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ORIGINAL ARTICLE

# Species diversity related to red maple (*Acer rubrum* L.) occurred on experimental stands in Rogów Arboretum (Poland)

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## Abstract

The paper gives a survey of biodiversity of planted red maple (*Acer rubrum* L.) stands in Rogów Arboretum according to the background of environmental data. Red maple is native species to the eastern United States and Canada. The study has shown the presence of 40 taxa of vascular plants, 11 taxa of macrofungi and 111 taxa of invertebrates. The documented biodiversity of *A. rubrum* stands has been commented concerning the respective data from natural habitats.

## Key words

*Acer rubrum*, biodiversity, vascular plants, fungi, nematodes, mites, insects



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## Introduction

Red maple (*Acer rubrum* L.) is one of the most widely distributed tree species in the eastern part of North America, with a range extending from Florida to Northern Quebec. It is adaptable to a broad spectrum of environment conditions (Walters et al. 1990) and occurs naturally in different habitats from southern swamps to boreal forests, in full sun or shade. Of all the maples, it has the widest tolerance to climatic conditions (Dansereau 1957). Except for box elder (*Acer negundo* L.), no other maple has a wider distribution in the United States and Canada (Townsend et al. 1979). In the northern part of the range, the red maple distribution is discontinuous (Tremblay et al. 2002). It occurs as a dominant or co-dominant tree species in several eastern deciduous forests and deciduous swamp communities with the following tree species: *Fraxinus nigra*, *Betula alleghaniensis*, *Quercus rubra*, *Q. velutinus*, *Populus tremuloides* and *Ulmus* spp.

Red maple is a typical component of wetland communities (Moizuk and Livingston 1966) and is very tolerant of flooding. It often dominates (80–90% of canopy cover and of basal area) lowland and headwater wetlands in the eastern United States (Mitsch and Gosselink 2000). It grows along the margins of lakes, swamps, marshes and on floodplains and stream terraces (Braun 1961; Duncan and Duncan 1988; Will et al. 1995; Elliott et al. 1997). In wetlands red maple trees can develop numerous shallow lateral roots instead of a taproot to help avoid anaerobic stress (Will et al. 1995; Mitsch and Gosselink 2000; Warren et al. 2004). Red maple grows also throughout much of other deciduous forests of eastern North America (Hosie 1969), but as an overstory dominant only in swamps and other wet sites (Lorimer 1984). Moreover, it occurs in drier upland forests, dry sandy plains and on stable dunes (Godfrey 1988). Red maple grows well on a wide range of soil types – it develops best on fertile, moist, loamy soils but it also grows on dry, rocky and upland soils (Erdmann et al. 1985; Walters and Yawney 1990). It grows from sea level up to 900 m a.s.l.

Red maple is a short- to medium-lived tree species and it reaches maturity in 70–80 years. It grows fairly quickly in favorable situations and on optimum sites mature red maple trees reach 46 to 76 (160) cm of d.b.h. and 18 to 27 m of height (Hutnick and Yawney 1961; Duncan and Duncan 1987; Chapman and Bessette 1990).

The maximum life span red maple is ca. 150 years (Hicks 1998). During the early life, growth of red maple is rapid, but slows after trees reach the pole stage (Stone 1977).

Red maple is characterized not only by a wide ecological amplitude but it occupies also a wide range of successional stages (Johnson et al. 1987; Sakai 1990). It is classified as a pioneer or subclimax tree species that is more shade tolerant than the usual early successional species (Hutnick and Yawney 1961). It is considered as moderately tolerant of shade in the North and intolerant in the Piedmont (Walters and Yawney 1990). In general, seedlings of red maple are more shade tolerant than larger trees and can survive in the understory for a number of years (Hutnick and Yawney 1961). For example, according to Marquis and Gearhart (1983) seedlings may number more than 44000 per ha and can survive up to 5 years under moderate shade. Red maple recruitment often corresponds with disturbance events (Canham and Marks 1985; Rankin and Pickett 1989; Peroni 1994).

