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Biodiversity of Balcan pine (*Pinus peuce* Griseb.) experimental stands in the Rogów Arboretum (Poland)

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Abstract

The Balkan pine (*Pinus peuce*) is a Balkan Peninsula endemic tree species, growing in high mountains of Bulgaria, Macedonia, Serbia, Montenegro, Kosovo, Albania, and Greece and forming pure and mixed stands in subalpine forests. The paper gives a survey of biodiversity of Balkan pine stands in the Rogów Arboretum in reference to environmental data. In the plots examined, 29 taxa of vascular plants, 29 taxa of macrofungi and 127 taxa of invertebrates were recorded. The revealed diversity is discussed with regard to the data from *Pinus peuce* natural habitats.

Key words

Pinus peuce, Balkan pine, biodiversity, vascular plants, macrofungi, nematodes, mites, insects

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Introduction

The Balkan pine (*Pinus peuce* Griseb.), known also as Macedonian pine or Molika pine, is probably a relict that has survived severe contractions of its natural range due to the Alpine glaciations during the Pleistocene; it is a Balkan endemic tree species of the high mountains of Bulgaria, Macedonia, Serbia, Montenegro, Kosovo, Albania, and Greece. In general, the Balkan pine occurs up to the upper timberline and is of great importance for the subalpine forests of the Balkan Peninsula (Eckenwalder 2009). Natural Molika pine forests form zonal vegetation of the subalpine belt in some mountain chains (e.g. on Pelister), but there are also known pure stands of anthropo-zoogenic character resulting from succession on abandoned pastures or burnt areas (Horvat et al. 1974). The natural range of the Balkan pine lies between 41º and 43º northern latitudes (Dimitrov 1980). The species mostly forms pure stands, although it can also appear in mixed ones with the European silver fir (*Abies alba*) and the Norway spruce (*Picea abies*) in dense or more or less open mountain coniferous forests. The taxonomic position of *Pinus peuce* is still uncertain (Klaus 1989; Piovesan et al. 1993; Wang et al. 1999; Kaundun, Lebreton 2010), since the Balkan pine successfully and spontaneously hybridizes with related pines. The Balkan pine is listed in the IUCN Red List of Threatened Species (IUCN 2010), in the category of lower risk/near threatened. Its stands prevent soil erosion in high mountains (Blada, Popescu 2004). Pejoski (1967) estimated Balkan pine total area in the Balkans, both in pure and in mixed stands, as 20 000 to 30 000 ha.

According to Farjon (2010), *Pinus peuce* grows between ca. 600 and 2200 m a.s.l. and usually on silicate rocks. However, in Albania and Serbia, the Balkan pine is also found on serpentine. It grows on a variety of acidic to basic soil types usually poor in nutrients and derived from granite and sandstone. According to Horvat et al. (1974) it can also grow on limestone. In the north-western part of its range, the Balkan pine grows on rocky substrate (e.g. granites, gneiss, shales and schists, siliceous rocks and serpentine) (Mayer 1979). Soil types found beneath different plant associations formed by *Pinus peuce* on Mt. Pelister vary from acidic brown forest soils in the communities with *Pteridium aquilinum* at 1000–1600 m a.s.l., through grey-brown podzolics in the communities with *Vaccinium myrtillus* at intermediate altitudes, up to humic rankers in *Pinus-Juniperus* forest at 1800–2000 m a.s.l. (Georgiev 1970; Vilarov 1970). In the Central Balkans, *Pinus peuce* is found in the high-montane belt of forests with *Abies alba* (1800–2000 and 2000–2200 m a.s.l. depending on mountain range) and in the subalpine zone of individual trees of *Pinus mugo* and others (2200–2500 m a.s.l.).

Within natural range of this pine species, the climate is mainly of Mediterranean mountain type, since natural stands seldom occur below 1100 m a.s.l. (Em and Đzekov 1970). Extreme conditions in which *Pinus peuce* has been found are characterized by mean annual temperatures ranging from 4.3ºC to –3.1ºC and a short vegetation period from ca. 83 days to ca. 68 days and long lasting snow cover from 168 to 200 days with annual precipitation varying from 1050 up to 1228 mm (Raev 2005).

The best growing Balkan pine stands are observed mostly in the areas with deeper soils at lower elevations (1300–1500 m a.s.l.). In these ecological conditions, trees may reach from 36 to 42 m in height and from 60 to 80 cm in diameter at breast height (Mayer 1979).

