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Post-fire macrofungi in the burnt area in the Jelonka reserve (Białowieża region, NE Poland)

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In the burnt area of the Jelonka nature reserve near Białowieża Primeval Forest mycological studies were carried out in the years 1994-1999. Carpophores of all macrofungi were identified and counted on 7 permanent observation plots repesenting different successional stages before the fire. Altogether 250 species of macromycetes were found, among them 16 species of post-fire fungi. *Pholiota carbonaria* and *Tephrocybe anthracophila* were the most abundant and frequent species occurring in the first years after the fire. It has been revealed that the presence of carbonised substrate is a limiting factor for the occurrence of post-fire *Basidiomycetes*.

Key words: post-fire macrofungi; Jelonka reserve, Białowieża.

INTRODUCTION

Abiotic disturbance, such as a fire, can change chemical, physical and biological features of the soil occurring in burnt sites. Thick layers of ash and charcoal form an unstable and ephemeral habitat. A special group of fungi that grow after the heat treatment of substrates are named as: anthracobionts, carbonicolous, carbothrophic, pyrophilous, phenicoid and fireplace or post-fire fungi (Moser 1949 a, b; Petersen 1970; Turnau 1984; Dix and Webster 1995).

The first ecological research of the fungi occurring on burnt grounds in Europe was carried out in Austria by Moser (1949 a). He distinguished four groups of species: anthracobionts (e.g. *Geopyxis carbonaria, Anthracobia nitida, Tephrocybe ambusta*), anthracophilous fungi (e.g. *Morchella esculenta, Psathyrella pennata*), anthracoxenous fungi (e.g. *Trametes hirsuta, Hypholoma capnoides*) and anthracophobs (mycorrhizal fungi). The investigations of fungi living on big fire-places were carried out in Denmark by Petersen (1970),

in Spain by Torre et al. (1976) and Calonge (1986), in Italy by Monti et al. (1992). Publications referring to the last 100 years of the research on pyrophilous fungi in Europe have been compiled by Lisiewska (1992) and Ebbert (1999).

The works concerning fireplace fungi in Poland are iniciated by Turnau (1984) who dealed, among other things, with anthracophilous species of *Ascomycetes*; Ginko (1984) displayed the correlation between soil acidity and sporocarp formation of the *Ascomycetes* living on burns. For the last years fire disasters have become a serious problem in European and Polish forests. After large fires in different parts of Poland in 1992, mycological observations on burnt grounds have been started e.g. Sumorok (1996, 1998), Dyląg and Gumińska (1997), Friedrich (2001).

In 1992 a part of the Jelonka nature reserve was also destroyed by fire. Investigations on the regeneration of plant communities were undertaken immediately (Faliński 1998). In 1994 the six-year-research on the effect of fire as an ecological factor disturbing functioning of the ecosystem and on the role of fungi in the plant communities regeneration was started (Sumorok 2000).

THE STUDY AREA

The Jelonka reserve (227 ha) is situated ca. 40 km to the south-west of the Białowieża Primeval Forest. The area is influenced by continental and boreal climate (Kondracki 1998). Fields, which were here in the past, have been abandoned in different periods for over 70 years. They are considerably homogeneous in respect of the habitat potential. There occur side by side subsequent stages of the successional series leading on to the formation of a continental mesophilous (fresh) pine forest (*Peucedano-Pinetum*): from the initial stage – grasslands, via optimal stage – grassland and juniper shrubs, to the terminal stage – aspen-pine-juniper brushwood.

In the reserve a system of permanent plots was established for extensive floristic-syndynamic research carried out by Faliński and co-operators (Faliński 1986, 1998; Faliński et al. 1993). As a result unique model of the secondary succession in abandoned farmland in North-East Poland has been elaborated.