The pre-European forests of eastern North America contained far fewer red maples than at present. It occurred mainly in poorly drained areas, whereas nowadays it dominates the understory and mid-canopy of many oak, pine and northern hardwood forests (Abrams 1998). The observed in the last decades proliferation of *Acer rubrum*, cannot be ascribed to any specific alterations in disturbance or climate regime. It inhibits the regeneration of *Quercus* and brings about shift towards *A. rubrum* dominance in the canopy. Red maple has become ubiquitous in eastern North America across sites differing in light, moisture and nutrient availability (Hart et al. 2012).

## Material and Methods

The study was conducted in two red maple (*Acer rubrum* L.) stands with age 61 years, 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 tab. 1.

**Tab. 1.** The features of *Acer rubrum* stands on experimental plots (2009) [Hotała 2010]

| Characteristics | Study site A | Study site B |
|---|---|---|
| Year of stand establishment | 1973 | 1973 |
| Year of seed sprouting | 1971 | 1971 |
| Area of experimental plot | 0.04 ha | 0.04 ha |
| Seed origin | Wisconsin, Argonne Exp. Forest, Forest Co., USA | |
| Stand density, trees $ha^{-1}$ | 1076 | 1051 |
| Stand age | 39 | 39 |

According to the long-term meteorological observations (55 years) from the closest meteorological station in Strzelna, mean annual temperature in the Arboretum 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 occurs 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 the flat terrain with altitude ca. 189 m a.s.l. The soils developed on a postglacial formation, in the region of a ground moraine. In the Arboretum there are haplic luvisoils forest soils with horizons O-A-Eet-Bt-C (Czępińska-Kamińska et al. 1991; Jagodziński and Banaszczak 2010). The average pH values (in $H_2O$) calculated for the upper soil layers of studied plots are as follows: Oll – 3.80, Ol – 4.59, Ofh – 4.15, and A – 3.34. The soils are rich, mesic, with the groundwater level beyond the reach of tree roots.

During the three-year study (2007–2010), vascular plants, mosses, and soil invertebrates (nematodes, mites and insects) were recorded and determined in the experimental plots. Observations of macrofungi (traditionally including Myxomycetes) 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 *Acer rubrum* plots was compared with the list of taxa found in the subcontinental oak-hornbeam forest *Tilio-Carpinetum calamagrostietosum* Traczyk 1962, situated in the western part of the Arboretum. The oak-hornbeam forest is dominated by native tree species. The upper stand layer is formed of *Quercus petraea* and *Pinus sylvestris* as well as *Populus tremula*. In the lower tree layer and undergrowth *Carpinus betulus* prevailed.

## Results

During the study 162 taxa of plants, fungi and invertebrates were found, among them 40 taxa of vascular plants, 11 taxa of fungi and 111 taxa of invertebrates. No mosses were found within the *Acer rubrum* plots. In the control sites (*Tilio-Carpinetum*) 281 taxa of the organisms studied were recorded: 52 taxa of vascular plants and mosses, 67 taxa of fungi and 162 taxa of invertebrates (fig. 1). Below is the list of the organisms found in the *Acer rubrum* stands.

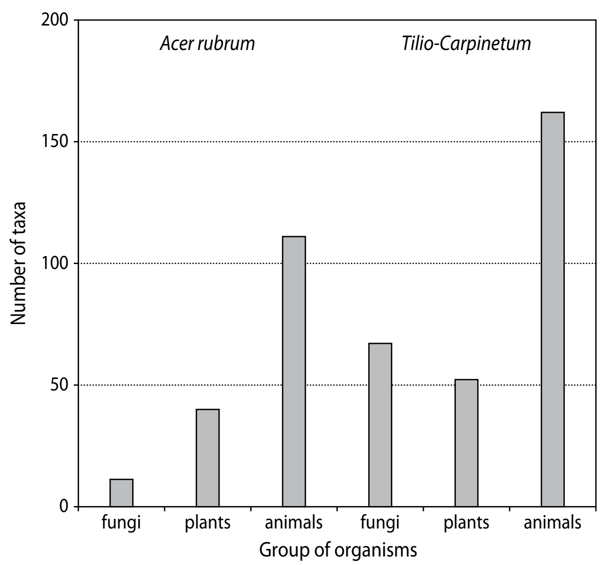


**Fig. 1.** Number of fungal, plant and animal taxa found in *Acer rubrum* stands and *Tilio-Carpinetum* sites (control)

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

*Abies cephalonica* Loudon, *Abies grandis* (Douglas ex D. Don) Lindl., *Acer rubrum* L., *Carya laciniosa* (F. Michx.) Loudon, *Castanea sativa* Mill., *Cornus alternifolia* L., *Kalopanax septemlobus* (Thunb.) Koidz., *Quercus cerris* L., *Quercus rubra* L., *Acer* L. sp., *Cornus* L. sp.

