidotus mollis* (Schaeff.) Staude	1/2,9	—	—	—
4	*Crucibulum crucibuliforme* (Scop.) V.S. White	—	1/6,3	—	—
5	*Cyathus striatus* (Huds.) Willd.	3/8,8	—	—	—
6	*Fistulina hepatica* (Schaeff.) With.	1/2,9	—	—	—
7	*Hypholoma fasciculare* (Huds.) P. Kumm.	—	—	1/8,3	—
8	*Inocutis dryophila* (Berk.) Fiasson et Niemelä	1/2,9	—	—	—
9	*Peniophora quercina* (Pers.) Cooke	1/2,9	—	—	—
10	*Phellinus robustus* (P. Karst.) Bourdot et Galzin	4/11,8	—	—	1/16,7
11	*Radulomyces molaris* (Chaillet ex Fr.) M.P. Christ.	3/8,8	1/6,3	—	—
12	*Schizophyllum commune* Fr.	1/2,9	1/6,3	—	—
13	*Schizopora paradoxa* (Schrad.) Donk	1/2,9	—	—	—
14	*Stereum gausapatum* (Fr.) Fr.	1/2,9	2/12,5	—	—
15	*Trametes versicolor* (L.) Lloyd	1/2,6	—	—	—
16	*Vuilleminia comedens* (Nees) Maire	2/5,9	1/6,3	—	—
Sum of findings of xylotrophic fungi / number of trees in each category (pcs.)		16/45	4/30	1/18	1/7

Note: * – % within the category of phytosanitary state.

indicates probable gradual decay of the growing forest in the absence of regular maintenance.

It is also clear that the composition and distribution of xylotrophic fungi is tightly connected not only with the vitality and phytosanitary structure of tree stands, but also with the type of substratum (Table 4). According to this, one half of the identified xylotrophic fungi (50%) occurred in the ground myco-horizon of *Q. robur*, and 37.5% – in the butt myco-horizon.

The frequency of xylotrophic fungi in stem and photosynthesising mycohorizons was equal – 8.3% at each horizon. Besides, the dead substrate of the two categories (woody debris and stumps of *Q. robur*) was also detected at the experimental plot (Fig. 2). It should be noted that the biggest number of species and findings of xylotrophic fungi on dead substrate coincides with the fine woody debris of *Q. robur*. We detected: *Ascocoryne sarcoides* (Jacq.) J.W. Groves et D.E. Wilson (1, finding), *Bjerkandera adusta* (Willd.) P. Karst. (1), *Crepidotus mollis* (Schaeff.) Staude (1), *Crucibulum crucibuliforme* (Scop.) V.S. White (1), *Cyathus striatus* (Huds.) Willd. (3), *Peniophora quercina* (Pers.) Cooke (1), *Radulomyces molaris* (Chaillet ex Fr.) M.P. Christ (2), *Schizophyllum commune* Fr. (2), *Schizopora paradoxa* (Schrad.) Donk (1), *Stereum gausapatum* (Fr.) Fr. (3), *Trametes versicolor* (L.) Lloyd (1), *Vuilleminia comedens* (Nees) Maire (6, findings). All together 13.3% stumps of *Q. robur* aged over 10 years occurred at EP1. The saprotrophs on large stumps of *Q. robur* (D_{ave} = 65.0 – 85.0 cm) were: *Fistulina hepatica* (4, findings), *Hymenochaete rubiginosa* (Dicks.) Lév. (2), *Hypholoma fasciculare* (Huds.) P. Kumm. (3), *Panellus stipticus* (Bull.) P. Karst. (1, finding). On the stumps of *Q. robur* with average diameter of 45.0 – 65.0 cm we found: *Ganoderma lipsiense* (Batsch) G.F. Atk. (1, finding), *Hypholoma fasciculare* (1), *H. lateritium* (Schaeff.) P. Kumm. (1), *Stereum hirsutum* (Willd.) Pers. (2), *Trametes hirsuta* (Wulfen) Lloyd (1, finding).

