

MACROFUNGI IN STANDS OF THE ENDEMIC PINE
PINUS PEUCE AS INFERRED FROM MORPHOLOGICAL
AND MOLECULAR DATA

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Abstract

Pinus peuce (Balkan, Macedonian or Molika pine) is an endemic tree for the Balkans and a Tertiary relict, one of the two European five-needled pines of the subgenus *Strobus* (white pines). This work summarizes the data on macrofungal diversity in natural forests and artificial plantations of Macedonian pine in Bulgaria, based on three year survey of epigeous and hypogeous fungi in selected sampling plots, and combining morphology-based and molecularly inferred identification. The study registered 190 species in total. Higher diversity of macrofungi was recorded on sampling plots in natural stands compared to artificial plantings. Nine species are reported for the first time for the Bulgarian mycobiota. The paper provides the first public set of sequences of macrofungi of *P. peuce* stands, comprising 62 accessions.

Key words: Balkan Peninsula, ascomycetes, basidiomycetes, biogeography, DNA-barcoding, nrITS, macromycetes

Introduction. *Pinus peuce* Griseb. is a member of *Pinus* subgenus *Strobus* (D. Don) Lemmon, encompassing the so-called white pines, also colloquially known as five-needled pines [1]. It is a Tertiary relict, endemic for the Balkan Peninsula, where it has relatively limited range, building stands in some of the

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highest mountains in Albania, Bosnia and Herzegovina, Bulgaria, Greece, Montenegro, North Macedonia, and Serbia [1,2]. In Bulgaria its natural range is restricted to the highest mountains, namely Central Stara Planina, Pirin, Rila and Rodopi, where it builds up monodominant or mixed stands with other conifers [3]. The habitats dominated by this pine are deemed to be ‘endangered’ at national level in this country [3].

As one of the only two European five-needled pines, next to the Alpine-Carpathian *P. cembra* L., *P. peuce* attracted the attention of several mycologists, although this interest developed relatively recently and the number of focused studies on its fungi is still limited. Data on macrofungi of Macedonian pine stands were published from North Macedonia, where the locus classicus (Pelister Mt.) of the species is situated [1,4–6]. Further on, some data on larger fungi from stands with this pine have been published from Bulgaria [7–9] and a list of characteristic fungi of *P. peuce* habitats was presented [3]. Large parts of the information in those publications were gathered during relatively short field trips and part of them refer to mixed stands with Macedonian pine. Very little is known about the macromycetes of artificial *P. peuce* plantations, with merely one study from Bulgaria and one from Poland [8,10]. Besides, no focused studies with application of DNA methods are known so far and a limited number of sequences of fungi of *P. peuce* was obtained in the context of other publications [11].

Materials and methods. The present study was held on selected permanent sampling plots of 10 000 m² in stands of *P. peuce* in Pirin, Rila, Stara Planina and Vitosha Mts. Coordinates and other data on the sampling plots are presented in Table 1. In the list below, the numbers after species names refer to those plots. Sampling was done between June and November during three consecutive years, starting in 2020 and held in accordance with previously published protocol [12]. Epigeous and hypogeous fungi were sampled by random transects during each visit, covering the entire plot area; the search for hypogeous fungi was done with the aid of trained dogs. The material was documented in the field and is preserved in air-dried state in the Mycological Collection of the Institute of Biodiversity and Ecosystem Research (SOMF). The identification of the collected macrofungi was achieved with the use of broad range of contemporary monographs, keys and atlases. The names of fungi in the text below follow the *Index Fungorum* database (<http://www.indexfungorum.org/>).

DNA extraction, amplification and sequencing of the nrITS region were outsourced to ALVALAB (Spain) and were performed in accordance with the protocol communicated by the laboratory and presented in previously published work [13]. In addition, small number of LSU and *tef-1α* sequences was also produced. The obtained sequences were subjected individually to BLAST search of the *GenBank* database [14] and the resulting alignments were critically examined in order to achieve or confirm taxonomic assignment. In a few cases when unambiguous identification could not be reached by BLAST alignments, phylogenetic analysis

