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Mycobiota of English Oak: Retrospective, Current State of Knowledge, Promising Problems

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Abstract—This review aims to evaluate the current state of knowledge regarding the mycobiota of English oak, focusing on biodiversity conservation, ecological and trophic aspects of fungi–plant interactions, forest phytopathology, and biotechnology. It also seeks to identify potential research opportunities for studying this vital tree species in European Russia. A retrospective examination of the fungal and oomycete biodiversity associated with English oak has been conducted, addressing the trophic classification challenges of these organisms. A comprehensive framework for assessing the trophic status of fungi is proposed, incorporating multiple criteria: (1) nutritional type (e.g., biotrophs, necrotrophs, saprotrophs, and hybrid categories such as “necrotrophs with residual saprotrophic activity” and “saprotrophs with necrotrophic activity”); (2) tissue specificity (including bark, cambium, sapwood with functional xylem, heartwood with nonfunctional xylem, wood detritus, and sclerenchyma in fruits and leaves); and (3) impact on living plants or mortality dynamics (e.g., pathogens or detrital saprobes). The review offers detailed data on the distribution of fungi and oomycetes across different ecological macroniches. These include the phyllosphere (30 species), terminal shoots (26 species), trunks and skeletal branches undergoing senescence (475 species), wounds on living trees (230 species), litter (62 species), rhizosphere and mycorrhizosphere (47 + 137 species), and oak seedlings (83 species). Additionally, key diseases affecting English oak and corresponding pathogen management strategies are discussed. The article examines studies focused on assessing oak stand conditions and developing forest scaling systems. It also highlights biotechnological and pharmacological research dedicated to specific fungal species associated with English oak. Finally, promising avenues for further investigation into the mycobiota of English oak are outlined.

Keywords: biodiversity, oak diseases, phytopathological monitoring, stand condition scales, Fungi, Oomycota, *Quercus*

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INTRODUCTION

English oak (*Quercus robur* L.)[1] is one of the few representatives of the genus *Quercus*, common in the north of the temperate zone of the Northern Hemisphere, characterized by wide morphogenetic and ecological plasticity. It has a European a range covering all of Western Europe (including England) with a northern border crossing Scandinavia from 63° N in the west to 61° N in the east. In the area of St. Petersburg in the north and Odessa in the south, the range *Q. robur* enters the Russian Plain in the form of a tongue, reaching such cities as Perm and Orenburg in the east. Exclaves stand out on the southern border of distribution of *Q. robur* in Crimea, the foothills of the Caucasus, and Asia Minor, and then the (already continuous) southern border of this species runs along the north of the Balkan, central part of the Apennine, and north of the Iberian Peninsulas (Bogdanov, 1974).

It is one of the most famous woody plants that have been actively used by humans for centuries. Its wood is characterized by high strength, hardness, and significant weight (density is 720 kg/m^3), which makes it extremely popular in the woodworking industry. In addition, various parts of the tree, including the wood and bark, are rich in tannins. Oak acorns serve as a substitute for making coffee and are used as animal feed. The importance of the oak in forestry and landscaping is difficult to overestimate. This once key forest-forming species is characterized by a high rate of accumulation of wood reserves, it improves the structure and level of acidity of the soil owing to leaf litter, and a powerful root system effectively drains it

[1] The Russian name of the plant (pedunculate oak) refers to the Latin name *Quercus pedunculata* Hoffm., which is today considered a synonym of the Linnaean name *Q. robur*.

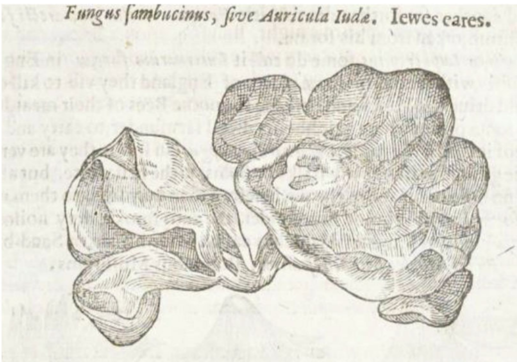

Fig. 1. One of the first surviving images in the literature affecting fungi on English oak is *Fungus sambucinus*, *sive Auricula Judaea* (modern name is *Auricularia auricula-judae*), which, according to Dodoens, is often found on English oak trees (Dodoens, 1557).

(Vikhrov, 1954; Grozdov, 1960; Bulygin and Yarmishko, 2000). The heterotrophic oak consortium is rich and diverse, and the presence of old-age specimens significantly increases the biological value of boreonemoral forests (Andersson et al., 2009). As an indicator of fertile and calcium-rich soils, the English oak accompanies humans and actively spreads north of its natural range. This is evidenced by place names such as "Dubki" and "Poddubnoye," which are found even in the middle taiga regions (Vasilevich and Bibikova, 2001; Smirnova, 2004; Sennikov, 2005; Zmitrovich, 2011; Kovyazin and Ivanova, 2022).

The exceptional utilitarian value of this woody plant also has its downside: natural forests with the participation of oak have significantly reduced their area. Against this background, the biological value is not only and not so much fragments of forest with oak, but preserved old-growth trees of this species (Bulygin et al., 1978; Tsaralunga, 2002; Firsov et al., 2021).

As part of tree stands and as isolated trees, English oak produces significant biomass, and the fungal consortium of this plant—phylloplane fungi, living and dead tree shoots, and the rhizosphere—is characterized by exceptional diversity. Among the fungi associated with English oak, there are biotrophs and necrotrophs, the physiological mechanisms of interaction of which with plant tissue are actively studied; pathogens of forest epiphytes, the study of which is important from the point of view of phytopathology; various saprotrophs, among which there are a number of model objects of biotechnology and medicinal mushrooms; and numerous ectomycorrhiza-forming fungi, a number of which are important as resource species. The purpose of this review is to assess the state of knowledge of the mycobiota of English oak in connection with the problems of identifying and preserving biodiversity, ecological and trophic aspects of the interaction of fungi and plants, forest phytopathology, and biotechnology, and to outline promising problems in studying the mycobiota of this one of the most important tree species in European Russia.

BIODIVERSITY

Retrospective

Pre-Linnaean times. Western Europe, the "cradle of civilization," which is associated with the development of botany as a science, represents the optimum habitat for the English oak. Oak groves and forests and parks with oak trees surrounded Antwerp, London, Paris, Frankfurt am Main, and Leipzig, where studies of the local flora were developed at universities or apothecary gardens, and epiphytic complexes of common oak naturally fell into the field of view of researchers. Pre-Linnean names were most often polynomial, with the name of the "genus" being placed in the first position.

The famous Flemish botanist Rembert Dodoens (1517–1585) describes in his work *Histoire des Plantes*... the fungus *Fungus sambucinus*, *sive Auricula Judaea* (modern name *Auricularia auricula-judae*), which is often found on English oak trees (Dodoens, 1557) (Fig. 1).

Some of the first species descriptions of fungi associated with the English oak are found in the work of the English naturalist John Ray (1627–1705) *Synopsis Methodica Stirpium Brittanicum*, where three "oak" species are listed: (1) *Fungoides quercinus*, *peltatum*, *nigrum* (most likely, we are talking about a mushroom with the modern name *Cyathus striatus*), (2) *Peziza acetabuliformis*, *coccinea*, *marginae pilosis* (with a high degree of probability, *Scutellinia scutellata* s.l.) (Ray, 1690), and (3) *Fungus coriaceus quercinus*, *haematodes* (modern name *Pseudoinonotus dryadeus*, a tinder fungus associated with oak trees with characteristic drops of exudate on the cap) (Ray, 1690).

The famous French botanist Joseph Pitton de Tournefort (1656–1708) mentions three other oak-associated fungi in his work *Institutiones Rei Herbariae*: (1) *Fungus bulbosus*, *fuscus*, *duplici pileolo* (presumably *Buglossoporus pulvinus*), (2) *Fungus orbicularis*, *secundum vias*, *et in Quercetis autumno nascens* (with a not very high probability, *Pachykytospora tuberculosa*), and (3) *Agaricus Daedaleis sinubus excavatus* (*Daedalea quercina*) (Tournefort, 1700).

The Thuringian botanist Heinrich Ruppius (1688–1719) takes the species Ray *Peziza acetabuliformis*, *coccinea*, *marginibus pilosis* in his work *Flora Jenensis* and the species Tunefor *Fungus bulbosus*, *fuscus*, *duplici pileolo*, but does not specify the substrate to which these fungi are confined (Ruppius, 1718).

The German-English botanist Johann Jacob Dillenius (1684–1747) in his *Catalogus Plantarum Sponte Circa Gissam Nascentium* mentions such mushrooms associated with oak wood as *Agaricus intybaceus* (*Grifola frondosa*), *Agaricus officinalis similis* (*Buglossoporus pulvinus*), *Agaricus villosus*, *lamellis sinuosis et invi-*

cem implexis (*Daedalea quercina*), and *Peziza miniata major* (?*Sarcoscypha coccinea*—this version is suggested, however, by a vague reference to the red color characteristic of a ripe apple) (Dillenius, 1719).

One of the founders of mycology, the Italian botanist Pier Antonio Micheli (1679–1737) in his fundamental work *Nova Plantarum Genera*... gives the polynomial name *Agaricum quercubus et ilicibus adnascens*, *ferruginum et glabrum*, *inferne album*, *et argutissime et densissime perforatum*, *foraminulus rotundis* (Micheli, 1729), which we today associate with *Fomitopsis pinicola* (a form found on oak and some other hardwoods).

The German-Russian botanist Johann Christian Buxbaum (1693–1730) in his fifth *Centuria*, published posthumously, accepts the species of fungi described by Dodoens, Ray, Tournefort, and especially Dillenius, in particular, the polynomial name of the oak sponge tinder fungus (*Daedalea quercina*), given to this mushroom by the latter (*Agaricus villosus*, *lamellis sinuosis et invicem implexis*) (Buxbaum, 1740).

After Lineaeus. In the fundamental work of the Swedish naturalist Carl Linnaeus, *Species Plantarum* (Linnaeus, 1753), which laid the foundations of modern taxonomy, Linnaeus identifies ten genera in the section "Cryptogamia, Fungi," and the species receive a binomial representation. For oak sponge, this scientist uses the binomial *Agaricus quercinus*. In total, after Linnaeus, at least 89 species of fungi and oomycetes were described, in the protologues of which the English oak was indicated as a host species, of which at least 62 species were ascomycetes, at least 22 species were basidiomycetes, and at least 5 species were oomycetes (Table 1).

The largest number of well-known species of fungi from the English oak were described by another of the founders of mycology, the Dutch citizen Christian Heinrich Persoon (1761–1836), during the period when he lived and worked in Göttingen. Most of these species were described by him in the work "Neuer versuch einer systematischen eintheilung der scwämme", published in the journal *Neues Magazin für die Botanik in ihrem ganzen Umfange* (Persoon, 1794). Mention should also be made of his works *Observationes mycologicae* (Persoon, 1796, 1799), *Commentarius, Schaefferi Fungorum Bavariae Indigenorum Icones Pictas, Differentiis Specificis Etc. Illustrans* (Persoon, 1800), and *Synopsis Methodica Fungorum* (Persoon, 1801). In total, these scientists described 12 species from the common oak: six species that are today classified as ascomycetes [*Hysterium pulicare*, *H. quercinum* (*Colpoma quercinum*), *Peziza inquinans* (*Bulgaria inquinans*), *Sphaeria quercina* (*Diatrypella quercina*), *S. uda* (*Euepixylon udum*), *S. pustula* (*Hypospilina pustula*)] and six species belong to the basidiomycetes [*Agaricus dryinus* (*Pleurotus dryinus*), *Boletus dryadeus* (*Pseudoinonotus dryadeus*), *Boletus pulvinus* (*Buglossoporus pulvinus*), *Odontia quercina* (*Hyphodontia quercina*), *Thelephora quercina* (*Peniophora quercina*), *Thelephora frustulata* (*Xylobolus frustulatus*)].

Of greatest importance for the taxonomy of fungi are the works of the Swedish botanist, the "father of mycology" Elias Fries (1794–1878) and, above all, his fundamental work *Systema Mycologicum* (Fries, 1821–1823). The species of Hymenomycetes accepted by Fries in this work (and also in "Elenchus" and "Index," considering as its parts) have the status of being conserved against earlier synonyms. Some species were also described by Fries in earlier and later works (Fries, 1819, 1874, etc.). From the English oak, Fries described three species of fungi which are now classified as ascomycetes [*Sphaeria mammilana* (*Clypeosphaeria mammilana*), *Sphaeria taleola* (*Caudospora taleola*), *Sphaeria leiphaemia*] and two species which belong to the basidiomycetes [*Polyporus tuberculosus* (*Pachykytospora tuberculosa*) and *Stereum gausapatum*]. Moreover, in his work *Systema Mycologicum*, Fries accepted all the "oak species" described by Persoon.

In addition to Persoon and Fries, special mention should also be made of the French botanist Jean Baptiste Demazières (1786–1862), who described from oak such fungal species as *Fusisporium album* (now basidiomycete *Microstroma album*), ascomycetes *Septoria quercina*, *Pestalotia monochaeta* (*Monochaetia monochaeta*), *Septoria incondita* var. *quercicola* (*Sphaerulina quercicola*) (Desmazières, 1838, 1847, 1848, 1953), and the Italian botanist Pierre Andrea Saccardo (1845–1920), who described from oak such species of ascomycetes as *Ceratophorum helicosporum*, *Phyllosticta quercus* (*Phomopsis quercus*), *Hendersonia quercina*, *Leptothyrium dryinum* (*Dicarpella dryina*), *Dothiorella advena* (*Fusicoccum advenum*), and *Camarosporium propinquum* (*Pseudocamarosporium propinquum*) (Saccardo, 1877, 1878; Roumeguère and Saccardo, 1881).

Current State

Analysis of Table 1 shows that 62% of the total number of ascomycetes and basidiomycetes described in association with English oak occurred in the late 17th–19th centuries and 38% occurred in the 20th century (for the group of ascomycetes, among which microfungi predominate, this ratio is slightly lower, and for basidiomycetes, represented mostly by macrofungi, this ratio is 66 : 34%). This may indicate that the classical methods of identifying and collecting fungi on this plant, which is characterized by a broad, but still limited, niche differentiation, had exhausted themselves by the beginning of the 20th century.

Nevertheless, in the 20th century, it is worth noting the works devoted to the targeted study of oak mycobiota, first of all, by the Polish researchers A. Borowska and T. Kowalski (Borowska, 1975; Kowalski, 1995;

Table 1. Species of mushrooms described from leaves, shoots, or wood of English oak

Year	Species	Author
	Ascomycota	
1785	*Hymenoscyphus fructigenus* (Bull.) Gray (ut *Peziza fructigena* Bull.)	Bulliard, 1785
1794	*Hysterium pulicare* Pers.	Persoon, 1794
1794	*Diatrypella quercina* (Pers.) Cook (ut *Sphaeria quercina* Pers.)	Persoon, 1794
1794	*Bulgarian inquinans* (Pers.) Fr. (ut *Peziza inquinans* Pers. 1794)	Persoon, 1794
1794	*Euepixylon udum* (Pers.) Læssøe et Spooner (ut *Sphaeria uda* Pers.)	Persoon, 1794
1794	*Hypospilina pustula* (Pers.) M. Monod (ut *Sphaeria pustula* Pers.)	Persoon, 1794
1796	*Colpoma quercinum* (Pers.) Wallr (ut *Hysterium quercinum* Pers.)	Persoon, 1796
1805	*Triblidium caliciforme* Rebent.	Rebentisch, 1805
1809	*Sporidesmium atrum* Link	Link, 1809
1816	*Coryneum umbonatum* Nees	Nees, 1816
1817	*C. depressum* J.C. Schmidt	Kunze and Schmidt, 1817
1819	*Clypeosphaeria mamillana* (Fr.) Lambotte (ut *Sphaeria mammilana* Fr.)	Fries, 1819
1823	*Caudospora taleola* (Fr.) Starbäck (ut *Sphaeria taleola* Fr.)	Fries, 1823
1823	*Dendrostoma leiphaemia* (Fr.) Senan. et K.D. Hyde (ut *Sphaeria leiphaemia* Fr.)	Fries, 1823
1832	*Phyllactinia roboris* (Gachet) S. Blumer (ut *Erysiphe roboris* Gachet)	Gachet, 1832
1847	*Septoria quercina* Desm.	Desmazières, 1847
1848	*Monochaetia monochaeta* (Desm.) Allesch. (ut *Pestalotia monochaeta* Desm.)	Desmazières, 1848
1852	*Amphisphaeria bufonia* (Berk. et Broome) Ces. et De Not (ut *Sphaeria bufonia* Berk. et Broome)	Berkeley and Broome, 1852
1853	*Sphaerulina quercicola* (Desm.) Quaedvl., Verkley et Crous (*Septoria incondita* var. *quercicola* Desm.)	Desmazières, 1853
1854	*Dendrostoma leiphaemia* (Fr.) Senan. et K.D. Hyde (ut *Gloeosporium quercinum* Westend.)	Westendorp, 1854
1856	*Pseudovalsa longipes* (Tul. et C. Tul.) Sacc. (ut *Melanconis longipes* Tul. et C. Tul.)	Tulasne, 1856
1864	*Coniothyrium quercinum* (Bonord.) Sacc. (ut *Torsellia quercina* Bonord.)	Bonorden, 1864
1866	*Guignardia punctoidea* (Cooke) J. Schröt. (ut *Sphaerella punctoidea* Cooke)	Cooke, 1866
1870	*Diaporthe insularis* Nitschke	Nitschke, 1870
1870	*Cytospora intermedia* Sacc. (ut *Valsa intermedia* Nitschke)	Nitschke, 1870
1870	*Botryosphaeria quercicola* A.J.L. Phillips (ut *Otthia quercus* Fuckel)	Fuckel, 1870
1870	*Pezicula cinnamomea* (DC.) Sacc. (ut *Pezicula quercina* Fuckel)	Fuckel, 1870
1877	*Ceratophorum helicosporum* (Sacc.) Sacc. (ut *Sporidesmium helicosporum* Sacc.)	Saccardo, 1877
1878	*Phomopsis quercus* (Sacc. et Speg.) Curzi et Barbaini (ut *Phyllosticta quercus* Sacc. et Speg.)	Saccardo, 1878
1878	*Hendersonia quercina* Sacc.	Saccardo, 1878
1878	*Cookella microscopica* Sacc.	Saccardo, 1878
1878	*Dicarpella dryina* Belisario et M.E. Barr (ut *Leptothyrium dryinum* Sacc.)	Saccardo, 1878
1880	*Rosellinia quercina* R. Hartig	Hartig, 1880
1881	*Fusicoccum advenum* (Sacc.) Died. (ut *Dothiorella advena* Sacc.)	Roumeguère and Saccardo, 1881

Table 1. (Contd.)

Year	Species	Author
1884	*Pseudocamarosporium propinquum* (Sacc.) Wijayaw., Camporesi et K.D. Hyde (ut *Camarosporium propinquum* Sacc.).	Saccardo, 1884
1888	*Cryptodiscus foveolaris* (Rehm) Rehm ut *Stictis foveolaris* Rehm	Britzelmayr and Rehm, 1888
1889	*Asteromella quercifolii* C. Massal.	Massalongo, 1889
1902	*Coniella quercicola* (Oudem.) L.V. Alvarez et Crous (ut *Sphaeropsis quercicola* Oudem.)	Oudemans, 1902
1908	*Marsonia matteiana* Sacc.	Saccardo, 1908
1912	*Erysiphe alphitoides* (Griffon et Maubl.) U. Braun et S. Takam. (ut *Microsphaera alphitoides* Griffon et Maubl.)	Griffon and Maublanc, 1912
1915	*Nothophoma quercina* (Syd. et P. Syd.) Qian Chen et L. Cai (ut *Cicinobolus quercinus* Syd. et P. Syd.)	Sydow, H. and Sydow, P., 1915
1921	*Phomopsis quercicola* Moesz	Moesz, 1921
1922	*Leptosphaeria alcides* f. *quercina* Cif.	Ciferri, 1922
1952	*Erysiphe hypophylla* (Nevod.) U. Braun et Cunningt. (ut *Microsphaera hypophylla* Nevod.)	Nevodovsky, 1952
1957	*Discula quercina* (Westend.) Arx	Arx, 1957
1973	*Tubakia dryina* (Sacc.) B. Sutton	Sutton, 1973
1975	*Corynesporopsis quercicola* (Borowska) P.M. Kirk (ut *Corynespora quercicola* Borowska)	Borowska, 1975
1975	*Septonema binum* Borowska	Borowska, 1975
1975	*Taeniolella dichotoma* Borowska	Borowska, 1975
1989	*Ceratocystis grandicarpa* Kowalski et Butin	Kowalski and Butin, 1989
1989	*C. prolifera* Kowalski et Butin	Kowalski and Butin, 1989
1995	*Cryptosporiopsis radicicola* Kowalski et C. Bartnik	Kowalski and Bartnik, 1995
1996	*Chalara angustata* T. Kowalski et Halmschl.	Kowalski and Halm-schlager, 1996
2004	*Ramularia endophylla* Verkley et U. Braun	Verkley et al., 2004
2005	*Botryosphaeria quercicola* A.J.L. Phillips	Phillips et al., 2005
2016	*Seimatosporium quercinum* Goonas, R.K. Schumach. et K.D. Hyde	Goonasekara et al., 2016
2017	*Saccharomyces jurei* Naseeb, S.A. James, Alsammar, Michaels, Gini, Nueno-Palop, C.J. Bond, McGhee, I.N. Roberts et Delneri	Nasseb et al., 2017
2018	*Rhinocladiella quercus* Crous et R.K. Schumach.	Crous et al., 2018
2019	*Ophiostoma solheimii* Strzałka and Jankow.	Jankowiak et al., 2019
2024	*Pseudopezicula epiphylla* Piątek, Czachura et Stryjak-Bogacka	Crous et al., 2024
2024	*Rugonectria wingfieldii* C.M.T. Anderson, Trollip, Carnegie et Priest	Trollip et al., 2024
	Basidiomycota	
1753	*Daedalea quercina* (L.) Pers. (ut *Agaricus quercinus* L.)	Linnaeus, 1753
1774	*Fistulina hepatica* (Schaeff.) With. (ut *Boletus hepaticus* Schaeff.)	Schaeffer, 1774
1788	*Collybiopsis peronata* (Bolton) R.H. Petersen (ut *Agaricus peronatus* Bolton)	Bolton, 1788
1789	*Boletus aereus* Bull.	Bulliard, 1789
1794	*Buglossoporus pulvinus* (Pers.) Donk (ut *Boletus quercinus* Schrad.)	Schrader, 1794

Table 1. (Contd.)

Year	Species	Author
1799	*Pseudoinonotus dryadeus* (Pers.) T. Wagner et M. Fisch. (ut *Boletus dryadeus* Pers.)	Persoon, 1799
1799	*Hyphodontia quercina* (Pers.) J. Erikss. (ut *Odontia quercina* Pers.)	Persoon, 1799
1800	*Pleurotus dryinus* (Pers.) P. Kumm. (ut *Agaricus dryinus* Pers.)	Persoon, 1800
1801	*Peniophora quercina* (Pers.) Cooke (ut *Thelephora quercina* Pers.)	Persoon, 1801
1801	*Xylobolus frustulatus* (Pers.) P. Karst. (ut *Thelephora frustulata* Pers.)	Persoon, 1801
1821	*Pachykytospora tuberculosa* (Fr.) Boiler et Pouzar (ut *Polyporus tuberculosus* Fr.)	Fries, 1821
1838	*Microstroma album* (Desm.) Sacc. (ut *Fusisporium album* Desm.)	Desmazières, 1838
1874	*Stereum gausapatum* (Fr.) Fr.	Fries, 1874
1889	*Fomitiporia robusta* (P. Karst.) Fiasson et Niemelä (ut *Fomes robustus* P. Karst.)	Karsten, 1889
1907	*Dendrothele commixta* (Höhn. et Litsch.) J. Erikss. et Ryvarden (ut *Corticium commixtum* Höhn. et Litsch.)	Hohnel and Litschauer, 1907
1956	*Krombholzia aurantiaca* f. *quercina* Pilát ex Vassilkov	Vasilkov, 1956
1960	*Leptosporomyces raunkiaeri* (M.P. Christ.) Jülich (ut *Athelia raunkiaeri* M.P. Christ.)	Christiansen, 1960
1966	*Boletus edulis* f. *quercicola* Vassilkov	Vasilkov, 1966
1972	*Laetiporus sulphureus* f. *zerovae* Bondartseva	Bondartseva, 1972
1976	*Marchandiomyces quercinus* (J. Erikss. et Ryvarden) D. Hawksw. et A. Henrici (ut *Laeticorticium quercinum* J. Erikss. et Ryvarden)	Eriksson and Ryvarden, 1976[1]
2006	*Vuilleminia comedens* f. *raduloides* Zmitr.	Zmitrovich and Vasiliev, 2006
2011	*Xylobolus frustulatus* f. *peripileatus* Zmitr. et V. Malysheva	Zmitrovich et al., 2011
2021	*Entoloma quercetorum* Kokkonen	Kokkonen, 2021
	Oomycota	
1999	*Phytophthora quercina* T. Jung	Jung et al., 1999
2002	*P. europaea* E.M. Hansen et T. Jung	Jung et al., 2002
2002	*P. uliginosa* T. Jung et E.M. Hansen	Jung et al., 2002
2003	*P. pseudosyringae* T. Jung et Delatour	Jung et al., 2003
2008	*P. gallica* T. Jung et Nechw.	Jung and Nechwatal, 2008

[1] The protologue indicates that the species is confined to branches of *Quercus robur*. It was later found that the fungus is a parasite *Colpoma quercinum* (Zmitrovich and Vasiliev, 2006; Legon and Henrici, 2015).

Kowalski and Butin, 1989; Kowalski and Bartnik, 1995; Kowalski, and Halmschlager, 1996) and the researcher from the Phytophthora Research Center in Brannenburg T. Jung, who described five new species of *Phytophthora* in association with English oak from France and Germany (Jung et al., 1999, 2002, 2003; Jung and Nechwatal, 2008).

The use of molecular identification methods for fungi, which became widespread in the late 1990s, actually marked the beginning of the modern period in the study of the mycobiota of English oak. Among the taxonomic works of this period, mention should be made of the work of J. Verkley et al., which describes a new species *Ramularia endophylla* living in leaves as an endophyte (Verkley et al., 2004), and I.D. Gunasekara et al., who described a new species of saprotrophic fungus *Seimatosporium quercinum* from the branches of English oak (Goonasekara et al., 2016). A new species of yeast fungus *Saccharomyces jurei* was isolated and described from oak bark by S. Nasseb's group (Nasseb et al., 2017). A new species of ophiostomoid fungus *Ophiostoma solheimii* was described under the bark of the common oak by V. Jankowiak's group, and a vector for transmitting the infection to neighboring trees was also identified—beetle *Anisandrus dispar* (Jankowiak, 2019). More recently, by M. Pientek's group, a new species of discomycete *Pseudopezicula* *epiphylla* was discovered in a community of black mold fungi growing on leaf litter of English oak (Crous et al., 2024). In Australia, where *Quercus robur* was successfully introduced, by K. Trollip's group, a new species of fungus *Rugonectria wingfieldii* associated with burl growths has been described (Trollip et al., 2024).