It was also detected that at the EP1 plantings of *T. cordata* (A = 100 – 120) located in the other storey, had the following inventory parameters of stand: G varied between 0.1205 m^2/ha and to 0.2801 m^2/ha, S.D. – 0.0840; G_n = 78.8 m^2/ha, N = 151 pcs./ha, H_{ave} = 15.2 m, H_{min} = 10.0 m, H_{max} = 19.5 m, S.D. – 2.71 m; D_{ave} = 29.7 cm, D_{min} = 16.5 cm, D_{max} = 37.5 cm, S.D. – 9.94 cm. Only heavily weakened trees of *T. cordata* of IV Kraft class (I = 2.2; 25% of the total amount of trees at the plot) were infested with xylotrophic fungi. The trees of II (41.7%) and III (8.3%) Kraft classes did not have a mycological component. In general, at the EP 58.3% (I = 1.21) of trees of *T. cordata* were healthy, 16.7% – weakened (I = 1.50) and 25% (I = 1.85) – heavily weakened. There were no fresh and old dead standing trees. Thus, the phytosanitary state of *T. cordata* was better compared to *Q. robur*. On *T. cordata* 3 fungi species were detected representing 3 genera, 3 families and 2 orders of Agaricomycetes class of Basidiomycota division. One of them is parasitic (there was dense fruiting of *Crepidotus variabilis* (Pers.) P. Kumm. on the intact stem bark), and two were saprotrophs on fine woody debris (*Polyporus alveolaris, Shizophyllum commune*). No stumps of *T. cordata* were found. 75% of observed fungi belonged to the ground myco-horizon and only 25% to the stem one (Table 4). The species, systematic and trophic structure of xylotrophs evidences that every fungi species of this group occupies its ecological niche depending on the conditions of the place in vegetation, its phytosanitary state, vital structure, morpho-metric parameters of *Q. robur, T. cordata*, and dead substrate.

An important component of the study of the co-adaptive system of tree vegetation and xylotrophic fungi in the dendrological park is the study of other soft-wooded broad-leaved tree species. At the second EP, the stand was two-storeyed, with the first storey composed of *Q. robur*, and the second storey composed of *C. betulus* (A = 120 – 140) and *F. excelsior* (A = 120 – 140); canopy cover 0.6 – 0.7. Stand parameters of *C. betulus* were: G_n = 95.5 m^2/ha, N = 202 pcs./ha, H_{ave} = 22.5 m, H_{min} = 18.1 m, H_{max} = 27.2 m, S.D. – 3.21 m; D_{ave} = 31.5 cm, D_{min} = 24.5 cm, D_{max} = 44.5 cm, S.D. – 7.11 cm. On *C. betulus* we detected 6 species of xylotrophic fungi, which

Table 3. Phytosanitary structure of *Quercus robur* L. and specific structure of xylotrophic fungi at the first experimental plot.

No.	Fungi-consorts	Category of phytosanitary structure			
		I	II	III	IV
1	*Ascocoryne sarcoides* (Jacq.) J.W. Groves et D.E. Wilson	1/2,6	—	—	—
2	*Bjerkandera adusta* (Willd.) P. Karst.	1/2,6	—	—	—
3	*Crepidotus mollis* (Schaeff.) Staude	1/2,6	—	—	—
4	*Crucibulum crucibuliforme* (Scop.) V.S. White	—	1/4,3	—	—
5	*Cyathus striatus* (Huds.) Willd.	2/5,1	1/4,3	—	—
6	*Fistulina hepatica* (Schaeff.) With.	1/2,6	—	—	—
7	*Hypholoma fasciculare* (Huds.) P. Kumm.	1/2,6	—	—	—
8	*Inocutis dryophila* (Berk.) Fiasson et Niemelä	1/2,6	—	—	—
9	*Peniophora quercina* (Pers.) Cooke	—	1/4,3	—	—
10	*Phellinus robustus* (P. Karst.) Bourdot et Galzin	4/10,3	1/4,3	—	—
11	*Radulomyces molaris* (Chaillet ex Fr.) M.P. Christ.	2/5,1	—	1/7,1	1/100
12	*Schizophyllum commune* Fr.	1/2,6	—	1/7,1	—
13	*Schizopora paradoxa* (Schrad.) Donk	1/2,6	—	—	—
14	*Stereum gausapatum* (Fr.) Fr.	1/2,6	1/4,3	1/7,1	—
15	*Trametes versicolor* (L.) Lloyd				1/100
16	*Vuilleminia comedens* (Nees) Maire	1/2,6	1/4,3	—	1/100
Sum of findings of xylotrophic fungi / number of trees in each category (pcs.)		14/51	4/31	2/15	2/3
% findings of xylotrophic fungi / % of trees in each category / WAKC		63,6/51,0/1,55	18,2/31,0/2,31	9,0/15,0/3,42	9,0/3,0/3,55