METHODS

Regular observations have been carried out since 1994 (two years after the fire) in 7 permanent plots, 1000 m^2, divided into 40 squares (5 × 5 m) each. They are a part of a system of regeneration monitoring and represent optimal and terminal stage of vegetation succession (Faliński et al. 1993):

Plots 71 and 72 – before the fire: *Spergulo morisonii-Corynephoretum cladinetosum* and *Koelerio glaucae-Astragaletum arenariae* (grassland and

juniper shrubs). At present – burnt pines and junipers, almost without new undergrowth – sparse young pines and aspens; field layer consisting mainly of *Corynephorus canescens* and *Calluna vulgaris*.

Plots 25, 76 and 70 – before the fire: *Sedo maximi-Juniperetum* (aspen-pine-juniper brushwood). At present – burnt pines, aspens and junipers, intensively regenerating aspens and birches.

Plots 75 and 78 – before the fire: pine plantation. At present a clear-cut with left stumps – sparse young pines, aspens and birches; field layer consisting mainly of *Corynephorus canescens*.

The observations were carried out in the years 1994–1999, every month in the season. Fruit bodies of fungi were identified and counted on each plot. The presence and abundance of post-fire fungi as well as the pH values of the soil in 1995 are presented on diagrams. The table comparing the range of pH values of the soil in which carbophilous fungi were recorded in the study area and the ranges noted by other authors is also presented.

RESULTS

On the permanent plots in burnt part of the Jelonka reserve 250 species of macromycetes were collected. Among them were 16 species of post-fire fungi. Most of them belong to *Basidiomycetes: Pholiota carbonaria, Tephrocybe anthracophila, T. atrata, T. ambusta, Coprinus angulatus, Psathyrella pennata, P. gossypina, Faerberia carbonaria, Myxomphalia maura, Cotylidia undulata, Hebeloma anthracophilum*. A few belong to *Ascomycetes: Peziza subviolacea, P. echinospora, Neotiella hetieri, Octospora humosa* and *Gyromitra esculenta*.

Post-fire fungi are associated with the specific substrate originating from a fire – ash and carbonised organic material. According to the origin, breaking down, degree of decomposition and carbonisation of the substrate, various groups with different preferences appeared on burned ground in different time.

Group 1. Anthracobionts according to M o s e r (1949 a).

Species associated with highly carbonised and crumbled substrate (ash), for example *Tephrocybe anthracophila*, which grew in the places of accumulation of burnt branches of junipers and pines or *Pholiota carbonaria* around burnt pines. They appeared in the first two years of observations (2–3 year after the fire) (Fig. 1) with high abundance and frequency on all the observation plots.

Group 2. Anthracobionts and anthracophilous fungi according to Moser's classification.

Species appearing with low abundance and frequency, not on all observation plots, for example *Coprinus angulatus* (Fig. 2), *Psathyrella pennata, P. gossypina, Tephrocybe ambusta, T. atrata* (Fig. 3), *Faerberia carbonaria, Peziza echinospora, P. subviolacea* and *Gyromitra esculenta*. They occur on burnt substrate of different origin in different stage of decomposition.