T a b l e 1

Sampling plots in stands of *Pinus peuce*

No	Mountain and plot name	Coordinates	Age* (yrs)	Elev. (m)	Tree composition and stand origin
1	Pirin Mts Vihren	41°45.715'N 23°25.017'E	140	1969	PP(100%) Natural stand
2	Rila Mts Malyovitsa	42°12.538'N 23°23.402'E	100	1760	PP(50%), PS(30%), PA(20%) Natural stand
3	Rila Mts Treshtenik	42°04.930'N 23°37.082'E	90	1915	PP(80%), PS(10%), PA(10%) Natural stand
4	Vitosha Mts Goli Vrah	42°35.518'N 23°17.557'E	80	1814	PP(90%), PA(10%) Artificial planting
5	Balkan Mts Petrohan	43°06.857'N 23°08.007'E	90	1472	PP(70%), PS(20%), PA(10%) Artificial planting

* In case of mixed stands the age refers to the age in years of the dominant species, *Pinus peuce*. Abbreviations of tree species, used in the last column: “PP” – *Pinus peuce*, “PS” – *Pinus sylvestris*, “PA” – *Picea abies*.

of suitable datasets (not shown) was performed on the portal *Phylogeny.fr* [15]. In the list below asterisked numbers indicate the plots from where the sequenced materials were collected; these are followed by the accession numbers of the sequences in *GenBank* (beginning with the prefix ‘OQ’).

Results.

List of the species. Ascomycetes: *Choiromyces meandriiformis* Vittad. – 2*, OQ398590; *Elaphomyces granulatus* Fr. – 3; *Gyromitra esculenta* Fr. – 2; *Helvella corium* (O. Weberb.) Masee – 4; *H. elastica* Bull. – 4; Basidiomycetes: *Agaricus augustus* Fr. – 2; *A. sylvaticus* Schaeff. – 2; *A. sylvicola* (Vittad.) Lév. – 1,2; *Aleurodiscus amorphus* (Pers.) J. Schrot. – 2; *Amanita* cf. *brunneofulginea* – 4; *A. gemmata* (Fr.) Bertill. – 1,2,3,4; *A. muscaria* (L.) Pers. – 3,4,5; *A. rubescens* Pers. – 2,4; *A. spissa* (Fr.) P. Kumm. – 2,3,4; *A. submembranacea* (Bon) Gröger – 1,2,3,4,5; *Amylocystis lapponica* (Romell) Singer – 2; *Armillaria ostoyae* (Romagn.) Herink – 1,4*, OQ398576; *Auriscalpium vulgare* Gray – 2; *Baeospora myosura* (Fr.) Singer – 1,4; *Boletus edulis* Bull. – 1,2,3,5; *B. pinophilus* Pilát & Dermek – 2,3,5; *Bovista plumbea* Pers. – 1,3; *Calocera cornea* (Batsch) Fr. – 2,3,4,5; *C. viscosa* (Pers.) Fr. – 2,3,4,5; *Cantharellus cibarius* Fr. – 1*,2, OQ388266; *Chalciporus piperatus* (Bull.) Bataille – 2; *Chlorophyllum rhacodes* (Vittad.) Vellinga – 2; *Chroogomphus helveticus* (Singer) M. M. Moser – 1*,2,3,4,5, OQ398587; *C. mediterraneus* (Finschow) Vila et al. – 2*, OQ456634; *Clavulina rugosa* (Bull.) J. Schröt. – 4*, OQ398559; *Climacocystis borealis* (Fr.) Kotl. & Pouzar – 2*, OQ398588; *Clitocybe fragrans* (With.) P. Kumm. – 1,2,4; *C. nebularis* (Batsch) P. Kumm. – 2,3; *C. odora* (Bull.) P. Kumm. – 2,4; *C.*