Table 4. Distribution of macromycetes by macromycetes in myco-horizons at the experimental plots.

№	Fungi-consorts	Trees-edificators of consortium	Mycohorizons *				
			1	2	3	4	5
1	*Ascocoryne sarcoides* (Jacq.) J.W. Groves et D.E. Wilson	*Q. robur* (1)	—	1/3,6	—	—	—
2	*Auriscalpium vulgare* Gray	*P. strobus* (2), *P. sylvestris* (3)	—	5/17,8	—	—	—
3	*Bjerkandera adusta* (Willd.) P. Karst.	*Acer negundo* L. (1), *C. betulus* (2), *Q. robur* (1)	—	1/3,6	1/3,7	—	2/20
4	*Boletus badius* (Fr.) Fr.	*P. strobus* (2), *P. sylvestris* (1)	3/16,7	—	—	—	—
5	*Crepidotus mollis* (Schaeff.) Staude	*Q. robur* (1)	—	1/3,6	—	—	—
6	*C. variabilis* (Pers.) P. Kumm.	*T. cordata* (1)	—	—	—	1/11,1	—
7	*Crucibulum crucibuliforme* (Scop.) V.S. White	*Q. robur* (1)	—	1/3,6	—	—	—
8	*Cyathus striatus* (Huds.) Willd.	*Q. robur* (3)	—	3/10,7	—	—	—
9	*Fistulina hepatica* (Schaeff.) With.	*Q. robur* (5)	—	—	5/18,5	—	—
10	*Fomes fomentarius* (L.) Fr.	*C. betulus* (1), *F. excelsior* (1)	—	—	—	2/22,2	
11	*Ganoderma lipsiense* (Batsch) G.F. Atk.	*F. excelsior* (1), *Q. robur* (1)	—	—	2/7,4	—	—
12	*G. lucidum* (Curtis) P. Karst.	*C. betulus* (2)	—	—	2/7,4	—	—
13	*Hymenochaete rubiginosa* (Dicks.) Lév.	*Q. robur* (2)	—	—	2/7,4	—	—
14	*Hypholoma fasciculare* (Huds.) P. Kumm.	*Q. robur* (5)	1/5,5	—	4/14,8	—	—
15	*H. lateritium* (Schaeff.) P. Kumm.	*Q. robur* (1)	—	—	1/3,7	—	—
16	*Inocutis dryophila* (Berk.) Fiasson et Niemelä	*Q. robur* (1)	—	—	—	1/11,1	—
17	*Laetiporus sulphureus* (Bull.) Murrill	*Juglans manshurica* Max. (1)	—	—	—	1/11,1	
18	*Panellus stipticus* (Bull.) P. Karst.	*Q. robur* (1)	—	—	1/3,7	—	—
19	*Peniophora quercina* (Pers.) Cooke	*Q. robur* (1)	—	1/3,6	—	—	—
20	*Phellinus robustus* (P. Karst.) Bourdot et Galzin	*Q. robur* (5)	—	—	—	3/33,3	2/20
21	*Polyporus alveolaris* (DC.) Bondartsev et Singer	*T. cordata* (1)	—	1/3,6	—	—	—
22	*Radulomyces molaris* (Chaillet ex Fr.) M.P. Christ.	*Q. robur* (4)	—	2/7	—	—	2/20
23	*Schizophyllum commune* Fr.	*Q. robur* (2), *Prunus avium* L. (1), *T. cordata* (1)	—	4/14,3	—	—	—
24	*Schizopora paradoxa* (Schrad.) Donk	*C. betulus* (1), *Q. robur* (1)	—	—	1/3,7	—	1/10
25	*Stereum gausapatum* (Fr.) Fr.	*Q. robur* (3)	—	3/10,7	—	—	—
26	*S. hirsutum* (Willd.) Pers.	*A. negundo* (1), *Q. robur* (2), *P. avium* (1)	—	—	3/11,1	1/11,1	1/10
27	*Suillus granulatus* (L.) Roussel	*P. sylvestris* (2)	2/11,1	—	—	—	—
28	*Thelephora terrestris* Ehrh.	*P. sylvestris* (1)	—	1/3,6	—	—	—
29	*Trametes gibbosa* (Pers.) Fr.	*C. betulus* (2), *F. excelsior* (1)	—	—	1/3,7	—	2/20
30	*T. hirsuta* (Wulfen) Lloyd	*Q. robur* (1)	—	—	1/3,7	—	—
31	*T. versicolor* (L.) Lloyd	*Q. robur* (1)	—	1/3,6	—	—	—
32	*Vuilleminia comedens* (Nees) Maire	*Q. robur* (3)	—	3/10,7	—	—	—
33	*Xerocomellus chrysenteron* (Bull.) Sutara	*Q. robur* (5)	5/27,8	—	—	—	—
34	*Xerocomus pruinatus* (Fr. et Hök) Quél.	*Q. robur* (5)	5/27,8	—	—	—	—
35	*X. rubellus* (Krombh.) Quél.	*Q. robur* (2)	2/11,1	—	—	—	—
36	*Xylaria polymorpha* (Pers.) Grev.	*C. betulus* (2), *F. excelsior* (1)	—	—	3/11,1	—	—
Sum of species /findings:		9/92	6/18	13/28	14/27	6/9	6/10
% of species /findings:			16,7/19,6	36,1/36,4	38,9/29,3	16,7/9,8	16,7/10,9