In Macedonia, Balkan pines form pure stands on gentle mountain slopes, interspersed with meadows and grassy glades. In most areas where *Pinus peuce* occurs, it is mixed with *Picea abies* and/or *Abies alba* and *Abies* × *borissi-regis*, with which it competes for light, water, nutrients and space. In Bulgaria, the Balkan pine covers an area of 14 223 ha. In 2000, the total wood volume of Balkan pine stands in Bulgaria reached 4 198 000 m^3. The stands of age classes V and VI occupied the largest area (6037 ha in total, 42.5% of all Balkan pine stands) with a growing stock of ca. 2 160 000 m^3. The average volume of the Balkan pine forests in Bulgaria is 295 m^3/ha, the average quality class is III (medium quality). The rotation period lasts 160 years (Alexandrov et al. 2004). The average stand volume of the Balkan pine exceeds that of Norway spruce and is noticeably higher than that of Scots pine (Krstanov 1970).

The Balkan pine is considered a pioneer tree species. The seedlings of this species are light-demanding, and while natural regeneration in mixed stands is mainly of spruce and silver fir, *Pinus peuce* natural regeneration is quite numerous mainly in larger gaps and less dense stands. Early growth of young trees is generally slow, even on favorable habitats (Lines 1985). In general, on more fertile and lower sites, diameter

growth of young Norway spruce and European silver fir trees is by and large greater than that of the Balkan pine. At the forest limit (ca. 2200 m a.s.l.), *P. peuce* develops a good stem and crown form, though the height of trees is comparatively reduced. According to Panayotov et al. (2010) *P. peuce* radial growth in the treeline belt (2000–2250 m a.s.l.) is limited in the years with dry and hot summers. *P. peuce* trees were found to be sensitive to previous summer temperatures. The trees that were studied in the cited paper grew on umbric and modic cambisols formed on granite bedrock. According to Krstanov (1970) Balkan pine most intensive height increment takes place between 20th and 40th year of growth, while the highest diameter increment at breast height is observed between 30th and 80th year. Moreover, the diameter and height increment declines considerably and almost ceases when trees are ca. 100 years old. Gogusevski and Parisko (1970) and Panić et al. (1970) revealed that annual volume increment of the Balkan pine reaches up to 8–9 m^3/ha. Total yield of this species depends on site factors (Krstanov 1970).

The Balkan pine, because of its relatively high tolerance against air pollutants, is suitable for afforestations in polluted areas, where other tree species (e.g. Norway spruce) have been damaged or even eliminated during recent decades (Lattke et al. 1987; Lattke 1998). The species shows good tolerance to SO_2 (Enderlein, Vogl 1966).

Material and methods

The study was conducted in two Balkan pine (*Pinus peuce*) experimental stands aged 40 (A) and 48 (B) years, situated in the Rogów Arboretum of the Warsaw University of Life Sciences (SGGW), Poland (51°49'N, 19°53'E). The detailed information for both stands is shown in table 1.

According to long-term meteorological observations (55 years) from the closest meteorological station in Strzelna, mean annual temperature equals 7.2°C (January: –3.2°C, July: 17.3°C), mean annual precipitation equals 596 mm (404–832 mm, with ca. 70% of annual precipitation in the growing season), and mean growing season length (calculated as the number of days with mean temperature ≥ 5°C) is 212 days (Bednarek 1993; Jagodziński, Banaszczak 2010).

Tab. 1. Characteristics of *Pinus peuce* stands in experimental plots (2009) (Hotała 2010)

Characteristics	Study site A	Study site B
Year of stand establishment	1971	1965
Year of seed sprouting	1970	1962
Area of experimental plot	0.04 ha	0.04 ha
Seed origin	Rogów Arboretum	Razlog, Bulgaria
Stand density, trees/ha	1900	1275
Stand age	40	48

The study plots are situated on flat terrain ca. 189 m a.s.l. The soils within the area of the Arboretum are rich, mesic, with the groundwater level beyond the reach of tree roots (Czępińska-Kamińska et al. 1991; Jagodziński, Banaszczak 2010). In the study area, haplic luvisoils forest soils with horizons O-A-Eet-Bt-C can be found. The average pH (in H_2O) assessed for the upper soil layers of studied plots was as follows: Oll – 4.48, Ol – 5.17, Ofh – 4.77, and A – 3.52.

