

RESULTS

During the study 29 taxa of vascular plants, 29 taxa of fungi (including 2 myxomycete species), and 127 taxa of invertebrates were found in the examined *Pinus peuce* stands. No mosses occurred within the plots. In the control sites (*Tilio-Carpinetum*), species richness of the organisms studied was almost by a hundred taxa higher, with the relatively greatest difference in the group of fungi and the least – in invertebrates: 52 taxa of vascular plants and mosses, 67 taxa of fungi and 162 taxa of invertebrates were found there (fig. 1). The list of organisms found in *Pinus peuce* stands is given below.

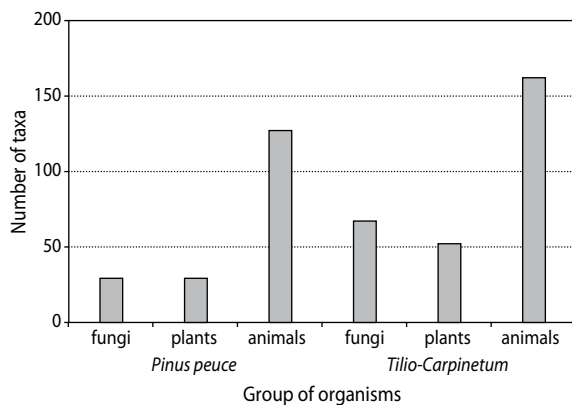


Fig. 1. Number of fungal, plant and animal taxa found in *Pinus peuce* stands and *Tilio-Carpinetum* sites (control)

Vascular plants cultivated in the Arboretum, spontaneous in the investigated plots

Pinus peuce Griseb., *Quercus rubra* L., *Crataegus* L. sp.

Spontaneous vascular plants

Anemone nemorosa L., *Calamagrostis arundinacea* (L.) Roth, *Carex digitata* L., *Carpinus betulus* L., *Chamaenerion angustifolium* (L.) Scop., *Convallaria majalis* L., *Corylus avellana* L., *Euonymus verrucosa* Scop., *Frangula alnus* Mill., *Lilium martagon* L., *Luzula pilosa* (L.) Willd., *Maianthemum bifolium* (L.) F.W. Schmidt, *Melica nutans* L., *Milium effusum* L., *Padus serotina* (Ehrh.) Borkh., *Pteridium aquilinum* (L.) Kuhn, *Quercus petraea* (Matt.) Liebl., *Quercus robur* L., *Rubus corylifolius* Sm. Agg., *Rubus hirtus* Waldst. & Kit. Agg., *Rubus idaeus* L., *Rubus saxatilis* L., *Sambucus racemosa* L., *Sorbus aucuparia* L., *Trientalis europaea* L., *Vaccinium myrtillus* L.

Mosses

None.

Mycorrhizal fungi

Amanita citrina (Schaeff.) Pers., *Boletus badius* (Fr.) Fr., *Lactarius aurantiacus* (Pers.) Gray, *Paxillus involutus* (Batsch) Fr., *Russula puellaris* Fr., *Xerocomellus chrysenteron* (Bull.) Šutara.

Saprotrophic fungi

Ampulloclitocybe clavipes (Pers.) Redhead, Lutzoni, Moncalvo & Vilgalys, *Auriscalpium vulgare* Gray, *Baeospora myosura* (Fr.) Singer, *Ceratiomyxa fruticulosa* (O.F. Müll.) T. Macbr., *Clitocybe* spp., *Daedaleopsis confragosa* (Bolton) J. Schröt., *Gymnopilus penetrans* (Fr.) Murrill, *Gymnopus peronatus* (Bolton) Antonin, Halling & Noordel., *Hygrophoropsis aurantiaca* (Wulfen) Maire, *Hypholoma capnoides* (Fr.) P. Kumm., *Hypholoma fasciculare* (Huds.) P. Kumm., *Lycogala epidendrum* (J.C. Buxb. ex L.) Fr., *Mycena epipterygia* (Scop.) Gray, *Mycena galopus* (Pers.) P. Kumm., *Mycena sanguinolenta* (Alb. & Schwein.) P. Kumm., *Mycena zephirus* (Fr.) P. Kumm., *Mycena* spp., *Panellus mitis* (Pers.) Singer, *Pholiota lenta* (Pers.) Singer, *Rhodocollybia butyracea* f. *asema* (Fr.) Antonin, Halling & Noordel., *Rhodocollybia butyracea* f. *butyracea* (Bull.) Lennox, *Stereum sanguinolentum* (Alb. & Schwein.) Fr., *Tapinella atrotomentosa* (Batsch) Šutara