Note: * – pcs./ %; 1 – root; 2 – ground; 3 – butt; 4 – stem; 5 –photosynthesising mycohorizon; "–" – not detected.

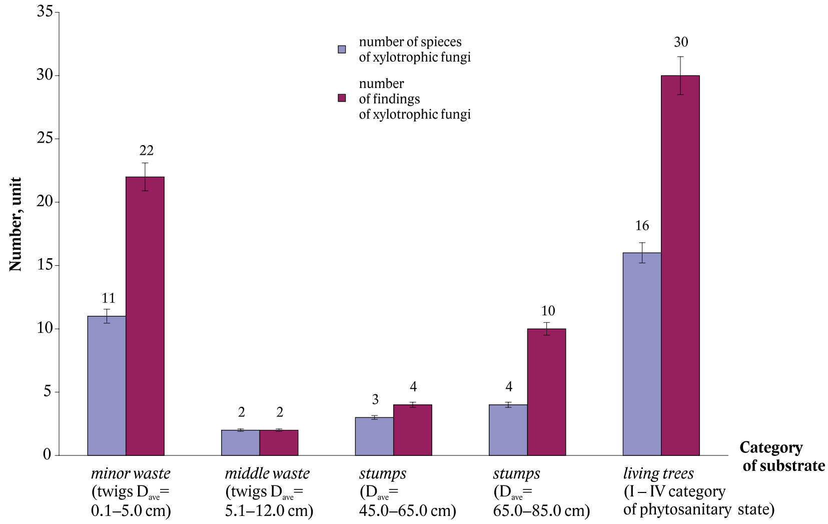

Fig. 2. Number of observed species and number of observations of xylotrophic fungi on *Quercus robur* L. in individual substrate categories