The aim of the study was determination of organisms from selected taxonomic groups which occur in the experimental plots to broaden knowledge of the species composition of exotic coniferous and broadleaves tree-stands. During the three-year study (2007–2009), vascular plants, mosses, and soil invertebrates (nematodes, mites and insects) were recorded and determined. Observations of macrofungi (mycorrhizal, saprotrophic and parasitic species, including Myxomycetes; corticioid taxa not included) were carried out in 2008–2010. The nomenclature of identified fungal taxa follows Index Fungorum (indexfungorum.org/Names/Names.asp). Vouchers of dried fungal materials have been deposited in the Herbarium Universitatis Lodziensis (LOD).

The list of the taxa found in *Pinus peuce* plots was compared with the list of taxa found in the control plot – the subcontinental oak-hornbeam forest *Tilio-Carpinetum* Traczyk 1962 *calamagrostietosum*, situated in the western part of the Arboretum and being a forest community developing naturally in the area. The upper layer of this stand is formed by *Quercus petraea* and *Pinus sylvestris* as well as *Populus tremula*; the lower tree layer and undergrowth is dominated by *Carpinus betulus*.

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.

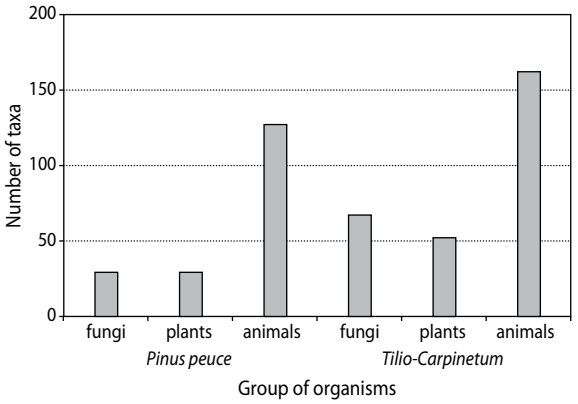

Fig. 1. Number of fungal, plant and animal taxa found in *Pinus peuce* stands and *Tilio-Carpinetum* sites (control)

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) Antonín, 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.) Antonín, 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* (Andrásssy) Raski et Geraert, *Filenchus misellus* (Andrássy) Raski et Geraert, *Paratylenchus straeleni* (de Coninck) Oostenbrink

Acari (Oribatida)

Achipteria coleoptrata (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), *Eueremaeus 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, *Microppia minus* (Paoli), *Microtritia 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), *Tectocepheus 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), Entomobyidae 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 pygmea* Borner, *Micraphorura absoloni* (Borner), *Orchesella* sp. juv., *Parisotoma notabilis* (Schaffer), *Pogonognatellus flavescens* (Tullberg), *Proisotoma minima* (Tullberg), *Protaphorura armata* (Tullberg), *Pseudachorutes corticicolus* (Schaffer), *Pseudachorutes parvulus* Borner, *Pseudosinella alba* (Packard), *Pseudosinella horaki* Rusek, *Sminthurinus* sp. juv., *Sphaeridia pumilis* (Krausbauer), Symphypleona 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.

Disscussion

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 *Querco-Fagetea* 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; Rossnew 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).

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References

Alexandrov A.H., Andonovski V. 2011. EUFORGEN Technical Guidelines for genetic conservation and use of Macedonian pine (*Pinus peuce*). Biodiversity International, Rome, Italy.

Alexandrov A.H., Dobrev R., Tsakov H. 2004. Genetic and conservation research on *Pinus peuce* in Bulgaria. In: Breeding and genetic resources of five-needle pines: growth, adaptability, and pest resistance (eds.: R.A. Sniezko, S. Samman, S.E. Schlarbaum, H.B. Kriebel), IUFRO Working Party 2.02.15., 2001 July 23–27, Medford, OR, USA. Proceedings RMRS-P-32. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 61–63.

Bednarek A. 1993. Klimat (Climate). In: Warunki przyrodnicze lasów doświadczalnych SGGW w Rogowie (ed.: R. Zielony), Wydawnictwo SGGW, Warszawa, 24–41 (in Polish).

Blada I., Popescu F. 2004. Genetic research and development of five-needle pines (*Pinus* subgenus *Strobus*) in Europe: an overview. In: Breeding and genetic resources of five-needle pines: growth, adaptability, and pest resistance (eds.: R.A. Sniezko, S. Samman, S.E. Schlarbaum, H.B. Kriebel), IUFRO Working Party 2.02.15., 2001 July 23–27, Medford, OR, USA. Proceedings RMRS-P-32. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 51–60.