ECOLOGICAL ESSAY OF MYCOBIOTA OF RUSSIAN OAK

Trophic Groups

Before the work of R. Cook and J. Whipps (1980), the terminology related to the description of the trophic status of fungi was diverse and not systematized. Concepts such as "parasites," "pathogens," "saprophytes" ... were in circulation—sometimes with clarifications ("obligate," "facultative," etc.). These authors proposed more consistent classification, highlighting the actual trophological series: (1) biotrophs that feed on the contents of living cells through special structures—appressoria and haustoria; (2) necrotrophs that use the contents and walls of dead plant cells as a food source; (3) saprotrophs that feed on the cell walls of functioning or nonfunctioning xylem, woody detritus, and humus; (4) symbiotrophs living in mycorrhizal or lichen symbiosis. Russian researchers have developed various aspects of this classification (Karatygin, 1993; Zmitrovich, 2008; Zmitrovich et al., 2015, 2023).

Cook and Whipps' approach was valuable in streamlining terminology and distinguishing between terms related to the nutrition of an organism and terms describing its lifestyle (parasites, symbionts). However, the authors did not go all the way in this distinction. Firstly, at the final link of cellular interaction, symbiotrophs are also biotrophs; accordingly, the term "symbiotrophs" (like "parasites") refers to the lifestyle of the organism, and not its trophic status, and in this sense, the trophic series is limited to the basic categories of biotrophs, necrotrophs, and saprotrophs.

Secondly, the classificatory dimension related to the lifestyle of the fungal organism (including its tissue confinement) is not the only alternative to the "trophic series"; its "reverse side" may be a classificatory series describing the effect that the fungus has on the host plant (endophyte, pathogen, destroyer of mortmass = detrital saprobe).

In connection with the aforementioned, it was proposed to differentiate the comprehensive assessment of the ecological and trophic status of the species by separately indicating (1) the trophic status of fungal species (biotrophs, necrotrophs, and saprotrophs with the introduction of additional categories for complex cases—"necrotrophs with residual saprotrophic activity," "saprotrophs with necrotrophic activity," etc.); (2) tissue confinement of fungi (bark, cambium, sapwood with functioning xylem, core with nonfunctioning xylem, and wood detritus, sclerenchyma of fruits and leaves); (3) the effect of the fungus on a living plant and litter (pathogen, detrital saprobe) (Zmitrovich and Shishlyannikova, 2025).

Fungi act on the wood substrate extracellularly, releasing hydrolytic and oxidative enzymes. As a result, the wood loses its structure and becomes subject to rot. Depending on the features of the fungal enzyme apparatus, a distinction is made between (1) "ancestral soft rot," the target of which is mainly cellulose, and in the enzymatic effect, hydrolysis dominates over oxidation; (2) white rot, the target of which is both lignin and cellulose, and in the enzymatic effect on the substrate, oxidative enzymes dominate—manganese peroxidases and laccases; and (3) brown rot, the target of which is mainly cellulose, and its oxidation occurs via the Fenton free radical mechanism (Nagy et al., 2015). Possessing a unique enzymatic complex, fungi play a dominant role in the humification of oak detritus (Zmitrovich and Shishlyannikova, 2025).

Distribution by Macro Niches

English oak is a powerful coenosis-forming tree. Generative and senile individuals of this plant are characterized by a spread of axes up to 30 m; the root system penetrates into the soil up to 5 m deep; the litter within the oak phytosphere, even in taiga forests, is rich in calcium. For fungi, generative and senile individuals of English oak offer an exceptional diversity of niches within the phyllosphere, the system of terminal shoots, trunk, and skeletal branches that are dying off, wounds on the trunk of a living tree, litter, rhizosphere (including the mycorrhizosphere), and oak regeneration. Information on the species composition of the designated macro niches is presented in Table 2.

Phyllosphere. The phyllosphere is associated with a number of the most important physiological processes of a woody plant, including photosynthesis, transpiration, gas exchange, and the outflow of metabolites. As a "buffer" zone, experiencing direct atmospheric and insolation impact, the phyllosphere is an extreme habitat for fungi; however, at least 30 species of the phylum Ascomycota are known for English oak, as well as four species from the phylum Basidiomycota (*Cronartium quercuum*, *Microstroma album*, *Sporobolomyces roseus*, and *Symmetrospora gracilis*) and two species (*Mortierella hyalina*, *Rhizopus oryzae*) from the phylum Mucoromycota in the broad sense (Table 2). The species composition includes a fraction of ubiquitous extremophiles (*Alternaria alternata*, *Aureobasidium pullulans*, *Botrytis cinerea*, *Cladosporium cladosporioides*, *C. herbarium*, *Epicoccum nigrum*). These are mainly saprotrophs, sometimes exhibiting necrotrophic activity. There are, however, a number of species specialized to the genus *Quercus*, which include biotrophic fungi of the genus *Erysiphe*, causing powdery mildew, causing leaf spots exobasidiomycete *Microstroma album*, and ascomycetes *Phyllactinia gut-*

Table 2. Species diversity of fungi and oomycetes associated with *Quercus robur*

Macro niche	Species composition	Source
Phyllosphere	*Alternaria alternata* (Fr.) Keissl., *Asteromella quercifolii* C. Massal., *Aureobasidium pullulans* (de Bary et Löwenthal) G. Arnaud, *Botrytis cinerea* Persian, *Capnodium citrifolia* Berk. et Desm., *Ceratophorum helicosporum* (Sacc.) Sacc., *Cladosporium cladosporioides* (Fresen.) G.A. de Vries, *C. herbarium* (Pers.) Link, *Coniothyrium quercinum* (Bonord.) Sacc., *Cookella microscopica* Sacc., *Cronartium quercuum* (Berk.) Miyabe ex Shirai, *Dendrostoma leiphaemia* (Fr.) Senan. et KD Hyde *Dicarpella dryina* Belisario et M.E. Barr, *Didymella glomerata* (Corda) Qian Chen et L. Cai, *Quercina discula* (Westend.) Arx, *Epicoccum nigrum* Link, *Erysiphe alphitoides* (Griffon et Maubl.) U. Braun et S. Takam., *E. hypophylla* (Nevod.) U. Braun et Cunningham, *E. quercicola* S. Takam. et U. Braun, *Fusicoccum advenum* (Sacc.) Died., *Marsonia matteiana* Sacc., *Microdochium nivale* (Fr.) Samuels et I.C. Hallett, *Microstroma album* (Desm.) Sacc., *Monochaetia kansensis* (Ellis et Barthol.) Sacc. et D. Sacc., *M. monochaeta* (Desm.) Allesch., *Mortierella hyalina* (Harz) W. Gams, *Naevala perexigua* (Roberge ex Desm.) K. Holm et L. Holm, *Phyllactinia guttata* (Wallr.) Lev, *P. roboris* (Gachet) S. Blumer, *Ramularia endophylla* Verkley et U. Braun, *Rhizopus oryzae* Went et Prins. Geerl., *Septoria quercina* Desm., *Sphaerulina quercicola* (Desm.) Quaedvl., Verkley et Crous, *Sporobolomyces roseus* Kluyver et C.B. Niel, *Symmetrospora gracilis* (Derx) Q.M. Wang, F.Y. Bai, M. Groenew. et Boekhout, *Taphrina carpini* (Rostr.) Johanson, *T. caerulescens* (Desm. et Mont.) Tul., *T. inositophila* (Á. Fonseca, J. Inácio et M.G. Rodrigues) Yurkov et Buzzini	Gachet, 1832; Desmazières, 1838, 1847; Bonorden, 1864; Saccardo, 1878, 1908; Massalongo, 1889; Arx, 1957; Sutton, 1973; Cox and Hall, 1978; Guseinov et al., 2002; Verkley et al., 2004; Zmitrovich and Vasiliev, 2006; Jakuschkin, 2015; Ivaschenko et al., 2021
Terminal shoot system	*Amphisphaeria bufonia* (Berk. et Broome) Ces. et De Not, *Botryosphaeria quercicola* A.J.L. Phillips, *Caudospora taleola* (Fr.) Starbäck, *Clypeosphaeria mamillana* (Fr.) Lambotte, *Colpoma quercinum* (Pers.) Wallr, *Coryneum depressum* J.C. Schmidt, *C. umbonatum* Nees, *Cryptodiscus foveolaris* (Rehm) Rehm, *Cytospora intermedia* Sacc., *Dendrostoma leiphaemia* (Fr.) Senan. et K.D. Hyde, *Dendrothele commixta* (Höhn. et Litsch.) J. Ericsson et Ryvarden, *Diatrypella quercina* (Pers.) Cooke, *Durella connivens* (Fr.) Rehm, *Hendersonia quercina* Sacc., *Hyphoderma cristulatum* (Fr.) Donk, *H. setigerum* (Fr.) Donk, *Hysterium pulicare* Pers., *Nectria cinnabarina* (Tode) Fr., *Peniophora cinerea* (Pers.) Cooke, *Peniophora quercina* (Pers.) Cooke, *Phomopsis quercicola* Moesz, *Pseudocamarosporium propinquum* (Sacc.) Wijayaw, *Pseudovalsa longipes* (Tul. et C. Tul.) Sacc., *Rosellinia quercina* Hartig, *Seimatosporium quercinum* Goonas, R.K. Schumach. et K.D. Hyde, *Vuilleminia comedens* (Nees) Maire	Persoon, 1794, Link, 1809; Nees, 1816; Kunze and Schmidt, 1817; Fries, 1819, 1823; Berkeley and Broome, 1852; Tulasne, 1856; Fukel, 1870; Nitschke, 1870; Saccardo, 1878, 1884; Phillips et al., 2005; Goonasekara et al., 2016; Shishlyannikova et al., 2023

Table 2. (Contd.)

Macro niche	Species composition	Source
Trunk, skeletal branches, detritus	*Abortiporus biennis* (Bull.) Singer, *Adustoporia sinuosa* (Fr.) Audet, *Aeruginoscyphus sericeus* (Alb. et Schwein.) Dougoud, *Aleurocystidiellum disciforme* (DC.) Boidin, *Amaropostia stiptica* (Pers.) B.K. Cui, L.L. Shen et Y.C. Dai, *Amaurodon mustialaensis* (P. Karst.) Kõljalg et K.H. Larss., *Amaurodon viridis* (Alb. et Schwein.) J. Schröt., *Amphinema byssoides* (Pers.) J. Erikss., *Amyloporia xantha* (Fr.) Bondartsev et Singer, *Amyloxenasma allantosporum* (Oberw.) Hjortstam et Ryvarden, *Antella niemelaeus* (Vampola et Vlasák) Miettinen, *Antrodia griseoflavescens* (Litsch.) Runnel, Spirin et K.H. Larss., *A. heteromorpha* (Fr.) Donk, *A. kuzyana* (Pilát) Spirin et Vlasák, *A. minuta* Spirin, *A. pulvinascens* (Pilát) Niemelä, *A. serialis* (Fr.) Donk, *Antrodiella faginea* Vampola et Pouzar, *A. pallescens* (Pilát) Niemelä et Miettinen, *A. romellii* (Donk) Niemelä, *A. serpula* (P. Karst.) Spirin et Niemelä, *Aphanobasidium pseudotsugae* (Burt) Boidin et Gilles, *Apioperdon pyriformes* (Schaeff.) Vizzini, *Aporipium canescens* (P. Karst.) Bondartsev et Singer, *Armillaria lutea* Gillet, *Artomyces pyxidatus* (Pers.) Jülich, *Ascocoryne sarcoides* (Jacq.) J.W. Groves et D.E. Wilson, *Athelia arachnoidea* (Berk.) Jülich, *A. bombacina* (Link) Pers., *A. cystidiolophora* Parmasto, *A. decipiens* (Höhn. et Litsch.) J. Erikss., *A. epiphylla* Pers., *A. fibulata* M.P. Christ, *A. sibirica* (Jülich) J. Erikss. et Ryvarden, *Auricularia auricula-judae* (Bull.) Quél., *A. mesenterica* (Dicks.) Pers., *Baltazaria galactina* (Fr.) Leal-Dutra, Dentinger et G.W. Griff., *Basidiodendron eyrei* (Wakef.) Luck-Allen, *B. rimulentum* (Bourdot et Galzin) Luck-Allen, *B. walleynii* Spirin, Malysheva et Schoutteten, *Biscogniauxia nummularia* (Bull.) Kutnze, *Bjerkandera adusta* (Willd.) P. Karst., *B. fumosa* (Pers.) P. Karst., *Botryobasidium botryosum* (Bres.) J. Erikss., *B. capitatum* (Link) Rossman et W.C. Allen, *B. conspersum* J. Erikss., *B. intertextum* (Schwein.) Jülich et Stalpers, *Botryobasidium isabellinum* (Fr.) D.P. Rogers, *B. laeve* (J. Erikss.) Parmasto, *B. medium* J. Erikss., *B. pruinatum* (Bres.) J. Erikss., *B. subcoronatum* (Höhn. et Litsch.) Donk, *Brevicellicium olivascens* (Bres.) K.H. Larss. et Hjortstam, *Buglossoporus pulvinus* (Pers.) Donk, *Bulgaria inquinans* (Pers.) Fr., *Byssomerulis corium* (Pers.) Parmasto, *Byssoporia terrestris* (Pers.) M.J. Larsen et Zak, *Calocera cornea* (Batsch) Fr., *Calocera glossoides* (Pers.) Fr., *Candelabrochaete septocystidia* (Burt) Burds., *Cellulariella warnieri* (Durieu et Mont.) Zmitser et Malysheva, *Ceraceomyces borealis* (Romell) J. Erikss. et Ryvarden, *C. elludens* K.H. Larss., *Ceratocystis grandicarpa* Kowalski et Butin, *C. prolifera* Kowalski et Butin, *Cerinomyces enatus* (Berk. et M.A. Curtis) A. Savchenko, *Cerioporus squamosus* (Huds.) Quél., *C. varius* (Pers.) Zmitser et Kovalenko, *Ceriporia aurantiocarnescens* (Henn.) M. Pieri et B. Rivoire, *C. bresadolae* (Bourdot et Galzin) Donk, *C. humilis* Spirin et Miettinen, *C. purpurea* (Fr.) Donk, *C. reticulata* (Hoffm.) Domański, *C. viridans* (Berk. et Broome) Donk, *Ceriporiopsis gilvescens* (Bres.) Domański, *Cerrena unicolor* (Bull.)	Bolton, 1788; Saccardo, 1878; Jaczewski, 1896, 1897; Borowska, 1975; Kowalski and Butin, 1989; Kowalski and Barthik, 1995; Kowalski and Halmschlager, 1996; Kolmakov, 2005; Przybył, 2007; Popov et al., 2008; Ordynets, 2012; Popov and Volobuyev, 2014; Zhukova et al., 2017; Song et al., 2017; Sidelnikova et al., 2018; Jankowiak et al., 2019; Zmitrovich et al., 2020; Volkova et al., 2020; Ivaschenko et al., 2021; Svetasheva, 2021; Firsov et al., 2021; Bolshakov et al., 2022; Shishlyannikova et al., 2023; Trollip et al., 2024

Table 2. (Contd.)

Macro niche	Species composition	Source
	Murrill, *Chaetosphaeria vermicularioides* (Sacc. et Roum.) W. Gams et Hol.-Jech., *Chalara angustata* T. Kowalski et Halmschl., *Chlorociboria aeruginascens* (Nyl.) Kanouse ex C.S. Ramamurthi, Korf et L.R. Batra, *Chondrosteroneum purpureum* (Pers.) Pouzar, *Cinereomyces lindbladii* (Berk.) Jülich, *Clavulina amethystina* (Bull.) Donk, *C. coralloides* (L.) J. Schröt., *Climacocystis borealis* (Fr.) Kotl. et Pouzar, *Climacodon septentrionalis* (Fr.) P. Karst., *Collybiopsis peronata* (Bolton) R.H. Petersen, *Coniophora arida* (Fr.) P. Karst., *C. fusispora* (Cooke et Ellis) Cooke, *C. olivacea* (Fr.) P. Karst., *C. puteana* (Schumach.) P. Karst., *Corticium roseum* Pers., *Corynesporopsis quercicola* (Borowska) P.M. Kirk, *Cremeoderma unicum* (H.S. Jacks. et Dearden) C.C. Chen et Sheng H. Wu, *Crepidotus lundellii* Pilát, *C. mollis* (Schaeff.) Staude, *Christina helvetica* (Pers.) Parmasto, *Crustomyces subabruptus* (Bourdot et Galzin) Jülich, *Cryphonectria naterciae* Bragança, E. Diogo et A.J.L. Phillips, *Cryptosporiopsis radicicolae* Kowalski et C. Bartnik, *Crystallicutis serpens* (Tode) El-Gharabawy, Leal-Dutra et G.W. Griff., *Cyanosporus alni* (Niemelä et Vampola) B.K. Cui, L.L. Shen et Y.C. Dai, *C. subcaesius* (A. David) B.K. Cui, L.L. Shen et Y.C. Dai, *Cylindrobasidium evolvens* (Fr.) Jülich, *Cystidiopostia hibernica* (Berk. et Broome) B.K. Cui, L.L. Shen et Y.C. Dai, *Cytidiella nitidula* (P. Karst.) Zmitr., *Dacrimyces enatus* (Berk. et M.A. Curtis) Massey, *D. minor* Peck, *D. stillatus* Nees, *Daedalea quercina* (L.) Pers., *Daedaleopsis confragosa* (Bolton) J. Schröt., *Dendrocorticium polygonioides* (P. Karst.) M.J. Larsen et Gilb., *Dendrothele acerina* (Pers.) P.A. Lemke, *D. commixta* (Höhn. et Litsch.) J. Erikss. et Ryvarden, *Dentipellis fragilis* (Pers.) Donk, *Diatrype stigma* (Hoffm.) Fr., *Dichosterum effuscatum* (Cooke et Ellis) Boidin et Lanq., *Donkia pulcherrima* (Berk. et M.A. Curtis Pilát, *Dothiorella iberica* A.J.L. Phillips, J. Luque et A. Alves, *Efibula tuberculata* (P. Karst.) Zmitr. et Spirin, *Elmerina caryae* (Schwein.) D.A. Reid, *Emmia latemarginata* (Durieu et Mont.) Zmitr., Spirin et Malysheva, *Eriopezia caesia* (Pers.) Rehm, *Etheirodon fimbriatum* (Pers.) Banker, *Euepixylon udum* (Pers.) Læssøe et Spooner, *Exidia candida* Lloyd, *E. cartilaginea* S. Lundell et Neuhoff, *E. nigricans* (With.) P. Roberts, *E. repanda* Fr., *Fibricium rude* (P. Karst.) Jülich, *Fibroporia gossypium* (Speg.) Parmasto, *Fistulina hepatica* (Schaeff.) With., *Fomes fomentarius* (L.) Fr., *F. inzengae* (Ces et De Not.) Cooke, *Fomitiporia punctata* (P. Karst.) Murrill, *Fomitiporia robusta* (P. Karst.) Fiasson et Niemelä, *Fomitopsis pinicola* (Sw.) P. Karst., *Frantisekia mentschulensis* (Pilát ex Pilát) Spirin, *Funalia gallica* (Fr.) Bondartsev et Singer, *F. trogii* (Berk.) Bondartsev et Singer, *Fuscoporia contigua* (Pers.) G. Cunn., *F. ferruginosa* (Schrad.) Murrill, *F. torulosa* (Pers.) T. Wagner et M. Fisch., *Ganoderma adspersum* (Schulzer) Donk, *G. applanatum* (Pers.) Pat., *G. lucidum* (Curtis) P. Karst., *G. pfeifferi* Bres., *G. resinaceum* Boud., *Gelatoporia subvermispora* (Pilát) Niemelä, *Gloeocystidiellum porosum* (Berk. et M.A. Curtis) Donk, *Gloeohypochnicium analogum* (Bourdot et Galzin) Hjortstam, *Gloeopeniophorella convolvens* (P. Karst.) Boidin, Lanq. et Gilles, *Gloeophyllum trabeum* (Pers.) Murrill, *Gloeoporus pannocinctus* (Romell) J. Erikss., *Gloiodon strigosus* (Sw.) P. Karst., *Gloiothele lactescens* (Berk.) Hjortstam, *Granulobasidium vellereum* (Ellis et Cragin) Jülich, *Grifola frondosa* (Dicks.) Gray, *Guepiniopsis estonica* (Raitv.) M. Dueñas,	

Table 2. (Contd.)

Macro niche	Species composition	Source
	Gymnopus erythropus (Pers.) Antonín, Halling et Noordel., *Hapalopilus croceus* (Pers.) Bondartsev et Singer, *H. rutilans* (Pers.) Murrill, *Hastodontia hastata* (Litsch.) Hjortstam et Ryvarden, *Henningsomyces candidus* (Pers.) Kuntze, *Hericium cirrhatum* (Pers.) Nikol., *H. coralloides* (Scop.) Pers., *H. erinaceus* (Bull.) Pers., *Hermanssonia centrifuga* (P. Karst.) Zmitr., *Heterobasidion annosum* (Fr.) Bref., *Heteroradulum deglubens* (Berk. et Broome) Spirin et Malysheva, *Hyalodon picicola* (Kühner ex Bourdot) Malysheva et Spirin, *Hydnocristella himantia* (Schwein.) R.H. Petersen, *Hydnoporia corrugata* (Fr.) K.H. Larss. et Spirin, *H. tabacina* (Sowerby) Spirin, Miettinen et K.H. Larss., *Hymenochaete cinnamomea* (Pers.) Bres., *H. fuliginosa* (Fr.) Lev., *H. rubiginosa* (Dicks.) Lev., *Hymenoscyphus scutula* (Pers.) W. Phillips, *Hyphoderma cristulatum*, *H. medioburiense* (Burt) Donk, *H. mutatum* (Peck) Donk, *H. obtusiforme* J. Erikss. et Å. Strid, *H. occidentale* (D.P. Rogers) Boidin et Gilles, *H. roseocremeum* (Bres.) Donk, *H. setigerum*, *H. transiens* (Bres.) Parmasto, *Hyphodermella corrugata* (Fr.) J. Erikss. et Ryvarden, *Hyphodontia arguta* (Fr.) J. Erikss., *H. microspora* J. Erikss. et Hjortstam, *H. pallidula* (Bres.) J. Erikss., *H. quercina* (Pers.) J. Erikss., *Fascicular hypothalamus* (Huds.) P. Kumm., *Hypochnicium bombycinum* (Sommerf.) J. Erikss., *H. cremicolor* (Bres.) H. Nilsson et Hallenb., *H. erikssonii* Hallenb. et Hjortstam, *H. lundellii* (Bourdot) J. Erikss., *H. punctulatum* (Cooke) J. Erikss., *H. wakefieldiae* (Bres.) J. Erikss., *Hypoxylon fuscum* (Pers.) Fr., *Inocutis dryophila* (Berk.) Fiasson et Niemelä, *I. rheades* (Pers.) Fiasson et Niemelä, *Inonotus cuticularis* (Bull.) P. Karst., *I. hispidus* (Bull.) P. Karst., *I. krawtzewii* (Pilát) Pilát, *I. obliquus* (Fr.) Pilát, *Irpex lacteus* (Fr.) Fr., *Irpiciporus pachyodon* (Pers.) Kotl. et Pouzar, *Ischnoderma resinosum* (Schrad.) P. Karst., *Jaapia ochroleuca* (Bres.) Nannf. et J. Erikss., *Jackrogersella cohaerens* (Pers.) L. Wendt., Kuhnert et M. Stadler, *Kavinia alboviridis* (Morgan) Gilb. et Budington, *Kneiffiella alienata* (S. Lundell) Jülich et Stalpers, *K. barba-jovis* (Bull.) P. Karst., *K. subalutacea* (P. Karst.) Jülich et Stalpers, *Kretzschmaria deusta* (Hoffm.) P.M.D. Martin, *Kurtia argillacea* (Bres.) Karasinski, *Lachnella alboviolascens* (Alb. et Schwein.) Fr., *Lachnum capitatum* (Peck) Svrček, *Laetiporus sulphureus* (Bull.) Murrill, *Laxitextum bicolor* (Pers.) Lentz, *Lentaria byssiseda* Corner, *Lentinus arcularius* (Batsch) Zmitr., *L. brumalis* (Pers.) Zmitr., *L. substrictus* (Bolton) Zmitr. et Kovalenko, *Lenzites betulina* (L.) Fr., *L. gibbosa* (Pers.) Hemmy, *Leucogyrophana mollusca* (Fr.) Pouzar, *Lilaceophlebia ochraceofulva* (Bourdot et Galzin) Spirin et Zmitr., *Lindtneria panphyliensis* Bernicchia et M.J. Larsen, *L. trachyspora* (Bourdot et Galzin) Pilát, *Loweomyces fractipes* (Berk. et M.A. Curtis) Jülich, *Lyomyces crustosus* (Pers.) P. Karst., *L. pruni* (Lasch) Riebesehl et Langer, *L. sambuci* (Pers.) P. Karst., *Marasmius epiphyllus* (Pers.) Fr., *M. rotula* (Scop.) Fr., *Meripilus giganteus* (Pers.) P. Karst., *M. sanguinolentus* (Alb. et Schwein.) Rajchenb. et Westph., *Metulodontia nivea* (P. Karst.) Parmasto, *Metuloidea fragrans* A. David et Tortič) Miettinen, *M. murashkinskyi* (Burt) Miettinen et Spirin, *Mollisia olivascens* (Feltgen) Le Gal et F. Mangenot, *Mycena algeriensis* Maire, *M. galericulata* (Scop.) Gray, *M. inclinata* (Fr.) Quél., *M. polygramma* (Bull.) Gray, *M. pseudocorticola* Kuhner, *M. vitilis* (Fr.) Quél., *Mycoacia aurea* (Fr.) J. Erikss. et Ryvarden, *M. fuscoatra* (Fr.) Donk, *Myxarium podlachicum* (Bres.) Raitv.,	

Table 2. (Contd.)