represented 6 genera, 5 families, 3 orders, and 2 classes of 2 divisions: Asco- and Basidiomycota (Table 1). The parasitic way of nutrition was characteristic for 4 fungi species (*Bjerkandera adusta, Fomes fomentarius* (L.) Fr., *Schizopora paradoxa, Trametes gibbosa* (Pers.) Fr.) observed at four trees of *C. betulus*, three of which had broken tops. The analysis of the vital structure of *C. betulus* revealed that the maximum number of observations of xylotrophic fungi (66.7%) was detected – for I Kraft developmental class of trees (with 40.9% frequency at the plot). The trees of II (40.9% of all trees at the experimental plot; *Bjerkandera adusta*) and IV (18.2%, *Trametes gibbosa*) Kraft classes had the same proportion of tree-destroying fungi at the plot – 16.7%, but the recorded fungi species differed between these two classes. No xylotrophic fungi were detected on trees of III and V Kraft classes. The analysis of the phytosanitary structure of *C. betulus* and the specific structure of xylotrophic fungi showed that the smallest number of xylotrophs (4.5%) was observed on the trees of I category (33.3%, I = 1.47). The greatest number of xylotrophs (77.3%) was recorded on the trees of IV state category (27.5%, I = 2.21). This is understandable since this category of trees has the highest probability of damage by wood pests and is the least resistant to other negative factors. In the weakened (18.5%) and heavily weakened trees (20.7%) the proportion of xylotrophic fungi was the same (9.1%, Fig. 3). Apart from this, in the vicinities of ruptures of *C. betulus* intensive development of carpophores was observed (over 50 pcs. of *Bjerkandera adusta*, and carpophores of Shizopora paradoxa growing up to 1 m high on substratum). There were not numerous fruitings on stems of *Fomes fomentarius* and *Trametes gibbosa*. Two species of saprotrophic nutrition: *Ganoderma lucidum* (Curtis) P. Karst. and *Xylaria polymorpha* (Pers.) Grev., were detected. The mycohorizontal distribution of xylotrophs on *C. betulus* was as follows: 50.0% of xylotrophic fungi were in photosynthesising myco-horizon, 40.0% – at the butt-end, and only 10.0% of findings were in the stem myco-horizon. This data differs from the myco-horizontal distribution of fungi on *Q. robur*, where they were concentrated on butt and stem (Table 4).

Stand parameters for *F. excelsior* were as follows: G_n = 88.5 m²/ha, N = 190 pcs./ha, H_{ave} = 23.7 m, H_{min} = 19.5 m, H_{max} = 27.5 m, S.D. –3.45 m; D_{ave} = 54.5 cm, D_{min} = 33.5 cm, D_{max} = 69.7 cm, S.D. – 15.19 cm. The analysis of phytosanitary structure of *F. excelsior* showed that the trees of I state category (I = 1.25; 44.5%) were most frequent at this EP. The frequency of weakened and heavily weakened trees was 30.5% (I = 1.85) and 15.5% (I = 2.85), respectively. Only 9.5% trees (I = 3.55) were drying. No recent and old dead standing trees were found at the plot. We detected 4 fungi species representing 4 genera, 2 families, 2 orders, 2 classes of Asco- and Basidiomycota divisions (Table 1). One parasitic species was observed on an old drying tree of II Kraft class with a sawn off crown (*Fomes fomentarius,* normally a saprotroph), and 3 saprotrophs occupied neighbouring ecological niches on the same stump (*Ganoderma lipsiense, Trametes gibbosa, Xylaria polymorpha* – 75% of findings in the butt-end myco-horizon (Table 4)). A special note shall be taken to the findings of 3 saprotrophic species on the same stump of *F. excelsior*: the whole surface of the shear cut was covered with carpophores of *Trametes gibbosa*, the side of the surface was covered with *Ganoderma lipsiense*, and on and around the butt-end we found – *Xylaria polymorpha*. Two saprotrophic species were observed on the same stump of *Acer negundo* L.: *Stereum hirsutum* and *Bjerkandera adusta*. In general the vital and phytosanitary structure of the stands at EP2 (“The Hornbeam Building”) composed of *C. betulus*, and *F. excelsior* together with the species, systematic, trophic structure of xylotrophic fungi depicts quantitative and qualitative parameters of the development and the state of the studied artificial phytocoenosis in the park. The results of the study indicate the absence of significant pathologic processes in ash-hornbeam oakery.