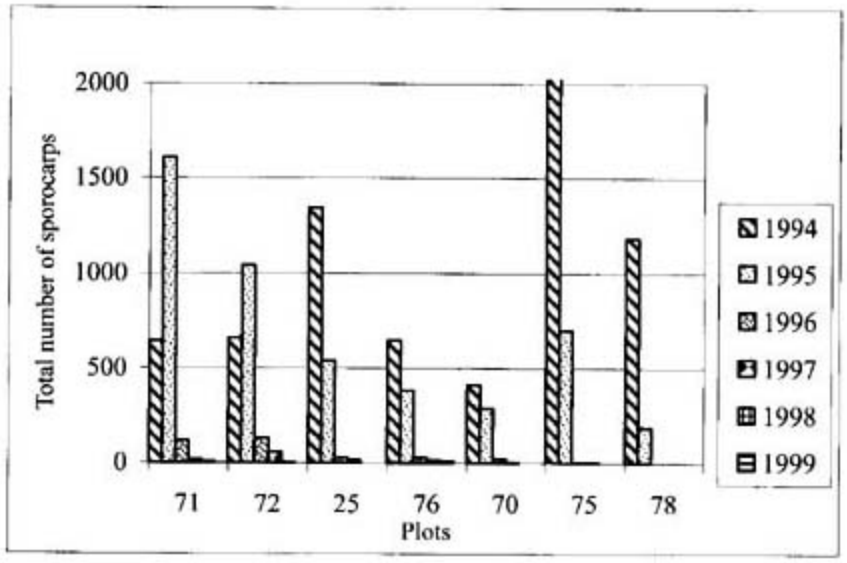

Fig. 1. Abundance of *Pholiota carbonaria* in subsequent years after fire

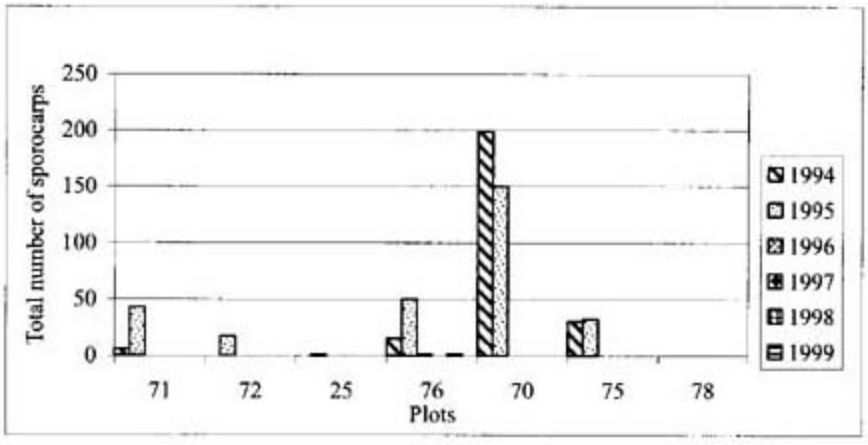

Fig. 2. Abundance of *Coprinus angulatus* in subsequent years after fire

Coprinus angulatus occurred on the layer of burned leaves on the plots where deciduous trees had grown before the fire – mainly on the plot no. 70 (Fig. 2).

Psathyrella pennata preferred open places, it occurred on the plots where hardly any trees were present – plots no. 25 and 71.

Tephrocybe atrata (Fig. 3) and *Faerberia carbonaria* appeared in the places where *Tephrocybe anthracophila* (group 1) had occurred before (compare Fig. 1).