Nematodes

Aphelenchoides spp., *Cephalenchus hexalineatus* (Geraert) Geraert et Goodey, *Ditylenchus anchilisposomus* (Tarjan) Fortuner, *Ditylenchus* spp., *Filenchus discrepans* (Andrássy) Raski et Geraert, *Filenchus misellus* (Andrássy) Raski et Geraert, *Paratylenchus straeleni* (de Coninck) Oostenbrink

Acari (Oribatida)

Achipteria coleoprata (L.), *Acrotritia duplicata* (Grandjean), *Adoristes ovatus* (C.L. Koch), *Autogneta longilamellata* (Michael), *Camisia segnis* (Hermann), *Carabodes coriaceus* C.L. Koch, *Carabodes labyrinthicus* (Michael), *Carabodes marginatus* (Michael), *Carabodes ornatus* Štorkán, *Carabodes subarcticus* Trägårdh, *Chamobates pusillus* (Berlese), *Chamobates voigtsi* (Oudemans), *Cultroribula bicultrata* (Berlese), *Damaeus auritus* C.L. Koch, *Damaeus verticillipes*

(Nicolet), *Eueremaus oblongus* (C.L. Koch), *Eupelops major* (Hull), *Eupelops torulosus* (C.L. Koch), *Galumna lanceata* (Oudemans), *Hafenrefferia gilvipes* (C.L. Koch), *Heminothrus peltifer* (C.L. Koch), *Liochthonius simplex* (Forsslund), *Liochthonius tuxeni* (Forsslund), *Metabelba pulverulenta* (C.L. Koch), *Micreremus gracilior* Willmann, *Micropopia minus* (Paoli), *Microtritria minima* (Berlese), *Nanhermannia nana* (Nicolet), *Neobrachychthonius marginatus* (Forsslund), *Nothrus silvestris* Nicolet, *Oppiella nova* (Oudemans), *Oribatula tibialis* (Nicolet), *Phauloppia rauschenensis* (Sellnick), *Phthiracarus boresetosus* Jacot, *Phthiracarus longulus* (C.L. Koch), *Porobelba spinosa* (Sellnick), *Quadroppia quadricarinata* (Michael), *Scheloribates laevigatus* (C.L. Koch), *Scheloribates latipes* (C.L. Koch), *Scheloribates pallidulus* (C.L. Koch), *Sellnickochthonius cricoides* (Weis-Fogh), *Sellnickochthonius jacoti* (Evans), *Sellnickochthonius zelawaiensis* (Sellnick), *Steganacarus carinatus* (C.L. Koch), *Suctobelbella acutidens* (Forsslund), *Suctobelbella sarekensis* (Forsslund), *Suctobelbella subcornigera* (Forsslund), *Suctobelbella subtrigona* (Oudemans), *Tectocephus velatus* (Michael), *Trichoribates berlesei* (Jacot)

Acari (Mesostigmata)

Eviphis ostrinus (C.L. Koch), *Gamasellodes bicolor* (Berlese), *Geholaspis longispinosus* (Kramer), *Leptogamasus suecicus* Trägårdh, *Pachylaelaps bellicosus* Berlese, *Pachylaelaps longisetis* Halbert, *Paragamasus vagabundus* (Karg), *Pergamasus mediocris* Berlese, *Prozercon kochi* Sellnick, *Rhodacarus reconditus* Athias-Henriot, *Trachytes aegrota* (C.L. Koch), *Urodiaspis tecta* (Kramer), *Veigaia nemorensis* (C.L. Koch), *Zercon* sp. 1, *Zercon triangularis* C.L. Koch

Insects (Collembola)