The stands of *Pinus* L. (A = 180 – 200) were studied at EP3 (“At the Great Glade”) represented by small biogroups of *P. sylvestris* and *P. strobus* with 3 – 4 individuals in each group. The stand was single-storeyed, canopy cover was 0.1 – 0.2, G_n = 22.6 m²/ha, N = 35 pcs./ha, H_{ave} = 22.7 m, H_{min} = 19.5 m, H_{max} = 24.5 m, S.D. – 2.69 m; D_{ave} = 82.5 cm, D_{min} = 62.5 cm, D_{max} = 95.8 cm, S.D. – 12.01 cm. Inside the biogroups grasses were significantly spread, from which graminoids prevailed. Therefore, the understorey of broadleaved species was absent. The intensity of the understorey regen-

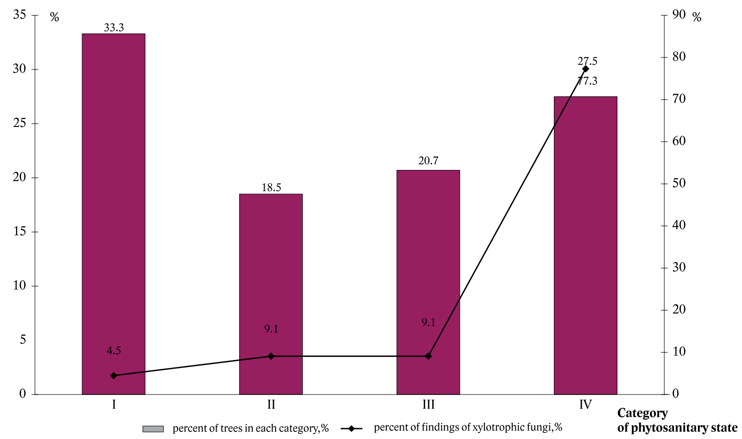

Fig. 3. Relationship between the categories of phytosanitary state of *Carpinus betulus* L. and the observations of xylotrophic fungi

eration of *P. sylvestris* and *P. strobus* was insufficient and irregular, and requires forest management measures. At the same time artificial plantings of *P. sylvestris* and *P. strobus*, regardless of stand age, continue saving viable stand state: 41.9% trees were healthy (I = 1.35), 34.9% were weakened trees(I = 2.25), and 20.9% were heavily weakened – (I = 2.80). No recent and old dead-wood was observed. According to the development of trees and their inhabitation with xylotrophs their distribution into individual categories was as follows: 32.6% of trees in I Kraft class (66.7% of fungi observations), 25.6% trees in II Kraft class (no fungi detected), 23.3% of trees in III Kraft class (16.7% of fungi observations), 16.3% in IV class (no fungi detected), 2.3% of trees in V Kraft class (16.7% of fungi observations). The study of *Pinus* L. plantings did not reveal any presence of pests and diseases.

It is known that in pine plantings moisture conditions for the development of xylotrophic fungi are subextremal, and the spectrum of tree substrates is due to the regular maintenance insignificant (absence of stumps, shear cuts and fine branch-wood), which in turn leads to the development of the limited number of wood-destroying fungi and the improvement of stand phytopathological state (Safonov & Malenkova 2011). This was confirmed by our study in the dendropark. Only 4 species of macromycetes were detected. Three species (*Boletus badius* (Fr.) Fr., *Suillus granulatus* (L.) Roussel and *Thelephora terrestris* Ehrh.) were mycorhizal fungi that develop in tight relationship with conifers. However, in our case the carpophores of *Thelephora terrestris* were not observed on roots, but in the butt-end myco-horizon of *P. sylvestris*, at the places mechanically damaged (ruptures and cracks of bark). On the cones of *P. strobus* (30%) and *P. sylvestris* (14%) we detected scanty fruitings of *Auriscalpium vulgare* Gray, which does not occur on other substrates. Single finding of carpophores of a saprotrophic fungus *Stropharia aeruginosa* on the ground was recorded. The data on the phytopathological state of artificial plantings of *P. sylvestris* and *P. strobus* at EP3 of the park evidence the possibility for further preservation of the resistance of structurally simplified ecosystems to negative ecological factors. The structures of xylotrophs of the studied artificial phytocoenoses in the dendropark were not balanced as observed in natural forests. This can be explained by the fact that in natural forests essential mechanical damages of different mycohorizons are absent, and that their stand structure (Kraft classes' distribution) and regular maintenance of site productivity are developed better.