vibecina (Fr.) Quél. – 1,2,3,5; *Clitopilus prunulus* (Scop.) P. Kumm. – 2; *Collybia cirrhata* (Schumach.) Quél. – 3,5; *Collybiopsis ramealis* (Bull.) Millsp. – 2; *Coprinopsis nivea* (Pers.) Redhead et al. – 2; *Cortinarius acutus* (Pers.) Fr. – 1; *C. croceus* (Schaeff.) Gray – 2; *C. jacobii-langei* Bidaud – 2*, OQ398581; *C. malicorius* Fr. – 2; *C. mucosus* (Bull.) J. Kickx f. – 2,3; *C. sommerfeltii* Høil. – 2*, OQ398585; *C. variegatus* (Pers.) Fr. – 3; *C. varius* (Schaeff.) Fr. – 3; *C. venetus* (Fr.) Fr. – 2*, OQ398572; *Cyathus striatus* (Huds.) Willd. – 2; *Cystoderma amianthinum* (Scop.) Fayod – 1,3,4; *Cystodermella granulosa* (Batsch) Harmaja – 1; *Dacrymyces stillatus* Nees. – 2,3,4,5; *Deconica coprophila* (Bull.) P. Karst. – 2; *D. merdaria* (Fr.) Noordel. – 2; *Ditiola peziziformis* (Lév.) D.A. Reid – 2; *Entoloma cetratum* (Fr.) M.M. Moser – 4; *E. hirtipes* (Schumach.) M.M. Moser – 2,3; *E. vernum* S. Lundell – 1,2,3; *Fomitopsis pinicola* (Sw.) P. Karst. – 2,3,4,5; *Galerina marginata* (Batsch) Kühner – 2,5; *Geastrum fimbriatum* Fr. – 2; *Gloeophyllum abietinum* (Bull.) P. Karst. – 2; *G. sepiarium* (Wulfen) P. Karst. – 1,2,4,5; *Gomphidius glutinosus* (Schaeff.) Fr. – 2,3; *Guepiniopsis* cf. *estonica* – 2; *Gymnopilus penetrans* (Fr.) Murrill – 2,5; *Gymnopus androsaceus* (L.) Della Magg. & Trassin. – 2,3,5; *G. dryophilus* (Bull.) Murrill – 1,2,3,4,5; *Heterobasidium annosum* (Fr.) Bref. – 3; *Hydnum repandum* L. – 2,3,4*,5, OQ398557; *H. rufescens* Pers. – 2*, OQ398575; *Hygrocybe conica* s. l. – 2*, OQ398606; *Hygrophoropsis aurantiaca* (Wulfen) Maire – 2; *Hygrophorus agathosmus* (Fr.) Fr. – 2*, OQ398568; *H. cf. persicolor* – 2*, OQ398580; *H. discoideus* (Pers.) Fr. – 1; *Hypholoma capnoides* (Fr.) P. Kumm. – 2,3; *H. fasciculare* (Huds.) P. Kumm. – 2,5; *Imleria badia* (Fr.) Vizzini – 1,2*,3,5, OQ398556; *Infundibulicybe gibba* (Pers.) Harmaja – 1*,2,3,4, OQ398592; *Inocybe asterospora* Quél. – 1; *I. geophilla* (Pers.) P. Kumm. – 2*,3,4,5, OQ398594; *I. lilacina* (Peck) Kauffman – 2*,3, OQ398578; *Inosperma maculatum* (Boud.) Matheny & Esteve-Rav. – 1; *Ischnoderma benzoinum* (Wahlenb.) P. Karst. – 1; *Laccaria amethystina* Cooke – 2,5; *L. bicolor* (Maire) P.D. Orton – 1,2*, OQ398565, OQ398583; *L. laccata* (Scop.) Cooke – 3; *L. 'macrocystidia'* – 2*, OQ398566; *Lactarius aurantiacus* (Pers.) Gray – 1*,2*,3*,4, OQ398573, OQ398574, OQ398586; *L. borzianus* (Cavara) Verbeken & Nuytinck – 1,2*, OQ398554; *L. deliciosus* (L.) Gray – 2,3,4; *L. deterrimus* Gröger – 2,4*, OQ398570; *L. picinus* Fr. – 2,3,4*, OQ398555; *L. piperatus* (L.) Pers. – 2; *L. rufus* (Scop.) Fr. – 1,3*,5, OQ398561; *L. scrobiculatus* (Scop.) Fr. – 2; *L. zonarioides* Kühner & Romagn. – 1*,4, OQ398569; *Laetia cutis cristata* (Schaeff.) Audet – 2; *Lepiota clypeolaria* (Bull.) P. Kumm. – 2; *Lepista nuda* (Bull.) Cooke – 1,2,5; *Leucocortinarius bulbiger* (Alb. & Schwein.) Singer – 1,2; *Leucogyrophana mollusca* (Fr.) Pouzar – 5; *Leucopaxillus gentianeus* (Quél.) Kotl. – 2; *Lycoperdon excipuliforme* (Scop.) Pers. – 1,2,3,5; *L. molle* Pers. – 2,4,5; *L. perlatum* Pers. – 2,3,4,5; *L. pyriforme* Schaeff. – 2,5; *Macrolepiota fuliginosa* (Barla) Bon – 1,2; *Malloocybe terrigena* (Fr.) Matheny et al. – 1; *Melanoleuca* cf. *subpulverulenta* – 5*, OQ398593; *Melanoleuca melaleuca* (Pers.) Murrill – 4; *Mycena aurantiomarginata* (Fr.) Quél. – 2; *M. capillar-*

