Acta Sci. Pol.
Silv. Colendar. Rat. Ind. Lignar. 10(4) 2011, 39-49

PLANTS, FUNGI AND INVERTEBRATES OF GRAND FIR [*ABIES GRANDIS* (DOUGLAS EX D. DON) LINDL.] EXPERIMENTAL STANDS IN ROGÓW ARBORETUM (POLAND)

Maciej Skorupski[1], Andrzej M. Jagodziński[1,2], Izabela Kałucka[3], Marek Kasprowicz[4], Maria Wojterska[4], Tomasz Dobies[1], Małgorzata Sławska[5], Anna Wierzbicka[1], Andrzej Łabędzki[1], Joanna Oleszyńska-Niżniowska[1], Mirosław Nowiński[1], Stanisław Małek[6], Piotr Karolewski[2], Jacek Oleksyn[2], Piotr Banaszczak[7]

[1]Poznań University of Life Sciences
[2]Institute of Dendrology of Polish Academy of Sciences, Kórnik
[3]University of Lodz
[4]Adam Mickiewicz University in Poznań
[5]Warsaw University of Life Sciences – SGGW
[6]University of Agriculture in Krakow
[7]Rogów Arboretum of Warsaw University of Life Sciences – SGGW

Abstract. The paper gives a survey of biodiversity of planted grand fir (*Abies grandis*) stands in Rogów Arboretum on the background of environmental data compared to those of its natural distribution. Some information concerns studies on grand fir plantations in Europe and their influence on chosen components of the ecosystem. During the study, 63 taxa of vascular plants, mosses and liverworts, 46 taxa of fungi and 110 of invertebrates were found.

Key words: *Abies grandis*, grand fir, biodiversity, vascular plants, fungi, nematodes, mites, insects

Corresponding author – Adres do korespondencji: Dr hab. Maciej Skorupski, Department of Game Management and Forest Protection of Poznań University of Life Sciences, Wojska Polskiego 71 C, 60-625 Poznań, Poland, e-mail: maskorup@up.poznan.pl

INTRODUCTION

Grand fir [*Abies grandis* (Douglas ex D. Don) Lindl.] grows naturally in northwestern part of the United States and southern British Columbia and has split distribution. Its native range stretches from latitude 39 to 51°N and from longitude 114 to 125°W. Grand fir occurs at elevations up to 1830 m a.s.l. and grows on a wide variety of sites. It is predominantly a lowland tree species, growing along valleys and stream bottoms having high ground-water levels. Average annual precipitation in its natural territory ranges from ca. 510 to more than 2540 mm and most of this precipitation occurs during winter. Average annual temperatures range from 6 to 10°C and those in growing season from 14 to 19°C. The average length of growing season within its natural range is from 100 (northern Idaho) to 250 days (northern Carolina). Grand fir grows well on soils derived from different parent materials; most of the soils where this species grows are classified as Spodosols [Foiles 1965, Tumiłowicz 1977].

Grand fir is considered either a seral or late-successional species in variable forest types within its natural range [Antos and Habeck 1981, Hall 1983]. It seldom grows in pure stands; it is much more common in mixed coniferous and hardwood forests. Grand fir is an indicator of productive forest sites and it is considered as a commercially valuable timber species [Foiles et al. 1990]. Grand fir is associated among others with *Pinus monticola*, *Larix occidentalis*, *Pseudotsuga menziesii*, *Tsuga heterophylla*, *Thuja plicata*, *Pinus contorta*, *Pinus ponderosa*, *Picea engelmannii*, *Abies lasiocarpa*, *Abies concolor*, *Pinus lambertiana* and *Quercus garryana*. Longevity of grand fir is intermediate among true firs (it may reach the age of 250-300 years). On optimum sites in the coastal lowlands of Washington, mature grand firs reach 51 to 102 cm of d.b.h. and 43 to 61 m of height [Foiles et al. 1990]. It is the fastest growing of all North American firs and in 50 years it may reach ca. 43 m of height [Schmidt 1957]. Grand fir has been planted successfully in many European countries, where it is considered one of the potentially most productive tree species, especially for sites where traditional European tree species achieve low performances [Aldhous and Low 1974, Liesebach et al. 2008]. Grand fir has been planted in Europe since around 1830, when seeds from the coastal areas of the Pacific Northwest were first brought to Europe [Konnert and Reutz 1997]. The provenance experiments established in Europe demonstrated that *Abies grandis* can adapt to a variety of environmental conditions without losing its natural growth potential, although large differences among provenances were observed, especially in respect to growth, frost hardiness and drought tolerance. For example von Liesebach et al. [2008] found in provenance experiment in Austria that at the age of 25 grand fir reaches diameters at breast height of about 20 cm and is considered as faster growing tree species than Norway spruce and silver fir, and comparable with Douglas fir. The cited authors mentioned the high susceptibility of that species to the honey fungus (*Armillaria mellea*) which is responsible for high damages of trees. Many studies on afforestation with grand fir in Europe have shown that this species grows well and has great ecological adaptability [Kleinschmit et al. 1996, Xu et al. 1997, Dolnicki and Kraj 1998, Rau et al. 1998, Socha and Kulej 2008, Kulej 2010]. For example Rau and Schönfelder [2008] revealed high variability among grand fir provenances in Western Germany; they found that the best growing provenances come from Vancouver Island and Western Washington, while coastal provenances from Southern Oregon showed completely negative results. Kulej and Socha [2005] found that the productivity of 27-year-old stands of