Arrhopalites spinosus Rusek, *Ceratophysella denticulata* (Bagnall), *Ceratophysella* sp. juv., *Desoria trispinata* (Mac Gillivray), *Desoria* sp. juv., *Entomobrya muscorum* (Nicolet), Entomobryidae juv., *Folsomia lawrencei* Rusek, *Folsomia manolachei* Bagnal, *Folsomia penicula* Bagnall, *Folsomia quadrioculata* (Tullberg), *Folsomia* juv., *Friesea truncata* Cassagnau, *Isotomiella minor* (Schaffer), *Lepidocyrtus lanuginosus* (Gmelin), *Lepidocyrtus lignorum* (Fabricius), *Lepidocyrtus lignorum* gr juv., *Lipotrix lubbocki* (Tullberg), *Megalothorax minimus* Willem, *Mesaphorura macrochaeta* Rusek,

Micranurida pygmaea Borner, *Micraphorura absoloni* (Borner), *Orchesella* sp. juv., *Parisotoma notabilis* (Schaffer), *Pogonognatellus flavescens* (Tullberg), *Proisotoma minima* (Tullberg), *Protaphorura armata* (Tullberg), *Pseudachorutes corticolus* (Schaffer), *Pseudachorutes parvulus* Borner, *Pseudosinella alba* (Packard), *Pseudosinella horaki* Rusek, *Sminthurinus* sp. juv., *Sphaeridia pumilis* (Krausbauer), *Symphyleona* juv., Tomoceridae juv., *Tomocerus minor* (Lubbock), *Willowsia buski* (Lubbock), *Xenylla* sp. juv.

Insects (Coleoptera)

Amara plebeja (Gyll.), Anobiidae spp., *Apion* sp., *Calathus erratus* (Sahlb.), *Cantharis fusca* L., *Carabus arcensis* Herbst, *Coccinella septempunctata* L., *Ectobius sylvestris* L., *Harpalus affinis* (Schrank), *Phyllopertha horticola* L., *Propylea quatuordecimpunctata* L., *Pterostichus cupreus* (L.), *Pterostichus diligens* (Sturm), *Pterostichus niger* (Schall.), Staphylinidae spp.

Other insects

Heteroptera spp., Homoptera spp.

DISCUSSION

Pinus peuce is an element of montane to uppermontane (subalpine) pine forests in the south nemoral, montane geographic region in Europe (Neuhäusl 1990). The syntaxonomy of natural Balkan pine forests has been studied mainly in former Yugoslavia (Horvat et al. 1974) and Bulgaria. Numerous plant associations were assembled in a separate alliance *Pinion peucis* Horvat 1950 (Wojterski 1971; Tzonev et al. 2009). Even on the poorest habitats forests with the Balkan pine are characterized by a high number of more demanding species of *Quercus-Fagetum* class (Horvat et al. 1974). Six species found in *Pinus peuce* stands in Rogów occur also in natural *Pinus peuce* forests on Balkan Peninsula: *Anemone nemorosa*, *Luzula pilosa*, *Pteridium aquilinum*, *Rubus hirtus*, *Sorbus aucuparia* and *Vaccinium myrtillus*.

Forest communities formed by *Pinus peuce* represent habitat protected by European law (95AO *Pinus peuce* Grisb. and *P. leucodermis* Ant. forests).

The first thorough inventory of fungal sporocarps in *Pinus peuce* forests was carried out in the *Pteridio-Pinetum peucis* association, in pure pine and

pine-fir stands on Mt. Pelister (FYR Macedonia) by Tortić (1968), who listed 85 species of macromycetes. Among them, there were 18 mycorrhizal species associated undoubtedly with the Balkan pine, 10 species growing apparently on the litter and debris originating from that tree and 12 species inhabiting its wood. Later on, the region of Mt. Pelister became one of the best mycologically explored areas occupied by *Pinus peuce*. At present, 196 taxa of ectomycorrhizal fungi, 129 saprotrophic taxa growing on litter and soil, and 66 lignicolous taxa are known to occur in the Balkan pine forests in FYR Macedonia, under *Pinus peuce*, on its litter and debris and on its wood (Tortić 1987; Karadelev 1995; Karadelev 1998a; Karadelev 1998b; Karadelev 2000; Karadelev et al. 2003; Karadelev et al. 2004; Karadelev, Spasikova 2004, 2006; Karadelev et al. 2007a; Karadelev et al. 2007b; Chavdarova et al. 2011; Karadelev, pers. comm.). Also, there are some records from *Pinus peuce* forests in Bulgaria (G'Osheva, Bogoev 1985; Rossnev 1985; Dörfelt, Müsch 1987; Roussakova 2011) and Montenegro (Kasom, Karadelev 2012).