ipes Peck – 1,2,3; *M. crocata* (Schrad.) P. Kumm. – 2; *M. epipterygia* (Scop.) Gray – 1,2,3,5; *M. galopus* (Pers.) P. Kumm. – 4; *M. pura* s. l. – 2,3,4,5; *M. rosea* (Schumach.) Gramberg – 5; *M. rosella* (Fr.) P. Kumm. – 1,2,3,4,5; *Mycetinis alliaceus* (Jacq.) A.W. Wilson & Desjardin – 2; *Myxomphalia maura* (Fr.) Hora – 2,4; *Neoboletus erythropus* (Pers.) C. Hahn – 2,3; *Onnia tomentosa* (Fr.) P. Karst. – 1; *Panaeolus semiovatus* (Sowerby) S. Lundell & Nannf. – 2; *Paragymnopus perforans* (Hoffm.) J.S. Oliveira – 1,2,3,4,5; *Paralepista flaccida* (Sowerby) Vizzini – 2,5; *Paxillus involutus* (Batsch) Fr. – 2,4; *Phaeoclavulina abietina* (Pers.) Giachini – 2; *Phaeocollybia festiva* (Fr.) R. Heim – 2,4; *Phlegmacium balteatum* (Fr.) A. Blytt – 3*, OQ398558; *Pholiota flammans* (Fr.) P. Kumm. – 4; *P. pinicola* Jacobsson – 4; *P. spumosa* (Fr.) Singer – 2*, OQ398597; *Polyporus melanopus* (Pers.) Fr. – 2; *Porphyrellus porphyrosporus* (Fr. & Hök) E.-J. Gilbert – 1*,2,4, OQ398562; *Protostropharia semiglobata* (Batsch) Redhead et al. – 2; *Pseudohydnum gelatinosum* (Scop.) P. Karst. – 1,2,3; *Ramaria aurea* (Schaeff.) Quél. – 1,3; *Rhizopogon salebrosus* s. l. – 1*, 5*, OQ398602, OQ398603, OQ398604, OQ398605; *Rhodocollybia butyracea* (Bull.) Lennox – 2,3,4,5; *Rhodophana nitellina* (Fr.) Larouz et al. – 2; *Rickenella fibula* (Bull.) Raithelh. – 2; *Russula adusta* (Pers.) Fr. – 3,5; *Russula amara* Kuhnra – 1,2*, OQ398584; *R. anthracina* Romagn. – 1*, OQ398551; *R. chloroides* (Krombh.) Bres. – 1*, OQ398563; *R. delica* s. lat. – 2,5; *R. foetens* (Pers.) Fr. – 3,5; *R. integra* (L.) Fr. – 1*,2,3,4,5, OQ398553; *R. mustelina* Fr. – 1,2*,4*,5, OQ398589, OQ398564; *R. ochroleuca* Fr. – 5*, OQ398567; *R. puellaris* s. l. – 2*, OQ398601; *R. rosea* Pers. – 2; *R. roseipes* Bres. – 1*,4, OQ398579; *R. torulosa* Bres. – 2; *R. turci* Bres. – 1*, OQ398591; *R. xerampelina* (Schaeff.) Fr. – 2,3; *Sarcodon imbricatus* (L.) P. Karst. – 2; *Skeletocutis amorphia* (Fr.) Kotl. & Pouzar – 2,4; *Sparassis crispa* (Wulfen) Fr. – 2*, OQ398560; *Stereum hirsutum* (Willd.) Gray – 1,2,3,4; *Strobilurus* sp. – 1, non-plot: Rila Mts, Panichishte area*, OQ398598, OQ402730; *S. stephanocystis* (Hora) Singer – 1,2,3,4*, OQ398550; *S. tenacellus* (Pers.) Singer – 2,3; *Stropharia aeruginosa* (Curtis) Quél. – 1,2,3,4; *Suillus americanus* (Peck) Snell – 1*,3,4, OQ398582, OQ402729, OQ411036; *S. bovinus* (L.) Roussel – 5; *S. granulatus* (L.) Roussel – 3,5; *S. luteus* (L.) Roussel – 3,5; *S. variegatus* (Sw.) Richon & Roze – 3,5; *Tapinella atrotomentosa* (Batsch) Šutara – 2; *T. panuoides* (Fr.) E.-J. Gilbert – 2; *Thaxterogaster turmalis* (Fr.) Niskanen & Liimat. – 3*, OQ398577; *Thelephora caryophyllea* (Schaeff.) Pers. – 3,5; *T. palmata* (Scop.) Fr. – 2; *T. terrestris* Ehrh. – 5; *Tremella mesenterica* Retz. – 2; *Tricholoma equestre* (L.) P. Kumm. – 1; *T. imbricatum* (Fr.) P. Kumm. – 2; *T. orirubens* Quél. – 4; *T. portentosum* (Fr.) Quél. – 1,2,3; *T. saponaceum* (Fr.) P. Kumm. – 2*,3, OQ398571; *T. terreum* (Schaeff.) P. Kumm. – 2*,3, OQ398552; *T. vaccinum* (Schaeff.) P. Kumm. – 1*,2,3, OQ398595; *T. virgatum* (Fr.) P. Kumm. – 2; *Tricholomopsis rutilans* s. l. – 2,4*, OQ398596; *Xerocomellus chrysenteron* (Bull.) Šutara – 1*,2,3, OQ398600; *Xerocomus ferrugineus* (Schaeff.) Alessio – 3,5*, OQ398599; *Xeromphalina campanella* (Batsch) Kühner & Maire – 1,2.