grand fir under mountain conditions of the Beskid Sądecki strongly depends on the provenance. The mean volume of individual provenances varied considerably from 43.7 $m^3 \cdot ha^{-1}$ to 151.3 $m^3 \cdot ha^{-1}$ and the mean annual increment of large wood volume ranged from 1.6 to 5.6 $m^3 \cdot ha^{-1}$.

Grand fir is classified as shade-tolerant tree species in all associations in which it occurs, although is not as shade-tolerant as western red cedar, hemlocks, or other firs and does not establish beneath a closed canopy [Schmidt 1957, Turner 1985]. It is also tolerant of fluctuating water tables and floods. For example Xu et al. [1997] found that roots of grand fir were more tolerant, expanded to greater depths and attained higher densities than roots of Norway spruce in a mountainous region in western Germany. Moreover, they found during the waterlogged period, that the fine roots had considerably greater dead than live biomass (5558 $kg \cdot ha^{-1}$ and 3594 $kg \cdot ha^{-1}$, respectively) and at the beginning of the non-waterlogged period the total biomass of live fine roots increased by 50%, whereas the dead fine roots biomass decreased by 27%.

MATERIAL AND METHODS

The study was conducted in two grand fir [*Abies grandis* (Douglas ex D. Don) Lindl.] stands with ages of 61 years (A) and 49 years (B), situated in the Rogów Arboretum of the Warsaw University of Life Sciences (SGGW), Poland (51°49'N, 19°53'E). The study plots were located in the central part of the Arboretum. The detailed information for both stands is shown in Table 1.

Table 1. Characteristics of *Abies grandis* experimental plots (2009) [Hotała 2010]
Tabela 1. Charakterystyka powierzchni doświadczalnych z *Abies grandis* (2009) [Hotała 2010]

Characteristics Charakterystyka	Study site A Powierzchnia doświadczalna A	Study site B Powierzchnia doświadczalna B
Year of stand establishment Rok założenia drzewostanu	1967	1969
Year of seed sprouting Rok skiełkowania nasion	1949	1961
Area of experimental plot Powierzchnia poletek badawczych	0.0408 ha	0.0408 ha
Seed origin Pochodzenie nasion	Denman Isl., B. C., Vancouver, Canada	Cascade Mts., USA
Stand density, trees·ha^{-1} Zagęszczenie, drzewa·ha^{-1}	490	515
Stand age Wiek drzewostanu	61	49

According to long-term meteorological observations (55 years) from the closest meteorological station in Strzelna, mean annual temperature is 7.2°C (January: –3.2°C, July: 17.3°C), mean annual precipitation is 596 mm (404-832 mm, ca. 70% of annual

precipitation is 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 and Banaszczak 2010].

The study plots are located on a flat terrain ca. 189 m a.s.l. The soils were developed on a postglacial formation, in the region of a ground moraine. The soils are rich, mesic, with the groundwater level beyond the reach of tree roots [Czępińska-Kamińska et al. 1991, Jagodziński and Banaszczak 2010]. Soil unit is haplic luvisol. Soil texture in the A horizon was sandy silt. The content of sand fraction was 50%, silt fraction 45.5%, clay fraction 4.5%. Soil reaction was strongly acidic, pH measured in M KCl in particular horizons was as followed: Oll 4.00, Ol 5.27, Ofh 4.11 and A 3.18. Total acidity was respectively: Oll 47.14 cmol(+)/kg, Ol 29.37 cmol(+)/kg, Ofh 56.74 cmol(+)/kg and A 13.24 cmol(+)/kg.