Macro niche	Species composition	Source
	Nemania serpens (Pers.) Gray, *Neodasyscypha cerina* (Pers.) Spooner, *Neofavolus alveolaris* (DC.) Sotome et T. Hatt., *Neonectria ditissima* (Tul. et C. Tul.) Samuels et Rossman (step cancer), *N. coccinea* (Pers.) Rossman et Samuels (cancer of trunks and branches), *Niemelaea consobrina* (Bres.) Zmitr., Ezhov et Khimich, *Ofella glaira* (Lloyd) Spirin et Malysheva, *Oligoporus rennyi* (Berk et Broome) Donk, *Ophiostoma solheimii* Strzałka et Jankow., *Orbilia aprilis* Velen., *O. vinosa* (Alb. et Schwein.) P. Karst., *Oxyporus corticola* (Fr.) Ryvarden, *O. obducens* (Pers.) Donk, *O. populinus* (Schumach.) Donk, *O. ravidus* (Fr.) Bondartsev et Singer, *Pachykytospora tuberculosa* (Fr.) Kotl. et Pouzar, *Pallidohirschioporus biformis* (Fr.) Y.C. Dai, Yuan Yuan et M. Zhou, *Panus conchatus* (Bull.) Fr., *Peniophora cinerea*, *P. incarnata* (Pers.) P. Karst., *P. lycii* (Pers.) Höhn. et Litsch., *P. nuda* (Fr.) Bres., *P. quercina*, *P. violaceolivida* (Sommerf.) Massey, *Peniophorella guttulifera* (P. Karst.) K.H. Larss., *P. praetermissa* (P. Karst.) K.H. Larss., *P. pubera* (Fr.) P. Karst., *Perenniporia medulla-panis* (Jacq.) Donk, *P. tenuis* (Schwein.) Ryvarden, *Phaeolus schweinitzii* (Fr.) Pat., *Phaeotremella foliacea* (Pers.) Wedin, J.C. Zamora et Millanes, *Phanerochaete aculeata* Hallenb, *P. alnea* (Fr.) P. Karst., *P. calotricha* (P. Karst.) J. Erikss. et Ryvarden, *P. cumulodentata* (Nikol.) Parmasto, *P. galactites* (Bourdot et Galzin) J. Erikss et Ryvarden, *P. laevis* (Fr.) J. Erikss. et Ryvarden, *P. livescens* (P. Karst.) Volobuev et Spirin, *P. sanguinea* (Fr.) Pouzar, *P. sordida* (P. Karst.) J. Erikss. et Ryvarden, *P. velutina* (DC.) P. Karst., *Phanerochaetella queletii* (Bres.) Yue Li, Nakasone et S.H. He, *Phellinopsis conchata* (Pers.) Y.C. Dai, *Phellinus alni* (Bondartsev) Parmasto, *P. laevigatus* (P. Karst.) Bourdot et Galzin, *Phlebia lilascens* (Bourdot) J. Erikss. et Hjortstam, *P. livida* (Pers.) Bres., *P. radiata* Fr., *P. rufa* (Fr.) M.P. Christ, *P. tremelloidea* (Bres.) Parmasto, *P. tremellosa* (Schrad.) Nakasone et Burds., *Phlebiodontia subochracea* (Bres.) Motato-Vasq. et Gugliotta, *Phlebiopsis gigantea* (Fr.) Jülich, *P. ravenelii* (Cooke) Hjortstam, *Pholiota squarrosa* (Vahl) P. Kumm., *Phomopsis quercus* (Sacc. et Speg.) Curzi et Barbaini (Gauls), *Phylloporia ribis* (Schumach.) Ryvarden, *Picipes badius* (Pers.) Zmitr. et Kovalenko, *P. melanopus* (Pers.) Zmitr. et Kovalenko, *Pilatotrama ljubarskyi* (Pilát) Zmitr., *Piloderma bicolor* (Peck) Jülich, *P. byssinum* (P. Karst.) Jülich, *Piptoporellus soloniensis* (Dubois) B.K. Cui, M.L. Han et Y.C. Dai, *Pleurotus cornucopiae* (Paulet) Rolland, *P. dryinus* (Pers.) P. Kumm., *P. pulmonarius* (Fr.) Quél., *Plicatura nivea* (Fr.) P. Karst., *Pluteus chrysophaeus* (Schaeff.) Quél., *Podofomes mollis* (Sommerf.) Gorjon, *P. stereoides* (Fr.) Gorjon, *Polyporus tuberculosis* (Jacques ex Pers.) Fr., *P. umbellatus* (Pers.) Fr., *Porostereum spadiceum* (Pers.) Hjortstam et Ryvarden, *Porotheleum fimbriatum* (Pers.) Fr., *Porpomyces mucidus* (Pers.) Jülich, *Postia balsamea* (Peck) Jülich, *P. lactea* (Fr.) P. Karst., *Propolis farinosa* (Pers.) Fr., *Protomerulius pertusus* Malysheva et Spirin, *Pseudoinonotus dryadeus* (Pers.) T. Wagner et M. Fisch., *Pseudophlebia setulosa* (Berk et M.A. Curtis) C.L. Zhao, *Pseudospongipellis delectans* (Murrill) Y.C. Dai et Chao G. Wang, *P. litschaueri* (Lohwag) Y.C. Dai et Chao G. Wang, *Pseudotomentella tristis* (P. Karst.) M.J. Larsen, *Pycnoporus cinnabarinus* (Jacq.) P. Karst., *Raduliporus aneirinus* (Sommerf.) Spirin et Zmitser, *Radulomyces confluens* (Fr.) M.P. Christ, *R. molaris* (Chaillet ex Fr.) M.P. Christ, *R. rickii* (Bres.) M.P. Christ,	

Table 2. (Contd.)

Macro niche	Species composition	Source
	Ramaria botrytis (Pers.) Bourdot, *R. stricta* (Pers.) Quél., *Resinicium bicolor* (Alb. et Schwein.) Parmasto, *Resiniporus resinascens* (Romell) Zmitr., *Resupinatus applicatus* (Batsch) Gray, *Rhizochaete radicata* (Henn.) Gresl., Nakasone et Rajchenb., *Rhizoctonia ochracea* (Massee) Oberw., R. Bauer, Garnica et R. Kirschner, *R. pseudocornigera* (M.P. Christ.) Oberw., R. Bauer, Garnica et R. Kirschner, *Rigidoporus crocatus* (Pat.) Ryvarden, *R. ulmarius* (Sowerby) Imazeki, *Riopa metamorphosa* (Fuckel) Miettinen et Spirin, *Rugonectria wingfieldii* C.M.T. Anderson, Trollip, Carnegie et Priest (galls), *Saccosoma farinaceum* (Höhn.) Spirin et K. Põldmaa, *S. floccosum* Malysheva et Spirin, *Sarcodontia uda* (Fr.) Nikol., *Sarcomyx serotina* (Pers.) P. Karst., *Schizophyllum ampulum* (Lev.) Nakasone, *S. commune* Fr., *Scopuloides hydnoides* (Cooke et Massee) Hjortstam et Ryvarden, *Scytinostromella heterogenea* (Bourdot et Galzin) Parmasto, *S. humifaciens* (Burt) G.W. Freeman et R.H. Petersen, *Septonema binum* Borowska, *Septotrullula bacilligera* Hohn, *Serpula lacrymans* (Wulfen) J. Schröt., *Sertulicium granuliferum* (Hallenb.) Spirin et Volobuev, *S. niveocremeum* (Höhn. et Litsch.) Spirin et K.H. Larss., *Sidera lenis* (P. Karst.) Miettinen, *S. vulgaris* (Fr.) Miettinen, *Sistotrema alboluteum* (Bourdot et Galzin) Bondartsev et Singer, *S. autumnale* Ryvarden et H. Solheim, *S. brinkmannii* (Bres.) J. Erikss., *S. coronilla* (Höhn.) Donk ex D.P. Rogers, *S. diademiferum* (Bourdot et Galzin) Donk, *S. muscicola* (Pers.) J. Erikss., *S. oblongisporum* M.P. Christ. et Hauerslev, *S. octosporum* (J. Schrot. ex Höhn. et Litsch.) Hallenb., *S. raduloides* (P. Karst.) Donk, *S. sernanderi* (Litsch.) Donk, *Skeletocutis carneogrisea* A. David, *S. nivea* (Jungh.) Jean Keller, *Skvortzovia furfuracea* (Bres.) G. Gruhn et Hallenberg, *Sparassis brevipes* Krombh., *S. crispa* (Wulfen) Fr., *Spongipellis spumea* (Sowerby) Pat., *Steccherinum aridum* Svrček, *S. bourdotii* Saliba et A. David, *S. lacerum* (P. Karst.) Kotir et Saaren, *S. laeticolor* (Berk. et M.A. Curtis) Banker, *S. nitidum* (Pers.) Westerh., *S. ochraceum* (Pers. ex J.F. Gmel.) Gray, *S. robustius* (J. Erikss. et S. Lundell) J. Erikss., *Stereophlebia pendula* (Fr.) K.H. Larss., *Stereum gausapatum* (Fr.) Fr., *S. hirsutum* (Willd.) Gray, *S. rugosum* Pers., *S. subtomentosum* Pouzar, *Subulicium rallum* (H.S. Jacks.) Jülich et Stalpers, *Subulicystidium longisporum* (Pat.) Parmasto, *Szczepkamyces campestris* (Quél.) Zmitr., *Taeniolella dichotoma* Borowska, *Tapesia fusca* (Pers.) Fuckel, *Terana coerulea* (Lam.) Kuntze, *Thelephora penicillata* (Pers.) Fr., *T. terrestris* Ehrh., *T. wakefieldiae* Zmitr., Shchepin, Volobuev et Myasnikov, *Tomentella atramentaria* Rostr., *T. badia* (Link) Stalpers, *T. bryophila* (Pers.) M.J. Larsen, *T. cinerascens* (P. Karst.) Höhn. et Litsch., *T. ferruginea* (Pers.) Pat., *T. fibrosa* (Berk. et M.A. Curtis) Kõljalg, *T. griseoumbrina* Litsch., *T. lapida* (Pers.) Stalpers, *T. olivascens* (Berk. et M.A. Curtis) Bourdot et Galzin, *T. pilosa* (Burt) Bourdot et Galzin, *T. radiosa* (P. Karst.) Rick, *T. stuposa* (Link) Stalpers, *T. umbrinospora* M.J. Larsen, *T. viridula* (Bourdot et Galzin) Svrček, *Tomentellopsis echinospora* (Ellis) Hjortstam, *T. zygodesmoides* (Ellis) Hjortstam, *Trametes hirsuta* (Wulfen) Lloyd, *T. ochracea* (Pers.) Gilb. et Ryvarden, *T. pubescens* (Schumach.) Pilát, *T. suaveolens* (L.) Fr., *T. versicolor* (L.) Lloyd, *Trametopsis cervina* (Schwein.) Tomšovský, *Trechispora candidissima* (Schwein.) Bondartsev et Singer, *T. cohaerens* (Schwein.) Jülich et Stalpers, *T. confinis* (Bourdot et Galzin) Liberta,	

Table 2. (Contd.)

Macro niche	Species composition	Source
	T. farinacea (Pers.) Liberta, *T. hymenocystis* (Berk. et Broome) K.H. Larss., *T. microspora* (P. Karst.) Liberta, *T. mollusca* (Pers.) Liberta, *T. nivea* (Pers.) K.H. Larss., *T. praefocata* (Bourdot et Galzin) Liberta, *T. stevensonii* (Berk. et Broome) K.H. Larss., *T. subsphaerospora* (Litsch.) Liberta, *Tremella globispora* D.A. Reid, *T. mesenterica* (Schaeff.) Pers., *Tretomyces lutescens* (J. Erikss. et Ryvarden) K.H. Larss., Kotir. et Saaren., *Triblidium caliciforme* Rebent., *Trichoderma strictipile* Bissett, *Tubulicrinus glebulosus* (Fr.) Donk, *T. subulatus* (Bourdot et Galzin) Donk, *Tulasnella albida* Bourdot et Galzin, *T. eichleriana* Bres., *T. saveloides* P. Roberts, *T. violea* (Quél.) Bourdot et Galzin, *Tylospora asterophora* (Bonord.) Donk, *Typhula spathulata* (Corner) Berthier, *T. sphaeroidea* Remsberg, *Tyromyces chioneus* (Fr.) P. Karst., *T. fumidiceps* G.F. Atk., *T. odorus* (Sacc.) Zmitr., *Vanderbylia fraxinea* (Bull.) D.A. Reid, *Vararia investiens* (Schwein.) P. Karst., *V. ochroleuca* (Bourdot et Galzin) Donk, *Vesiculomyces citrinus* (Pers.) E. Hagstr., *Vitreoporus dichrous* (Fr.) Zmitr., *Verticillium dahliae* Kleb. (wilt), *Vuilleminia comedens* (Nees) Maire (ulcers, necrosis), *V. coryli* Boidin, Lanq. et Gilles, *V. megalospora* Bres., *Xanthoporia radiata* (Sowerby) Ţura, Zmitr., Wasser, Raats et Nevo, *Xenasma tulasnelloideum* (Höhn. et Litsch.) Donk, *X. alnicola* (Bourdot et Galzin) K.H. Larss. et Ryvarden, *X. vaga* (Fr.) Stalpers, *Xylaria polymorpha* (Pers.) Grev., *Xylobolus frustulatus* (Pers.) P. Karst., *X. subpileatus* (Berk. et M.A. Curtis) Boidin, *Xylodon asper* (Fr.) Hjortstam et Ryvarden, *Xylodon borealis* (Kotir. et Saaren.) Hjortstam et Ryvarden, *X. brevisetus* (P. Karst.) Hjortstam et Ryvarden, *X. detriticus* (Bourdot) K.H. Larss., Viner et Spirin, *X. flaviporus* (Berk. et M.A. Curtis ex Cooke) Riebesehl et Langer, *X. nesporii* (Bres.) Hjortstam et Ryvarden, *X. paradoxus* (Schrad.) Chevall., *X. pruinosus* (Bres.) Spirin et Viner, *X. radula* (Fr.) Ţura, Zmitser, Wasser et Spirin, *X. raduloides* Riebesel et Langer, *X. spathulatus* (Schrad.) Kuntze, *X. tuberculatus* (Kotir. et Saaren.) Hjortstam et Ryvarden, *X. verruculosus* (J. Erikss. et Hjortstam) Hjortstam et Ryvarden, *Yuchengia narymica* (Pilát) B.K. Cui, C.L. Zhao et K.T. Steffen	
Stem ulcers and wounds	*Acremonium alternatum* Link, *A. asperulatum* A. Giraldo, Guarro, Gené et Cano, *A. rutilum* W. Gams ex L.W. Hou, L. Cai et Crous, *Alternaria angustiovoidea* E.G. Simmons, *Apiospora kogelbergensis* (Crous) Pintos et P. Alvarado, *Apiotrichum otae* M. Takash., Kurakado, O. Cho, K. Kikuchi, Sugiy. et Sugita, *A. porosum* Stautz, *Aposphaeria corallinolutea* Gruyter, Aveskamp et Verkley, *Armillaria lutea*, *Ascocoryne sarcoides*, *Aspergillus amstelodami*, *A. domesticus* F. Sklenář, Houbraken, Zalar et Hubka, *Aureobasidium pullulans*, *Bacidina arnoldiana* (Körb.) V. Wirth et Vězda, *Bacilliformis hyalinus* Ekanayaka et K.D. Hyde, *Bartalinia robillardoides* Tassi, *Beauveria virella* (Fr.) F. Mangenot, *Bisporella subpallida* (Rehm) Dennis, *Bjerkandera adusta*, *Botrytis californica* S. Saito et C.L. Xiao, *Buckleyzyma aurantiaca* (Saito) Q.M. Wang, F.Y. Bai, M. Groenew. et Boekhout, *Bullera alba* (W.F. Hannah) Derx, *Cadophora luteo-olivacea* (J.F.H. Beyma) T.C. Harr. et McNew, *C. malorum* (Kidd et Beaumont) W. Gams, *Calycellina fagina*, *Calycina herbarum* (Pers.) Gray, *Candida boidini* C. Ramirez, *C. norvegica* (Reiersöl) SA Mey. et Yarrow, *C. sophiae* C. Ramirez et A.E. Gonzalez, *Candolleomyces candolleanus* (Fr.) D. Wächt. et A. Melzer, *Capronia pulcherrima* (Munk) E. Müll., Petrini, P.J. Fisher, Samuels et Rossman, *Cephalotrichum nanum*	Sieber et al., 1995; Marčiulinas et al., 2023

Table 2. (Contd.)

Macro niche	Species composition	Source
	(Ehrenb.) S. Hughes, *Chaetosphaeria decastyla* (Cooke) Réblová et W. Gams, *Chalara cylindrosperma* (Corda) S. Hughes, *Chloridium clavaeforme* (Preuss) W. Gams et Hol.-Jech., *C. virescens* (Pers.) W. Gams et Hol.-Jech., *Cladosporium cladosporioides* (Fresen.) G.A. de Vries, *Claussenomyces prasinulus* (P. Karst.) Korf et Abawi, *Coniochaeta velutina* (Fuckel) Cooke, *Coniophora puteana*, *Coprinellus micaceus* (Bull.) Vilgalys, Hopple et Jacq. Johnson, *Cosmospora berkeleyana* (P. Karst.) Gräfenhan, Seifert et Schroers, *Cryptocoryneum condensatum* (Wallr.) E.W. Mason et S. Hughes, *Cylindrobasidium evolvens*, *Cyphellophora olivacea* (W. Gams) Réblová et Unter., *C. sessilis* (de Hoog) Réblová et Unter., *Cystobasidium laryngis* (Reiersöl) Yurkov, Kachalkin, H.M. Daniel, M. Groenew., Libkind, V. de García, Zalar, Gouliam., Boekhout et Begerow, *Cystofilobasidium capitatum* (Fell, I.L. Hunter et Tallman) Oberw. et Bandoni, *Cytospora galegicola* Q.J. Shang, Camporesi et K.D. Hyde, *C. predappioensis* Q.J. Shang, Norph., Camporesi et K.D. Hyde, *Dactylonectria torresensis* (A. Cabral, Rego et Crous) L. Lombard et Crous, *Debaryomyces hansenii* (Zopf) Lodder et Kreger-van Rij, *Dematioscypha richonis* (Boud.) Huhtinen, *Dendrostoma leiphaemia* (Fr.) Senan. et K.D. Hyde, *Diaporthe eres* Nitschke, *Diatrype stigma*, *Dothiora prunorum* (C. Dennis et Buhagiar) Crous, *Dichomera saubinetii* (Mont.) Cooke, *Dothiorella sarmentorum* (Fr.) A.J.L. Phillips, A. Alves et J. Luque, *Ejnerjensenia myriocarpa* (Fr.) W.P. Wu et Y.Z. Diao, *Entomortierella jenkinii* (A.L. Sm.) Telagathoti, Probst et Peintner, *Erythrobasidium hasegawianum* Hamam., Sugiy. et Komag., *Eutypella virescens* Wehm., *Exophiala angulospora* Iwatsu, Udagawa et T. Takase, *E. castellanii* Iwatsu, Nishim. et Miyaji, *E. lignicola* Crous et Sharks, *E. xenobiotica* de Hoog, J.S. Zeng, Harrak et Deanna A. Sutton, *Fimetariella rabenhorstii* (Niessl) N. Lundq., *Flavopunctelia flaventior* (Stirt.) Hale, *Fonsecazyma betulae* Yurkov, Kachalkin et Boekhout, *Furcasterigmium furcatum* (C. Moreau et Moreau ex W. Gams) Giraldo López et Crous, *Fusarium acuminatum* Ellis et Everh., *F. fujikuroi* Nirenberg, *F. oxysporum* Schltdl., *F. sambucinum*, *F. tenuicristatum* (S. Ueda et Udagawa) O'Donnell, Geiser et T. Aoki, *Fusicolla merismoides* (Corda) Gräfenhan, Seifert et Schroers, *Gibellulopsis nigrescens* (Pethybr.) Zare, W. Gams et Summerb., *Gliomastix murorum* (Corda) S. Hughes, *Graphium penicillioides* Corda, *Haglundia perelegans* Haglund ex Nannf., *Hannaella surugaensis* (Nagah., Hamam. et Nakase) F.Y. Bai et Q.M. Wang, *Haplographium catenatum* (Preuss) Hol.-Jech., *Helicogloea pellucida* Spirin et Malysheva, *Hormodochis aggregata* Crous et R.K. Schumach., *Hyaloscypha fuckelii* Nannf., *H. hepaticicola* Grelet et Croz.) Baral, Huhtinen et JR De Sloover, *H. usitata* Huhtinen, *Hyphodiscus luxurianis* (Bogale et Unter.) Hosoya, *Hyphodontia pallidula*, *Hypochnicium geogenium*, *H. punctulatum*, *Hypoxylon howeanum* Peck, *H. rubiginosum* (Pers.) Fr., *Infundichalara microchona* (W. Gams) Réblová et W. Gams, *Knufia perfecta* Mehrabi, Asgari et Hemmati, *Kregervanrija fluxuum* (Phaff et E.P. Knapp) Kurtzman, *Kuraishia floccosa* (G. Péter, Dlauchy et Tornai-Leh.) Kurtzman et Robnett, *Kwoniella shivajii* (R. Sreen. Rao, S.A. James, C.J. Bond, I.N. Roberts, K. Cross, Retter et P.J. Hobbs) Xin Zhan Liu, F.Y. Bai, M. Groenew. et Boekhout, *Laetiporus sulphureus*, *Leptodontidium beauverioides* (de Hoog) de Hoog, *Leptographium flavum* Jankow. et Ostaf.,	

Table 2. (Contd.)

Macro niche	Species composition	Source
	Leptosillia macrospora (Eitner) Voglmayr et Jaklitsch, *Lophiostoma compressum* (Pers.) Ces. et De Not., *L. corticola* (Fuckel) E.C.Y. Liew, Aptroot et K.D. Hyde, *L. cynaroidis* Marinc., M.J. Wingf. et Crous, *Magnohelicospora iberica* R.F. Castañeda, Hern.-Restr., Gené et Guarro, *Malassezia caprae* J. Cabanas et Boekhout, *M. globosa* Midgley, E. Guého et J. Guillot, *M. sympodialis* R.B. Simmons et E. Guého, *Mariannaea elegans* (Corda) Samson, *Massarina rubi* (Fuckel) Sacc., *Melanomma sanguinarium* Sacc., *Menispora glauca* (Link) Pers., *Meyerozyma guilliermondii* (Wick.) Kurtzman et M. Suzuki, *Mollisia cinerea* (Batsch) P. Karst., *Moristroma germanicum* C. Kraus, Damm, S. Bien, Vögele et M. Fisch., *Mortierella hypsicladia* Degawa et W. Gams, *Mrakia aquatica* (E.B.G. Jones et Slooff) Xin Zhan Liu, F.Y. Bai, M. Groenew. et Boekhout, *M. gelida* (Fell, Statzell, I.L. Hunter et Phaff) Y. Yamada et Komag., *Mucor flavus* Bainier, *M. racemosus* Fresen, *Muriphaeosphaeria viburni* Crous, D. Savic et R.K. Schumach., *Mycena alcalina* (Fr.) P. Kumm., *M. epipterygia*, *M. galericulata*, *M. vitilis*, *M. zephyrus* (Fr.) P. Kumm., *Mycoaciella bispora* (Stalpers) J. Erikss. et Ryvarden, *Nectria nigrescens*, *Nemania serpens*, *Neoascochyta exitialis* (Morini) Qian Chen et L. Cai, *Neocatenulostroma germanicum* (Crous et U. Braun) Quaedvl. et Crous, *Neocucurbitaria quercina*, *Neofabraea vagabunda* (Desm.) Rossman, *Neoleptosphaeria rubefaciens* (Togliani) H.A. Ariy. et K.D. Hyde, *Neophaeothecoidea proteae* (Crous) Quaedvl. et Crous, *Neosetophoma italica* W.J. Li, Camporesi et K.D. Hyde, *N. samarorum* (Desm.) Gruyter, Aveskamp et Verkley, *Niesslia exilis* (Alb. et Schwein.) G. Winter, *N. tenuis* (W. Gams) W. Gams, *Nigrograna mycophila* Jaklitsch, Friebes et Voglmayr, *Ophiostoma quercus*, *Orbilia aprilis*, *O. trapeziformis* Baral et G. Marson, *Paradevriesia pseudoamericana* (J. Frank, B. Oertel, Schroers et Crous) Crous, *Paraphaeosphaeria sporulosa* (W. Gams et Domsch) Verkley, Göker et Stielow, *Paraphoma radica* (McAlpine) Morgan-Jones et J.F. White, *Parascedosporium putredinis* (Corda) Lackner et de Hoog, *Parastagonospora avenae* (A.B. Frank) Quaedvl., Verkley et Crous, *Pascua guehoae* (Middelhoven, Scorzetti et Fell) M. Takash., Manabe, Y. Nishim., Sriswasdi, Ohkuma, W. Iwasaki et Sugita, *Patinella hyalophaea* Sacc., *Penicillium angularis* S.W. Peterson, E.M. Bayer et Wicklow, *P. bialowiezense*, *P. camemberti* Thom, *P. cosmopolitanum* Houbraken, Frisvad et Samson, *P. roqueforti*, *Peniophora incarnata*, *Peniophorella pertenuis* (P. Karst.) Hallenb. et H. Nilsson, *P. pubera*, *Periconia cookei* E.W. Mason et M.B. Ellis, *P. macrospinosa* Lefebvre et Aar.G. Johnson, *Peristomialis corynospora* (Samuels) Samuels, *Petriella sordida* (Zukal) G.L. Barron et J.C. Gilman, *Pezicula cinnamomea* (DC.) Sacc., *P. sporulosa* Verkley, *Phaeoacremonium viticola* J. Dupont, *Phaeostalagmus cyclosporus* (Grove) W. Gams, *Phallus impudicus* L., *Phialemonium inflatum* (Burnside) Dania García, Perdomo, Gené, Cano et Guarro, *Phialocephala compacta*, *P. oblonga* (C.J.K. Wang et B. Sutton) Tanney, Seifert et B. Douglas, *Phialophora verrucosa* Medlar, *Phlebia rufa*, *Phlebia tremellosa*, *Phlyctis argena* (Spreng.) Flot., *Pholiota adiposa* (Batsch) P. Kumm., *Phomatodes aubrietiae* (Moesz) Qian Chen et L. Cai, *Phomopsis quercina* (Sacc.) Höhn. ex Died., *Pichia manshurica* Saito, *Plagiostoma salicellum* (Fr.) Sogonov, *Plenodomus hendersonii* (Fuckel) Gruyter, Aveskamp et Verkley, *Pleurotus dryinus*, *Polyporus umbellatus*,	

Table 2. (Contd.)