Bonfante P., Balestrini R., Martino E., Perotto S., Plassard C., Mousain D. 1998. Morphological analysis of early contacts between pine roots and two ectomycorrhizal *Suillus* strains. *Mycorrhiza*, 8, 1–10.

Chavdarova S., Kajevska I., Rusevska K., Grebenc T., Karadelev M. 2011. Distribution and ecology of hypogeous fungi (excluding *Tuber*) in the Republic of Macedonia. *Biologia Macedonica*, 62, 37–48.

Czępińska-Kamińska D., Janowska E., Konecka-Batley K. 1991. Gleby Arboretum w Rogowie (Soils of the Rogów Arboretum). Arboretum Rogów. Manuscript in Polish.

Dimitrov M. 1980. The Macedonian pine (*Pinus peuce* Grisb.). Zemizdat, Sofia.

Dominik J., Grzywacz A. 1998. Zagrożenie obcych gatunków drzew iglastych ze strony rodzimej entomofauny oraz mikoflory. Katedra Ochrony Lasu i Ekologii SGGW, Warszawa.

Dörfelt H., Müsch A. 1987. Mykologische Studien in *Pinus peuce*-Wäldern der Volksrepublik Bulgarien. *Feddes Repertorium*, 98 (7/8), 419–431.

Eckenwalder J.E. 2009. Conifers of the world. The complete reference. Timber Press, Portland, London.

Em H., Đzekov S. 1970. Molikata i molikovata šuma na Pelister. In: Report of a Symposium on *Pinus peuce*, 2–6 IX 1969, University of Skopje, 49–62.

Enderlein H., Vogl M. 1966. Experimentelle Untersuchungen über die SO_2 Empfindlichkeit der Nadeln verschiedener Koniferen. *Archiv für Forstwesen und Landschaftsökologie*, 15 (11/12), 1207–1224.

Farjon A. 2010. A handbook of the world's conifers 2. Koninklijke Brill NV, Leiden, The Netherlands.

Foit J. 2007. A species of longhorn beetle (Coleoptera: Cerambycidae) new to the Albanian fauna – new record of *Tragosoma depsarium* (L.). *Acta Entomologica Serbica*, 12 (1), 87–89.

Georgiev G.A. 1970. Characteristique des sols sous le pin peuce en Bulgarie. In: Report of a Symposium on *Pinus peuce,* 2–6 IX 1969, University of Skopje, 243–250.

Gogusevski M., Parisko Z. 1970. Strukturelement und Holzproduktionsfähigkeit von Molikakiefernbeständen der Ass. *Pteridio-Pinetum peucis* auf dem Pelister. In: Report of a Symposium on *Pinus peuce,* 2–6 IX 1969, University of Skopje, 323–340.

G'Osheva M.M., Bogoev V.M. 1985. Mycoecological investigation into two Balkan pine stands of the Vitosha National Park Bulgaria. *Godishnik na Sofiiskiya Universitet "Kliment Okhridski" Biologicheski Fakultet, Kniga 1, Zoologiya*, 79, 64–78.

Hadzi-Ristova L. 1974. Lepidoptera of the family Noctuidae in the *Pinus peuce* stands on Pelister (Mt. Pelister, Macedonia). *Godisen Zbornik na Zemjodelsko-Sumarskiot Fakultet na Univerzitetot Skopje*, 26, 161–164.

Horvat I., Glavač V., Ellenberg H. 1974. Vegetation Südosteuropas. Gustav Fischer Verl., Jena.

Hotała S. 2010. Sezonowa zmienność warunków świetlnych w drzewostanach obcych gatunków drzew leśnych [Seasonal variation of light conditions in stands of exotic tree species]. MSc Thesis in the Department of Game Management and Forest Protection, Faculty of Forestry, Poznań University of Life Sciences (manuscript in Polish).

IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. www.iucnredlist.org. Downloaded on 16 January 2011.

Jagodziński A.M., Banaszczak P. 2010. Stem volume and aboveground woody biomass in noble fir (*Abies procera* Rehder) stands in the Rogów Arboretum (Poland). *Acta Scientiarum Polonorum, Silvarum Colendarum Ratio et Industria Lignaria*, 9 (2), 9–24.