**Spontaneous vascular plants**

*Anemone nemorosa* L., *Calamagrostis arundinacea* (L.) Roth, *Carex digitata* L., *Carex ovalis* Gooden., *Carex pilulifera* L., *Carpinus betulus* L., *Cerasus avium* (L.) Moench, *Convallaria majalis* L., *Corylus avellana* L., *Crataegus rhipidophylla* Gand. var. *rhipidophylla*, *Daphne mezereum* L., *Euonymus europaea* L., *Fagus sylvatica* L., *Frangula alnus* Mill., *Galium schultesii* Vest, *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 hirtus* Waldst. & Kit. Agg., *Sambucus racemosa* L., *Scrophularia nodosa* L., *Sorbus aucuparia* L., *Vaccinium myrtillus* L., *Viola riviniana* Rchb.

**Mosses**

No mosses.

**Mycorrhizal fungi**

No ectomycorrhizal fungi.

**Saprotrophic and parasitic fungi**

*Armillaria* sp., *Calocera viscosa* (Pers.) Fr., *Hygrophoropsis aurantiaca* (Wulfen) Maire, *Hypholoma fasciculare* (Huds.) P. Kumm., *Leocarpus fragilis* (Dicks.) Rostaf., *Megacollybia platyphylla* (Pers.) Kotl. & Pouzar, *Mycena zephirus* (Fr.) P. Kumm., *Rhodocollybia butyracea* f. *asema* (Fr.) Antonín, Halling & Noordel., *Stereum hirsutum* (Willd.) Pers., *Stereum rugosum* Pers., *Stereum subtomentosum* Pouzar.

**Nematodes**

Aphelenchoides spp., *Cephalenchus hexalineatus* (Geraert) Geraert et Goodey, *Ditylenchus longimatricalis* (Kazachenko) Brzeski, *Ditylenchus* spp., *Filenchus discrepans* (Andrásssy) Raski et Geraert, *Filenchus misellus* (Andrássy) Raski et Geraert, *Pratylenchus penetrans* Cobb, *Rotylenchus robustus* (de Man) Filipjev.

**Acari (Oribatida)**

*Achipteria coleoptrata* (L.), *Acrotritia duplicata* (Grandjean), *Adoristes ovatus* (Koch), *Carabodes subarcticus* Trägårdh, *Chamobates voigtsi* (Oudemans), *Dissorhina ornata* (Oudemans), *Eueremaeus oblongus* (Koch), *Galumna lanceata* (Oudemans), *Hypochthonius rufulus* Koch, *Lauroppia falcata* (Paoli), *Liochthonius leptaleus* Moritz, *Liochthonius simplex* (Forsslund), *Liochthonius tuxeni* (Forsslund), *Metabelba pulverulenta* (Koch), *Microtritia minima* (Berlese), *Nanhermannia nana* (Nicolet), *Neoliochthonius piluliferus* (Forsslund), *Nothrus silvestris* Nicolet, *Oppiella nova* (Oudemans), *Oribatula tibialis* (Nicolet), *Phthiracarus longulus* (Koch), *Porobelba spinosa* (Sellnick), *Quadroppia quadricarinata* (Michael), *Ramusella insculpta* (Paoli), *Rhinoppia subpectinata* (Oudemans), *Scheloribates laevigatus* (Koch), *Scheloribates pallidulus latipes* (Koch), *Sellnickochthonius jacoti* (Evans), *Sellnickochthonius zelawaiensis* (Sellnick), *Steganacarus carinatus* (Koch), *Suctobelbella subcornigera* (Forsslund), *Suctobelbella subtrigona* (Oudemans), *Tectocepheus velatus* (Michael)