Macro niche	Species composition	Source
	Priceomyces carsonii (Phaff et E.P. Knapp) M. Suzuki, *Pseudogymnoascus pannorum*, *Punctelia borreri* (Sm.) Krog, *Rachicladosporium eucalypti* Crous, *Rhamphoria buxi* Richon, *Rhinocladiella atrovirens* Nannf., *R. coryli* Crous et R.K. Schumach., *R. quercus* Crous et R.K. Schumach., *Rhizodiscina lignyota* (Fr.) Hafellner, *Rhodosporidiobolus colostri* (T. Castelli) Q.M. Wang, F.Y. Bai, M. Groenew. et Boekhout, *Rhodoveronaea everniae* Crous et Boers, *Rhopalophora clavispora* (W. Gams) Réblová, Unter. et W. Gams, *Saccharomyces cariocanus* G.I. Naumov, S.A. James, E.S. Naumova, E.J. Louis et I.N. Roberts, *Saccharomycopsis selenospora* (Nadson et Krassiln.) Kurtzman et Robnett, *Sarcodontia uda*, *Sarocladium strictum* (W. Gams) Summerb., *Sclerostagonospora cycadis* Crous et G. Okada, *Scoliciosporum umbrinum* (Ach.) Lojka, *Simplicilium minatense* Nonaka, Kaifuchi et Masuma, *Sistotrema brinkmannii*, *Skeletocutis amorpha*, *Spencermartinsiella ligniputridi* G. Péter et Dlauchy, *Sporidesmium tetracoilum* (Corda) G. Delgado et Koukol, *Sporocadus trimorphus* F. Liu, L. Cai et Crous, *Stereum hirsutum*, *S. rugosum*, *Sterigmatosporidium polymorphum* G. Kraep. et U. Schulze, *Talaromyces resedanus* (McLennan et Ducker) A.J. Chen, Houbraken et Samson, *Taphrina carpini* (Rostr.) Johanson, *Tausonia pullulans* (Lindner) Xin Zhan Liu, F.Y. Bai, M. Groenew. et Boekhout, *Thelephora terrestris*, *Toniniopsis subincompta* (Nyl.) Kistenich, Timdal, Bendiksby et S. Ekman, *Trametes versicolor*, *Tremella indecorata*, *T. sanguinea*, *Triadelphia heterospora* Shearer et J.L. Crane, *Trichoderma atrovirida*, *Vexillomyces atrovirens* (Pers.) Baral, Quijada et G. Marson, *Vishniacozyma dimennae* (Fell et Phaff) Xin Zhan Liu, F.Y. Bai, M. Groenew. et Boekhout, *V. heimaeyensis* Vishniac ex Xin Zhan Liu, F.Y. Bai, M. Groenew. et Boekhout, *V. tephrensis* Vishniac ex Xin Zhan Liu, F.Y. Bai, M. Groenew. et Boekhout, *Wickerhamomyces anomalus* (E.C. Hansen) Kurtzman, Robnett et Bas.-Powers, *Xanthonectria pseudopeziza* (Desm.) Lechat, J. Fourn. et P.-A. Moreau, *Xylaria hypoxylon*, *Xylodon radula*, *Xylodon spathulatus*, *Zygosaccharomyces lentus* Steels, C.J. Bond, M.D. Collins, I.N. Roberts, Stratford et S.A. James, *Z. parabailii* S.O. Suh, Gujjari, Beres, B. Beck et J.J. Zhou, *Zygotorulaspora florentina* (T. Castelli ex Kudryavtsev) Kurtzman	
Litter (leaf litter, acorns)	*Acremonium bacillisporum* (Onions et G.L. Barron) W. Gams, *A. charticola* (J. Lindau) W. Gams, *A. strictum* W. Gams, *A. zeae* W. Gams et D.R. Sumner, *Akanthomyces lecanii* (Zimm.) Spatafora, Kepler et B. Shrestha, *Alternaria alternata*, *A. doliconidium* Jun F. Li, Camporesi et K.D. Hyde, *A. consortialis* (Thum.) J.W. Groves et S. Hughes, *A. hordeicola* E.G. Simmons et Kosiak, *A. raphani* J.W. Groves et Skolko, *Apiospora montagnei* Sacc., *Aspergillus flavus* Link, *A. fumigatus* Fresen., *A. niger* Tiegh., *Aureobasidium pullulans*, *Botrytis cinerea*, *Calycellina fagina* (Ant. Schmidt et Arendh.) Baral, *C. punctata* (Fr.) Lowen et Dumont, *Candida railenensis* C. Ramírez et A.E. González, *Ceratocystis piceae* (Münch) B.K. Bakshi, *Ciboria batschiana* (Zopf) NF Buchw., *Cladosporium cladosporioides*, *C. herbarium*, *Coccomyces coronatus*, *Cordyceps farinosa* (Holmsk.) Kepler, B. Shrestha et Spatafora, *Cystofilobasidium capitatum*, *Cytospora intermedia* Sacc., *Microdiplodia citricola* (McAlpine) Tassi, *Epicoccum nigrum*, *Fusarium avenaceum* (Fr.) Sacc., *F. poae* (Peck) Wollenw.,	Persoon, 1794; Christiansen, 1960; Moody et al., 1999; Jankowiak, 2008; Zmitrovich, 2008; Popov et al., 2008; Isaeva et al., 2009; Ivaschenko et al., 2021; Svetasheva, 2021; Shishlyannikova et al., 2023; Crous et al., 2024; Zmitrovich and Shishlyannikova, 2025

Table 2. (Contd.)

Macro niche	Species composition	Source
	F. sporotrichioides, *F. stilboides* Wollenw., *F. torulosum* (Berk. et M.A. Curtis) Nirenberg, *Geotrichum candidum*, *Guignardia punctoidea* (Cooke) J. Schröt., *Gymnopus androsaceus* (L.) Della Magg. et Trassin., *Hymenoscyphus fructigenus* (Bull.) Gray, *Hypospilina pustula* (Pers.) M. Monod, *Incrucipulum ciliare* (Schrad. ex J. F. Gmel.) Baral, *Lachnum capitatum* (Peck) Svrček, *Leptosphaeria coniothyrium* (Fuckel) Sacc., *Leptosporomyces galzinii* (Bourdot) Jülich, *L. raunkiaeri* (M.P. Christ.) Jülich, *Marasmius epiphyllus* (Pers.) Fr., *Mucor hiemalis* Wehmer, *Naganishia albida* (Saito) Xin Zhan Liu, F.Y. Bai, M. Groenew. et Boekhout, *Nectria inventa* Pethybr., *Neopestalotiopsis clavispora* (G.F Atk.) Maharachch., K.D. Hyde et Crous, *Penicillium hordei* Stolk, *P. Janczewski* K.W. Zaleski, *P. purpurogenum* Stoll, *P. spinulosum* Thom, *Phomopsis quercina*, *Pseudopezicula epiphylla* Piątek, Czachura et Stryjak-Bogacka, *Rhodotorula glutinis*, *Rutstroemia sydowiana* (Rehm) White, *Stachybotrys chartarum* (Ehrenb.) S. Hughes, *Stereum hirsutum* (yellow rot of acorns), *S. armeniacum* Boidin et Gilles (dry rot of acorns), *Stemphylium amaranthi* Y.F. Pei ye X.G. Zhang, *Trichoderma harzianum*, *T. viride*	
Rhizosphere[1]	*Alternaria alternata*, *Aspergillus niger* Tiegh., *Aureobasidium pullulans*, *Calonectricia kyotensis* Terash., *Chaetomium globosum* Kunze, *Cladosporium cladosporioides*, *C. herbarium*, *Clonostachys candelabrum* (Bonord.) Schroers, *C. rosea* (Link) Schroers, Samuels, Seifert et W. Gams, *Corynespora citricola* M.B. Ellis, *Cylindrocarpon didymum* (Harting) Wollenw., *Dicyma biophila* (Cif.) Arx, *Geotrichum candidum* Link, *Globisporangium intermedium* (de Bary) Uzuahshi et Tojo, *G. irregulare* (Buisman) Uzuhashi, *Ilyonectria destructans* (Zinssm.) Rossman, L. Lombard et Crous, *Isaria fumosorosea* Wize, *Lehetua indrekii* Tedersoo, *Metarhizium anisopliae* (Metschn.) Sorokin, *Oidiodendron griseum* Robak, *Parnigua craigii* Tedersoo, *Pezicula radicicolae* (T. Kowalski et C. Bartnik) P.R. Johnst., *Phialocephala fortinii* C.J.K. Wang et H.E. Wilcox, *Phialophora bubakii* (Laxa) Schol-Schwarz, *P. cinerescens* (Wollenw.) J.F.H. Beyma, *P. cyclaminis* J.F.H. Beyma, *P. verrucosa* Medlar, *Phytophthora cactorum* (Lebert et Cohn) J. Schröt., *P. citricola* Sawada, *P. europaea* E.M. Hansen et T. Jung, *P. gallica* T. Jung et Nechw., *P. gonapodyides* (H.E. Petersen) Buisman, *P. plurivora* T. Jung et T.I. Burgess, *P. pseudosyringae* T. Jung et Delatour, *P. quercina* T. Jung, *P. uliginosa* T. Jung et E.M. Hansen, *Phytopythium citrinum* (B. Paul) Abad, de Cock, Bala, Robideau, A.M. Lodhi et Lévesque, *P. litorale* (Nechw.) Abad, de Cock, K. Bala, Robideau, A.M. Lodhi et Lévesque, *Pyrenochaeta cava* (Schulzer) Gruyter, Aveskamp et Verkley, *Riederbergia sylviae* Tedersoo, *Sporendocladia bactrospora* (W.B. Kendr.) M.J. Wingf., *Thelonectria lucida* (Höhn.) P. Chaverri et C. Salgado, *Trichoderma citrinoviride* Bissett, *T. harzianum* Rifai, *T. polysporum* (Link) Rifai, *T. pubescens* Bissett, *T. virens* (J.H. Mill., Giddens et A.A. Foster) Arx	Jung et al., 1999, 2002, 2003; Jung and Nechwatal, 2008; Vedenyapina et al., 2014; Kwaśna and Szewczyk, 2016; Tedersoo et al., 2024; López-García et al., 2025

Table 2. (Contd.)

Macro niche	Species composition	Source
Seedlings	*Alternaria alternata*, *Apiognomonia errabunda* (Roberge ex Desm.) Höhn, *A. hystrix* (Tode) Sogonov, *Apiotrichum porosum* Stautz, *Aureobasidium pullulans*, *Bipolaris sorokiniana* Shoemaker, *Boeremia exigua* (Desm.) Aveskamp, Gruyter et Verkley, *Botrytis cinerea*, *Cadophora orchidica* (Sigler et Currah) M.J. Day et Currah, *Clonostachys compactiuscula* (Sacc.) D. Hawksw. et W. Gams, *C. rosea* (Preuss) Mussat, *Colletotrichum fioriniae* R.G. Shivas et Y.P. Tan, *C. lineola* Corda, *Colletotrichum salicis* (Auersw. ex Fuckel) Damm, P.F. Cannon et Crous, *Colpoma quercinum*, *Coniella quercicola* (Oudem.) L.V. Alvarez et Crous, *Curvibasidium cygneicollum* J.P. Samp, *Cylindrium elongatum* Bonord, *Cylindrocladiella parva* (P.J. Anderson) Boesew., *Cylindrocladiella pseudoparva* L. Lombard et Crous, *Cylindrodenrum hubeiense* (W.Y. Zhuang, Y. Nong et J. Luo) L. Lombard et Crous, *Diaporthe eres* Nitschke, *Dicarpella dryina* Belisario et M.E. Barr, *Didymella macrostoma* (Mont.) Qian Chen et L. Cai, *Diplodia corticola* A.J.L. Phillips, A. Alves et J. Luque, *D. sapinea* (Fr.) P. Karst., *Discosia artocreas* (Tode) Fr., *Epicoccum italicum* Qian Chen, Crous et L. Cai, *E. layuense* Qian Chen, Crous et L. Cai, *E. nigrum*, *Fusarium avenaceum* (Fr.) Sacc., *F. citri* M.M. Wang, Qian Chen et L. Cai, *F. graminearum* Schwabe, *F. sambucinum* Brond., *F. sporotrichioides* Sherb., *F. tricinctum* (Corda) Sacc., *Gnomoniopsis paraclavulata* Sogonov, *Ilyonectria cyclaminicola* A. Cabral et Crous, *I. pseudodestructive* A. Cabral, Rego et Crous, *I. rufa* A. Cabral et Crous, *Microsphaeropsis olivacea* (Bonord.) Höhn, *Monochaetia ilicis* N.I. de Silva, Phookamsak et K.D. Hyde, *Mortierella longigemmata* Linnem., *Mucor abundans* Povah, *M. fragilis* Bainier, *M. genevensis* Lendn., *M. moelleri* (Vuill.) Lendn., *Mycena galopus* (Pers.) P. Kumm., *Nectria nigrescens*, *Nemania diffusa* (Sowerby) Gray, *Neocucurbitaria cava* (Schulzer) Valenz.-Lopez, Crous, Stchigel, Guarro et Cano, *Neonectria quercicola* B. Mora-Sala, A. Cabral, Armengol et Abad-Campos, *Nigrospora gorlenkoana* Novobr., *Nothophoma quercina* (Syd. et P. Syd.) Qian Chen et L. Cai, *Penicillium angulare* S.W. Peterson, E.M. Bayer et Wicklow, *P. bialowiezense* K.W. Zaleski, *P. chrysogenum* Thom, *P. glabrum* (Wehmer) Westling, *P. glandicola* (Oudem.) Seifert et Samson, *P. palitans* Westling, *P. pancosmium* Houbraken, Frisvad et Samson, *P. soppii* K.W. Zaleski, *P. vancouverense* Houbraken, Frisvad et Samson, *Phacidium mollerianum* (Thum.) Crous, *Phanerochaete livescens* (P. Karst.) Volobuev et Spirin, *Phialocephala fortinii* C.J.K. Wang et H.E. Wilcox, *Plectania melastoma* (Sowerby) Fuckel, *Rhizodermea veluwensis* Verkley et J.D. Zijlstra, *Rosellinia corticium* (Schwein.) Sacc., *Sordaria fimicola* (Roberge ex Desm.) Ces. et De Not., *Sporothrix aurorae* (X.D. Zhou et M.J. Wingf.) Z.W. de Beer, T.A Duong et M.J. Wingf., *Stemphylium vesicarium* (Wallr.) E.G. Simmons, *Tainosphaeria simplex* (S. Hughes et W.B. Kendr.) Réblová et Hern.-Restr., *Talaromyces minioluteus* (Dierckx) Samson, N. Yilmaz, Frisvad et Seifert, *Trichoderma atroviride* P. Karst., *T. harzianum* Rifai, *T. parapilulilliferum* (B.S. Lu, Druzhin et Samuels) Jaklitsch et Voglmayr, *T. paraviridescens* Jaklitsch, Samuels et Voglmayr, *T. spirale* Bissett, *T. tomentosum* Bissett, *Trichoderma viride*, *Umbelopsis changbaiensis* Y.N. Wang, X.Y. Liu et R.Y. Zheng, *U. isabellina* (Oudem.) W. Gams, *U. ramanniana* (Möller) W. Gams, *Varicosporium elodeae* W. Kegel	Jankowiak et al., 2022

[1] Ectomycorrhizal fungi—see Table 3.

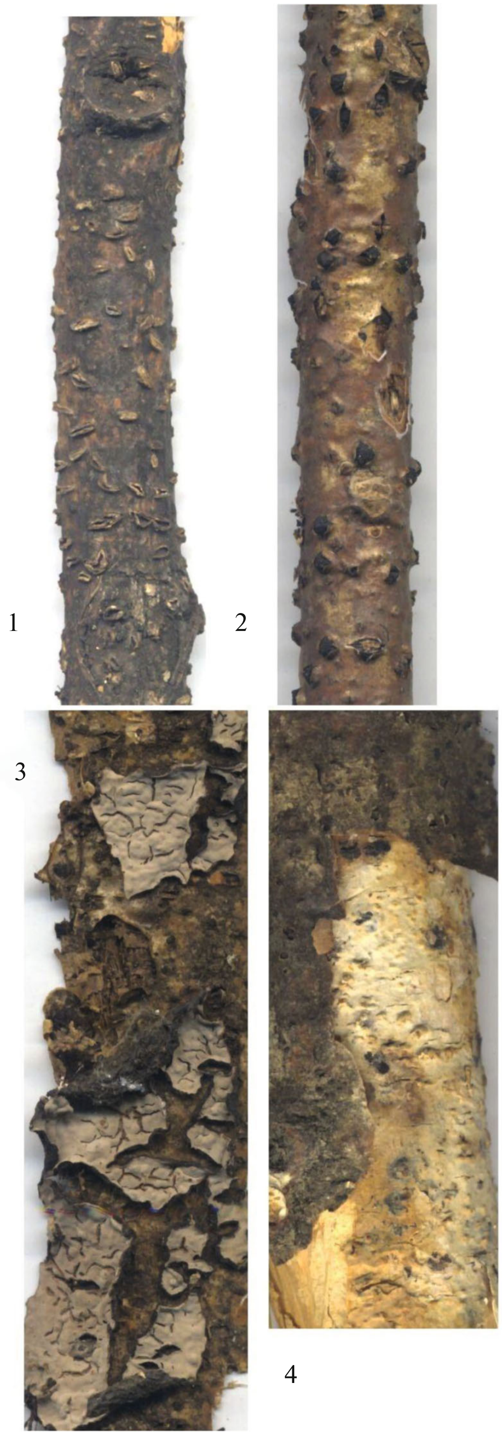

Fig. 2. The most well-known species associated with woody shoots of *Quercus robur* throughout the range of this breed: (1) *Colpoma quercinum*; (2) *Diatrypella quercina*; (3) *Peniophora quercina*; (4) *Vuilleminia comedens*.

tata, *P. roboris*, and *Septoria quercina*. A number of species of biotrophic fungi found on the leaves of English oak have a wider host range, such as *Taphrina carpini*, *T. caerulescens*, and *T. inositophila*. Among the specialized endophytes, it is worth noting *Ramularia endophylla*. An important role in the degradation of leaf cuticle is played by bacterial-yeast communities, one of the dominants of which is *Sporobolomyces roseus*. Some necrotrophic fungi of the phylloplane of English oak also have saprotrophic activity and begin their development on a living leaf and continue to develop on it after its death and even falling off (*Sphaerulina quercicola*).

Terminal shoot system. The increase in the area of the photosynthetic surface of growing trees and its maintenance in senile individuals are determined by processes occurring in the system of terminal shoots, and fungi make a certain contribution to these processes. There are at least 26 known species of fungi associated with the terminal shoots of English oak, of which 20 species are Ascomycota and six species (*Dendrothele commixta*, *Hyphoderma cristulatum*, *H. setigerum*, *Peniophora cinerea*, *P. quercina*, *Vuilleminia comedens*) are Basidiomycota (Table 2, Fig. 2). The process of dying off of shoots of the first and second years is started by necrotrophs *Cytospora intermedia* and *Dendrostoma leiphaemia*; older terminal shoots are colonized by corticophilic fungi *Amphisphaeria bufonia* and *Botryosphaeria quercicola* and, having residual necrotrophic activity, *Caudospora taleola*, *Coryneum depressum*, *C. umbonatum*, *Colpoma quercinum*, *Nectria cinnabarina*, and *Rosellinia quercina*. The wood is then colonized by saprotrophs *Diatrypella quercina* and the bark begins to peel off. At this stage, the resulting ulcers are colonized by basidiomycetes *Vuilleminia quercina*, whose activity is associated with progressive peeling of the bark, and basidiomycetes *Hyphoderma* spp., *Peniophora* spp., and *Dendrothele commixta* develop on the remaining areas of the bark. All the mentioned species of basidiomycetes cause white rot.

Trunk, skeletal branches, detritus. At least 475 species of fungi are known to grow on trunks, skeletal branches, stumps, fallen trees, and branch debris of English oak, of which at least 37 species (*Aeruginoscyphus sericeus*, *Ascocoryne sarcoides*, *Biscogniauxia nummularia*, *Bulgaria inquinans*, *Ceratocystis grandicarpa*, *C. prolifera*, *Chalara angustata*, *Chaetosphaeria vermicularioides*, *Chlorociboria aeruginascens*, *Corynesporopsis quercicola*, *Cryphonectria naterciae*, *Cryptosporiopsis radicicola*, *Diatrype stigma*, *Dothiorella iberica*, *Euepixylon udum*, *Hymenoscyphus scutula*, *Hypoxylon fuscum*, *Jackrogersella cohaerens*, *Kretzschmaria deusta*, *Mollisia olivascens*, *Nemania serpens*, *Neonectria ditissima*, *N. coccinea*, *Ophiostoma solheimii*, *Orbilia aprilis*, *O. vinosa*, *Phomopsis quercus*, *Propolis farinosa*, *Rugonectria wingfieldii*, *Septonema binum*, *Septotrullula bacilligera*, *Taeniolella dichotoma*, *Tapesia fusca*, *Triblidium caliciforme*, *Trichoderma strictipile*, *Verticillium dahliae*, *Xylaria polymorpha*) belong to ascomycetes and at least 438 species belong to basidiomycetes (Table 2, Fig. 2).

Necrotrophic ascomycetes (*Ceratocystis grandicarpa*, *C. prolifera*, *Chalara angustata,* etc.) are confined to cambium and cause vascular mycosis. Necrotrophs *Phomopsis quercus* and *Rugonectria wingfieldii* cause galls on the branches and trunks of oak trees, *Neonectria ditissima* causes stepped cancer, *N. coccinea* causes cancer of trunks and branches, and *Dothiorella iberica* casuses blockage of vessels. Saprotrophs with necrotrophic activity *Biscogniauxia nummularia* and *Diatrype stigma* cause peeling of the bark; *Kretzschmaria deusta*, in addition to peeling off the bark, can cause ulcerative cancer, but this species can also develop on stumps as a saprotroph.

Basidiomycetes associated with trees and the decay of English oak are saprotrophs, but some of them (*Inocutis dryophila*, *Fomitiporia robusta*, *Laetiporus sulphureus*, *Pseudoinonotus dryadeus*, *Vuilleminia comedens*, and some others) are associated with the bioinert structures of living trees and act as pathogens. The substrate spectrum of saprotrophic fungi is quite wide, although the listed species give statistically significant preference to English oak.

White rot fungi dominate the xylomycocomplex of English oak. These are mainly representatives of the class Agaricomycetes. Examples of active wood destroyers that cause white rot include *Fomitiporia robusta*, *Ganoderma applanatum*, *Inocutis dryophila*, and *Xylobolus frustulatus*. "Ancestral soft rot" is caused by ascomycetes and representatives of the orders Atheliales, Auricularia, Cantharellales, Trechisporales of class Agaricomycetes. Brown rot is caused by representatives of the families Fomitopsidaceae and Laetiporaceae of the order Polyporales, *Fistulina* (Agaricomycetes), and genera *Calocera* and *Dacrymyces* (Dacrymycetes).

Among the species more or less related to the genus *Quercus*, it is worth mentioning *Daedalea quercina*, *Fistulina hepatica*, *Fomitiporia robusta*, *Grifola frondosa*, *Hapalopilus croceus*, *Laetiporus sulphureus*, *Peniophora quercina*, *Stereum gausapatum*, and *Xylobolus frustulatus*. There are ubiquitous species (*Trichoderma viride*) and species widespread in the temperate zone of the Holarctic (*Amphinema byssoides*, *Ascocoryne sarcoides*, *Fomes fomentarius*, *Fomitopsis pinicola*, *Ganoderma applanatum*, *Panus conchatus*, *Peniophora incarnata*, *Schizophyllum commune*, *Stereum hirsutum*, *Trametes* spp., *Vuilleminia comedens*), but the "alder suite" is also widely represented—species complexes common in broad-leaved forests and in the taiga zone, confined mainly to black and grey alder forests (*Hypochnicium bombycinum*, *Hyphoderma* spp., *Hyphodontia quercina*, *Lyomyces crustosus*, *Peniophora cinerea*, *Scopuloides hydnoides*, *Stereum rugosum*, *Xylodon* spp.).

Stem ulcers and wounds. Work in recent years, including those involving molecular identification data (Marčiulynas et al., 2023) showed an unexpectedly high level of diversity of fungi colonizing cancerous ulcers and wood wounds of English oak. Here, in conditions of chronic disruption of protective structures and biofilms that stabilize species diversity and the presence of liquid and oligosaccharide-rich environments, unlike other habitats, it is possible to observe not only the results of the succession of fungal groups but also its various stages in different parts of these formations, corresponding to different times and different depths of damage.

The association with ulcers and wounds of common oak has been shown for at least 230 species of fungi, of which the predominant ones are representatives of Ascomycota (185 species), Basidiomycota (41 species—*Armillaria lutea*, *Bjerkandera adusta*, *Coniophora puteana*, *Coprinellus micaceus*, *Cylindrobasidium evolvens*, *Cystobasidium laryngis*, *Cystofilobasidium capitatum*, *Erythrobasidium hasegawianum*, *Helicogloea pellucida*, *Laetiporus sulphureus*, *Malassezia caprae*, *M. globosa*, *Mrakia aquatica*, *M. gelida*, *Mycena alcalina*, *M. epipterygia*, *M. galericulata*, *M. vitilis*, *M. zephirus*, *Mycoaciella bispora*, *Pascua guehoae*, *Peniophora incarnata*, *Peniophorella pertenuis*, *P. pubera*, *Phlebia rufa*, *Phlebia tremellosa*, *Pholiota adipose*, *Pleurotus dryinus*, *Polyporus umbellatus*, *Rhodosporidiobolus colostri*, *Sistotrema brinkmannii*, *Skeletocutis amorpha*, *Stereum hirsutum*, *S. rugosum*, *Thelephora terrestris*, *Trametes versicolor*, *Tremella indecorata*, *T. sanguinea*, *Vishniacozyma dimennae*, *Xylodon radula*, *Xylodon spathulatus*), and also Mucoromycota in the broad sense (four species—*Entomortierella jenkinii*, *Mortierella hypsicladia*, *Mucor flavus*, *M. racemosus*) (Table 2). Moreover, obligate association with mucus secretions is characteristic only of the group of ascomycete and basidiomycete yeasts and some microascoccal yeasts, while other groups of fungi have a broader ecological association. A clearly expressed component of extremotolerant ubiquists is also distinguished here (*Aspergillus amstelodami*, *A. domesticus*, *Aureobasidium pullulans*, *Penicillium angularis*, *P. bialowiezense*, *P. camemberti*, *P. cosmopolitanum*).

The cause of cancerous ulcers is the tree's response to an attack by necrotrophic fungi (*Phomopsis quercus*, *Rugonectria wingfieldii*, *Neonectria ditissima*, *Fusarium* spp., *Kretzschmaria deusta*), gall-forming bacteria (*Agrobacterium*, etc.), or insects; the etiology of many cancers and mucus discharges is still poorly understood. Pioneer complexes of fungi colonizing wounds and ulcers determine the direction of pathogenetic processes that can further develop along the path of vascular mycosis (*Ophiostoma quercus*), peeling of the bark (*Cytospora* spp., *Diatrype stigma*), stem rot (*Laetiporus sulphureus*, *Bjerkandera adusta*), and root rot (*Armillaria lutea*).

Litter. The specificity of oak litter is given by its leaves rich in calcium oxalate, acorns rich in antifungal activity, and its abundant annual replenishment. In total, 62 species have been noted for this macroniche (if we limit it to leaf litter and acorns that have not lost their structure), among which ascomycetes predominate, but there are also basidiomycetes (*Cystofilobasidium capitatum*, *Gymnopus androsaceus*, *Leptosporomyces galzinii*, *L. raunkiaeri*, *Marasmius epiphyllus*, *Naganishia albida*, *Rhodotorula glutinis*) and zygomycetes (*Mucor hiemalis*) (Table 2). Extremophile ubiquitous species include *Alternaria alternata*, *Aspergillus fumigatus*, *A. niger*, *Aureobasidium pullulans*, *Botrytis cinerea*, *Epicoccum nigrum*, *Mucor hiemalis*, and *Trichoderma viride*. Typical soil microfungi are present in the lower layers of the litter: *Acremonium bacillisporum*, *A. charticola*, *A. strictum*, *A. zeae*, *Fusarium avenaceum*, *F. poae*, *F. sporotrichioides*, *F. stilboides*, *F. torulosum*, *Geotrichum candidum*, *Penicillium hordei*, *P. janczewski*, *P. purpurogenum*, *P. spinulosum*, *Phomopsis quercina*, *Pseudopezicula epiphylla*. Characteristic of those associated with fallen leaves are *Leptosporomyces galzinii*, *L. raunkiaeri*, *Marasmius epiphyllus*, and *Gymnopus androsaceus* and those associated with acorns are *Ciboria batschiana*, *Hymenoscyphus fructigenus*, *Incrucipulum ciliare*, and *Rutstroemia sydowiana*. Pathogenic species *Ceratocystis piceae* and *Phomopsis quercina* represents the infectious principle here. Species of genera *Alternaria*, *Aspergillus*, and *Botrytis* cause mold in acorns.