The studies of the relationship between tree vegetation and mycorhiza-creating fungi are also important for a deeper understanding of peculiarities of functioning of a co-adaptive system of xylotrophic fungi and tree vegetation also. Mycorhiza fungi positively affect: tree supply of mineral substances and water; secretion of vitamins and growth regulating substances which accelerate the growth of seedlings and enhance seed germination; increase the resistance of plants to ground parasitic infections; increase chlorophyll amount in acerose and broad leaves, and increase transpiration. Mycorhiza ensures not only the interaction between individuals of the same species, but mycelium also connects roots of different tree species, thus creating a physiological unity of organisms and causing re-distribution of ground resources among them (Shemakhanova 1962). The analysis of distribution of mycorhiza-creating fungi at all EP of the ecoprofile showed that in artificial phytocoenoses where *P. sylvestris* was a co-edificator of tree stratum, *Boletus badius* dominated, whereas in the phytocoenoses where *Q. robur* was the co-edificator of the tree stratum, *Xerocomellus chrysenteron* (Bull.) Sutara was dominant.

4. Conclusions

The phytopathological state of old-aged plantings of *Q. robur* in the dendropark evidences the intensification of the pathological process due to the absence of regular maintenance, which is a natural phenomenon for oaks aged over 200 years. It was determined that from the artificial broad-leaved phytocoenoses the artificially created oak plantings were influenced to the most extent, especially their small isolated bio-groups aged 220 – 240 years, in which 23 species of xylotrophic fungi were detected. 9% of them were parasitic species: *Fistulina hepatica* (butt-end myco-horizon; I Kraft class), *Inocutis dryophila* (stem myco-horizon; I Kraft class) and *Phellinus robustus* (stem and photosynthesising myco-horizon; I and IV Kraft classes). The remaining xylotrophic fungi have a saprotrophic way of nutrition and are related to fine woody debris of *Q. robur* and stumps (with a proportion of 3:2). At the same time, the age, vitality, and phytosanitary structure of stands of *C. betulus, F. excelsior* and the spieces, systematic and trophic structure of xylotrophic fungi evidence insignificant pathological processes in the ash-hornbeam oakery. At these tree species we detected a small number of xylotrophic species. For the artificial plantings of *P. sylvestris* grown in isolated biogroups at sodded open landscape elements, the lesser specific variety of xylotrophic fungi is characteristic. This is caused by biological peculiarities of *Pinus* L., by a simplified structure of tree stands, absence of significant mechanical damage of stems and insignificant amount of dead substrate. Thus, the changes of species composition and structure (vitality, phytosanitary) of artificial phytocoenoses alter both the composition of xylotrophs and the levels of tree and stand damage caused by them. In contrast to natural forests, the structure of xylotrophic fungi in old-aged, and middle-aged ash-hornbeam oakery and monocultures of *Pinus* L. of the dendropark is not balanced, since the spread of xylotrophic fungi in them is limited due to a smaller quantity of available living and dead substrate, greater canopy openness, smaller protectiveness of herbaceous cover etc.

To conclude, we proved the study‘s hypothesis that species, trophic, systematic structure of xylotrophic fungi depicts the phytosanitary state, vitality and age structure of stands. This confirms the unity and the inter-connection of these components at all hierarchical levels of forest ecosystem‘s structural organisation.