**Acari (Mesostigmata)**

*Discourella* sp., *Gamasellodes bicolor* (Berlese), *Leptogamasus cuneoliger* Athias-Henriot, *Leptogamasus suecicus* Trägårdh, *Pachylaelaps bellicosus* Berlese, *Paragamasus vagabundus* (Karg), *Parazercon radiatus* (Berlese), *Prozercon kunsti* Halaškova, *Prozercon traegardhi* (Halbert), *Rhodacarus reconditus* Athias-Henriot, *Trachytes aegrota* (C.L. Koch), *Urodiaspis tecta* (Kramer), *Uropoda minima* Kramer, *Veigaia cerva* (Kramer), *Veigaia nemorensis* (C.L. Koch), *Zercon triangularis* C.L. Koch.

**Insects (Collembola)**

*Allacma fusca* (Linnaeus), *Arrhopalites spinosus* Rusek, *Anurida granulata* Agrell, *Arrhopalites secundarius* Gisin, *Ceratophysella denticulata* (Bagnall), *Ceratophysella* sp. juv., *Desoria germanica* (Huther & Winter), *Desoria* sp. juv., *Entomobrya muscorum* (Nicolet), Entomobyidae juv., *Folsomia penicula* Bagnall, *Folsomia quadrioculata* (Tullberg), *Folsomia* juv., *Friesea truncata* Cassagnau, *Isotomiella minor* (Schaffer), *Lepidocyrtus lanuginosus* (Gmelin), *Lepidocyrtus lignorum* (Fabricius), *Lepidocyrtus lignorum* gr juv., *Megalothorax minimus* Willem, *Mesaphorura macrochaeta* Rusek, *Mesaphorura* sp. juv., *Micraphorura absoloni* (Borner), *Paratullbergia callipygos* (Borner), *Parisotoma notabilis* (Schaffer), *Pogonognatellus flavescens* (Tullberg), *Proisotoma minima* (Tullberg), *Protaphorura armata* (Tullberg), *Protaphorura* sp. juv., *Pseudachorutes parvulus* Borner, *Pseudachorutes* sp. juv., *Pseudosinella alba* (Packard), *Pseudosinella ho-*

*raki* Rusek, *Sminthurinus* sp. juv., *Sphaeridia pumilis* (Krausbauer), Tomoceridae juv., *Tomocerus minor* (Lubbock)

#### Insects (Coleoptera)

*Agonum assimile* (Payk.), *Apion* sp., *Calathus ambiguus* (Payk.), *Cantharis fusca* L., *Carabus nemoralis* O.F.Muller, *Ectobius sylvestris* L., *Lagria hirta* L., *Otiorrhynchus ovatus* L., *Phyllopertha horticola* L., *Pterostichus cupreus* (L.), *Pterostichus niger* (Schall.), *Rhagonycha fulva* Scop., *Selatosomus affinis* Payk., Staphylinidae spp., *Strophosoma melanogramma* L.

#### Other insects

Heteroptera spp., Homoptera spp., Tipulidae ssp.

## Discussion

Red maple tree stands were subject of many investigations. The studies on dynamics of *Acer rubrum* (McDonald et al. 2003) have shown that the observed expansion of this species limits the establishment of ingrowth of different *Quercus spp.* species i.e. *Q. alba, Q. falcata, Q. rubra, Q. stellata* and *Q. velutina.* To this successful spread of red maple contributed: wind dispersal mode, diaspores ability to resist decay and to germinate through moist litter in conditions of low light availability (Artigas and Boemer 1989).