Rhizosphere. Confined to the rhizosphere of *Quercus robur*, excluding ectomycorrhizal fungi, there are at least 47 species, of which 32 species belong to the phylum Ascomycota, two species (*Lehetua indrekii*, *Parnigua craigii*) belong to the class Endogonomycetes of the phylum Mucoromycota, and 13 species (*Globisporangium intermedium*, *G. irregulare*, *Phytophthora cactorum*, *P. citricola*, *P. europaea*, *P. gallica*, *P. gonapodyides*, *P. plurivora*, *P. pseudosyringae*, *P. quercina*, *P. uliginosa*, *Phytopythium citrinum*, *P. litorale*) belong to the group of "fungal analogues" from the phylum Oomycota (for the history of the taxonomy of the group and its current position in the eukaryotic system, see Zmitrovich et al., 2022b) (Table 2). This group of protists is characterized by reproduction both by zoosporangia, which function in much the same way as the macroconidia of ascomycetes, and (in waterlogged soils) by zoospores. Often, under unfavorable hydrological conditions, oomycetes and, above all, late blight harm the root system of the tree and cause it to dry out (Vedenyapina et al., 2014).

Ubiquitous extremophiles are also present in the rhizosphere of English oak (*Alternaria alternata*, *Aspergillus niger*, *Aureobasidium pullulans*), as well as typical soil microfungi (*Chaetomium globosum, Clonostachys candelabrum*, *C. rosea*, *Corynespora citricola*, *Cylindrocarpon didymum*, *Geotrichum candidum*, and others). All of them are saprotrophs, causing "ancestral soft rot" (Nagy et al., 2019) with decomposition of cellulose and deep modification of amorphous lignin. In the southern habitats of English oak, where evaporation prevails over moisture, the activity of these fungal complexes is associated with the active development of the humus soil layer. In taiga soils with an intense leaching regime, most of these products are carried into watercourses as part of humic and fulvic acids (Orlov, 1990).

It is believed that arbuscular mycorrhiza is generally not characteristic of beech trees (Karatygin, 1993), but recently taxa of fungi from the Endogonomycetes class have been described in the oak rhizosphere, in particular, *Lehetua indrekii* and *Parnigua craigii* (Tedersoo et al., 2024).

Seedlings. The introduction of molecular identification methods made it possible to assess the species diversity of fungi associated with oak seedlings (Jankowiak et al., 2022). Currently, 83 taxa from the phyla Ascomycota, Basidiomycota, and Mucoromycota have been classified as species. Ascomycota absolutely predominate, making up more than 90% (Table 2). The main fungi species always or almost always found on affected oak seedlings are species of the genera *Fusarium* (*F. avenaceum*, *F. citri*, *F. graminearum*, *F. sambucinum*, *F. sporotrichioides*, *F. tricinctum*) and *Diplodia* (*D. corticola*, *D. sapinea*), which pose a particular danger to young plants owing to their pronounced necrotrophic activity.

Ectomycorrhizae. The role of ectomycorrhizal fungi in the growth and reproduction of tree species in the forest zone is key: they optimize the mineral nutrition of the plant, distribute photosynthate between adult trees and renewal, participate in the destruction and humification of woody detritus and optimization of mineral metabolism in so-called redusphere (Karatygin, 1993), "pull" nitrogen from the leaching horizon into actively functioning soil strata (Shubin, 2010), and participate in coupling the processes of delignification and immobilization of bases extracted by acidic delignification products from the soil absorption complex (Harvey et al., 1979; Kropp, 1982; Dighton et al., 2005).

At least 137 species of ectomycorrhizal fungi have been recorded in association with English oak, among which representatives of the phylum Basidiomycota predominate (129 species). The phylum Ascomycota is represented by eight species (*Cenococcum geophilum*, *Elaphomyces aculeatus*, *Genea verrucosa*, *Tuber aestivum*, *T. borchii*, *T. macrosporum*, *T. magnatum*, *T. melanosporum*) (Table 3). In addition, two morphological groups of mycorrhizae have been noted in association with English oak—"Quercirhiza alboviolacea" and "Quercirhiza squamosa"—the species attribution of these formations is difficult so far (Palfner, 1995; Jakusc, 2001). The counting of ectomycorrhizal fungi is further complicated by the fact that some of the corticioid fungi (*Amphinema byssoides*, *Byssoporia terrestris*, *Tomentella* spp., *Tylospora* spp.), considered as xylotrophs, are also observed in litter and root tips.

The greatest species diversity is demonstrated by such ectomycorrhizal genera as *Russula* (17 species) and *Amanita* and *Cortinarius* (13 species each), with

Table 3. Ectomycorrhizal fungi associated with English oak

View	Source
Amanita argentea Huijsman	Lindsey, 2004
A. caesarea (Scop.) Pers.	Meotto et al., 1997
A. ceciliae (Berk. et Broome) Bas	Lindsey, 2004
A. citrina Pers.	Lindsey, 2004
A. crocea (Quél.) Singer	Lindsey, 2004
A. excelsa (Fr.) Bertill.	Lindsey, 2004
A. gemmata (Fr.) Bertil.	Lindsey, 2004
A. lividopallescens (Gillet) Bigeadrd. et H. Guill.	Lindsey, 2004
A. muscaria (L.) Lam.	Michelot et al., 2003
A. pantherina (DC.) Krombh.	Lindsey, 2004
A. phalloides Secr.	Wolfe et al., 2012
A. rubescens Pers.	Lindsey, 2004
A. vaginata (Bull.) Lam.	Lindsey, 2004
Aureoboletus gentilis (Quél.) Pouzar	Galli, 2007
Boletus aereus Bull.	Galli, 2007
B. edulis Bull.	Luppi and Gautero, 1967
B. reticulatus Schaeff.	Galli, 2007
Butyriboletus fechtneri (Velen.) D. Arora and J.L. Frank	Pilát, 1969; Galli, 2007
B. regius (Krombh.) D. Arora and J.L. Frank	Pilát, 1969; Galli, 2007
Calonarius callochrous (Pers.) Niskanen and Liimat.	Nezdoyminogo, 1996
C. claroflavus (Rob. Henry) Niskanen and Liimat.	Nezdoyminogo, 1996
C. odoratus (Joguette ex M.M. Moser) Niskanen and Liimat.	Ivanov and Ermolaeva, 2021
C. sodagnite (Rob. Henry) Niskanen and Liimat.	Ivanov and Ermolaeva, 2021
Cantharellus cibarius Fr.	Olariaga et al., 2017
C. friesii Quél.	Olariaga et al., 2017
C. pallens Pilát	Olariaga et al., 2017
C. romagnesianus Eyssart. et Buick	Olariaga et al., 2017
Cenococcum geophilum Fr.	Palfner, 1994
Chalciporus rubinus (W.G. Sm.) Singer	Alessio et al., 1985
Clavulina alpina Franchi et M. Marchetti	Milovíc et al., 2023
C. cristata	Milovíc et al., 2023
Clitopilus prunulus (Scop.) P. Kumm.	Ivanov and Ermolaeva, 2021
Cortinarius alboviolaceus (Pers.) Zawadski	Voiry, 1981
C. bolaris (Pers.) Zawadski	Nezdoyminogo, 1996
C. bulliardii (Pers.) Fr.	Nezdoyminogo, 1996
C. citrinolilacinus (M.M. Moser) M.M. Moser	Nezdoyminogo, 1996
C. cotoneus Fr.	Nezdoyminogo, 1996
C. hinnuleus Fr.	Ivanov and Ermolaeva, 2021
C. infractus (Pers.) Fr.	Ivanov and Ermolaeva, 2021
C. orellanus Fr.	Nezdoyminogo, 1996
C. rickenianus Maire	Nezdoyminogo, 1996
C. subannulatus Jul. Schäff. et M.M. Moser	Nezdoyminogo, 1996
C. torvus (Fr.) Fr.	Nezdoyminogo, 1996
C. venetus (Fr.) Fr.	Nezdoyminogo, 1996
Craterellus tubaeformis (Fr.) Quél.	Fransson, 2004
Cystinarius rubicundulus (Rea) Niskanen et Liimat.	Nezdoyminogo, 1996
Elaphomyces aculeatus Vittad.	Agerer, 1999, 2002
Entoloma lividoalbum (Kühner et Romagnesi) Kubicka	Lindsey, 2008
E. quercetorum Kokkonen	Kokkonen, 2021
E. sinuatum (Pers.) P. Kumm.	Ivanov and Ermolaeva, 2021
Genea verrucosa Vittad.	Jakusc et al., 1998
Gyroporus castaneus (Bull.) Quél.	Raidl et al., 1996
Hebeloma crustuliniforme (Bull.) Quél.	Voiry, 1981

Table 3. (Contd.)

View	Source
H. lateritium (Batsch) Westerth.	Ivanov and Ermolaeva, 2021
H. sacchariolens Quél.	Leski et al., 2009
Hemileccinum depilatum (Redeuilh) Šutara	Ivanov and Ermolaeva, 2021
H. impolitum (Fr.) Šutara	Pilát, 1969
Hortiboletus bubalinus (Oolbekk. et Duin) L. Albert et Dima	Biketova et al., 2025
H. engelii (Hlaváček) Biketova et Wasser	Biketova et al., 2025
H. rubellus (Krombh.) Simonini, Vizzini et Gelardi	Galli, 2007
Hygrophorus arbustivus Fr.	Ivanov and Ermolaeva, 2021
H. chrysodon (Batsch) Fr.	Ivanov and Ermolaeva, 2021
H. eburneus (Bull.) Fr.	Ivanov and Ermolaeva, 2021
H. glutinifer Fr.	Ivanov and Ermolaeva, 2021
Imperator luteocupreus (Bertéa et Estadès) Assyov et al.	Galli, 2007
I. rhodopurpureus (Smotl.) Assyov et al.	Galli, 2007
I. torosus (Fr.) Assyov	Galli, 2007
Inocybe asterospora Quél.	Nezdoyminogo, 1996
I. bresadolae Massee	Nezdoyminogo, 1996
I. cryptocystis D.E. Stuntz	Nezdoyminogo, 1996
I. griseovelata Kühner	Nezdoyminogo, 1996
I. oblectabilis (Britzelm.) Sacc.	Nezdoyminogo, 1996
I. ochroalba Bruyl.	Nezdoyminogo, 1996
I. pusio P. Karst.	Nezdoyminogo, 1996
I. splendens R. Maire	Nezdoyminogo, 1996
I. whitei (Berk. et Broome) Sacc.	Nezdoyminogo, 1996
Inosperma adaequatum (Britzelm.) Matheny et Esteve-Rav.	Nezdoyminogo, 1996
Laccaria amethystina Cooke	Palfner, 1994
Lactarius azonites (Bull.) Fr.	Ivanov and Ermolaeva, 2021
L. chrysorrheus Fr.	Palfner, 1998
L. fuliginosus (Fr.) Fr.	Ivanov and Ermolaeva, 2021
L. pyrogalus (Bull.) Fr.	Ivanov and Ermolaeva, 2021
L. quietus (Fr.) Fr.	Ivanov and Ermolaeva, 2021
L. serifluus (DC.) Fr.	Palfner and Agerer, 1996
L. volemus (Fr.) Fr.	Ivanov and Ermolaeva, 2021
Lactifluus piperatus (L.) Roussel	Ivanov and Ermolaeva, 2021
Leccinellum crocipodium (Letell.) Della Magg. et Trassin.	Galli, 2007
Leccinum aurantiacum (Bull.) Gray	Dunaev et al., 2010
Lyophyllum decastes (Fr.) Singer	Agerer and Beenken, 1998; Agerer, 1998
Neoboletus erythropus (Pers) C. Hahn.	Pilát, 1969
Paxillus rubicundulus P.D. Orton	Ivanov and Ermolaeva, 2021
Phlegmacium caesiocortinatus (Jul. (Schaff.) M.M. Moser	Ivanov and Ermolaeva, 2021
Piloderma croceum	Tarkka et al., 2021
Porphyrellus porphyrosporus (Fr.) E.-J. Gilbert	Galli, 2007
“Quercirhiza alboviolacea”	Jakucs, 2001
“Quercirhiza squamosa”	Palfner, 1995
Ramaria subbotrytis (Coker) Corner	Agerer, 1996
Rheubarbariboletus armeniacus (Quél.) Vizzini, Simonini et Gelardi	Palfner and Agerer, 1995
Rhizopogon verii Pacioni	Sulzbacher et al., 2016
Rubroboletus legaliae (Pilát et Dermek) Della Magg. et Trassin.	Janda et al., 2017
R. satanas (Lenz) Kuan Zhao et Zhu L. Yang	Pilát, 1969; Galli, 2007
Russula amoena Quél.	Beenken, 2004
R. atropurpurea (Krombh.) Britz.	Beenken, 2004
R. cyanoxantha (Schaeff.) Fr.	Ivanov and Ermolaeva, 2004
R. farinipes Romell	Ivanov and Ermolaeva, 2004

Table 3. (Contd.)

View	Source
R. faustiana Sarnari	Beenken, 2004
R. foetens Pers.	Ivanov and Ermolaeva, 2004
R. grisea Gill.	Beenken, 2004
R. heterophylla Fr.	Beenken, 2004
R. insignis Quél.	Beenken, 2004
R. luteotacta Rea	Beenken, 2004
R. nigricans Fr.	Beenken, 2004
R. ochroleuca (Pers.) Fr.	Pillukat, 1991
R. odorata Romagn.	Beenken, 2004
R. pectinatoides Peck	Beenken, 2004
R. pseudointegra Arnould et Goris	Ivanov and Ermolaeva, 2021
R. vesca Fr.	Beenken, 2001
R. virescens (Schaeff.) Fr.	Beenken, 2001a
Scleroderma citrinum Pers.	Voiry, 1981
S. verrucosum (Bull.) Pers.	Ivanov and Ermolaeva, 2021
Strobilomyces strobilaceus (Scop.) Berk.	Pilát, 1969
Suillellus luridus (Schaeff.) Murrill	Haas, 1969, Pilat, 1969
S. queletii (Schulzer) Vizzini, Simonini et Gelardi	Pilát, 1969
Tuber aestivum Vittad.	Meotto et al., 1995
T. borchii Vittad.	Meotto et al., 1995
T. brumale Vittad.	Meotto et al., 1995
T. macrosporum Vittad.	Meotto et al., 1995
T. magnatum Picco	Granetti, 1995
T. melanosporum Vittad.	Granetti, 1995
Thelephora terrestris Ehrh.	Olchowik et al., 2019; Bolshakov et al., 2022
Tomentella galzinii Bourdot	Jakucs et al., 1997
Tricholoma orirubens Quél.	Ivanov and Ermolaeva, 2021
T. ustaloides Romagn.	Ivanov and Ermolaeva, 2021
Tylopilus felleus (Bull.) P. Karst.	Pilát, 1969
Tylospora asterophora (Bonord.) Donk	Olchowik et al., 2019
Xerocomellus porosporus (Imler ex Watling) Šutara	Ivanov and Ermolaeva, 2021
Xerocomus subtomentosus (L.) Quél.	Palfner, 1995

the last genus being presented in a narrow interpretation (genera *Calonarius* and *Phlegmacium* are considered separately).

Apparently, despite the presence of such background species as *Amanita muscaria*, *A. rubescens*, *A. vaginata*, *Cenococcum geophilum*, *Boletus edulis*, *Cantharellus cibarius*, *Craterellus tubaeformis*, *Hebeloma crustuliniforme*, *Hygrophorus eburneus*, *Laccaria amethystina*, *Lactarius fuliginosus*, *L. pyrogalus*, *L. volemus*, *Lactifluus piperatus*, *Leccinum aurantiacum*, *Paxillus rubicundulus*, *Russula cyanoxantha*, *R. foetens*, *R. vesca*, *Scleroderma citrinum*, *S. verrucosum*, *Thelephora terrestris*, *Tylopilus felleus*, and *Xerocomus subtomentosus*, the ectomycorrhizal complexes of English oak exhibit a certain geographical differentiation. So, species of genera *Aureoboletus*, *Butyriboletus*, *Imperator*, and *Tuber* gravitate towards the southwestern part of the range of English oak; species of the genera *Hortiboletus*, *Hemileccinum*, and *Rubroboletus* are better represented south of the subtaiga zone; *Cantharellus friesii* and *C. romagnesianus* gravitate towards Central and Southern Europe. Lurid bolete *Suillellus luridus* accompanies English oak to the northern border of its natural range (floodplains of large rivers of the southern taiga subzone) and is no longer found in the northern cultigenic "crown" of the oak range, being replaced *Boletus edulis* and *Xerocomus subtomentosus*. Clarification of the ranges of ectomycorrhizal fungi is important for zoning of English oak cultivars.

PHYTOPATHOLOGICAL CHARACTERISTICS OF ENGLISH OAK

Diseases of English Oak

Many manifestations of fungi colonizing adult trees, acorns, and seedlings of English oak have come to the attention of phytopathologists (*Alternaria alternata*, *A. hordeicola*—acorn mold; *Aspergillus niger*—

black mold of acorns; *Botrytis cinerea*—gray mold of acorns; *Ciboria batschiana*—mummification of acorns; *Cronartium quercuum*—causative agent of rust, important for Far Eastern oaks; *Cytospora intermedia*—acorn cytosporosis; *Fusarium oxysporum*—pink mold; *Microstroma album*—leaf spot; *Phomopsis quercina*—white rot of acorns; *Stereum armeniacum*—dry rot of acorns; *S. hirsutum*—yellow rot of acorns; *Trichoderma harzianum*; *T. viride*—green mold of leaves and acorns; *Aureobasidium pullulans*, *Capnodium citri*—black leaves; *Dendrostoma leiphaemia*—anthracnose; *Taphrina caerulescens*—curly leaves; *Biscogniauxia nummularia*—Nummularia necrosis; *Cryphonectria naterciae*—necrosis of branches; *Verticillium dahlia*—verticillous wilt—see Duby, 1830; Phillips and Burdekin, 1982; Ivashchenko et al., 2021); however, there are a number of diseases recognized as the most dangerous spread throughout the range of oak, which are the object of phytopathological monitoring.

These include, in order of decreasing severity, (1) oak wilt, (2) stepped cancer, (3) late blight, (4) seedling root rot, (5) white sapwood rot of roots, (6) sapwood rot of trunks, (7) necrosis of branches, and (8) powdery mildew.

Oak wilt. The disease is also known as oak tracheomycosis. In English oak in its natural range, the main causative agent is the ascomycete *Ceratocystis fagacearum*, although *C. grandicarpa* and *C. prolifera* also cause similar damage to the cambium. The fungus affects the vascular system of the tree, causing the death of the circulatory parenchyma and the active formation of till. The latter block the vessels, disrupting the water supply to the upper parts of the tree, which leads to wilting of the branches and the death of current shoots. The disease can occur in acute or chronic forms—in the first case, the symptoms appear quickly: wilting begins at the ends of the branches and covers the entire crown in a short time; the leaves curl up at the edges, acquire a yellowish or bronze hue, and fall off 3–6 weeks after infection. If the disease develops in late summer, the leaves turn brown and fall off without twisting, and some of them remain on the branches until winter. Mycelium accumulations form under the bark of withered trees, which can noticeably protrude from cracks in the bark. The fungus secretes a fragrant substance that attracts vector beetles to the infection zone (Campbell and French, 1955; Appel and Billings, 1992). Control of oak wilt usually involves digging the soil (below) to separate root grafts and protect neighboring oaks, as well as removing infected trees, preferably before the next summer season of beetles (the main vector is *Colopterus truncatus*). Injections of fungicides into the tree trunk are suggested as a preventive measure to protect individual valuable or small groups of trees (Billings, 2000; Koch et al., 2010). Pheromone disruptor substances aimed at disease-transmitting beetles are also being developed (Kyhl et al., 2002).

Step cancer. The main species that causes step cancer is considered to be ascomycete *Neonectria ditissima* and its anamorph *Cylindrocarpon willkommii* (Lindau) Wollenw. The plant's response to a fungal attack is the activation of callus tissue, but, unlike other gall-forming fungi, *Neonectria ditissima* causes, along with galls, extensive necrosis. As a result, perennial wounds with pronounced gradation, weakening of photosynthetic shoots, and dry tops form on the tree. In spring and autumn, abundant conidial sporulation of the fungus is observed in affected areas (Weber, 2014). As control measures, pruning of affected areas of bark and removal of affected shoots are proposed (Bondartsev, 1912), and protocols for the use of fungicides are being developed (Weber, 2014; Walter et al., 2014).

Late blight. The following species of oomycetes are associated with symptom complexes of late blight in English oak: *Globisporangium intermedium*, *G. irregulare*, *Phytophthora cactorum*, *P. citricola*, *P. europaea*, *P. gallica*, *P. gonapodyides*, *P. plurivora*, *P. pseudosyringae*, *P. quercina*, *P. uliginosa*, *Phytopythium citrinum*, *P. litorale* (Jung et al., 1999, 2002, 2003; Jung and Nechwatal, 2008; Vedenyapina et al., 2014; Firsov et al., 2019). The main symptoms of tree damage by late blight are ulcers/necrosis of the roots and the root part of the trunk, and at advanced stages of the disease, defoliation occurs. A comparative study of fine and coarse roots of healthy and declining oak trees using light and scanning electron microscopy revealed a progressive deterioration of the fine roots and mycorrhizal system in mature trees. Histopathological phenomena such as filling of cortical and vascular root tissues with protist hyphae, leading to damage to lignified roots, have been described (Blashke, 1994). The use of various fungicides has been proposed as control measures (Belisle et al., 2019, 2023; Adaskaveg et al., 2024). Passive pathogen control measures may include maintaining litter in gardens and maintaining drainage systems in gardens and parks (Firsov et al., 2019). Studies conducted in various climatic conditions and on various plants have shown that good biological protection against *Phytophthora* spp. can provide mycorrhization of the corresponding species (Marais and Kotze, 1976; Guillemin et al., 1994).

Root rot of seedlings. The causative agent of this disease is ascomycete *Rosellinia quercina*. This fungus affects seedlings aged 1–3 years, developing mainly on waterlogged and poorly aerated soils. The infection starts from the fine roots and penetrates into the woody parts of the root system; eventually the young plant dies. The first sign of infestation is yellowing of the leaves of the English oak tree, which later turn brown. In wet weather, a white or gray cottony superficial mycelium may form on the affected roots and root canal. The fungal hyphae affect not only the bark but also the wood, as a result of which the trees can break at the root collar (Walde, 1930). The most effective measures of passive control of the pathogen are reducing humidity under the forest canopy, proper pruning and creation of an effective drainage system, liming of soils to increase pH, and removal of large woody debris (Wakin, 1954). Of the fungicides, Topsin 700M at a concentration of 10% has proven to be the best (Pârvu, 2000).

White sapwood rot of roots. The main agents of white sapwood rot of the roots of English oak are basidiomycetes *Armillaria lutea = A. gallica* Marxm. et Romagn. and flat tinder fungus *Ganoderma applanatum*, causing active white rot. Most often, butt frost cracks become infected, and then the rot spreads along the sapwood to the skeletal roots and up the trunk. The rot caused by honey fungus and flat tinder fungus is quite active and the afflicted skeletal roots can lose strength over several years. Oak trees in parks, which are particularly characterized by scattering of axes, become susceptible to windfall when skeletal roots are damaged (Firsov et al., 2021; Shishlyannikova, 2024). Silvicultural measures to control pathogens include drainage and liming of soils (Firsov et al., 2021); chemical measures involve the selection of effective fungicides (Aguín et al., 2006; Amiri and Schnabel, 2012; Elias-Roman et al., 2019); biological measures involve elimination of the imbalance of the microbiome in the root zone of the soil (Kedves et al., 2021).

Sapwood rot of trunks. Sapwood white rot of the trunks of English oak is much more dangerous than heartwood rot caused by the sulfur yellow tinder fungus *Laetiporus sulphureus* and oak sponge *Daedalea quercina*, because it leads to the death of skeletal branches and roots. Sapwood rot of common oak is caused by false alder tinder fungus (*Phellinus alni*), oak-loving tinder fungus (*Inocutis dryophila*), oak grove tinder fungus (*Pseudoinonotus dryadeus*), and scaly polypore (*Cerioporus squamosus*). However, the false oak tinder fungus (*Fomitiporia robusta*) is especially harmful, causing active white rot, leading to progressive death of branches and dieback of the tops of English oak and capable, in conditions unfavorable for planting, of causing dying out of oak from forest stands (Sunhede and Vasiliauskas, 2002; Dunaev et al., 2011; Shabunin and Semakova, 2022; Shishlyannikova, 2024). Effective chemical measures against *F. robusta* do not exist. Silvicultural measures are limited to recommending the removal of affected trees, timely thinning, and drainage of the area (Hatsch et al., 1999).

Branch necrosis. This group of diseases includes *Vuilleminia* necrosis (causative agent is basidiomycete *Vuilleminia comedens*) and Clithris necrosis (causative agent is ascomycete *Colpoma quercinum*) of branches of the crown of English oak. *C. quercinum*, a saprotroph with residual necrotrophic activity, attacks lignified shoots through insect bites and bark perforations caused by fungi of the genera *Cytospora*, *Caudospora*, *Coryneum*, and *Hysterium*. This species completes the pathogenetic process initiated by the listed necrotrophic species and leads to the slow drying out of small branches of the crown. A similar dying off of larger branches of the crown is caused by *Vuilleminia comedens*, affecting branches through frost cracks and perforations caused by *Colpoma quercinum* and saprotroph *Diatrypella quercina*, and cancerous ulcers caused by fungi of the genus *Neonectria* and *Phomopsis*. *Vuilleminia comedens* significantly expands the zone of necrosis, causing a characteristic picture of cortex peeling. The attention of plant pathologists is attracted by the *Vuilleminia* necrosis of large branches; as observations show, it is correlatively associated with damage to the trunk by *Fomitiporia robusta*, while under favorable conditions for the tree, *Vuilleminia* and clytris necrosis of branches contribute to self-thinning of the crown and the formation of shoot architecture of senile individuals (Shishlyannikova et al., 2023; Shishlyannikova, 2024).