During three-year study (2007-2009), vascular plants, mosses, and soil invertebrates (nematodes, mites and insects) were recorded and determined in the experimental plots. The subject of mycological examination were mycorrhizal, saprotrophic and parasitic species, excluding corticioid taxa; traditionally, Myxomycetes were also considered in the list of taxa. Observations were carried out in 2008-2010. Identification of sporocarps was based on standard methods used in mycological studies. The nomenclature 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 *Abies grandis* plots were compared with the list of taxa found in the subcontinental oak-hornbeam forest *Tilio-Carpinetum* Traczyk 1962 *calamagrostietosum*, situated in the western part of the Arboretum. The oak-hornbeam forest was dominated by native tree species. The upper stand layer is formed by *Quercus petraea* and *Pinus sylvestris* as well as *Populus tremula*. The lower tree layer and undergrowth were dominated by *Carpinus betulus*.

RESULTS

During the study 219 taxa of plants, fungi and invertebrates were found in *Abies grandis* stands. There are 63 taxa of vascular plants, mosses and liverworts, 46 taxa of fungi and 110 of invertebrates. In the control sites (*Tilio-Carpinetum*) 281 taxa of the organisms studied were found. There are 52 taxa of vascular plants and mosses, 67 taxa of fungi and 162 taxa of invertebrates (Fig. 1). The list of organisms is given below.

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

Abies grandis (Douglas ex D. Don) Lindl., *Acer caudatum* ssp. *ukurunduense* (Trautv. & C. A. Mey.) A. E. Murray, *Acer rubrum* L., *Acer rufinerve* Siebold & Zucc., *Amelanchier spicata* (Lam.) K. Koch, *Aralia elata* (Miq.) Seem., *Castanea sativa* Mill., *Cerasus vulgaris* Mill., *Kalopanax septemlobus* (Thunb.) Koidz., *Quercus rubra* L., *Sorbus commixta* Hedl., *Thuja plicata* Donn ex D. Don in Lamb., *Berberis* L. sp., *Carya* sp., *Cornus* sp., *Crataegus* sp.

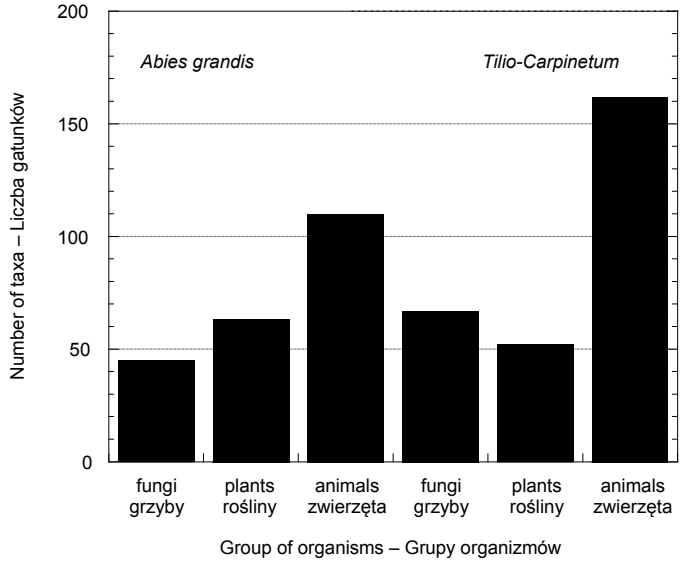

Fig. 1. Number of fungi, plants and animals taxa found in *Abies grandis* stands and *Tilio-Carpinetum* sites (control)
Rys. 1. Liczba gatunków grzybów, roślin i zwierząt stwierdzonych w drzewostanach *Abies grandis* i na powierzchni kontrolnej *Tilio-Carpinetum*