Great majority of fungi that were mentioned by the above authors as found in association with natural stands of *Pinus peuce* are the species known for their occurrence also in other forests, especially in coniferous or mixed stands all over Europe. None of them can be ascribed as a species exclusively associated with the Balkan pine. This means that *Pinus peuce* is a species capable of forming symbiosis with a vast range of ectomycorrhizal fungi, and also the substrate formed of its litter and wood can be inhabited by a variety of different species showing different ecological preferences. In spite of that, only six species of ectomycorrhizal fungi were found in the *Pinus peuce* experimental plots in the Rogów Arboretum. Moreover, sporocarps of dozens of species that accompany the Balkan pine in its natural range were present in the neighboring stands; this phenomenon probably results from ecological incompatibility between the Balkan pine and most of ectomycorrhizal fungal strains living far away from its natural range (compare Bonfante et al. 1998). Among the six ectomycorrhizal species found, four are the species that can associate with both coniferous and deciduous trees in the whole Northern hemisphere; two species, *Lactarius aurantiacus* and *Boletus badius*, typically form symbiosis with conifers, although they can be found

also under deciduous trees. Interestingly, the latter species is the only one that has not been recorded in association with *Pinus peuce* within its natural range. It must be kept in mind that some of the ectomycorrhizal fungi found in the Balkan pine plots observed might have been associated also with other host trees scattered there (*Carpinus betulus*, *Quercus* spp.).

The number of saprotrophic species found in soil, litter and wood in the Balkan pine stands examined does not differ from the number found in the control plot. Although *Pinus peuce* products – wood, cones, needles – are rich in resins and resinous substances, and thus – more resistant to fungal decay (Lines 1985; Alexandrov, Andonovski 2011), they are a substrate for relatively high diversity of saprotrophic fungi. Circa half of them are known to grow in association with *Pinus peuce* in natural sites as well, e.g., *Auriscalpium vulgare*, *Hygrophoropsis aurantiaca*, *Hypholoma fasciculare*, *Lycogala epidendrum*, *Mycena epipterygia*, *Mycena sanguinolenta*, *Panellus mitis*, *Pholiota lenta*, *Rhodocollybia butyracea* (both varieties), *Stereum sanguinolentum*, and *Tapinella atrotomentosa*.

In their natural sites, Balkan pines are known to suffer from a few fungal diseases, although they are more resistant than other conifer species (Tsanova, Rossnev 1974; Rossnev 1985; Karadelev 1998a; Karadelev 1998b; Tomanic et al. 1998; Alexandrov, Andonovski 2011). The trees are attacked by macrofungal parasites like *Heterobasidion annosum*, *Phaeolus schweinitzii*, *Armillaria mellea*, *Trametes pini*, *Polyporus* spp., and *Stereum* spp. None of these species were recorded on *Pinus peuce* in the experimental stands examined, although the first three were present or even abundant on other tree species in the Arboretum. However, Dominik and Grzywacz (1998) reported the presence of *Heterobasidion annosum* and *Armillaria mellea* s.l. on *Pinus peuce* in Poland.

There are not many records on invertebrates biodiversity of Balkan pine forests. Hadzi-Ristova (1974) explored fauna of Lepidoptera (Noctuidae) which were not investigated in our research. During research on nematodes in *Pinus peuce* stands in the Pirin Mountains (Mincheva et al. 2008), 58 genera were found, but these which were dominant in natural stands did not occur in the plots observed in the Rogów Arboretum. Two species of the genus *Criconemella* were found on *Pinus peuce*, during the research on parasitic nematodes

in Bulgaria (Katalan-Gateva et al. 1991) and also these species were not present in our study plots. There are also papers containing data on particular insects found on the Balkan pine (Foit 2007; Scheurer 1991).

ACKNOWLEDGMENTS

This research was supported by the Polish Ministry of Science and Higher Education (grant No. N304 071 32/2761).

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