Discussion. A total of 190 species were registered during the study. Natural stands appeared to be richer, compared to artificial plantations, with 59 (plot 1), 69 (plot 3) and 135 species (plot 2) in the former, against 49 (plot 4) and 54 (plot 5) in the latter. Among the plots in natural forests, the one in the area of Malyovitsa (plot 2) is richest, with twice or more species. This plot has different stand composition and is the only one where trees other than *P. peuce* have 50% participation, while in the remaining sampling stands this figure does not exceed 30% (Table 1). We hypothesize that the observed higher diversity of macrofungi is at least partly driven by the diversity and abundance of different host trees. When pooled data from natural and artificial plots are compared, the former host 170 species versus twice less in the latter (85 species). Shared between the two types of plots are 67 species, of which almost half – 33 species are saprotrophs with different substrate specialisation, and the rest are ectomycorrhizal fungi. Should plot 2 is excluded and the pooled data for the remaining natural (plots 1 & 3) and artificial stands (plots 4 & 5) are examined, the plots in natural stands still harbour higher diversity (100 species) than those in artificial ones (85 species). Of the recorded species, 103 (54.2%) were only found in plots in natural forests, while merely 18 (9.5%) were recorded only on plots in artificial plantings.

A handful of species were found on all sampling plots and some of them were even common (Fig. 1a-c). Among these is *Chroogomphus helveticus* (Fig. 1b), species already outlined as a characterizing taxon for stands of *P. peuce* [4,16]. Other such common species appeared to be the saprotrophs *Gymnopus dryophilus*, *Mycena rosella*, *Paragymnopus perforans*, and the mycorrhizal *Russula integra*, which are, however, ubiquitous in coniferous forests in all studied areas. One species that drew attention during our study was *Amanita submembranacea* (Fig. 1a). It was detected on all plots and during all visits, even in unfavourable seasons, while in rainy periods it created characteristic aspect, dominating all other mycorrhizal fungi by the number of fruitbodies. This outlines it as one of the characteristic species of the stands of *P. peuce*, suggesting also a high degree of ecological plasticity and possible pioneer behaviour. *Suillus americanus* (Fig. 1c), known to bind mycorrhizally only to five-needled pines in Europe, where it was previously known as *S. sibiricus* (Singer) Singer [4,9], appeared in a few but not all sampling plots. It was, however, found in nearly all studied areas outside of the plots boundaries, often fruiting under seedlings of *P. peuce*, suggesting that tree age may be important for its mycorrhizae. In fact, suilloid fungi are known to be important for the establishment of pines in native and non-native ranges [17]. *Tricholoma terreum*, generally uncommon in the studied plots where mostly mature trees were present, exhibited somewhat similar behaviour, occurring prolifically in areas with seedlings of Macedonian pine present. It may be examined in future whether it might play somewhat similar role as suilloid fungi.