Spontaneous vascular plants

Acer campestre L., *Acer platanoides* L., *Anemone nemorosa* L., *Athyrium filix-femina* (L.) Roth, *Betula pubescens* Ehrh., *Calamagrostis arundinacea* (L.) Roth, *Carex digitata* L., *Carex ovalis* Gooden., *Carex pilulifera* L., *Carpinus betulus* L., *Cerasus avium* (L.) Moench, *Chamaenerion angustifolium* (L.) Scop., *Convallaria majalis* L., *Corylus avellana* L., *Dryopteris carthusiana* (Vill.) H. P. Fuchs, *Dryopteris dilatata* (Hoffm.) A. Gray, *Euonymus europaea* L., *Euonymus verrucosa* Scop., *Fagus sylvatica* L., *Frangula alnus* Mill., *Geranium robertianum* L., *Laserpitium* sp., *Luzula pilosa* (L.) Willd., *Maianthemum bifolium* (L.) F. W. Schmidt, *Melica nutans* L., *Moehringia trinervia* (L.) Clairv., *Mycelis muralis* (L.) Dumort., *Oxalis acetosella* L., *Padus avium* Mill., *Padus serotina* (Ehrh.) Borkh., *Quercus petraea* (Matt.) Liebl., *Quercus robur* L., *Rubus hirtus* Waldst. & Kit. Agg., *Sambucus nigra* L., *Sambucus racemosa* L., *Sorbus aucuparia* L., *Sorbus torminalis* (L.) Crantz, *Taraxacum officinale* F. H. Wigg., *Trientalis europaea* L., *Vaccinium myrtillus* L., *Viola riviniana* Rchb.

Mosses

Atrichum undulatum (Hedw.) P. Beauv., *Dicranella heteromalla* (Hedw.) Schimp., *Plagiothecium curvifolium* Schlieph. ex Limpr., *Plagiothecium laetum* B., S. & G., *Pohlia nutans* (Hedw.) Lindb.

Liverwort

Lophocolea heterophylla (Schrad.) Dum.

Mycorrhizal fungi

Amanita citrina (Schaeff.) Pers., *Amanita fulva* Fr., *Amanita rubescens* Pers., *Boletus edulis* Bull., *Cantharellus cibarius* Fr., *Cortinarius* cf. *cinnamomeus* (L.) Fr., *Cortinarius* sp. 1, *Cortinarius* sp. 2, *Inocybe* sp. 5, *Laccaria amethystina* (Huds.) Cooke, *Lactarius aurantiacus* (Pers.) Gray, *Paxillus involutus* (Batsch) Fr., *Russula* cf. *brunneoviolacea* Crawshay, *Russula ochroleuca* (Pers.) Fr., *Russula puellaris* Fr., *Russula vesca* Fr., *Russula* sp. 4, *Russula* sp. 5, *Russula* sp. 6, *Xerocomus badius* (Fr.) E.-J. Gilbert, *Xerocomus chrysenteron* (Bull.) Quél.

Saprotrophic and parasitic fungi

Agaricus sp. 1, *Ampulloclitocybe clavipes* (Pers.) Redhead, Lutzoni, Moncalvo & Vilgalys, *Armillaria* spp., *Calocera viscosa* (Pers.) Fr., *Ceratiomyxa fruticulosa* (O.F. Müll.) T. Macbr., *Chlorophyllum rhacodes* (Vittad.) Vellinga, *Clitocybe* spp., *Crepidotus* spp., *Entoloma* spp., *Gymnopilus penetrans* (Fr.) Murrill, *Gymnopus dryophilus* (Bull.) Murrill, *Heterobasidion annosum* (Fr.) Bref., *Hygrophoropsis aurantiaca* (Wulfen) Maire, *Hypholoma fasciculare* (Huds.) P. Kumm., *Hypholoma lateritium* (Schaeff.) P. Kumm., *Lepista flaccida* (Sowerby) Pat., *Mycena epipterygia* (Scop.) Gray, *Mycena pura* (Pers.) P. Kumm., *Mycena zephirus* (Fr.) P. Kumm., *Mycena* spp., *Pholiota* sp. 1, *Pluteus cervinus* (Schaeff.) P. Kumm., *Pseudohydnum gelatinosum* (Scop.) P. Karst., *Rhodocollybia butyracea* f. *asema* (Fr.) Antonín Halling & Noordel., *Tricholomopsis rutilans* (Schaeff.) Singer.

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, *Malenchus acarayensis* Andrássy, *Ogma menzeli* (Stefański) Schuurmans Stekhoven et Teunissen, *Paratylenchus straeleni* (de Coninck) Oostenbrink, Rhabditida spp.