There are several papers concerning the decomposition issues (Ball et al. 2009; Barbara et al. 2003; Blair and Crossley 1988; Cote and Fyles 1994; Gartner and Cardon 2004; Heneghan et al. 2004; Hutchens and Wallace 2002; Mudrick et al. 1994) in which invertebrate fauna was used as a bioindicator of the process (Whalen 2004). Unfortunately in these studies the animals were usually determined to the order level only. More detailed investigation concerned the topic of leaf litter colonization, but in wetland or water environment (Braccia and Batzer 2001; Pope et al. 1999). The species composition was determined during the study on parasitic nematodes in forest nurseries in Tennessee (Niblack and Bernard 1985a, b; Ruehle 1971), but none of those species repeats on the lists from Rogów Arboretum. There are also results of investigations on arthropod fauna in red maple canopy in North America (Costa and Crossley 1991; Miller et al. 2008). The research on soil fauna concerned either other tree species (Dindal 1998) or succession issues (Abell et al. 1982), and in red maple tree stands was focused on the influence of forest practices on it (Shure and Phillips 1991). In all these studies only insects were explored.

Red maple is a tree species that forms symbiotic relationships with arbuscular mycorrhizal fungi that do not form macroscopic sporocarps, and not with ectomycorrhizal fungi (Smith and Read 2008). Thus only the sporocarps of saprotrophic and parasitic fungi associated with the stands studied were found. Only three species growing on litter were found, *Hygrophoropsis aurantiaca, Mycena zephirus* and *Rhodocollybia butyracea* f. *asema,* and none of them seemed to utilize maple leaves but rather the litter originating from other trees growing in close vicinity. The presence of *Armillaria* sp., a dangerous parasite, was recorded with low frequency; the species is known to attack various exotic trees in Poland apart of its native hosts (Dominik and Grzywacz 1998 and the literature cited therein). The remaining species of fungi grew on stumps and fallen branches; *Calocera viscosa* and *Hypholoma fasciculare* were found on dead coniferous wood that was present in the plots. One species of common myxomycete was recorded – *Leocarpus fragilis.* The stands of red maple do not favour the occurrence of macrofungi, the number of species found is very low in comparison with native forest community (fig. 1).

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## References

Abell D.H., Wasti S.S., Hartmann G.C. 1982. Saprophagous arthropod fauna associated with turtle carrion. *Applied Entomology and Zoology*, 17 (3), 301–307.

Abrams M.D. 1998. The red maple paradox: What explains the widespread expansion of red maple in eastern forests? *BioScience*, 48 (5), 355–364.

Artigas F.J., Boemer R.E.J. 1989. Advance regeneration and seed banking of woody plants in Ohio pine plantations: Implications for landscape change. *Landscape Ecology*, 2, 139–150.

Ball B.A., Bradford M.A., Coleman D.C., Hunter M.D. 2009. Spatial and temporal distribution of earthworm patches in corn field, hayfield and forest systems of southwestern Quebec, Canada. *Soil Biology and Biochemistry*, 41 (6), 1155–1163.

Barbara C., Reynolds D.A., Crossley Jr., Huntera M.D. 2003. Response of soil invertebrates to forest canopy inputs along a productivity gradient. *Pedobiologia*, 47 (2), 127–139.

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

Blair J.M., Crossley D.A. Jr. 1988. Litter decomposition, nitrogen dynamics and litter microarthropods in a southern Appalachian hardwood forest 8 years following clearcutting. *Journal of Applied Ecology*, 25 (2), 683–698.

Braccia A., Batzer D.P. 2001. Invertebrates associated with woody debris in a Southeastern U.S. forested floodplain wetland. *Wetlands*, 21 (1), 18–31.

Braun E.L. 1961. The woody plants of Ohio. Ohio State University Press, Columbus, OH, pp. 362.

Canham C.D., Marks P.L. 1985. The response of woody plants to disturbance: patterns of establishment and growth. In: The Ecology of Natural Disturbances and Patch Dynamics (eds.: S.T.A. Pickett, P.S. White). Academic Press, Orlando, FL, USA, 201–216.

Chapman W.K., Bessette A.E. 1990. Trees and shrubs of the Adirondacks. North Country Books Inc., Utica, NY, pp. 131.

Costa J.T., Crossley D.A. 1991. Diel patterns of canopy arthropods associated with 3 tree species. *Environmental Entomology*, 20 (6), 1542–1548.

Cote B., Fyles J.W. 1994. Leaf litter disappearance of hardwood species of southern Quebec : interaction between litter quality and stand type. *Ecoscience*, 1 (4), 322–328.