Powdery mildew. The most well-known and less harmful oak disease, which manifests itself in the life cycle of each English oak tree. The main causative agent is the ascomycete *Erysiphe alphitoides*. The disease manifests itself as an intense white coating of mycelium, which spreads to leaf blades, petioles, and terminal shoots. Soon, the leaves begin to deform, bend, or curl, and the growth of the vegetative mass completely stops. This disease is especially dangerous for seedlings and young oak plantations, whereas adult trees are seriously affected only by damage to leaves that have grown back in the current season after damage by leaf-eating pests (the so-called "Ivan shoots"). In such cases, a significant spread of powdery mildew in the crown of the tree makes it difficult for shoots to prepare for wintering, slows down growth, and leads to depletion of nutrient reserves. This significantly increases the vulnerability of the tree to more dangerous diseases. To reduce the risk of disease, it is useful to thin out excessively dense plantings (Zmitrovich and Vasiliev, 2006; Marçais et al., 2014). A number of synthetic and chitooligosaccharide-based fungicides have been approved by the European Union and the Forest Stewardship Council (FSC) (Turczański et al., 2014; Tăut et al., 2024).

Phytopathological Condition of Oak Groves

There are many works devoted to oak grove diseases in the foreign and domestic literature that deserve a separate review. Among them, the works by A.T. Vakin *Fungal Diseases and Other Defects of Oak Groves* (Vakin, 1932) and "Phytopathological Condition of Oak Groves of Tellermanovsky Forest" (Vakin, 1954) are highlighted (a repeated phytopathological examination of this forest object was undertaken 60 years later—Storozhenko et al., 2014; Selochnik et al., 2015). It is also worth noting the series of works by B.P. Churakov and his students in the oak groves of Ulyanovsk oblast (Churakov, 2000; Churakov, B.P. and Churakov, R.A., 2018; Churakov et al., 2022), by N.A. Kharchenko et al. in oak groves of the Central Black Earth Region (Kharchenko et al., 2010), and by N.N. Selochnik in oak groves of the Central Russian forest steppe as a whole (Selochnik, 2015). A student of A.T. Vakin, G.I. Zarudnaya and her student A.B. Shishlyannikova, examined oak groves of the Central zone of Russia and the Northwest region (Shishlyannikova et al., 2014, 2020; Shishlyannikova and Zmitrovich, 2024).

In the work on surveying oak groves in recent decades, the methodological arsenal has come to the forefront—modification of scales for assessing the condition of forest stands and an adequate choice of statistical methods and models.

There are a large number of scales designed to assess the physiological state of trees. The so-called universal scales for assessing the condition of coniferous and deciduous trees adopted in forest pathology monitoring—6-point scales for the sanitary condition of trees (*Prikaz Ministerstva*..., 2020; *Postanovlenie Pravitel'stva*..., 2020)—are focused, first of all, on assessing the condition of trees taking into account the need to obtain wood growth and increase forest production. In parkland conditions, the main purpose of the tree changes. As an element of landscaping, trees primarily perform an aesthetic and recreational function; old-growth trees have historical significance. In the conditions of protected areas, plantings have scientific and historical significance, special requirements are imposed on them, and factors for increasing the stock and growth cease to be relevant (Leontyev, 2022). Thus, during a detailed examination of valuable forest stands (old-growth, historical, etc.), universal scales turn out to be too crude and uninformative.

During a detailed examination of oak plantations in parks and protected areas, a specialized scale of oak condition categories (Zvyagintsev et al., 2019) turns out to be more informative, with a number of additions (Selochnik and Kaplina, 2011; Furmenkova and Kochergina, 2021). Studies conducted using the cited specialized scales and variance analysis yield interesting results.

On test plots laid out along the Tula–Vyborg transect, reflecting the movement from the optimum range zone of this breed to its periphery, a complex of key species of xylosaprotrophic fungi has been identified that determines the appearance of the shoot system of late generative and subsenile individuals of English oak: *Colpoma quercinum*, *Vuilleminia comedens* (promotes crown thinning), *Daedalea quercina*, *Laetiporus sulphureus*, *Fomitiporia robusta* (cause stem rot), *Armillaria lutea* (affects mainly the butt area of the tree). It is shown that the adaptive potential of English oak trees is determined by local soil and hydrological conditions. There are "eutrophic" and "oligotrophic" ecades, characterized by the diameter of the trunk (at the height of 1.3 m) more and less than 50 cm, respectively. The studies conducted confirm the greater resistance of trees of the "eutrophic" ecade to progressive crown death and deterioration of condition: the high correlation of crown necrosis with the rank by trunk diameter is explained by the constitutional difference between the "eutrophic" and "oligotrophic" ecades of English oak and the greater resistance to stress effects of eutrophic ecads. In the forest-steppe/broadleaf forest section of the transect, oak trees are weakly differentiated into two sections and are generally suppressed by linden stands. In the subtaiga section of the transect, a variegated picture of differentiation of oak trees by phytopathological condition is observed, with "eutrophic" ecades demonstrating a low phytosanitary condition score (Shishlyannikova et al., 2024).

An analysis of the macromorphological parameters of the crown characteristic of the forest and meadow groups of ecotypes of English oak and a comparative phytopathological characterization of these two groups of ecotypes were also carried out. To achieve this goal, we conducted comprehensive studies of the crown parameters of 28 ecotypes of English oak and the phytopathological state of the corresponding trees. In particular, we selected 14 individuals of pedunculate oak of subsenile age (VI< age class), currently confined to open spaces (the so-called solitary oaks). The crown width was considered as a characteristic feature of this group of ecotypes, the quantitative assessment of which is the ratio of the tree height to the maximum crown width. For comparison, we also randomly selected 14 subsenile trees (VI< age class) from the studied array of forest oak ecotypes and their crown was characterized by the same parameter. The conducted rank analysis of variance using the Kruskal–Wallis criterion showed a statistically significant difference between the two samples: $p \leq 0.00001$ at the level of $p < 0.05$, trees of the meadow and forest groups of the ecotypes of English oak statistically significantly differ in the condition category. To identify the correlation between the diameters of tree trunks of meadow and forest groups of English oak ecotypes with the condition category and crown lesions by *Colpoma quercinum* and *Vuilleminia comedens*, a rank correlation analysis was performed using the Spearman criterion, which showed the following: (1) for trees of the meadow group of oak ecotypes, a statistically significant relationship was found between the tree diameter rank and the condition category Rs = 0.73 at $p <$ 0.05; for trees of the forest group of English oak ecotypes, no reliable relationship was found (correlation is not traced)—Rs = –0.28; (2) for trees of the meadow group of English oak ecotypes, a moderate correlation of crown lesion by *Colpoma quercinum* with trunk diameter rank was found, but was statistically insignificant—Rs = 0.24 at $p > 0.1$; (3) for trees of the forest group of oak ecotypes, the correlation of crown damage by *C. quercinum* with the trunk diameter rank is weak, but not statistically significant (Rs = –0.20); (4) for trees of the meadow group of English oak ecotypes, a weak correlation of crown damage by *Vuilleminia comedens* with the tree diameter rank is revealed, but is statistically insignificant (Rs = 0.10 at $p > 0.1$); (5) for trees of the forest group of English oak ecotypes, the correlation of crown lesions by *Vuilleminia comedens* with the tree diameter rank is not traced, since it is not statistically significant—Rs = –0.26.

Thus, it was shown that the phytopathological state of trees of the two comparable groups of ecotypes is significantly influenced not by local hydrological conditions of the habitat, expressed in the thickness of the trunk, but by the size of the crown projection, expressed through the "crown coefficient." Differentiation of meadow and forest groups of English oak ecotypes by resistance to the main pathogens causing crown and trunk drying, as well as identifying its main causes, allows us to formulate a number of proposals (recommendations) in the field of park construction related to planning plantings and felling taking into account the negative impact of the shading factor on growing oaks; measures to sanitize the crown while maintaining the maximum photosynthetic surface and sanitize the trunk, ensuring the cleaning of the core cavity from brown rot; reassessment of the role of crown thinning agents in control measures; and the need for water reclamation of park areas on the northern border of the English oak distribution (Shishlyannikova et al., 2025).

BIORESOURCE POTENTIAL OF MYCOBIOTA OF ENGLISH OAK

The English oak itself can be considered as a significant resource of medicinal raw materials. The Russian pharmacopoeia has long used the bark of the English oak (the drug is called Quercus cortex), which has an astringent and wound-healing effect. Oak bark contains tannins, free gallic and ellagic acids, catechins, flavonoids, triterpenoids, sitosterol, and pantothenic and ascorbic acids. Acorns contain a significant amount of the flavonoid quercetin (*Gosudarstvennaya*..., 2023). Less studied as a promising medicinal raw material are fungi that have adapted to develop on the bark and wood of the English oak. The overwhelming majority of these are xylosaprotrophs, sometimes with residual necrotrophic activity, possessing an enzymatic apparatus configured to oxidize lignocellulose complexes. Secondary metabolites formed via the shikimate (terphenylquinones, benzoquinones), polyketide (terpeniodes, including carotenoids), or combined (styrylpyrones) pathways are considered as promising fungal medicinal raw materials (Velíšek and Cejpek, 2011). These metabolites, being complementary in their structure to the binding centers of nuclear and membrane receptors and molecules of intermediate signaling pathways, have pronounced antioxidant, radical-scavenging, pro-apoptotic, immunomodulatory, antiviral, and antibacterial activity (Zmitrovich et al., 2022a). Xylosaprotrophic fungi do not form specifically "oak" secondary metabolites; moreover, quercetin has pronounced antifungal activity; they are valuable as agents for processing oak wood and bark. Species of xylotrophic fungi confined in the temperate zone to *Q. robur* are also found on xerophilous Mediterranean oaks, indicating that these fungi have been related to the genus *Quercus* since the Tertiary Period, when it was more diversified and widespread in the Holarctic (Zmitrovich, 2008; Ţura et al., 2011). The following are the species of fungi associated with *Q. robur*, studied pharmacologically.

Colpoma quercinum. Saprotrophic with residual necrotrophic activity, the species attacks dying terminal shoots of oak, developing numerous elongated apothecia on dead branches, peeling off the bark; it causes corrosive rot. Submerged cultures of this fungus produce colposetins A–C, colpomenic acids A and B, penicillide, and monodictyphenone. Colposetin B exhibits pronounced antimicrobial (*Bacillus subtilis*) and antifungal (*Mucor hiemalis*) activity (Primahana et al., 2021).

Fomitiporia robusta. Widely distributed in oak groves, the naturally occurring white rot saprotroph colonizes mainly the sapwood and large skeletal branches of oaks, causing the death of the plants. Hispidin, hypholomin B, 3,14'-bihispidinyl, melanins, tryptamine, L-tryptophan, and phenolic acids were found in the culture liquid and extracts of fruiting bodies and mycelium of this fungus (Ghobad-Nejhad et al., 2024). Ethanol extracts of this fungus have been shown to have antibacterial, antioxidant, cytotoxic, genoprotective, immunostimulating, and anti-inflammatory effects (Fiasson et al., 1982; Kovács et al., 2017; Wu et al., 2019; Badalyan and Gharibyan, 2020).

Hymenochaete rubiginosa. This white rot saprotroph develops mainly on stumps and oak deadwood. Hispidin, protocatechuic acid, fumaric acid, gallic acid, caffeic acid, vanillin, *p*-coumaric acid, and rosmarinic acid were found in the culture liquid and extracts of this fungus (Ghobad-Nejhad et al., 2024). Extracts of *H. rubiginosa* have been shown to possess antioxidant, anticholinesterase, antibacterial, and antifungal activity (Fiasson et al., 1982; Çayan et al., 2021; İnci et al., 2022).

Daedalea quercina. This brown rot saprotroph often colonizes living oak trees, although it is capable of developing on stumps and deadwood. Ethyl acetate extract of *D. quercina* contained ergosterol, 5-dihydroergosterol (ergosta-7,22-dien-38-ol), and ergosterol peroxide (5,8-epidioxyergosta-6,22-dien-38-ol) (Tanahashi and Takahashi, 1966). In human nutrition, ergosterol is the provitamin form of vitamin D2. As a result of fractionation of the extract of the mycelial culture of *D. quercina*, a new substance was isolated, called quercinol—(2S)-2-hydroxymethyl-2-methyl-6-hydroxychromen. Hydroquinone exhibits anti-inflammatory and antioxidant activity (cyclooxygenase 2, xanthine oxidase and horseradish peroxidase inhibitor) (Gebhardt et al., 2007).

Grifola frondosa. This saprotroph of white rot colonizes the space near the butt and root paws of oak (often near the places of unloading of heartwood brown rot caused by *Laetiporus sulphureus*), known as Meitake, and has long been used as a medicinal raw material. Basidiomas *Grifola frondosa* are rich in 1-6-β- and 1-3-β-D-glucans, glycoproteins, proteins, and low molecular weight compounds (ergosterol, triterpenoids, free amino acids) that have antitumor, immunostimulating, antiangiogenic, antidiabetic, antioxidant, antibacterial, and antiviral effects, affecting lipid metabolism (Boh and Berovič, 2007).

Inocutis dryophila. In ethanol extracts of basidiomata of this species, associated with the trunks of living trees (white rot), hispidin and hypholomin B were found (Fiasson et al., 1982). Endomelanins were found in the culture fluid, and IDM-2 melanin exhibited high radical-absorbing activity (Gornostay, 2024).

Laetiporus sulphureus. This brown rot saprotroph, colonizing the heartwood of oak, forms massive intergrowths of edible fruiting bodies. Ethanol extracts of *L. sulphureus* have been well studied, rich in 1-6-β- and 1-3-β-D-glucans, laminaran, fucomanogalactan, triterpenoids, organic acids, benzofurans, flavonoids, coumarins, and nitrogen-containing compounds. Quite rare compounds such as 6-((2E,6E)-3,7-dimethyl deca-2,6-dienyl)-7-hydroxy-5-methoxy-4-methylphlan-1-one, and *N*-phenethylhexadecanamide were isolated from the methanol extract of fruiting bodies (Khatua et al., 2017). Numerous studies have shown that ethanol extracts obtained from this fungus have antioxidant, antibacterial, and antitumor properties and regulate metabolism and digestion processes in humans. Aqueous extracts also have food preservative properties, exhibiting broad-spectrum antibacterial activity (Adamska, 2023).

Pseudoinonotus dryadeus. From the fruiting bodies of this saprotroph, which colonizes the heartwood of living oak trees and causes white rot, a complex mixture of free fatty acids, cerevisterol, sphingosine, and a complex mixture of diacylglycerophospholipids were extracted. High antioxidant and radical scavenging activity of the ethanol extract of this mushroom has been shown (Cateni et al., 2015). Its antibacterial and skin-protective properties are also known (Harms et al., 2014; Zeb and Lee, 2021).

Stereum spp. From the fungi of genus *Stereum*, the most studied is *S. hirsutum*, which affects the sapwood of many deciduous trees, including oak, and causes white rot. Of particular interest are the hirsutan sesquiterpenoids isolated from this fungus: hirsutenols A–F, hirsutonic acids C–E, N, stergirsutins A–L. Hirsutenols A–C showed moderate activity against *Escherichia coli*. Hirsutenols D–F have pronounced activity in the absorption of superoxide anions. Hirsutinic acids C and D exhibited cytotoxicity against K562 and HCT116 cancer cell lines. Stergirsutins A–L exhibited weak cytotoxicity against the same cell lines. Stergirsutins J and K exhibit potent autophagy-inducing activity (Tian et al., 2020). The species *S. gausapatum* specialized to *Quercus* has not yet been studied much. Three new compounds were isolated from it: strobilol N, strobilol O, strobilol P, as well as strobilol E and stereumin D. Strobilol N showed pronounced activity against nematode *Caenorhabditis elegans* (Huang et al., 2020).

Xylobolus frustulatus. From the cultures of this fungus, which causes active pitted corrosion rot of oak deadwood, hydroquinones frustulosin and frustulosinol were isolated, which have antimicrobial activity and pronounced phytotoxicity (Naie and Anchel, 1972; Goddard and Tabacchi, 2006; Yurchenko et al., 2025).

At least 178 species of xylosaprotrophic fungi are associated with English oak in the northwestern part of the Russian part of its range (taking into account the southern and eastern parts of the range of this species, the number of xylosaprotrophs associated with English oak may exceed, according to our estimates, two hundred species), of which at least 10% show a pronounced specialization for trees of the genus *Quercus* (Zmitrovich and Shishlyannikova, 2025), while less than 50% of the species of xylosaprotrophic fungi specialized on oaks have been studied in biochemical and biomedical terms. Of the poorly studied specialized "oak species" in biochemical and biomedical terms, of particular interest are basidiomycetes *Hapalopilus croceus* and *Peniophora quercina* and ascomycete *Diatrypella quercina*, characterized by pronounced physiological activity and active biomass production under cultivation conditions (Zmitrovich et al., 2025).

CONCLUSIONS

English oak is a derivative of the heat-loving Tertiary flora adapted to a moderate climate, characterized by a rich fungal suite, the core of which apparently formed in the Tertiary. At least 30 species of fungal organisms are associated with the phyllosphere of this plant, at least 26 are associated with the system of terminal shoots, at least 475 are associated with the trunk, skeletal branches, and waste, at least 230 are associated with trunk ulcers and wounds, at least 62 are associated with oak litter, at least 47 are associated with the rhizosphere, and at least 83 are associated with seedlings. At least 137 species of fungi are associated with English oak in ectomycorrhizal associations. The lists presented reflect in general terms the documented biodiversity, which appears to be deliberately incomplete.

Firstly, the molecular revision did not cover all taxa described in the 17th–20th centuries on the basis of morphological characteristics. Secondly, multigene phylogenies and whole-genome comparisons will correct a number of concepts that arose in "rDNA era" in taxonomy. A deeper understanding of the "taxonomic dark matter" associated with *Quercus robur* could yield significant results, as demonstrated by additional studies of unidentified endogonaceous fungal sequences associated with the rhizosphere of this plant (Tedersoo et al., 2024).

The introduction of molecular methods opens new horizons in the study of the relationship between fungi, insects, and phytopathogenic nematodes in the early stages of the pathogenetic process (Hyun et al., 2007).

Over its vast European range, the population of English oak is heterogeneous. Within the Russian part of the range, seven climatypes of this plant are distinguished (Rostovtsev, 1962), each of which is adapted to a set of forest growth conditions of certain territories. The study of macroregional groups of fungi associated with oak began in the Northwest of Russia (Shishlyannikova et al., 2024, 2025), but in the future, their distribution to other territories is of great theoretical and practical interest.

Climate changes in recent decades occurring in the range of oak have led to a new situation—July waterlogging of soils in the taiga zone of Europe (Nikolaev, 2023) and an increase in the risk of drought in the southeastern Cis-Urals, especially on the territory of Obshchy Syrt (Nikolaev, 2024). These changes directly affect the processes occurring in the oak rhizosphere. And if changes in the soil mycobiota of English oak in the Northwest region are already being monitored (Vedenyapina et al., 2014; Firsov et al., 2019; etc.), then monitoring the rhizosphere of English oak in the Cis-Urals—on one of the harshest boundaries of the range of this species—seems to be one of the important promising areas of research.

Of particular interest is the comparison of fungal groups of oak in its natural and cultigenic range.

The trophic confinement of fungi of English oak will undoubtedly be clarified with more active use of the experimental tools of the "postgenomic era." This will undoubtedly lead to a reassessment of the pathogenic potential of many species and will allow adjustments to measures to control pathogens of English oak.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This work does not contain any studies involving human and animal subjects.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

REFERENCES

Adamska, I., The possibility of using sulphur shelf fungus (*Laetiporus sulphureus*) in the food industry and in medicine—A review, *Foods*, 2023, vol. 12, no. 7, p. e1539. https://doi.org/10.3390/foods12071539

Adaskaveg, J.E., Förster, H., and O'Fallon, C., New fungicides for managing Phytophthora diseases of tree crops with foliar and soil applications, *J. Plant Dis. Prot.*, 2024, vol. 131, pp. 1203–1209. https://doi.org/10.1007/s41348-024-00873-6

Agerer, R., *Ramaria subbotrytis* (Coker) Corner + *Quercus robur* L., *Descriptions of Ectomycorrhizae*, 1996, vol. 1, pp. 125–130.

Agerer, R., *Lyophyllum decastes*, in *Colour Atlas of Ectomycorrhizae*, Schwabisch Gmund: Einhorn Verlag, 1998, p. 18.

Agerer, R., *Elaphomyces aculeatus* Tul. + *Quercus robur* L., *Descriptions of Ectomycorrhizae*, 1999, vol. 4, pp. 37–41.

Agerer, R., *Elaphomyces aculeatus*, in *Colour Atlas of Ectomycorrhizae*, Schwabisch Gmund: Einhorn Verlag, 2002, p. 158.

Agerer, R. and Beenken, L., *Lyophyllum decastes* (Fr.) Sing. + *Quercus robur* L., *Descriptions of Ectomycorrhizae*, 1998, vol. 3, pp. 43–47.

Aguín, O., Mansilla, J.P., and Sainz, J.M., In vitro selection of an effective fungicide against *Armillaria mellea* and control of white root rot of grapevine in the field, *Pest Manage. Sci.*, 2006, vol. 62, pp. 223–228. https://doi.org/10.1002/ps.1149

Allesio, C.L., *Boletus* Dill. ex L. (sensu lato). *Fungi Europaei*, Saronno: Libreria editrice Giovanna Biella, 1985, vol. 2.

Amiri, A. and Schnabel, G., Persistence of propiconazole in peach roots and efficacy of trunk infusions for Armillaria root rot control, *Int. J. Fruit Sci.*, 2012, vol. 12, pp. 437–449. https://doi.org/10.1080/15538362.2012.679183

Andersson, L., Alekseeva, N.M., and Kuznetsova, E.S., *Vyyavlenie i obsledovanie biologicheski tsennykh lesov na Severo-Zapade evropeiskoi chasti Rossii* (Identification and Survey of Biologically Valuable Forests in the Northwest of the European Part of Russia), vol. 2: *Posobie po opredeleniyu vidov, ispol'zuemykh pri obsledo-*

vanii na urovne vydelov (Guide for Species Identification Used in Plot-level Surveys), St. Petersburg: Pobeda, 2009.

Badalyan, S.M. and Gharibyan, N.G., Pharmacological properties and resource value of hymenochaetoid Fungi (Agaricomycetes) distributed in Armenia, *Int. J. Med. Mushrooms*, 2020, vol. 22, no. 12, pp. 1135–1146.

Beenken, L., *Russula virescens* (Schaeff.) Fr. + *Quercus robur* L., *Descriptions of Ectomycorrhizae*, 2001a, vol. 5, pp. 199–203.

Beenken, L., *Russula vesca* Fr. + *Quercus robur* L., *Descriptions of Ectomycorrhizae*, 2001b, vol. 5, pp. 187–192.

Belisle, R.J., Hao, W., McKee, B., et al., New Oomycota fungicides with activity against *Phytophthora cinnamomi* and their potential use for managing avocado root rot in California, *Plant Dis.*, 2019, vol. 103, pp. 2024–2032.

Belisle, R.J., Hao, W., Riley, N., et al., Root absorption and limited mobility of mandipropamid as compared to oxathiapiprolin and mefenoxam after soil treatment of citrus plants for managing Phytophthora root rot, *Plant Dis.*, 2023, vol. 107, pp. 1107–1114.

Berkeley, M.J. and Broome, C.E., Notices of British Fungi [615–639], *Annals and Magazine of Natural History, Ser. 2*, 1852, vol. 9, no. 52, pp. 317–329.

Biketova, A.Yu., Svetasheva, T.Yu., Taylor, A.F.S., et al., Morphological and molecular re-assessment of European and Levantine species of the genus *Hortiboletus* (Boletaceae), *IMA Fungus*, 2025, vol. 16, p. e144731. https://doi.org/10.3897/imafungus.16.144731

Billings, R.F., State forest health programs: A survey of state foresters, *J. For.*, 2000, vol. 98, pp. 20–25.

Blashke, H., Decline symptoms on roots of *Quercus robur*, *Eur. J. For. Pathol.*, 1994, vol. 24, no. 6–7, pp. 386–398.
https://doi.org/10.1111/j.1439-0329.1994.tb00832.x

Bogdanov, P.L., *Dendrologiya* (Dendrology), Moscow: Lesnaya Promyshlennost', 1974.

Boh, B. and Berovič, M., *Grifola frondosa* (Dicks.: Fr.) S.F. Gray (Maitake mushroom): Medicinal properties, active compounds, and biotechnological cultivation, *Int. J. Med. Mushrooms*, 2007, vol. 9, no. 2, pp. 89–108. https://doi.org/10.1615/IntJMedMushr.v9.i2.10

Bol'shakov, S.Yu., Volobuev, S.V., Ezhov, O.N., et al., *Afilloforoidnye griby evropeiskoi chasti Rossii: annotirovannyi spisok vidov* (Aphyllophoroid Fungi of the European Part of Russia: An Annotated Species List), St. Petersburg: S.-Peterb. Gos. Elektrotekh. Univ. "LETI," 2022.

Bolton, J., *An History of Fungusses, Growing About Halifax*, London, 1788, vol. 2.

Bondartsev, A.S., *Gribnye bolezni kul'turnykh rastenii i mery bor'by s nimi: Pole. Ogorod. Sad* (Fungal Diseases of Cultivated Plants and Control Measures: Field. Vegetable Garden. Orchard), St. Petersburg: Tip. M. Merkusheva, 1912.

Bondartseva, M.A., New form of polypore fungus *Laetiporus sulphureus* (Fr.) Bond. et Sing., *Nov. Sist. Nizshikh Rast.*, 1972, vol. 9, pp. 137–139.

Bonorden, H.F., Abhandlungen aus dem Gebiete der Mykologie, *Abhandlungen der Naturforschenden Gesellschaft zu Halle*, 1864, vol. 8, pp. 1–168.

Borowska, A., New species of *Bactrodesmium*, *Corynespora, Septonema* and *Taeniolella*, *Acta Mycol.*, 1975, vol. 11, no. 1, pp. 59–65.

Britzelmayr, M. and Rehm, H., Beiträge zur Ausburger Pilzflora, in *Rabenh. Krypt.-Fl.*, Leipzig, 1888, 2nd ed., pp. 49–89.

Bulliard, J.B.F., *Herbier de la France; ou, Collection Complette des Plantes Indigenes de ce Royaume; avec leurs Propriétés, et leurs Usages en Medecine*, Paris, 1785, vol. 5, p. 228.

Bulliard, J.B.F., *Herbier de la France, Paris*, 1789, vol. 9, p. 432.

Bulygin, N.E. and Yarmishko, V.T., *Dendrologiya* (Dendrology), St. Petersburg: Nauka, 2000.

Bulygin, N.E., Veretennikova, G.A., and Reshetnyak, V.N., *Dendroinventarizatsiya parka "Dubki". Ego geobotanicheskoe obsledovanie i razrabotki rekomendatsii po sokhraneniyu dubov, predstavlyayushchikh istoricheskuyu tsennost': otchet po nauch.-issled. rabote* (Dendro-Inventory of Dubki Park. Its Geobotanical Survey and Development of Recommendations for Preserving Oaks of Historical Value: Research Report), Leningrad, 1978, no. 3117.

Buxbaum, J.C., *Plantarum Minus Cognitarum. Plantas circa Byzantim et in Oriente Observatas. Centuria V*, Petropolis, 1740.

Campbell, R.N. and French, D.W., A study of mycelial mats of oak wilt, *Phytopathology*, 1955, vol. 45, pp. 485–489.