Acari (Oribatida)

Achipteria coleoptrata (L.), *Achipteria quadridentata* (Willmann), *Acrotritia duplicata* (Grandjean), *Adoristes ovatus* (C.L. Koch), *Camisia spinifer* (C.L. Koch), *Carabodes coriaceus* C.L. Koch, *Carabodes labyrinthicus* (Michael), *Chamobates pusillus* (Berlese), *Chamobates voigtsi* (Oudemans), *Damaeus auritus* C.L. Koch, *Damaeus clavipes* (Hermann), *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), *Lauroppia falcata* (Paoli), *Liochthonius tuxeni* (Forsslund), *Metabelba pulverulenta* (C.L. Koch), *Micreremus gracilior* Willmann, *Neoliochthonius piluliferus* (Forsslund), *Nothrus silvestris* Nicolet, *Oppiella nova* (Oudemans), *Oribatula tibialis* (Nicolet),

Phthiracarus longulus (C.L. Koch), *Porobelba spinosa* (Sellnick), *Quadroppia quadricarinata* (Michael), *Ramusella insculpta* (Paoli), *Scheloribates latipes* (C.L. Koch), *Sellnickochthonius jacoti* (Evans), *Sellnickochthonius zelawaiensis* (Sellnick), *Steganacarus carinatus* (C.L. Koch), *Suctobelbella sarekensis* (Forsslund), *Suctobelbella subcornigera* (Forsslund), *Suctobelbella subtrigona* (Oudemans), *Tectocepheus velatus* (Michael), *Xenillus tegeocranus* (Hermann).

Acari (Mesostigmata)

Amblyseius sp., *Arctoseius brevichelis* Karg, *Arctoseius eremitus* (Berlese), *Leioseius magnanalis* (Evans), *Leptogamasus cuneoliger* Athias-Henriot, *Leptogamasus suecicus* Trägårdh, *Pachylaelaps bellicosus* Berlese, *Pachylaelaps furcifer* Oudemans, *Pachylaelaps suecicus* Sellnick, *Paragamasus vagabundus* (Karg), *Pergamasus barbarus* (Berlese), *Prozercon kochi* Sellnick, *Rhodacarus coronatus* Berlese, *Zercon peltatus* C.L. Koch, *Zercon* sp. 1, *Zercon triangularis* C.L. Koch.

Insects (Collembola)

Anurida granulata Agrell, *Arrhopalites* sp. juv., *Arrhopalites spinosus* Rusek, *Ceratophysella denticulata* (Bagnall), *Ceratophysella* sp. juv., Entomobyidae spp. juv., *Folsomia lawrencei* Rusek, *Folsomia penicula* Bagnall, *Folsomia quadrioculata* (Tullberg), *Friesea truncata* Cassagnau, *Isotomiella minor* (Schaffer), *Karlstejnia norvegica* Fjellberg, *Lepidocyrtus lignorum* gr juv., *Lepidocyrtus violacea* gr juv., *Lipotrix lubbocki* (Tullberg), *Megalothorax minimus* Willem, *Mesaphorura macrochaeta* Rusek, *Mesaphorura yosii* Rusek, *Mesaphorura* sp. juv., *Onychiuroides* sp. juv., *Parisotoma notabilis* (Schaffer), *Pogonognatellus flavescens* (Tullberg), *Protaphorura armata* (Tullberg), *Protaphorura* sp. juv., *Pseudachorutes parvulus* Borner, *Pseudosinella horaki* Rusek, *Sminthurinus aureus* (Lubbock), *Sminthurinus* sp. juv., *Sphaeridia pumilis* (Krausbauer), Tomoceridae juv., *Tomocerus minor* (Lubbock), *Willemia denisi* Mills s. Fjellberg.

Insects (Coleoptera)

Adalia bipunctata L., *Agonum fuliginosum* (Panz.), *Apion* sp., *Bembidion lampros* (Herbst), *Carabus cancellatus* Ill., *Coccinella septempunctata* L., *Harpalus tardus* (Panz.), *Malachius aeneus* L., *Pterostichus niger* (Schall.), *Rhagonycha fulva* Scop., Staphylinidae spp., Scarabaeidae spp.

Other insects

Homoptera spp.

DISCUSSION

There are some studies on biodiversity of grand fir stands. For example Deharveng [1996] has explored the fauna of Collembola in natural and planted tree stands in the

French Pyrenees. One of the investigated tree species was not native *Abies grandis*. The author concluded, that endemic component suffered a particularly severe loss in species richness and abundance, whereas non-endemic species were less affected by reforestation. Hayes [1965] has investigated phthiracarid mites fauna under several coniferous tree species in North Wales. He found four species of the group. Those species, except for *Steganacarus spinosus* (Sellnick), showed consistently lower number under *Abies grandis* than under the other tree species (Scots pine, Sitka spruce and European larch). There is a paper on interaction of arboreal spiders and grand fir pests, after an outbreak of western spruce budworm [Mason et al. 1997], and description of a new to the science species of false spider mite *Brevipalpus grandis* Mitchell [Mitchell 1975], but there are no data on the soil fauna of *Abies grandis* stands. Also research on colonization of *Abies grandis* by indigenous to France bark beetles [Bertheau et al. 2009] presents new records of insects on this tree species, but not from soil environment.