Fig. 1. Basidiomata of selected characteristic species of macrofungi for *Pinus peuce* stands: a – *Amanita submembranacea*; b – *Chroogomphus helveticus*; c – *Suillus americanus*; d – *Rhizopogon salebrosus* s. l.; e – *Strobilurus* sp.

Several incompletely resolved taxa were recovered in this study, which are worthy of further observations. *Rhizopogon salebrosus* (Fig. 1d) occurred in two of the studied sites, undoubtedly forming mycorrhizae with *P. peuce* as the only tree in the surveyed areas. Recently, a new species – *R. confusus* Koukol & Valda, was proposed to accommodate European collections of this group [18]. In

general, our ITS sequences seem compatible to and cluster together with those of *R. confusus*. However, as the taxonomy of this group relies on the use of anonymous loci to improve the resolution of the phylogenetic inferences, we prefer to treat those collections as *R. salebrosus* s. l. for the time being. A specimen of the genus *Laccaria* Berk. & Broome, which could not be plausibly matched to any taxon in the existing European keys, yielded a sequence, identical to sequences, dubbed as *L. 'macrocystidia'* (*nom. nud.*). Apparently further work is necessary as to show whether some of the existing binomials may be attached to it or it will represent an undescribed entity. Further on, a morphologically distinct, autumnal *Strobilurus* was detected (Fig. 1e), which sequence matches an unnamed species of the *S. wyomingensis* complex, uncovered by a recent study [11]. Those sequences also come from collections on cones of *P. peuce*, from North Macedonian sites, and this taxon is pending further judgement. Lastly, a sequenced specimen of the *Tricholomopsis rutilans* complex turns out to represent one of the known, but not yet formally described cryptic species in this group [19].

Nine new species for the Bulgarian mycota [20] were revealed by the present study, namely *Cortinarius jacobii-langei*, *C. malicorius*, *C. sommerfeltii*, *Mallocybe terrigena*, *Pholiota pinicola*, *Rhizopogon salebrosus* s. l., *Phlegmacium balteatum*, *Russula anthracina*, and *Thaxterogaster turmalis*, the majority of them supported by nrITS sequences. Over half of these are cortinarioid fungi (*Cortinarius*, *Phlegmacium*, *Thaxterogaster*), which fact is not surprising, as this group of larger fungi is among the most diverse in Europe and is apparently understudied in Bulgaria.

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REFERENCES

- [1] TORTIĆ M. (1968) Fungus collections in the *Pinus peuce* forests in the Pelister National Park (Macedonia, Yugoslavia), *Česká Mykol.*, **22**(3), 189–201.
- [2] BUCALO V., V. STUPAR, Đ. MILANOVIĆ (2012) Characteristics and origin of the population of Macedonian pine (*Pinus peuce* Griseb.) at Jadovnik Mt. in Western Bosnia, *Glasn. Šum. Fak. Univ. Banjoj Luci*, **16**, 7–29.
- [3] ROUSSAKOVA V. (2015) Macedonian pine (*Pinus peuce*) forests. In: Red Data Book of Republic of Bulgaria, vol. 3 Natural habitats (ed. V. Biserkov), Sofia, BAS & MOEW, 358–360.
- [4] TORTIĆ M. (1987) Main characters of the mycoflora in forests of *Pinus peuce* Griseb., *Acta Bot. Croat.*, **46**(1), 145–151.
- [5] KARADELEV M., G. KOST, K. H. REXER (2003) Macromycetes diversity in *Pinus peuce* forest in the Republic of Macedonia. In: Atti del III Convegno Nazionale di Studi Micologici “I Funghi del Monte Amiata”, 32–47.