Côté B., Fyles J.W. 1994. Nutrient concentration and acid-base status of leaf litter of tree species characteristic of the hardwood forest of southern Quebec. *Canadian Journal of Forest Research*, 24, 192–196.

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

Dansereau P.M. 1957. Biogeography. Ronald Press, New York, pp. 394.

Dindal D.L. 1998. Soil arthropod microcommunities of the pine barrens. Pine barrens: ecosystem and landscape. Rutgers University Press, 527–539.

Dominik I., Grzywacz A. 1998. Zagrożenie obcych gatunków drzew iglastych ze strony rodzimej entomofauny oraz mikoflory. Fundacja Rozwój SGGW, Warszawa.

Duncan W.H., Duncan M.B. 1987. The Smithsonian guide to seaside plants of the Gulf and Atlantic Coasts from Louisiana to Massachusetts, exclusive of lower peninsular Florida. Smithsonian Institution Press, Washington, DC, pp. 409.

Duncan W.H., Duncan M.B. 1988. Trees of the southeastern United States. The University of Georgia Press, Athens, GA, pp. 322.

Elliott K.J., Boring L.R., Swank W.T., Haines B.R. 1997. Successional changes in plant species diversity and composition after clearcutting a southern Appalachian watershed. *Forest Ecology and Management*, 92, 67–85.

Erdmann G.G., Peterson R.M. Jr., Oberg R.R. 1985. Crown releasing of red maple poles to shorten high-quality sawlog rotations. *Canadian Journal of Forest Research* 15 (4), 694–700.

Gartner T.B., Cardon Z.G. 2004. Decomposition dynamics in mixed-species leaf litter. *Oikos*, 104 (2), 230–246.

Godfrey R.K. 1988. Trees, shrubs, and woody vines of northern Florida and adjacent Georgia and Alabama. The University of Georgia Press, Athens, GA, pp. 734.

Hart J.L., Buchanan M.L., Clark S.L., Torreano S.J. 2012. Canopy accession strategies and climate-growth relationships in *Acer rubrum*. *Forest Ecology and Management*, 282, 124–132.

Heneghan L. 2004. Recovery of decomposition and soil microarthropod communities in an Appalachian watershed two decades after a clearcut. *Forest Ecology and Management*, 189 (1/3), 353–362.

Hicks R.R. 1998. Ecology and management of central hardwood forests. John Wiley & Sons Inc., New York.

Hosie R.C. 1969. Native trees of Canada. 7th ed. Canadian Forestry Service, Department of Fisheries and Forestry, Ottawa, ON, pp. 380.

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), pp. 153.

Hutchens J.J., Wallace J.B. 2002. Ecosystem linkages between southern Appalachian headwater streams and their banks: Leaf litter breakdown and invertebrate assemblages. *Ecosystems*, 5 (1), 80–91.

Hutnick R.J., Yawney H.W. 1961. Silvical characteristics of red maple (*Acer rubrum*). USDA Forest Service, Station Paper 142. Northeastern Forest Experiment Station, Upper Darby, PA, pp. 18.

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 Sci. Pol., Silv. Colend. Rat. Ind. Lignar.*, 9 (2), 9–24.

Johnson J.E., Haag C.L., Bockheim J.G., Erdmann G.G. 1987. Soil-site relationships and soil characteristics associated with even-aged red maple (*Acer rubrum*) stands in Wisconsin and Michigan. *Forest Ecology and Management*, 21, 75–89.

Lorimer C.G. 1984. Development of the red maple understory in northeastern oak forests. *Forest Science*, 30 (1), 3–22.

Marquis D.A., Gearhart P. 1983. Cherry-maple. In: Silvicultural systems for the major forest types of the United States (ed.: R.M. Burns). Agric. Handb. No. 445. Department of Agriculture, Forest Service, Washington, DC, U.S., 137–140.

McDonald R.I., Peet R.K., Urban D.L. 2003. Spatial pattern of *Quercus* regeneration limitation and *Acer rubrum* invasion in a Piedmont forest. *Journal of Vegetation Science*, 14, 441–450.