References

Anuchin, P., 1982: Forestry taxation. Moscow, Lesnaja Prom., 547 p.

Arefyev, S., 2010: Systems analysis of biota of xylotrophic fungi. Novosibirsk: Nauka 260 p.

Bernicchia, A., Gorjón, S., 2010: Corticiaceae s.l. In: Fungi Europaei, 12. Italia: Ed. Candusso, 1008 p.

Boddy, L., Rayner, A., 1983: Ecological roles of basidiomycetes forming decay communities in attached oak branches. New Phytologist 93: 77–88.

Clémençon, H., 2009: Methods for working with macrofungi: Laboratory, cultivation and preparation of larger fungi for light microscopy. Eaching: IHW Verlag, 88 p.

Deriy, I., 1958: Dendroflora of park “Oleksandriya” of botanical garden AS USSR. Aklimatizacia rasteniy 5:110–132.

Dragan, N., 2010: State and perspectives of artificial pine plantations in dendropark “Oleksandriya” of NASU. Scientific bulletin of National University of life and environmental sciences of Ukraine, 152:10–17.

Dragan, N., 2012: Artificial oak plantations productivity in dendropark “Oleksandriya” of NASU. Tavriysky naukovy visnuk 80:186–191.

Hibbett, D. et al., 2007: Higher-Level Phylogenetic Classification of the Fungi. Mycological Research 111:509–547.

Kirk, P., Ansell, A., 1992: Authors of fungal names. A list of authors of scientific names of fungi, with recommended standard forms of theirs names, including abbreviation. Kew: Int. Myc. Inst., 95 p.

Klymenko, Y., Mordatenko, L., 2001: Dendropark “Oleksandriya”: characteristics of new and old territory. Plant introduction 3–4: 121–131.

Küffer, N. et al., 2008: Ecological determinants of fungal diversity on dead wood in European forests. Fungal Diversity, 30: 83–95.

Rio Declaration on Environment and Development. 1992. Resolution of the United Nations Conference on Environment and Development (3–14 June 1992). Rio de Janeiro, 19 p.

Robert, V., Stegehuis, G., Stalpers, J., 2005: The MycoBank engine and related databases. Available at: <http://www.mycobank.org>

Ryvarden, L., Gilbertson, R., 1993: European polypores. Part 1. Abortiporus – Lindtneria. Oslo: Fungiflora, p. 1–387.

Ryvarden, L., Gilbertson, R., 1994: European polypores. Part 2. Meripilus – Tyromyces. Oslo: Fungiflora, p. 388–743.

Safonov, M., Malenkova, A., 2011: Wood-destroying fungi in artificial conifer plantations of Southern Preurals. Vestnik of OSU 12:140–142.

Sanitary Forest Regulation in Ukraine. 1995. Resolution of Government of Ukraine No 555 (27 July 1995). Kyiv, 20 p.

Schmidt, O., 2006: Wood and Tree Fungi. Biology, Damage, Protection, and Use. Heidelberg: Springer, 336 p.

Shemakhanova, N., 1962: Mycotrophy of woody plants. Moscow: publ. AN SSSR, p. 1–375.

Stepanova, N., Mykhin, V., 1979: Basis of ecology of wood-destroying fungi. Moscow: Nauka, 100 p.

Vorobyov, D., 1967: Metodology for forest typology research. Kyiv: Urojay, 388 p.

Zmitrovich, I., 2001: Macrosystem and phylogeny of Basidiomycetes: the case for a red algal progenitor. Mycena 1:3–58.

Zmitrovich, I., Wasser, S., 2004: Modern view on the origin and phylogenetics reconstruction of Homobasidiomycetes fungi. Evolutionary theory and processes: Modern Horizons. Dordrecht, Boston, L.: Kluwer Academic Publishers, p. 230–263.

Zmitrovich, I., Vasilyev, N., 2006: The fungi which produce trees diseases in St. Petersburg and its vicinities. 1. Oak diseases producers. Novosti sistematiki nizshux rastenij 40:121–131.