Cateni, F., Zacchigna, M., and Altieri, T., Antioxidant properties of oak bracket mushroom, *Pseudoinonotus dryadeus* (Higher Basidiomycetes): A mycochemical study, *Int. J. Med. Mushrooms*, 2015, vol. 17, no. 7, pp. 627–637.
https://doi.org/10.1615/intjmedmushrooms.v17.i7.30

Çayan, F., Tel-Çayan, G., and Deveci, E., A comprehensive study on phenolic compounds and bioactive properties of five mushroom species via chemometric approach, *J. Food Process. Preserv.*, 2021, vol. 45, no. 9, p. e15695.

Christiansen, M.P., Danish resupinate fungi, *Dansk Botanisk Arkiv*, 1960, vol. 19, no. 2, pp. 63–388.

Churakov, B.P., Phytopathogenic fungi of oak forests, in *Gribnye soobshchestva lesnykh ekosistem* (Fungal Communities of Forest Ecosystems), Moscow: Petrozavodsk, 2000, pp. 292–316.

Churakov, B.P. and Churakov, R.A., The study of sanitary state of oak groves of Ulyanovsk oblast, *Byull. Gos. Nikitskogo Bot. Sada*, 2018, vol. 128, pp. 15–22.

Churakov, R.A., Churakov, B.P., and Churakova, Yu.A., Infection of oak with heart rot pathogens in stands with different taxation characteristics, in *Problemy lesnoi fitopatologii i mikologii: materialy XI mezhdunarodnoi konferentsii* (Issues of Forest Phytopathology and Mycology: Proc. XI Int. Conf.), Petrozavodsk, 2022, pp. 111–113.

Ciferri, R., Notae mycologicae et phytopathologicae, *Ann. Mycol.*, 1922, vol. 20, nos. 1–2.

Cooke, M.C., Foliicolous Sphaeriae, *J. Bot., Br. Foreign*, 1866, vol. 4, pp. 241–253.

Cooke, R.C. and Whipps, J.M., The evolution of modes of nutrition in fungi parasitic on terrestrial plants, *Biol. Rev.*, 1980, vol. 55, pp. 341–362.

Cox, L.A. and Hall, A.M., Phylloplane fungi of *Quercus robur*, *Ann. Appl. Biol.*, 1978, vol. 89, no. 1, pp. 119–122.

Crous, P.W. and Groenewald, J.Z., The Genera of Fungi—G 4: *Camarosporium* and *Dothiora*, *IMA Fungus*, 2017, vol. 8, no. 1, pp. 131–152. https://doi.org/10.5598/imafungus.2017.08.01.10

Crous, P.W., Schumacher, R.K., Wingfield, M.J., et al., Fungal systematics and evolution, *FUSE*, 2018, vol. 1, no. 1, pp. 169–215. https://doi.org/10.3114/fuse.2018.01.08

Crous, P.W., Jurjević, Z., Balashov, S., et al., Fungal Planet description sheets: 1614–1696, *Fungal Syst. Evol.*, 2024, vol. 13, pp. 183–440. https://doi.org/10.3114/fuse.2024.13.11

Desmazières, J.B.H.J., Notice sur quelques cryptogames inédites, récemment découvertes en France, et qui vent paraître publiées, en nature, dans les fascicules V et VI de la seconde édition des Plantes Cryptogames de France, *Ann. Sci. Nat., Bot., Sér. 2*, 1838, vol. 10, pp. 308–314.

Desmazières, J.B.H.J., Quatorzième notice sur les plantes cryptogames récemment découvertes en France, *Ann. Sci. Nat., Bot., Sér. 3*, 1847, vol. 8, pp. 9–37.

Desmazières, J.B.H.J., Seizième notice sur les plantes cryptogames récemment découvertes en France, *Ann. Sci. Nat., Bot.*, 1848, sér. 3, vol. 10, pp. 342–361.

Desmazières, M.J.-B.H.-J., Quelques *Septoria* noveaux, *Ann. Sci. Nat., Bot., Sér. 3*, 1853, vol. 20, pp. 85–96.

Dillenius, J.J., *Catalogus Plantarum Sponte circa Gissam Nascentim*, Frankfurt am Main, 1719.

Dodoens, R., *Histoire des Plantes, en Laquelle est Contenue la Description Entire des Herbes...non Seulement de Celles qui Croissant en ce Pais, mais Aussi des Autres Estrangeres qui Viennent en Usage de Medicine*, Antwerpen, 1557.

Duby, J.É., *Botanicon Gallicum*, 1830, vol. 2, pp. 545–1068.

Dunaev, A.V., Dunaeva, E.N., and Kalugina, S.V., The macromycetes, connected with root system of the oak in forest-steppe oak-groves, *Nauchn. Vedomosti, Ser. Estestv. Nauki*, 2010, no. 15 (86), pp. 79–81.

Dunaev, A.V., Dunaeva, E.N., and Kalugina, S.V., False oak polypore *Phellinus robustus* Bourd. et Galz. in Belgorod oak forests (bioecology, distribution, harmfulness), *Nauchn. Vedomosti, Ser. Estestv. Nauki*, 2011, no. 9 (104), pp. 35–42.

Elias-Roman, R.D., Galderon-Zavala, G., Guzman-Mendoza, R., et al., 'Mondragon': A clonal plum rootstock to enhance management of Armillaria root disease in peach orchards of Mexico, *Crop Prot.*, 2019, vol. 121, pp. 89–95. https://doi.org/10.1016/j.cropro.2019.03.011

Eriksson, J. and Ryvarden, L., *The Corticiaceae of North Europe*, vol. 4: *Hyphodermella—Mycoacia*, Oslo, 1976, pp. 547–886.

Fiasson, J.L., Distribution of styrylpyrones in the basidiocarps of various Hymenochaetaceae, *Biochem. Syst. Ecol.*, 1982, vol. 10, no. 4, pp. 289–296.

Firsov, G.A., Yarmishko, V.A., Volchanskaya, A.V., et al., Drying out of woody plants at Peter the Great Botanical Garden Biol. Inst. Russ. Acad. Sci. (Saint Petersburg) and distribution of Phytophthora and Pythium species: Monitoring in 2018, *Hortus Botanicus*, 2019, vol. 14. http://hb.karelia.ru.

Firsov, G.A., Yarmishko, V.T., Zmitrovich, I.V., et al., *Morozoboiny i patogennye ksilotrofnye griby v parke-dendrarii Botanicheskogo sada Petra Velikogo* (Frost Cracks and Pathogenic Xylotrophic Fungi in the Arboretum Park of Peter the Great Botanical Garden), St. Petersburg: Ladoga, 2021.

Fransson, P., *Craterellus tubaeformis* (Fr.) Quel. (syn. *Cantharellus tubaeformis* Fr.: Fr.) + *Quercus robur* L., *Descriptions of Ectomycorrhizae*, 2004, vols. 7–8, pp. 37–43.

Fries, E., Upsstalnning af de i Sverige Vartsvampar (Scleromyci), *K. Sven. Vetenskapsakad. Handl., Ser. 3*, 1819, vol. 6, pp. 100–120.

Fries, E., *Systema Mycologicum, Sistens Fungorum Ordines, Genera et Species, huc Usque Cognitas, quas ad Normam Methodi Naturalis Determinavit, Disposuii Atque Descripsit*, Gryphiswald, 1821, vol. 1.

Fries, E., *Systema Mycologicum: Sistens Fungorum Ordines, Genera et Species, huc Usque Cognitas, quas ad Normam Methodi Naturalis Determinavit*, Gryphiswald, 1823, vol. 3.

Fries, E., *Hymenomycetes Europaei sive Epicriseos Systematis Mycologici*, Uppsala, 1874.

Fuckel, L., *Symbolae mycologicae, Beiträge zur Kenntniss der Rheinischen Pilze, Jahrb. Nassau. Ver. Naturkd.*, 1870, pp. 1–459.

Furmenkova, E.S. and Kochergina, M.V., Methods for diagnosing the state of woody plants by external pathological signs, *Vestn. Buryat. Gos. S-kh. Akad. imeni V.R. Filippova*, 2021, no. 4 (65), pp. 164–171.

Gachet, H., Note sur quelques especes et une variete inedites de champignons, *Actes Soc. Linn. Bordeaux*, 1832, vol. 5, pp. 227–233.

Galli, R., *I Boleti. Atlante Pratico-monographico per la Determinazione dei Boleti*, Milan: Dalla Natura, 2007, 3rd ed.

Gebhardt, P., Dornberger, K., and Gollmick, F.A., Quercinol, an anti-inflammatory chromene from the wood-rotting fungus *Daedalea quercina* (Oak Mazegill), *Bioorg. Med. Chem. Lett.*, 2007, vol. 17, no. 9, pp. 2558–2560. https://doi.org/10.1016/j.bmcl.2007.02.008

Ghobad-Nejhad, M., Zhou, L.W., Tomšovský, M., et al., Unlocking nature's pharmacy: diversity of medicinal properties and mycochemicals in the family Hymenochaetaceae (Agaricomycetes, Basidiomycota), *Mycosphere*, 2024, vol. 15, no. 1, pp. 6347–6438. https://doi.org/10.5943/mycosphere/15/1/27

Goddard, M.L. and Tabacchi, R., Total synthesis of bioactive frustulosin and frustulosinol, *Tetrahedron Lett.*, 2006, vol. 47, pp. 909–911.

Goonasekara, I.D., Maharachchikumbura, S.S.N., Wijayawardene, N.N., et al., *Seimatosporium quercina* sp. nov. (Discosiaceae) on *Quercus robur* from Germany, *Phytotaxa*, 2016, vol. 255, no. 3, pp. 240–248.

http://www.mapress.com/j/pt/article/view/phytotaxa.255.3.5

Gornostai, T.G., Physicochemical characteristics of melanins from culture medium of *Inocutis dryophila* (Berk) Flasson et Niemela, *Izv. VUZov, Prikl. Khim. Biotekhnol.*, 2024, vol. 14, no. 3, pp. 416–420. https://doi.org/10.21285/achb.930

Gosudarstvennaya farmakopeya Rossiiskoi Federatsii XV izdaniya. Duba Kora – Quercus cortex, Prikaz Minzdrava Rossii ot 20.07.2023 № 377 (State Pharmacopoeia of the Russian Federation XV Edition. Oak Bark – Quercus cortex, Order of the Ministry of Health of Russia dated July 20, 2023 No. 377), 2023.

Granetti, B., Caratteristiche morfologiche, biometriche e strutturali delle micorrize di *Tuber* di interesse economic, *Micol. Ital.*, 1995, vol. 2, pp. 101–117.

Griffon, E. and Maublanc, A., Les *Microsphaera* des Chênes, *Bull. Trimest. Soc. Mycol. Fr.*, 1912, vol. 28, pp. 88–103.

Grozdov, B.V., *Dendrologiya* (Dendrology), Moscow: Goslesbumizdat, 1952.

Guillemin, J.P., Gianinazzi, S., Gianinazzipearson, V., and Marchal, J., Contribution of arbuscular mycorrhizas to biological protection of micropropagated pineapple (*Ananas-comosus* (L) Merr) against *Phytophthora cinnamomi* Rands, *Agric. Sci. Finl.*, 1994, vol. 3, pp. 241–251.

Guseinov, E., Mel'nik, V., and Sel'chuk, F., *Ceratophorum helicosporum*—A new genus and species of hyphomycetes of family Dematiaceae for the mycoflora of Turkey, *Mikol. Fitopatol.*, 2002, vol. 36, no. 3, pp. 11–13.

Haas, H., *The Young Specialist Looks at Fungi*, London: Burki, 1969.

Harms, M., Lindequist, U., and Wende, K., Biological activity of different Inonotus species on human keratinocytes, *Planta Med.*, 2014, vol. 80, p. 34.

Hartig, R., *Lehrbuch der Baumkrankheiten*, Berlin, 1880, p. 100.

Harvey, A.E., Larsen, M.J., and Jurgensen, M.F., Comparative distribution of ectomycorrhizae in soils of three Western Montana forest habitat types, *For. Sci.*, 1979, vol. 25, pp. 350–358.

Hatsch, E., Dupouey, J.L., Dubreuil, B., and Guillaud, J., Impact du champignon parasite *Phellinus robustus* et des cavités nidifiables sur la croissance des Chênes sessile et pédonculé, *Rev. For. Fr.*, 1999, vol. 51, no. 4, pp. 511–521.

Huang, J.R., Yang, B.J., Mo, M.H., et al., Secondary metabolites from the fungus *Stereum gausapatum* ATCC60954, *Phytochem. Lett.*, 2020, vol. 35, pp. 171–174.

Hyun, M.W., Kim, J.H., Suh, D.Y., et al., Fungi isolated from pine wood nematode, its vector Japanese pine sawyer, and the nematode-infected Japanese black pine wood in Korea, *Mycobiology*, 2007, vol. 35, no. 3, pp. 159–161. https://doi.org/10.4489/myco.2007.35.3.159

İnci, Ş., Sevindik, M., Kırbağ, S., et al., Antioxidant, antibacterial, and antifungal activity of *Hymenochaete rubiginosa*, *Indian J. Nat. Prod. Resour.*, 2022, vol. 13, no. 1, pp. 67–71.

Isaeva, O.V., Glushakova, A.M., Yurkov, A.M., et al., The yeast *Candida railenensis* in the fruits of English oak (*Quercus robur* L.), *Microbiology*, 2009, vol. 78, pp. 355–359. https://doi.org/10.1134/S002626170903014x

Ivanov, A.I. and Ermolaeva, A.A., Influence of ecological factors on spatial distribution of agaricomycetes (Agaricomycetes) in floodplain habitats, *Mikol. Fitopatol.*, 2021, vol. 55, no. 4, pp. 239–255. https://doi.org/10.31857/S002636482104005x

Ivashchenko, L.O., Panteleev, S.V., Romanenko, M.O., and Baranov, O.Yu., Specific identification of the English oak fungus infecting agents using the marker DNA-loci size, *Vestn. Povolzh. Gos. Tekhnol. Univ., Ser.: Les, Ekol., Prirodopol'zovanie*, 2021, no. 4 (52), pp. 89–97. https://doi.org/10.25686/2306-2827.2021.4.89

Jakucs, E., "*Quercirhiza alboviolacea*" + *Quercus robur* L., *Descriptions of Ectomycorrhizae*, 2001, vol. 5, pp. 61–65.

Jakucs, E. and Bratek, Z., *Genea verrucosa*, in *Colour Atlas of Ectomycorrhizae*, Schwabisch Gmund: Einhorn Verlag, 1998, p. 120.

Jakucs, E., Agerer, R., and Bratek, Z., "Quercirhiza fibulocystidiata" + *Quercus* spec., *Descriptions of Ectomycorrhizae*, 1997, vol. 2, pp. 67–71.

Jakuschkin, B., *Genetic Architecture of the Interactions between English Oak (Quercus robur L.) and the Microbial Community of Its Phyllosphere. Symbiosis*, Université de Bordeaux, 2015.

Janda, V., Kříž, M., Konvalinková, T., and Borovička, J., Makroskopická variabilita druhu *Rubroboletus legaliae* se zvláštním zřetelem na *Boletus spinarii*, *Czech Mycology*, 2017, vol. 69, no. 1, pp. 31–50.

Jankowiak, R., Fungi occurring in acorn of *Quercus robur* L. infested by insects, *Acta Sci. Pol., Silvarum Colendarum Ratio et Industria Lignaria*, 2008, vol. 7, no. 1, pp. 19–29.

Jankowiak, R., Bilański, P., Strzałka, B., et al., Four new *Ophiostoma* species associated with conifer- and hardwood-infesting bark and ambrosia beetles from the Czech Republic and Poland, *Antonie van Leeuwenhoek*, 2019, vol. 112, pp. 1501–1521.

Jankowiak, R., Stępniewska, H., Bilański, P., and Taerum, S.J., Fungi as potential factors limiting natural regeneration of pedunculate oak (*Quercus robur*) in mixed-species forest stands in Poland, *Plant Pathol.*, 2022, vol. 1, no. 4, pp. 805–817. https://doi.org/10.1111/ppa.13529

Jung, T. and Nechwatal, J., *Phytophthora gallica* sp. nov., a new species from rhizosphere soil of declining oak and reed stands in France and Germany, *Mycol. Res.*, 2008, vol. 112, pp. 1195–1205.

Jung, T., Cooke, D.E.L., Blaschke, H., et al., *Phytophthora quercina* sp. nov., causing root rot of European oaks, *Mycol. Res.*, 1999, vol. 103, pp. 785–798.

Jung, T., Hansen, E.M., Winton, L., et al., Three new species of *Phytophthora* from European oak forests, *Mycol. Res.*, 2002, vol. 106, no. 4, pp. 397–411.

Jung, T., Nechwatal, J., Cooke, D.E.L., et al., *Phytophthora pseudosyringae* sp. nov., a new species causing root and collar rot of deciduous tree species in Europe, *Mycol. Res.*, 2003, vol. 107, pp. 772–789.

Karatygin, I.V., *Koevolyutsiya gribov i rastenii* (Coevolution of Fungi and Plants), St. Petersburg: Gidrometeoizdat, 1993.

Karsten, P.A., Kritisk öfversigt af Finlands Basidsvampar (Basidiomycetes; Gastero- and Hymenomycetes), *Bidrag till Kännedom af Finlands Natur och Folk*, 1889, vol. 48, pp. 1–482.

Kedves, O., Shahab, D., Champramary, S., et al., Epidemiology, biotic interactions and biological control of armillarioids in the Northern Hemisphere, *Pathogens*, 2021, vol. 16, no. 1. https://doi.org/10.3390/pathogens10010076

Kharchenko, N.A., Mikhno, V.B., and Kharchenko, N.N., *Degradatsiya dubrav Tsentral'nogo Chernozem'ya* (Degradation of Oak Forests of the Central Black Earth Region), Voronezh: Voronezh. Lesotekh. Akad., 2010.

Khatua, S., Ghosh, S., and Acharya, K., *Laetiporus sulphureus* (Bull.: Fr.) Murr. as food as Medicine, *Pharmacogn. J.*, 2017, vol. 9, no. 6, pp. S1–S15.

Koch, K.A., Quiram, G.L., and Venette, R.C., A review of oak wilt management: A summary of treatment options and their efficacy, *Urban Forestry and Urban Greening*, 2010, vol. 9, no. 1, pp. 1–8. https://doi.org/10.1016/j.ufug.2009.11.004

Kokkonen, K., New northern records of *Entoloma* with three new species of subgenus *Rhodopolia* and typification of *E. nidorosum, Karstenia*, 2021, vol. 59, nos. 1–2, pp. 55–69. https://doi.org/10.29203/ka.2021.510

Kolmakov, P.Yu., Agaricoid basidiomycetes of the Belarusian-Valdai Lake District (within the Republic of Belarus and Pskov oblast of Russia), *Cand. Sci. (Biol.) Dissertation*, St. Petersburg: Bot. Inst. named after V.L. Komarov, Russ. Acad. Nauk, 2005.

Kovács, B., Zomborszki, Z.P., and Orban-Gyapai, O., Investigation of antimicrobial, antioxidant, and xanthine oxidase inhibitory activities of *Phellinus* (Agaricomycetes) mushroom species native to central Europe, *Int. J. Med. Mushrooms*, 2017, vol. 19, no. 5, pp. 387–394.

Kovyazin, V.F. and Ivanova, E.A., Soil and vegetation complex of the "Dubki" Park in St. Petersburg, Russia, *Izv. S.-Peterb. Lesotekh. Akad.*, 2022, vol. 238, pp. 6–22.

Kowalski, T. and Bartnik, C., *Cryptosporiopsis radicicola* sp. nov. from roots of *Quercus robur, Mycol. Res.*, 1995, vol. 99, no. 6, pp. 663–665. https://doi.org/10.1016/S0953-7562(09)80524-8

Kowalski, T. and Butin, H., Taxonomie bekannter und neuer Ceratocystis-Arten an eiche (*Quercus robur* L.), *J. Phytopathol.*, 1989, vol. 124, pp. 236–248.

Kowalski, T. and Halmschlager, E., *Chalara angustata* sp. nov. from roots of *Quercus petraea* and *Quercus robur, Mycol. Res.*, 1996, vol. 100, pp. 1112–1116.

Kropp, B.R., Fungi from decayed wood as ectomycorrhizal symbionts of western hemlock, *Can. J. For. Res.*, 1982, vol. 12, pp. 36–39.

Kunze, G. and Schmidt, J.C., *Mykologische Hefte*, Leipzig, 1817, vol. 1.

Kwaśna, A. and Szewczyk, W., Effects of fungi isolated from *Quercus robur* roots on growth of oak seedlings, *Dendrobiology*, 2016, vol. 75, pp. 99–112. https://doi.org/10.12657/denbio.075.010

Kyhl, J.F., Bartelt, R.J., and Cossé, A., Semiochemical-mediated flight responses of sap beetle vectors of oak wilt, *Ceratocystis fagacearum*, *J. Chem. Ecol.*, 2002, vol. 28, pp. 1527–1547. https://doi.org/10.1023/A:1019968211223

Legon, N. and Henrici, A., *Marchandiomyces quercinus* distribution and relationships, *Field Mycol.*, 2015, vol. 16, no. 1, pp. 18–22.

Leontev, L.L., Problems of surveying and assessing the condition of trees in cities, in *Zhizn' dvortsovykh sadov i parkov, Problemy sokhraneniya istoricheskikh nasazhdenii i bezopasnosti posetitelei* (Life of Palace Gardens and Parks, Problems of Preserving Historical Plantations and Visitor Safety), St. Petersburg, 2022, pp. 260–265.

Leski, T., Pietras, M., and Rudawska, M., Ectomycorrhizal fungal communities of pedunculate and sessile oak seedlings from bare-root forest nurseries, *Mycorrhiza*, 2010, vol. 20, pp. 179–190. https://doi.org/10.1007/s00572-009-0278-6

Lindsey, J.K., Amanitaceae mycorrhizae, 2004. https://www.commanster.eu/Commanster/Plants/Trees/Trees/Quercus.robur_Amanitaceae_Mycorrhizae.html.

Lindsey, J.K., Ecology of Commanster, 2008. https://www.commanster.eu/Commanster/Fungi/Agaric/AAgaric/Entoloma.lividoalbum.html.

Link, H.F., Observationes in ordines plantarum naturales. Dissertatio Ima, *Magazin für die Neuesten Entdeckungen in der Gesammten Naturkunde, Ges. Naturforsch. Freunde Berlin*, 1809, vol. 3, no. 1, pp. 3–42.

Linnaeus, C., *Species Plantarum, Exhibentes Plantas Rite Cognitas ad Genera Relatas, cum Differentiis Specificis, Nominibus Trivialibus, Synonymis Selectis, Locis Natalibus, Secundum Systema Sexuale Digestas*, Holm: L. Salm, 1753, vol. 2.

López-García, N., Romeralo, C., Andersen, C.B., et al., Metabarcoding reveals rhizosphere microbiome shifts between healthy and declining *Quercus robur* trees, *Rhizosphere*, 2025, vol. 34, p. 101070. https://doi.org/10.1016/j.rhisph.2025.101070

Luppi, A.M. and Gautero, C., Ricerche sulle micorrize di *Quercus robur, Q. petraea* e *Q. pubescens* in Piemonte, *Allionia*, 1967, vol. 13, pp. 129–148.

Marais, L.J. and Kotze, J.M., Ectomycorrhizae of *Pinus patula* as biological deterrents to *Phytophthora cinnamomea, South African Journal of Forestry*, 1976, vol. 99, pp. 35–39.

Marçais, B. and Desprez-Loustau, M.L., European oak powdery mildew: Impact on trees, effects of environmental factors, and potential effects of climate change, *Ann. For. Sci.*, 2014, vol. 71, pp. 633–642.

Marčiulynas, A., Sirgedaitė-Šėžienė, V., and Menkis, A., Fungi inhabiting stem wounds of *Quercus robur* following bark stripping by deer animals, *Forests*, 2023, vol. 14, no. 10, p. 2077. https://doi.org/10.3390/f14102077

Massalongo, C., Nuovi miceti dell'agro Veronese, *Nuovo G. Bot. Ital.*, 1889, vol. 21, no. 2, pp. 161–170.

Meotto, F., Mello, A., Nosenzo, C., and Vezzola, V., Morphological and molecular characterization of *Amanita caesarea* ectomycorrhizas, *Allionia*, 1997, vol. 35, pp. 87–93.

Meotto, F., Nosenzo, C., and Fontana, A., Le micorrize delle specie pregiate di Tuber, *L'Informatore Agrario*, 1995, vol. 31, pp. 41–45.

Micheli, P.A., *Nova Plantarum Genera Juxta Tournefortii Methodum Disposita*, Florentia, 1729.

Milović, M., Kovačević, B., Drekić, M., et al., Ectomycorrhizal diversity in a mature pedunculate oak stand near Morović, Serbia, *iForest*, 2023, vol. 16, pp. 345–351. https://doi.org/10.3832/ifor4362-016

Moody, S.A., Newsham, K.K., Ayres, P.G., and Nigel, P.D., Variation in the responses of litter and phylloplane fungi to UV-B radiation (290–315 nm), *Mycol. Res.*, 1999, vol. 103, no. 11, pp. 1469–1477. https://doi.org/10.1017/S0953756299008783

Nagy, L.G., Riley, R., and Tritt, A., Comparative genomics of early-diverging mushroom-forming fungi provides insights into the origins of lignocellulose decay capabilities, *Mol. Biol. Evol.*, 2015, vol. 334, pp. 959–970. https://doi.org/10.1093/molbev/msv337

Nair, M. and Anchel, M., An antibacterial quinone hydroquinone pair from the ascomycete, *Nectria coryli*, *Tetrahedron Lett.*, 1972, vol. 9, pp. 795–796.

Nair, M. and Anchel, M., Frustulosinol, an antibiotic metabolite of *Stereum frustulosum*: Revised structure of frustulosin, *Phytochemistry*, 1977, vol. 16, pp. 390–392.

Naseeb, S., James, S.A., Alsammar, H., et al., *Saccharomyces jurei* sp. nov., isolation and genetic identification of a novel yeast species from *Quercus robur, Int. J. Syst. Evol. Microbiol.*, 2017, vol. 67, no. 6, pp. 2046–2052. https://doi.org/10.1099/ijsem.0.002013

Nees von Esenbeck, C.D.G., *System der Pilze und Schwämme*, Würzburg, 1816, pp. 1–329.

Nevodovskii, G.S., *Griby SSSR* (Fungi of the USSR), Alma-Ata, 1952–1961.

Nezdoiminogo, E.L., *Opredelitel' gribov Rossii. Poryadok agarikovye. Semeistvo pautinnikovye* (Key to Fungi of Russia. Order Agaricales. Family Cortinariaceae), St. Petersburg: Nauka, 1996, vol. 1.

Nikolaev, M.V., The impact of climate change on crop farming in the drained lands of the European nonchernozem region of Russia: Vulnerability and adaptation assessment, *S-kh. Biol.*, 2023, vol. 58, no. 1, pp. 60–74.

Nikolaev, M.V., Identification of grain-producing areas vulnerable to moisture deficiency under climate change based on meso-zoning of the dry farming cropland in European Russia, *S-kh. Biol.*, 2024, vol. 59, no. 3, pp. 473–491.