Karadelev M. 1995. Qualitative and quantitative investigations of lignicolous macromycetes in different forest associations on Pelister Mountain. *Ecology and Protection of the Environment*, 3 (1/2), 3–12.

Karadelev M. 1998a. Fungal Biodiversity in Macedonia I. With special regard to substrates with a disjunct range and relict origin. *Mycologia Montenegrina*, 1 (1), 49–55.

Karadelev M. 1998b. Lignicolous Basidiomycetes on Molika pine (*Pinus peuce* Griseb.) – relict and endemic pine on Central Balkan. Forest Research Institute – Bulgarian Academy of Sciences, Sofia, Bulgaria, 266–269.

Karadelev M. 2000. New and noteworthy species of *Aphyllophorales* (Basidiomycotina) from the Republic of Macedonia. *Pagine di Micologia* 14, 62–67.

Karadelev M., Kost G., Rexer K.-H. 2003. Macromycetes diversity in *Pinus peuce* forest in the Republic of Macedonia. Atti del III. Convegno Nazionale di Studi Micologici: I Funghi del Monte Amiata. 14–19 Ottobre 2003, Piancastagnaio, Italy, 32–47.

Karadelev M., Kost G., Rexer K.-H. 2007a. New macromycetes species (Ascomycetes and Basidiomycetes) for mycota of the Republic of Macedonia. Collection of papers Devoted to Academic Kiril Micevski, Macedonian Academy of Sciences and Arts, Skopje, 311–327.

Karadelev M., Miteva S., Stojkoska K. 2004. Checklist of humano-toxic macromycetes in the Republic of Macedonia. Proceedings of the 2nd Congress of Ecologists of the Republic of Macedonia with International Participation, 25–29.10.2003, Ohrid. Special issues of Macedonian Ecological Society, Skopje, 6, 472–478.

Karadelev M., Rusevska K., Spasikova S. 2007b. The family Boletaceae s.l. (excluding *Boletus*) in the Republic of Macedonia. *Turkish Journal of Botany*, 31, 539–550.

Karadelev M., Spasikova S. 2004. Hallucinogenic fungi in the Republic of Macedonia. Proceedings of the 2nd Congress of Ecologists of the Republic of Macedonia with International Participation. 25–29.10.2003, Ohrid. Special issues of Macedonian Ecological Society, Skopje, 6, 479–483.

Karadelev M., Spasikova S. 2006. Second contribution to hallucinogenic fungi in the Republic of Macedonia. Proceedings of IV Balkan Botanical Congress – Plant, fungal and habitat diversity investigation and conservation, Sofia, 20–26 June 2006. Scientific Area D, Fungal diversity. Bulgarian Academy of Sciences, 441–449.

Kasom G., Karadelev M. 2012. The family Boletaceae s.l. (excluding *Boletus*) in Montenegro. *Turkish Journal of Botany*, 36, 566–579.

Katalan-Gateva S., Aleksiev A.D., Iliev I.L., Ilieva Z.I. 1991. On the species composition and distribution of the family Criconematidae (Taylor, 1936) Thorne, 1949 (Nematoda) in Bulgaria. *Acta Zoologica Bulgarica*, 41, 53–57.

Kaundun S.S., Lebreton P. 2010. Taxonomy and systematics of the genus *Pinus* based on morphological, biogeographical and biochemical characters. *Plant Systematics and Evolution*, 284, 1–15.

Klaus W. 1989. Mediterranean pines and their history. *Plant Systematics and Evolution*, 162, 133–163.

Krstanov K. 1970. Wachstum, Leistung und Technisches Haltbarkeitsalter von *Pinus peuce* – Bestände in Bulgarien. In: Report of a Symposium on *Pinus peuce*, 2–6 IX 1969, University of Skopje, 277–289.

Lattke H. 1998. Kiefern für die Immissionsschadgebiete der Mittelgebirge – züchterische Ergebnisse und Perspektiven. *Schriftenreihe der Sächsischen Landesanstalt für Forsten*, 13, 24–35.

Lattke H., Braun H., Richter G. 1987. *Pinus peuce* Griseb., eine erfolgversprechende Alternativbaumart für die Schadgebiete des oberen Erzgebirges. *Sozialistische Forstwirtschaft*, 37, 279–282.

Lines R. 1985. The Macedonian Pine (*Pinus peuce* Grisebach) in the Balkans and Great Britain. *Forestry*, 58 (1), 27–40.