The data on macromycetes associated with native stands of *Abies grandis* are very sparse what may result from the fact that this tree species rarely forms pure stands and the influence of other tree species cannot be excluded. However, Trappe [1962 a] in his review of ectomycorrhizal fungi accompanying plant species, for *Abies grandis* mentioned *Boletus edulis* [Trappe 1961], *Cenococcum graniforme* (= *C. geophilum*) [Trappe 1962 b], *Lactarius deliciosus* [Trappe 1957], and *Russula delica* [Trappe 1957, 1961]. A few ectomycorrhizal fungi were reported from the roots of *Abies grandis* by Massicotte et al. [1999]: *Amphinema byssoides*, *Byssoporia terrestris*, *Coenococcum geophilum*, *Thelephora* sp., *Tomentella* sp., and *Tuber californicum*. The fungi recorded in the plots of *Abies grandis* in the present study are mainly the species showing broad ecological range and typically occurring in mixed and coniferous forests [Ławrynowicz et al. 2004]. It means that grand fir, an alien tree species, found symbiotic partners among native ectomycorrhizal fungi. On the other hand, native saprotrophs cope well with decomposition of litter and woody debris of that tree.

Native forests dominated by *Abies grandis* occurring in Pacific Northwest are known to be very rich in hypogeous fungi. Lehmkuhl et al. [2004] found several species, on average 9.3 species producing 3.56 kg d.w./ha of sporocarp standing biomass in young (av. 65-year-old) forest and 10.8 species producing 4.11 kg d.w./ha of sporocarp standing biomass in mature (av. 100-year-old, with maximum age of trees 180-325) forest of that type; among hypogeous species found basidiomycete fungi prevailed, among them *Gautieria monticola*, *Hysterangium coriaceum*, and *Leucogaster rubescens* being the most abundant. Out of the three species mentioned, only *H. coriaceum* is known to occur in Europe. During the present study hypogeous fungi were not searched for to avoid habitat disturbance; no sporocarps of that kind were found on the soil surface.

In one of the two plots examined (plot A) sparse fruitbodies of two severe fungal parasites were found: *Armillaria* sp. and *Heterobasidion annosum*. Both species are mentioned by Dominik and Grzywacz [1998] as fungi pathogenic to *Abies grandis* in Poland. The former is also claimed to cause high damage and loss of grand fir trees of different provenance in Austria [Liesebach et al. 2008]. The latter is known to infect grand fir in plantations in Sweden, although this tree species turned to be much less susceptible than European larch (*Larix decidua* Mill.), Japanese larch (*Larix kaempferi* (Lamb.) Carr.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) [Vollbrecht et al. 1995].

ACKNOWLEDGMENTS

The authors express gratitude to Dr. Anna Rusińska for verification of the determination of bryophytes. This research was supported by the Polish Ministry of Science and Higher Education (grant No. N304 071 32/2761).

REFERENCES

Aldhous J.R., Low A.J., 1974. The potential of western hemlock, western redcedar, grand fir, and noble fir in Britain. Forest Commission Bulletin 49. Her Majesty's Stationary Office London.

Antos J.A., Habeck J.R., 1981. Successional development in *Abies grandis* (Dougl.) Forbes forests in the Swan Valley, western Montana. Northw. Sci. 55 (1), 26-39.

Bednarek A., 1993. Klimat [Climate]. In: Warunki przyrodnicze lasów doświadczalnych SGGW w Rogowie. Ed. R. Zielony. Wyd. SGGW Warszawa, 24-41 [in Polish].

Bertheau C., Salle A., Rossi J-P., Bankhead-Dronnet S., Pineau X., Roux-Morabito G., Lieutier F., 2009. Colonisation of native and exotic conifers by indigenous bark beetles (Coleoptera: Scolytinae) in France. For. Ecol. Manag. 258, 1619-1628.

Czępińska-Kamińska D., Janowska E., Konecka-Batley K., 1991. Gleby Arboretum w Rogowie [Soils of the Rogów Arboretum]. Arboretum Rogów [manuscript in Polish].

Deharveng L., 1996. Soil Collembola diversity, endemism, and reforestation: a case study in the Pyrenees (France). Conserv. Biol. 10, 1, 74-84.

Dolnicki A., Kraj W., 1998. Dynamics of frost resistance in various provenances of *Abies granids* Lindl. Acta Soc. Bot. Pol. 67, 1, 51-58.