Nitschke, T., *Pyrenomycetes Germanici*, *Breslau*, 1870, vol. 2, pp. 161–320.

Oak Wilt Perspectives: Proc. Natl. Oak Wilt Symp., June 22–25, 1992, Austin, Texas, Appel, D.N. and Billings, R.F., Eds., Austin, 1992.

Olariaga, I., Moreno, G., Manjón, J.L., et al., *Cantharellus* (Cantharellales, Basidiomycota) revisited in Europe through a multigene phylogeny, *Fungal Diversity*, 2017, vol. 83, pp. 263–292. https://doi.org/10.1007/s13225-016-0376-7

Olchowik, J., Hilszczańska, D., Bzdyk, R.M., et al., Effect of deadwood on ectomycorrhizal colonisation of old-growth oak forests, *Forests*, 2019, vol. 10, p. 480. https://doi.org/10.3390/f10060480

Ordynets, O., New records of corticioid fungi with heterobasidia from Ukraine, *Turk. J. Bot.*, 2012, vol. 36, pp. 590–602. https://doi.org/10.3906/bot-1109-1

Orlov, D.S., *Gumusovye kisloty pochv i obshchaya teoriya gumifikatsii* (Humic Acids of Soils and General Theory of Humification), Moscow: Mosk. Gos. Univ., 1990.

Oudemans, C.A.J.A., Contributions á la flore mycologique des Pays-Bas. XVIII, *Nederlandsch Kruidkundig Archief*, 1902, vol. 2, no. 3, pp. 633–781.

Palfner, G., Charakterisierung und Identifizierung einiger Ektomykorrhizen an Eiche (*Quercus robur* L.) in Slowenien, *Diploma Thesis*, München: Univ. Press, 1994.

Palfner, G., Quercirhiza squamosa, in *Colour Atlas of Ectomycorrhizae*, Schwabisch Gmund: Einhorn Verlag, 1995a, p. 86.

Palfner, G., *Xerocomus subtomentosus*, in *Colour Atlas of Ectomycorrhizae*, Schwabisch Gmund: Einhorn Verlag, 1995b, p. 90.

Palfner, G., *Lactarius chrysorrheus*, in *Colour Atlas of Ectomycorrhizae*, Schwabisch Gmund: Einhorn Verlag, 1998, p. 121.

Palfner, G. and Agerer, R., Sind die Ektomykorrhizen von *Xerocomus subtomentosus* und *X. armeniacus* unterscheidbar?, *Z. Mykol.*, 1995, vol. 61, no. 1, pp. 45–58.

Palfner, G. and Agerer, R., Die Ektomykorrhizen von *Lactarius chrysorrheus* und L. serifluus an *Quercus robur, Sendtnera*, 1996, vol. 3, pp. 119–136.

Pârvu, M., *Bolile Plantelor Forestiere (Ghid Practic de Fitopatologie)*, Cluj-Napoca: Ed. Presa Universitară Clujeană, 2000.

Persoon, C.H., Neuer versuch einer systematischen eintheilung der scwämme, *Neues Magazin für die Botanik in ihrem ganzen Umfange*, 1794, vol. 1, pp. 63–80.

Persoon, C.H., *Observationes Mycologicae*, Leipzig, 1796, vol. 1.

Persoon, C.H., *Observationes Mycologicae*, Leipzig, 1799, vol. 2.

Persoon, C.H., *Commentarius, Schaefferi Fungorum Bavariae Indigenorum Icones Pictas, Differentiis Specificis etc. Illustrans*, Erlangen, 1800.

Persoon, C.H., *Synopsis Methodica Fungorum*, Gotting, 1801.

Phillips, A., Alves, A., Correia, A., and Luque, J., Two new species of *Botryosphaeria* with brown, 1-septate ascospores and *Dothiorella anamorphs, Mycologia*, 2005, vol. 97, no. 2, pp. 513–529.

Phillips, D.H. and Burdekin, D.A., Diseases of oak (*Quercus* spp.), in *Diseases of Forest and Ornamental Trees*, London: Palgrave Macmillan, 1982. https://doi.org/10.1007/978-1-349-06177-8_10

Pilát, A., *Houby Ceskoslovenska Vesvem Zivotm'm Prostredi*, Praha: Academia, 1969, p. 90.

Pillukat, A., Vergleichende Untersuchungen der Ektomykorrhizen von *Russula ochroleuca* und *Paxillus involutus* an Verschiedenen Baumarten, *Diploma Thesis*, München: Univ. Press, 1991.

Popov, E.S. and Volobuev, S.V., New data on wood-inhabiting macromycetes in key protected areas of the southwestern part of the non-chernozem zone, *Mikol. Fitopatol.*, 2014, vol. 48, no. 4, pp. 231–239.

Popov, E.S., Kovalenko, A.E., Gapienko, O.S., et al., *Mikobiota Belorussko-Valdaiskogo poozer'ya* (Mycobiota of the Belarusian-Valdai Lake District), Moscow: KMK, 2013.

Postanovleniye Pravitel'stva RF ot 09.12.2020 № 2047 "Ob utverzhdenii Pravil sanitarnoi bezopasnosti v lesakh" (Resolution of the Government of the Russian Federation No. 2047 "On Approval of the Rules of Sanitary Safety in Forests" Dated December 9, 2020), 2020.

Prikaz Ministerstva prirodnykh resursov i ekologii Rossiiskoi Federatsii ot 09.11.2020 g. № 910 "Ob utverzhdenii Poryadka provedeniya lesopatologicheskikh obsledovanii i formy akta lesopatologicheskogo obsledovaniya" (Order of the Ministry of Natural Resources and Ecology of the Russian Federation No. 910 "On Approval of the Procedure for Conducting Forest Pathological Surveys and the Form of the Forest Pathological Survey Report" Dated November 9, 2020), 2022.

Primahana, G., Narmani, A. and Surup, F., Five tetramic acid derivatives isolated from the Iranian fungus *Colpoma quercinum, Biomolecules*, 2021, vol. 11, p. 783. https://doi.org/10.3390/biom11060783

Przybył, K., Fungi and minerals occurring in heartwood discoloration in *Quercus robur* trees, *Acta Soc. Bot. Pol.*, 2006, vol. 76, no. 1, pp. 55–60.

Raidl, S., Scattolin, L. and Agerer, R., *Gyroporus castaneus* (Bull.: Fr.) Quél. + *Quercus robur* L., *Descriptions of Ectomycorrhizae*, 2006, vol. 9/10, pp. 39–44.

Ray, J., *Synopsis Methodica Stirpium Brittanicum*, London, 1690.

Rebentisch, J.F., *Index Plantarum Circum Berolinum Sponte Nascentium Adiectis Aliquot Fungorum Descriptionibus*, Berlin, 1805.

Rostovtsev, S.A., *Raionirovanie perebrosok zheludei duba chereshchatogo* (Zoning of Acorn Transfers of English Oak), Voronezh, 1962.

Roumeguère, C. and Saccardo, P.A., Reliquiae mycologicae Libertianae. Series Altera, *Revue Mycologique*, 1881, vol. 3, no. 11, pp. 39–59.

Ruppius, H.B., *Flora Jenensis*, Frankfurt, 1718.

Saccardo, P.A., Fungi Italici autographice delineati a Prof. P.A. Saccardo, *Michelia*, 1877, vol. 1, no. 1, pp. 73–100.

Saccardo, P.A., Fungi novi ex herbario professoris Doct. P. Magnus Berolinensis, *Michelia*, 1878a, no. 1, pp. 117–132.

Saccardo, P.A., Fungi veneti novi vel critici, *Michelia*, 1878b, no. 1, pp. 133–221.

Saccardo, P.A., Sylloge Sphaeropsidearum et Melanconiearum omnium hucusque cognitarum, *Sylloge Fungorum*, 1884, vol. 3, pp. 1–840.

Saccardo, P.A., Notae mycologicae. Series X, *Ann. Mycol.*, 1908, vol. 6, no. 6, pp. 553–569.

Schäffer, J.C., *Fungorum Qui in Bavaria Et Palatinatu Circa Ratisbonam Nascuntur Icones*, Palm, 1774, vol. 4.

Schrader, H.A., *Spicilegium Florae Germanicae*, Hannover, 1794, pp. 1–194.

Selochnik, N.N., *Sostoyanie dubrav srednerusskoi lesostepi i ikh gribnye soobshchestva* (The State of Oak Forests of the Central Russian Forest-Steppe and Their Fungal Communities), Moscow: Inst. Lesovedeniya Ross. Akad. Nauk, 2015.

Selochnik, N.N. and Kaplina, N.F., Assessment of oak stands with regard to tree crown development in unfavourable conditions both anthropogenic (Moscow region) and climatic (forest-steppe), *Vestn. Mosk. Gos. Univ. Lesa, Lesn. Vestn.*, 2011, no. 4 (80), pp. 103–108.

Selochnik, N.N., Pashenova, N.V., Sidorov, E., et al., Ophiostomatoid fungi and their roles in *Quercus robur* die-back in Tellermann forest, Russia, *Silva Fennica*, 2015, vol. 49, no. 5, p. 1328. https://doi.org/10.14214/sf.1328

Sennikov, A.N., Phytogeography of northwest Russia (Saint-Petersburg, Pskov and Novgorod oblasts), in *Biogeografiya Karelii, Trudy Karel'skogo nauchnogo tsentra RAN* (Biogeography of Karelia, Proc. Karel. Sci. Center Russ. Acad. Sci.), Petrozavodsk, 2005, vol. 7, pp. 206–243.

Shabunin, D.A. and Semakova, T.A., Etiology of old-growth oak tree dieback in St. Petersburg parks in connection with the dynamics of surrounding tree stands, in *Zhizn' dvortsovykh sadov i parkov. Problemy sokhraneniya istoricheskikh nasazhdenii i bezopasnosti posetitelei* (Life of Palace Gardens and Parks. Problems of Preserving Historical Plantations and Visitor Safety), St. Petersburg, 2022, pp. 87–95.

Shishlyannikova, A.B., Xylosaprotrophic mycocomplex of common oak in the zone of cenooptimum and on the northern border of the range, *Cand. Sci. (Biol.) Dissertation*, St. Petersburg: St. Petersb. State Forest Eng. Univ., 2024.

Shishlyannikova, A.B. and Zmitrovich, I.V., English oak under different growing conditions: Phytopathological aspect, in *Lesa Rossii: politika, promyshlennost', nauka, obrazovanie, Mat. IX Vseros. nauch.-tekhn. Konf.* (Forests of Russia: Politics, Industry, Science, Education, Proc. IX All-Russ. Sci.-Tech. Conf.), St. Petersburg: S.-Peterb. Gos. Lesotech. Univ., 2024, pp. 506–509.

Shishlyannikova, A.B., Zarudnaya, G.I., and Zinchuk, T.M., Analysis of changes in the health conditions of memorial woody plants of the museum-reserve "Monrepos park," *Izv. S.-Peterb. Lesotekh. Akad.*, 2014, vol. 207, pp. 212–224.

Shishlyannikova, A.B., Zarudnaya, G.I., Popovichev, B.G., and Musolin, D.L., Diseases and stem pests in Babolovo Park in Pushkin, in *Dendrobiontye bespozvonochnye zhivotnye i griby i ikh rol' v lesnykh ekosistemakh (XI Chteniya pamyati O.A. Kataeva)* (Dendrobiontic Invertebrates and Fungi and Their Role in Forest Ecosystems (XI Readings in Memory of O.A. Kataev)), St. Petersburg: S.-Peterb. Gos. Lesotech. Univ., 2020, pp. 369–370.

Shishlyannikova, A.B., Zmitrovich, I.V. and Zarudnaya, G.I., Micromycetes Rossicae: Chorological and taxonomical notes. 6. *Diatrypella quercina* (Xylariales, Ascomycota) in Russia, *Mikol. Fitopatol.*, 2023a, vol. 57, no. 5, pp. 378–382. https://doi.org/10.31857/S0026364823050082

Shishlyannikova, A.B., Zmitrovich, I.V., Zarudnaya, G.I., et al., Results of mycological examination of the shoot system of "Irinovsky oak" (Leningrad oblast, Russia), *Mikol. Fitopatol.*, 2023b, vol. 57, no. 6, pp. 456–461. https://doi.org/10.31857/S0026364823060120

Shishlyannikova, A.B., Danilov, D.A., Zmitrovich, I.V., and Bacherikov, I.V., Phytopathological characteristics of pedunculate oak under different growing conditions, *Izv. S.-Peterb. Lesotekh. Akad.*, 2024, vol. 250, pp. 116–143.
https://doi.org/10.21266/2079-4304.2024.250.116-143

Shishlyannikova, A.B., Zmitrovich, D.A., and Bacherikov, I.V., Forest and meadow groups of English oak ecotypes and their phytopathological characteristics, *Izv. S.-Peterb. Lesotekh. Akad.*, 2025, vol. 251 (in press).

Shubin, V.I., The role of symbiosis and nitrogen content in soil for ectomycorrhizal fungi fruiting. II. The role of nitrogen, *Mikol. Fitopatol.*, 2010, vol. 44, no. 4, pp. 352–358.

Sidel'nikova, M.V., Tobias, A.V., and Vlasov, D.Yu., Ascomycetous fungi (teleomorphs) on trees and shrubs in the suburban parks of St. Petersburg, *Mikol. Fitopatol.*, 2018, vol. 52, no. 4, pp. 259–266.

Sieber, T.N., Kowalski, T. and Holdenrieder, O., Fungal assemblages in stem and twig lesions of *Quercus robur* in Switzerland, *Mycol. Res.*, 1995, vol. 99, no. 5, pp. 534–538.
https://doi.org/10.1016/S0953-7562(09)80709-0

Song, J. and Cui, B.K., Phylogeny, divergence time and historical biogeography of *Laetiporus* (Basidiomycota, Polyporales), *BMC Evol. Biol.*, 2017, vol. 17, p. 102.
https://doi.org/10.1186/s12862-017-0948-5

Storozhenko, V.G., Kotkova, V.M., and Chebotarev, P.A., Dynamics of transformation of native oak forests and wood-destroying basidial fungi of Tellerman forest, *Lesn. Vestn.*, 2014, vol. 4, pp. 77–85.

Sulzbacher, M.A., Grebenc, T., Garcia, M.A., et al., Molecular and morphological analyses confirm *Rhizopogon verii* as a widely distributed ectomycorrhizal false truffle in Europe, and its presence in South America, *Mycorrhiza*, 2016, vol. 26, no. 5, pp. 377–388.

Sunhede, S. and Vasiliauskas, R., Ecology and decay pattern of *Phellinus robustus* in old-growth *Quercus robur, Karstenia*, 2002, vol. 42, pp. 1–11.

Sutton, B.C., *Tubakia* nom. nov., *Trans. Br. Mycol. Soc.*, 1973, vol. 60, no. 1, pp. 164–165.

Svetasheva, T.Yu., Macromycetes of the state museum-reserve "Kulikovo Pole" vicinities, *Raznoobrazie Rastitel'nogo Mira*, 2021, no. 4 (11), pp. 61–79.

Sydow, H. and Sydow, P., Novae fungorum species, *Ann. Mycol.*, 1915, vol. 13, no. 1, pp. 35–43.

Tanahashi, Y. and Takahashi, T., Sterol constituents of *Daedalea quercina* L. (Fr.), *Bull. Chem. Soc. Jpn.*, 1966, vol. 39, no. 4, pp. 848–849.

Tarkka, M.T., Grams, T.E.E. and Angay, O., Ectomycorrhizal fungus supports endogenous rhythmic growth and corresponding resource allocation in oak during various below- and aboveground biotic interactions, *Sci. Rep.*, 2021, vol. 11, p. 23680.
https://doi.org/10.1038/s41598-021-03132-y

Tăut, I., Moldovan, M., Șimonca, V., et al., Control of pathogen Erysiphe alphitoides present in forest crops in current climatic conditions, *Microbiol. Res.*, 2024, vol. 15, pp. 1441–1458.
https://doi.org/10.3390/microbiolres15030097

Tedersoo, L., Magurno, F., Alkahtani, S. and Mikryukov, V., Phylogenetic classification of arbuscular mycorrhizal fungi: New species and higher-ranking taxa in Glomeromycota and Mucoromycota (class Endogonomycetes), *MycoKeys*, 2024, vol. 107, pp. 273–325.
https://doi.org/10.3897/mycokeys.107.125549

The Fungal Community. Its Organization and Role in the Ecosystem, Dighton, J., White, J.F., and Oudemans, P., Eds., London: Taylor and Francis, 2005, 3rd ed.

Tian, M., Zhao, P. and Li, G., In depth natural product discovery from the basidiomycetes *Stereum* species, *Microorganisms*, 2020, vol. 8, p. e1049.
https://doi.org/10.3390/microorganisms8071049

Tournefort, J.P., *Institutiones Rei Herbariae*, Paris, 1700.

Trollip, C., Carnegie, A.J., Anderson, C.M.T., et al., Response to the detection of *Rugonectria castaneicola* and *Rugonectria wingfieldii* sp. nov. on *Quercus* in Australia, *Fungal Syst. Evol.*, 2024, vol. 13, pp. 123–130.

Tsarlunga, V.V., Cyclicity of accelerated oak mortality, *Lesn. Vestn.*, 2002, no. 2, pp. 31–35.

Tulasne, L.R., Note sur l'appareil reproducteur multiple des Hypoxylées (DC.) ou Pyrénomycètes (Fr.), *Ann. Sci. Nat., Bot., Sér. 4*, 1856, vol. 5, pp. 107–118.

Ţura, D., Zmitrovich, I.V., Wasser, S.P., et al., *Biodiversity of Heterobasidiomycetes and Non-Gilled Hymenomycetes (Former Aphyllophorales) of Israel*, Ruggell: A.R.A. Gantner Verlag K.-G., 2011.

Turczański, K., Bełka, M., Spychalski, M., et al., Resistance inducers for the protection of pedunculate oak (*Quercus robur* L.) seedlings against powdery mildew *Erysiphe alphitoides, Plants*, 2023, vol. 12, p. 635.
https://doi.org/10.3390/plants12030635

Vakin, A.T., *Gribnye bolezni i drugie poroki dubrav* (Fungal Diseases and Other Defects of Oak Forests), Moscow: Goslestekhizdat, 1932.

Vakin, A.T., Phytopathological condition of oak forests of Tellermanovsky forest, *Tr. Inst. Lesa Akad. Nauk SSSR*, 1954, vol. 16, pp. 5–109.

Vasilevich, V.I. and Bibikova, T.V., Broad-leaved forests of the northwest of European Russia. I. Types of oak forests, *Bot. Zh.*, 2001, vol. 86, no. 7, pp. 88–101.

Vasil'kov, B.P., Systematic review of aspen *Krombholzia aurantiaca* (Roques) Gilb. and its forms found in the USSR, *Bot. Mater. Inst. Sporovykh Rastenii Gl. Bot. Sada RSFSR*, 1956, vol. 11, pp. 134–140.

Vasil'kov, B.P., *Belyi grib. Opyt monografii odnogo vida* (White Mushroom. Experience of Monograph of One Species), Moscow: Nauka, 1966.

Vedenyapina, E.G., Volchanskaya, A.V., Malysheva, V.F., et al., Soil-borne species of genus *Phytophthora* in the Botanical Garden of Biol. Inst. Russ. Acad. Sci. I. First records of *Ph. citricola, Ph. plurivora* and *Ph. quercina* in Russia, *Mikol. Fitopatol.*, 2014, vol. 48, no. 4, pp. 261–271.

Velíšek, J. and Cejpek, K., Pigments of higher fungi—A review, *Czech J. Food Sci.*, 2011, vol. 29, pp. 87–102.

Verkley, G.J.M., Crous, P.W., Groenewald, J.Z., et al., *Mycosphaerella punctiformis* revisited: Morphology, phylogeny, and epitypification of the type species of the genus *Mycosphaerella* (Dothideales, Ascomycota), *Mycol. Res.*, 2004, vol. 108, pp. 1271–1282.

Vikhrov, V.E., *Stroenie i fiziko-mekhanicheskie svoistva drevesiny duba* (Structure and Physical-Mechanical

Properties of Oak Wood), Moscow: Akad. Nauk SSSR, 1954.

Voiry, H., Classification morphologique des ectomycorhizes du chene et du hetre dans le nord-est de la France, *Eur. J. For. Pathol.*, 1981, vol. 11, pp. 284–299.

Volkova, E.A., Isachenko, G.A., and Khramtsov, V.N., *Priroda zakaznika "Severnoe poberezh'e Nevskoi guby"* (Nature of the "Northern Shore of the Neva Bay" Reserve), St. Petersburg, 2020.

von Arx, J.A., Revision der zu *Gloeosporium* gestellten Pilze, *Verhandelingen der Koninklijke Nederlandse Akademie van Wetenschappen. Afdeeling Natuurkunde, Sectie 2*, 1957, vol. 51, no. 3, pp. 1–153.

von Höhnel, F. and Litschauer, V., Beiträge zur Kenntnis der Corticieen: II, *Sitzungsber. Akad. Wiss. Wien, Math.-Naturwiss. Kl., Abt. 1*, 1907, vol. 116, pp. 739–852.

von Moesz, G., Mykologiai közlemények. IV, *Bot. Kozl.*, 1921, vol. 19, pp. 44–66.

Vostochnoevropeiskie lesa: istoriya v golotsene i sovremennost' (East European Forests: History in the Holocene and Present), Smirnova, O.V., Ed., Moscow: Nauka, 2004, vols. 1–2.

Walde, J.S.L., An oak seedling disease caused by *Rosellinia quercina* Hartig, *Int. J. For. Res.*, 1930, vol. 4, no. 1, pp. 1–6.

Walter, M., Stevenson, O.D., Amponsah, N.T., et al., Sensitivity of *Neonectria ditissima* to carbendazim fungicide in New Zealand, *N. Z. Plant Prot.*, 2014, vol. 67, pp. 133–138. https://doi.org/10.30843/nzpp.2014.67.5743

Weber, R.W.S., Biology and control of the canker fungus *Neonectria ditissima* (syn. *N. galligena*) from a Northwestern European perspective, *Erwerbs-Obstbau*, 2014, vol. 56, pp. 95–107. https://doi.org/10.1007/s10341-014-0210-x

Westendorp, G.D., Quatrième notice sur quelques cryptogames récemment découvertes en Belgique, *Bull. Séances Cl. Sci. Acad. R. Sci. Lett. Beaux Arts Belg.*, 1854, vol. 21, no. 2, pp. 229–246.

Wolfe, B.E. and Pringle, A., Geographically structured host specificity is caused by the range expansions and host shifts of a symbiotic fungus, *ISME J.*, 2012, vol. 6, no. 4, pp. 745–755. https://doi.org/10.1038/ismej.2011.155

Wu, F., Zhou, L.W. and Yang, Z.L., Resource diversity of Chinese macrofungi: Edible, medicinal and poisonous species, *Fungal Diversity*, 2019, vol. 98, no. 1, pp. 1–76. https://doi.org/10.1007/s13225-019-00432-7

Yurchenko, E., Krasowska, M., Kowczyk-Sadowy, M., et al., Investigation of the possible antibacterial effects of corticioid fungi against different bacterial species, *Int. J. Mol. Sci.*, 2025, vol. 26, p. e3292. https://doi.org/10.3390/ijms26073292

Zeb, M. and Lee, C.H., Medicinal properties and bioactive compounds from wild mushrooms native to North America, *Molecules*, 2021, vol. 26, no. 2, p. 251. https://doi.org/10.3390/molecules26020251

Zhukova, E.A., Morozova, O.V., Volobuev, S.V., and Bryantseva, Yu.S., *Basidiomycetous macrofungi* and their influence on the state of green plantations in the Russian Museum gardens (St. Petersburg), *Mikol. Fitopatol.*, 2017, vol. 51, no. 6, pp. 328–339.

Zmitrovich, I.V., Editor's preface, in *Vysshie bazidiomitsety lesnykh i lugovykh ekosistem Zhigulei* (Higher Basidiomycetes of Forest and Meadow Ecosystems of Zhiguli), Moscow: KMK, 2008a, pp. 1–3.

Zmitrovich, I.V., *Semeistva atelievye i amilokortitsievye* (Atheliaceae and Amylocorticiaceae Families), St. Petersburg: KMK, 2008b.

Zmitrovich, I.V., Middle taiga of the Karelian Isthmus: Zonal, intrazonal and extrazonal phenomena, *Vestn. Ekol., Lesoved. Landshaftoved.*, 2011, no. 12, pp. 54–76.

Zmitrovich, I.V. and Shishlyannikova, A.B., Xylosapotrophic fungi associated with *Quercus robur* within the northeastern part of its range (Central and Northwestern Regions of Russia), *Biol. Bull. Rev.*, 2025. https://doi.org/10.1134/S2079086425600018

Zmitrovich, I.V. and Vasil'ev, N.P., Fungi—pathogens of tree species in St. Petersburg conditions. 1. Oak mycoses, *Nov. Sist. Nizshikh Rast.*, 2006, vol. 40, pp. 121–131.

Zmitrovich, I.V., Vasil'ev, N.P., and Malysheva, V.F., Ecotypic differentiation of key species of xylotrophic basidiomycetes on introduced trees in boreal zone, *Turczaninowia*, 2011, vol. 14, no. 1, pp. 81–89.

Zmitrovich, I.V., Wasser, S.P. and Ţura, D., Wood-inhabiting fungi, in *Fungi from Different Substrates*, Misra, J.K., Tewari, J.P., Deshmukh, S.K., and Vágvölgyi, C., Eds., New York: CRC Press, Taylor and Francis Group, 2015, pp. 17–74.

Zmitrovich, I.V., Kalinovskaya, N.I., and Myasnikov, A.G., Additional data report on the mycobiota of "The Northern Coast of the Neva Bay" Nature Sanctuary: Xylotrophic Basidiomycetes of the park at the "Blizhnie Dubki" estate, *Mikol. Fitopatol.*, 2020, vol. 54, no. 3, pp. 228–232.

Zmitrovich, I.V., Bondartseva, M.A., Arefyev, S.P., and Perelygin, V.V., Professor Solomon P. Wasser and Medicinal Mushroom Science with a special attention to the problems of mycotherapy in oncology, *Int. J. Med. Mushrooms*, 2022a, vol. 24, no. 1, pp. 13–26. https://doi.org/10.1615/IntJMedMushrooms.2021041831

Zmitrovich, I.V., Perelygin, V.V., and Zharikov, M.V., *Nomenclature and Rank Correlation of Higher Taxa of Eukaryotes: Monograph*, Moscow: INFRA-M, 2022b.

Zmitrovich, I.V., Arefiev, S.P., Kapitonov, V.I., et al., Substrate ecology of wood-inhabiting basidiomycetes, in *Ecology of Macrofungi*, Sridhar K.R. and Deshmukh, S.K., Eds., Boca Raton: CRC Press, 2023, pp. 179–221.

Zvyagintsev, V.B., Blintsov, A.I., Kozel, A.V., Kukhta, V.N., Sazonov, A.A., Seredich, M.O., and Khvasko, A.V., *Zashchita lesa* (Forest Protection), Minsk: Beloruss. Gos. Tech. Univ., 2019.

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