Mayer H. 1979. The tallest trees in Europe, the phytosociological basis for optimal growth. *Phytocoenologia*, 6, 71–72.

Mincheva Y., Lazarova S., Peneva V. 2008. Nematode assemblages from Macedonian pine communities in Northern Pirin Mountain. *Comptes Rendus de l'Academie Bulgare dès Sciences*, 61 (9), 1169–1174.

Neuhäusl R. 1990. Unified classification of European natural forests: the approach of the vegetation map of Europe. *Vegetatio*, 89, 173–181.

Panayotov M., Bebi P., Trouet V., Yurukov S. 2010. Climate signal in tree-ring chronologies of *Pinus peuce* and *Pinus heldreichii* from the Pirin Mountains in Bulgaria. *Trees*, 24, 479–490.

Panić D.J., Sekulić Z., Černjavski S., Golubović R. 1970. Struktur und Produktivität von Molikabeständen in deren Hauptwuchsgebiet in Serbien. In: Report of a Symposium on *Pinus peuce,* 2–6 IX 1969, University of Skopje, 291–312.

Pejoski B. 1967. Die Molika-kiefer (*Pinus peuce*). *Allgemeine Forstzeitschrift für Waldwirtschaft und Umweltvorsorge*, 22, 61–67.

Piovesan G., Pelosi C., Schirone A., Schirone B. 1993. Taxonomic evaluations of the genus *Pinus* (Pinaceae) based on electrophoretic data of salt soluble and insoluble seed storage proteins. *Plant Systematics and Evolution*, 186, 57–68.

Raev I. 2005. Virgin forests of Bulgaria – inventory and strategy for sustainable management and protection of virgin forests. Royal Dutch Society for Nature Conservation. Bulgarian Forest Research Institute.

Rossnev B. 1985. *Phaeolus schweinitzii* on *Pinus peuce* in Bulgarien. *European Journal of Forest Pathology*, 15 (2), 66–70.

Roussakova V. 2011. Macedonian pine (*Pinus peuce*) forests. In: Red Data Book of the Republic of Bulgaria. Digital Edition. Vol. 3. Natural Habitats (eds.: V. Biserkov, C. Gussev), Bulgarian Academy of Sciences and Ministry of Environment and Water, Sofia.

Scheurer S. 1991. Ein Beitrag zum Vorkommen und zur Biologie eniger *Cinara*-Species in den Rhodopen (Bulgaria). (Homoptera, Aphidina). *Deutsche Entomologische Zeitschrift*, 38 (4/5), 371–378.

Tomanic L., Stojanovic L., Stevanovic V., Karadzic D., Ostojic D. 1998. Phytocenological and associative characteristics of Macedonia pine forests on Jazinacko lake on Šar Planina (mountain, Yugoslavia). *Zaštita prirode* (*Protection of Nature*), 50, 305–318.

Tortić M. 1968. The Mycoflora of Gorski Kotar in Yugoslavia. *Acta Mycologica*, 4 (2), 351–354.

Tortić M. 1987. Main Characters of the Mycoflora in Forests of *Pinus peuce* Griseb. *Acta Botanica Croatica*, 46, 145–154.

Tsanova P., Rossnev B. 1974. Injuries from *Fomes-Annosus* on *Pinus-Peuce Pinus-Leucodermis Pseudotsuga-Douglasii* and *Pinus-Strobus* Stands. *Gorskostopanska Nauka*, 11, 73–84.

Tzonev R.T., Dimitrov M.A., Roussakova V.H. 2009. Syntaxa according to the Braun-Blanquet approach in Bulgaria. *Phytologia Balcanica*, 15, 209–233.

Vilarov M.L. 1970. The soil beneath some plant communities on Mt Pelister. In: Report of a Symposium on *Pinus peuce*, 2–6 IX 1969, University of Skopje, 233–237.

Wang X.-R., Tsumura Y., Hiroshi Y., Kazutoshi N., Szmidt A.E. 1999. Phylogenetic relationships of Eurasian pines (*Pinus*, Pinaceae) based on chloroplast *rbc*L, *matK*, *rpl20-rps18* spacer, and *trnV* intron sequences. *American Journal of Botany*, 86, 1742–1753.

Wojterski T. 1971. Parki Narodowe Jugosławii. *Ochrona Przyrody*, 36, 1–129.