Dominik I., Grzywacz A., 1998. Zagrożenie obcych gatunków drzew iglastych ze strony rodzimej entomofauny oraz mikoflory [Threats to alien species of coniferous trees from inoligenous entomofauna and micoflora]. Fund. Rozwój SGGW Warszawa.

Foiles M.W., 1965. Grand fir, *Abies grandis* (Dougl.) Lindl. In: Silvics of forest trees of the United States. H.A. Fowells, U.S. Depart. Agric. Washington, DC, 19-24.

Foiles M.W., Graham R.T., Olson D.F. Jr., 1990. *Abies grandis* (Dougl. ex D. Don) Lindl. grand fir. In: Silvics of North America. Vol. 1. Eds R.M. Burns, B.H. Honkala. Conifers. Agric. Handb. 654. U.S. Depart. Agric. Forest Serv. Washington, DC, 52-59.

Hall F.C., 1983. Ecology of grand fir. In: Proceedings of the biology and management of true fir in the Pacific Northwest symposium; 1981 February 24-26; Seattle-Tacoma. WA. Contribution No. 45. Eds C.D. Oliver, R.M. Kenady. Univ. Wash., Coll. For. Res. Seattle, 43-52.

Hayes A.J., 1965. Studies on the distribution of some phthiracarid mites (Acari: Oribatidae) in a coniferous forest soil. Pedobiologia 5, 3, 252-261.

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. Depart. Game Manag. For. Prot. Pozn. Univ. Life Sci. Poznań [manuscript in Polish].

Jagodziński A., Banaszczak P., 2010. Stem volume and aboveground woody biomass in noble fir (*Abies procera* Rehder) stands in the Rogów Arboretum (Poland). Acta Sci. Pol., Silv. Colend. Rat. Ind. Lignar. 9, 2, 9-24.

Kleinschmit J., Svolba J., Rau H.M., Weisgerber H., 1996. The IUFRO *Abies grandis* provenance experiment in Germany – results at age 18/19. Silvae Genet. 45 (5-6), 311-317.

Konnert M., Reutz W.F., 1997. Genetic variation among provenances of *Abies grandis* from the Pacific Northwest. Forest Genet. 4, 2, 77-84.

Kulej M., 2010. Wartość genetyczno-hodowlana wybranych pochodzeń jodły olbrzymiej (*Abies grandis* Lindl.) w warunkach Beskidu Sądeckiego [Genetic and silvicultural value of selected grand fir (*Abies grandis* Lindl.) provenances in Beskid Sądecki]. Leśn. Pr. Bad. 71, 3, 249--256.

Kulej M., Socha J., 2005. Productivity of selected provenances of grand fir in the provenance experiment in the Krynica Experimental Forest. EJPAU 8 (4), #10.

Lehmkuhl J.F., Gould L.E., Cázares E., Hosford D.R., 2004. Truffle abundance and mycophagy by northern flying squirrels in eastern Washington forests. For. Ecol. Manag. 200, 49-65.

Ławrynowicz M., Bujakiewicz A., Mułenko W., 2004. Mycocoenological studies in Poland 1952--2002. Monogr. Bot. 93, 1-102.

Mason R.R., Jennings D.T., Paul H.G., Wickman B.E., 1997. Patterns of spider (Aranea) abundance during an outbreak of western spruce budworm (Lepidoptera: Tortricidae). Environ. Entomol. 26, 3, 507-518.

Massicotte H.B., Molina R., Tackaberry L.E., Smith J., Amaranthus M.P., 1999. Diversity and host specificity of ectomycorrhizal fungi retrieved from three adjacent forest sites by five host species. Can. J. Bot. 77, 1053-1076.

Mitchell R.G., 1975. *Brevipalpus grandis*; a new species of false spider mite (Acarina: Tenulpalpidae) on grand fir. Ann. Entomol. Soc. Am. 68, 1, 4-6.

Rau H.M., Kleinschmit J., Konig A., Ruetz W. Svolba J., 1998. Grand fir (*Abies grandis* Lindl.) provenance experiment in Western Germany. Allg. Forst Jagdzeit. 169, 6-7, 109-115.

Rau V.H.M., Schönfelder E., 2008. Experiences of cultivation with Grand fir (*Abies grandis* Lindl.) provenances in Western Germany – results of assessments on 18 sites at age 27. Aust. J. For. Sci. 125, 3, 201-216.