- [6] KARADELEV M., K. RUSEVSKA, G. KOST, D. M. KOPANJA (2018) Checklist of macrofungal species from the phylum Basidiomycota of the Republic of Macedonia, *Acta Mus. Macedon. Sci. Nat.*, **21**(1), 23–112.
- [7] HINKOVA TS. (1958) On the distribution of the fungi in Eastern Rila Mts, *Izv. Bot. Inst. Sofia*, **6**, 131–162.
- [8] GYOSHEVA M. M., V. M. BOGOEV (1985) Mycoecological investigation into two Balkan Pine stands of the Vitosha National Park, *God. Sof. Univ., Biol. Fak.*, **79**(2), 64–77.
- [9] DÖRFELT H., A. MÜSCH (1987) Mykologische Studien in *Pinus peuce*-Wäldern der Volksrepublik Bulgarien, *Feddes Repert.*, **98**(7–8), 419–431.
- [10] KAIUCKA I., A. M. JAGODZIŃSKI, M. SKORUPSKI, M. KASPROWICZ, M. WOJTERSKA et al. (2013) Biodiversity of Balcan pine (*Pinus peuce* Griseb.) experimental stands in the Rogów Arboretum (Poland), *Folia Forest. Polon.*, **55**(4), 181–189.
- [11] QIN J., E. HORAK F., POPA, K. H. REXER, G. KOST et al. (2018). Species diversity, distribution patterns, and substrate specificity of *Strobilurus*, *Mycologia*, **110**(3), 584–604.
- [12] LOIZIDES M., J.-M. BELLANGER, B. ASSYOV, P.-A. MOREAU, F. RICHARD (2019) Phylogenetic and distributional data on boletoid fungi (Boletaceae) in Cyprus and description of a new sampling methodology, *Data in Brief*, **25**, 104115.
- [13] ASSYOV B. (2022) Barcoding and morphological characterization of *Mycena cupressina* (Agaricales, Fungi), a little-known and controversially treated member of section *Supinae*, *C. R. Acad. Bulg. Sci.*, **75**(11), 1595–1603.
- [14] ALTSCHUL S. F., W. GISH, W. MILLER, E. W. MYERS, D. J. LIPMAN (1990) Basic local alignment search tool, *J. Mol. Biol.*, **215**(3), 403–410.
- [15] DEREPPER A., V. GUIGNON, G. BLANC, S. AUDIC, S. BUFFET et al. (2008) Phylogeny.fr: robust phylogenetic analysis for the non-specialist, *Nucl. Acids Res.*, **36**(Suppl. 2), 465–469.
- [16] DÖRFELT H. (1977) Zur Taxonomie, Verbreitung und Ökologie des filzigen Schmierlings *Chroogomphus helveticus* (Sing.) Moser, *Feddes Repert.*, **88**(4), 273–285.
- [17] POLICELLI N., T. D. BRUNS, R. VILGALYS, M. A. NUÑEZ (2019) Suiloid fungi as global drivers of pine invasions, *New Phytol.*, **222**(2), 714–725.
- [18] KOUKOL O., S. VALDA, J. GAISLER, V. KUNCA, N. J. DOWIE (2022) *Rhizopogon confusus* sp. nov., a correct name for a fungus previously recorded in Central Europe as the North American *Rhizopogon salebrosus*, *Mycol. Progress*, **21**(5), 49.
- [19] OLARIAGA I., X. LASKIBAR, J. HOLEC (2015) Molecular data reveal cryptic speciation within *Tricholomopsis rutilans*: description of *T. pteridicola* sp. nov. associated with *Pteridium aquilinum*, *Mycol. Progress*, **14**(4), 1–12.
- [20] DENCHEV C. M., B. ASSYOV (2010) Checklist of the larger basidiomycetes in Bulgaria, *Mycotaxon*, **111**(1), 279–282.

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