Miller K.M., Wagner R.G., Woods S.A. 2008. Arboreal arthropod associations with epiphytes following gap harvesting in the Acadian forest of Maine. *Bryologist*, 111 (3), 424–434.

Mitsch W.J., Gosselink J.G. 2000. Wetlands. 3rd edition. Van Nostrand Reinhold, New York, NY, USA.

Moizuk G.A., Livingston R.B. 1966. Ecology of red maple (*Acer rubrum* L.) in a Massachusetts upland blog. *Ecology*, 47 (6), 942–650.

Mudrick D.A., Hoosein M., Hicks R.R., Townsend E.C. 1994. Decomposition of leaf litter in an Appalachian forest: effects of leaf species, aspect, slope position and time. *Forest Ecology and Management*, 68 (23), 231–250.

Niblack T.L., Bernard E.C. 1985a. Nematode community structure in dogwood, maple and peach nurseries in Tennessee. *Journal of Nematology*, 17 (2), 126–131.

Niblack T.L., Bernard E.C. 1985b. Plant parasitic nematode communities in dogwood, maple and peach nurseries in Tennessee. *Journal of Nematology*, 17 (2), 132–139.

Peroni P.A. 1994. Invasion of red maple (*Acer rubrum* L.) during old field succession in the North Carolina Piedmont: age structure of red maple in young pine stands. *Bulletin of the Torrey Botanical Club*, 121, 357–359.

Pope R.J., Gordon A.M., Kaushik N.K. 1999. Leaf litter colonization by invertebrates in the littoral zone of a small oligotrophic lake. *Hydrobiologia*, 392, 99–112.

Rankin W.T., Pickett S.T.A. 1989. Time of establishment of red maple (*Acer rubrum*) in early oldfield succession. *Bulletin of the Torrey Botanical Club*, 116 (2), 182–186.

Ruehle J.L. 1971. Nematodes parasitic on forest trees: III. Reproduction on selected hardwoods. *Journal of Nematology*, 3 (2), 170–173.

Sakai A.K. 1990. Sex ratios of red maple (*Acer rubrum*) populations in northern lower Michigan. *Ecology*, 7 (2), 571–580.

Shure D.J., Phillips D.L. 1991. Patch size of forest openings and arthropod populations. *Oecologia*, 86 (3), 325–334.

Smith S.E., Read D. 2008. Mycorrhizal Symbiosis. 3rd ed. Academic Press, Elsevier, Amsterdam.

Stone D.M. 1977. Fertilizing and thinning northern hardwoods in the Lake States. USDA Forest Service, Research Paper NC-141. North Central Forest Experiment Station, St. Paul, MN, pp. 7.

Townsend A.M., Wright J.W., Kwolek W.F., Beinke W.F., Lester D.T., Mohn C.A., Dodge A.F. 1979. Geographic variation in young red maple grown in north central United States. *Silvae Genetica*, 28 (1), 33–36.

Tremblay M.F., Bergeron Y., Lalonde D., Mauffette Y. 2002. The potential effects of sexual reproduction and seedling recruitment on the maintenance of red maple (*Acer rubrum* L.) populations at the northern limit of the species range. *Journal of Biogeography*, 29, 365–373.

Walters R.S., Yawney H.W. 1990. *Acer rubrum* L., red maple. In: Silvics of North America. Vol. 2. Hardwoods (ed.: R.M. Burns, B.H. Honkala). Agric. Handb. 654. U.S. Department of Agriculture, Forest Service, Washington, DC, 60–69.

Warren II R.J., Rossell I.M., Moorhead K.K. 2004. Colonization and establishment of red maple (*Acer rubrum*) in a southern Appalachian wetland. *Wetlands*, 24 (2), 364–374.

Whalen J.K. 2004. Spatial and temporal distribution of earthworm patches in corn field, hayfield and forest systems of southwestern Quebec, Canada. *Applied Soil Ecology*, 27, 143–151.

Will R.E., Seiler J.R., Feret P.P., Aust W.M. 1995. Effects of rhizosphere inundation on the growth and physiology of wet and dry-site *Acer rubrum* (red maple) populations. *American Midland Naturalist*, 134, 127–140.