Schmidt R.L., 1957. The silvics and plant geography of the genus *Abies* in the coastal forests of British Columbia. Technical Publication T. 46. British Columbia For. Serv., Depart. Lands For. Victoria, BC.

Socha J., Kulej M., 2008. Provenance-dependent variability of *Abies grandis* stem form under mountain conditions of Beskid Sadecki (southern Poland). Can. J. For. Res. 35, 1, 2539-2552.

Trappe J.M., 1957. Some probable mycorrhizal associations in the Pacific Northwest. Northw. Sci. 31, 183-185.

Trappe J.M., 1961. Some probable mycorrhizal associations in the Pacific Northwest. III. Northw. Sci. 35, 91-94.

Trappe J.M., 1962 a. Fungus associates of ectotrophic mycorrhizae. Bot. Rev. 28, 538-606.

Trappe J.M., 1962 b. *Cenococcum graniforme* – its distribution, ecology, mycorrhiza formation and inherent variation. Ph.D. Diss., Univ. Wash. Seattle.

Tumiłowicz J., 1977. Jodła olbrzymia – *Abies grandis* Ldl. [Grand fir – *Abies grandis* Ldl.]. In: Obce gatunki drzew w gospodarstwie leśnym. Eds S. Bellon, J. Tumiłowicz, S. Król. PWRiL Warszawa 39-47 [in Polish].

Turner D.P., 1985. Successional relationships and a comparison of biological characteristics among six northwestern conifers. Bull. Torrey Bot. Club 112, 4, 421-428.

Vollbrecht G., Johansson U., Eriksson H., Stenlid J., 1995. Butt rot incidence, yield and growth pattern in a tree species experiment in southwestern Sweden. For. Ecol. Manag. 76 (1-3), 87-93.

Liesebach von M., Schueler S., Weissenbacher L., 2008. Provenance trials with Grand fir (*Abies grandis* [D. Don] Lindl.) in Austria – suitability, growth performance and variation. Austr. J. For. Sci. 125, 3, 183-200.

Xu Y.-J., Röhrig E., Fölster H., 1997. Reaction of root systems of grand fir (*Abies grandis* Lindl.) and Norway spruce (*Picea abies* Karst.) to seasonal waterlogging. For. Ecol. Manag. 93, 9-19.

ROŚLINY, GRZYBY I BEZKRĘGOWCE WYSTĘPUJĄCE NA POWIERZCHNIACH DOŚWIADCZALNYCH Z JODŁĄ OLBRZYMIĄ [*ABIES GRANDIS* (DOUGLAS EX D. DON) LINDL.] W ARBORETUM SGGW W ROGOWIE (POLSKA)

Streszczenie. W pracy przedstawiono różnorodność gatunkową stwierdzoną na powierzchniach doświadczalnych jodły olbrzymiej (*Abies grandis*) założonych na terenie Arboretum SGGW w Rogowie i porównano z danymi uzyskanymi w drzewostanach tego gatunku rosnących w warunkach naturalnego zasięgu występowania (zachodnia część Ameryki Północnej). Do porównania wykorzystano także wyniki badań uzyskane w drzewostanach jodły olbrzymiej założonych w Europie. W wyniku badań wykonanych w Arboretum SGGW w Rogowie, na powierzchniach doświadczalnych z jodłą olbrzymią wykazano obecność 63 gatunków roślin naczyniowych, mchów i wątrobowców, 46 gatunków grzybów wielkoowocnikowych oraz 110 gatunków bezkręgowców. Dane te porównano również z bogactwem gatunkowym stwierdzonym w rodzimym zbiorowisku leśnym (*Tilio-Carpinetum*), występującym w bliskim sąsiedztwie powierzchni doświadczalnych.

Słowa kluczowe: *Abies grandis*, jodła olbrzymia, różnorodność biologiczna, rośliny naczyniowe, grzyby, nicienie, roztocze, owady

Accepted for print – Zaakceptowano do druku: 22.12.2011

For citation – Do cytowania: Skorupski M., Jagodziński A.M., Kałucka I., Kasprowicz M., Wojterska M., Dobies T., Sławska M., Wierzbicka A., Łabędzki A., Oleszyńska-Niżniowska J., Nowiński M., Małek S., Karolewski P., Oleksyn J., Banaszczak P., 2011. Plants, fungi and invertebrates of grand fir [Abies grandis (Douglas ex D. Don) Lindl.] experimental stands in Rogów Arboretum (Poland). Acta Sci. Pol., Silv. Colendar. Rat. Ind. Lignar. 10(4), 39-49.