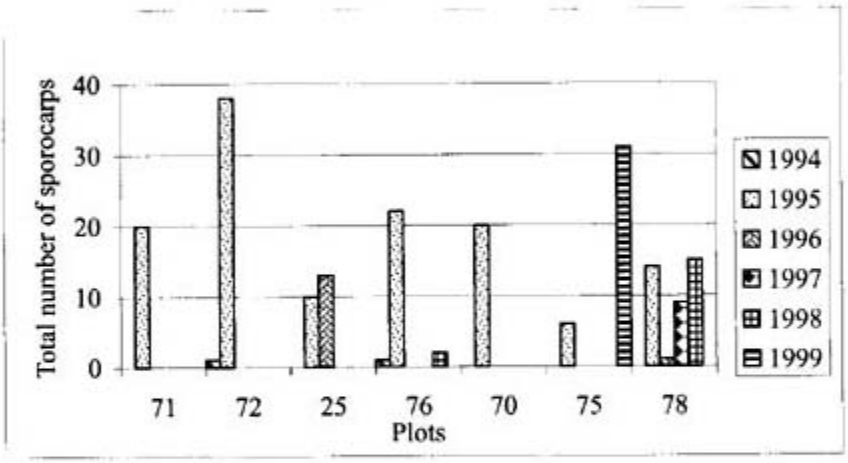

Fig. 3. Abundance of *Tephrocybe atrata* in subsequent years after fire

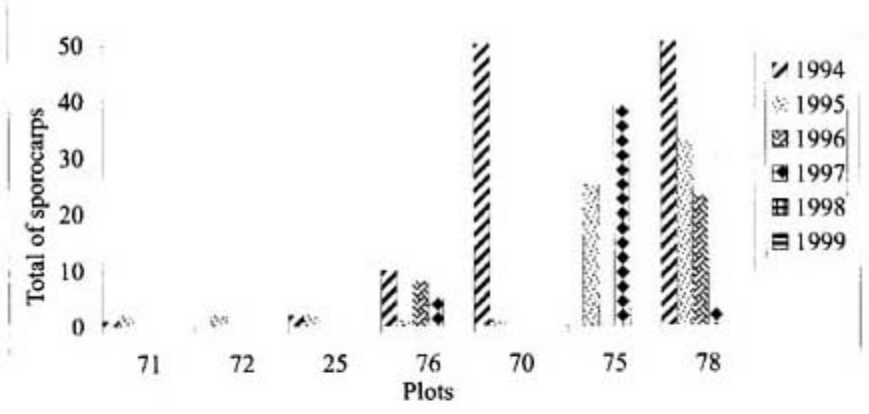

Fig. 4. Abundance of *Myxomphalia maura* in subsequent years after fire

Group 3. Species, which appeared on burnt ground together with bryophytes, e.g. *Myxomphalia maura* (Fig. 4), *Cotylidia undulata, Hebeloma anthracophilum* and from *Ascomycetes: Neotiella hettiri* and *Octospora humosa.*

One of remarkable factors determining the occurrence of post-fire fungi is the pH value of the substrate. In the table 1 the literature and author's data concerning pH preferences of some species are presented. H i n t i k k a (1960), who observed anthracophilous fungi *in vitro*, recorded that the mycelium can grow within the wider spectrum of pH (5—10) then in the natural conditions.

Table 1
Data on the occurrence of post-fire fungi in relation to the soil acidity

Species	Petersen (1970)	Hintikka (1960)	Monti et al. (1992)	The author's study
Pholiota carbonaria	9.5–7.5	8.2–6.2	–	7.0–6.0
Tephrocybe anthracophila	9.5–7.5	7.8–6.4	7.8–7.3	7.0–6.0
T. ambusta	–	–	7.8–7.3	7.0–5.0
T. atrata	–	–	7.8–7.3	7.0–5.0
Coprinus angulatus	9.5–7.5	8.0–7.8	7.5	7.0–6.0
Psathyrella pennata	–	–	7.4–7.0	7.0–6.0
Faerberia carbonaria	–	–	7.6	7.0–5.0
Myxomphalia maura	8.5–7.0	8.8–5.5	–	7.0–5.0
Cotylidia undulata	–	–	7.7	7.0–5.0
Hebeloma antracophilum	–	–	7.1	7.0–5.0
Peziza subviolacea	–	–	8.0–7.3	7.0
P. echinospora	10.0–7.5	–	–	7.0

On the observation plots the pH value of the surface layer of the soil ranged between 7.0–4.0 (Fig. 5).

Post-fire macrofungi collected in the Jelonka reserve

Abbreviations of the names of authors carring out the research on fire-places and burnt areas in Europe:

Tu – Turnau (1984)
M – Moser (1949a)
P – Petersen (1970)
To – Torre (1976)
C – Calonge (1986)
Mn – Monti (1992)
B – Bendiksen (1995)
DG – Dyląg and Gumińska (1997)

ASCOMYCETES

Gyromitra esculenta (Pers.) Fr. – on burnt substrate (bark, branches, roots); plots: 71, 72, 25, 76, 75; V 95, V 96, V 97; (M).

Octospora humosa (Fr.: Pers.) Dennis – on *Polytrichum piliferum*; plots: 71, 72, 25, 76, 70, 75, 78; IX–X 95, IX–XI 96, VII–XI 97, VII–X 98, IX 99; (P).

Neotiella hetieri Boud. – on *Ceratodon purpureus*; plots: 71, 70; X 95; (P).

Peziza echinospora Karst. = *P. anthracophila* Dennis – on humus; plots: 70, 75; IX–X 94, IX–X 95, VII 96; (Tu, B, K, P, M).

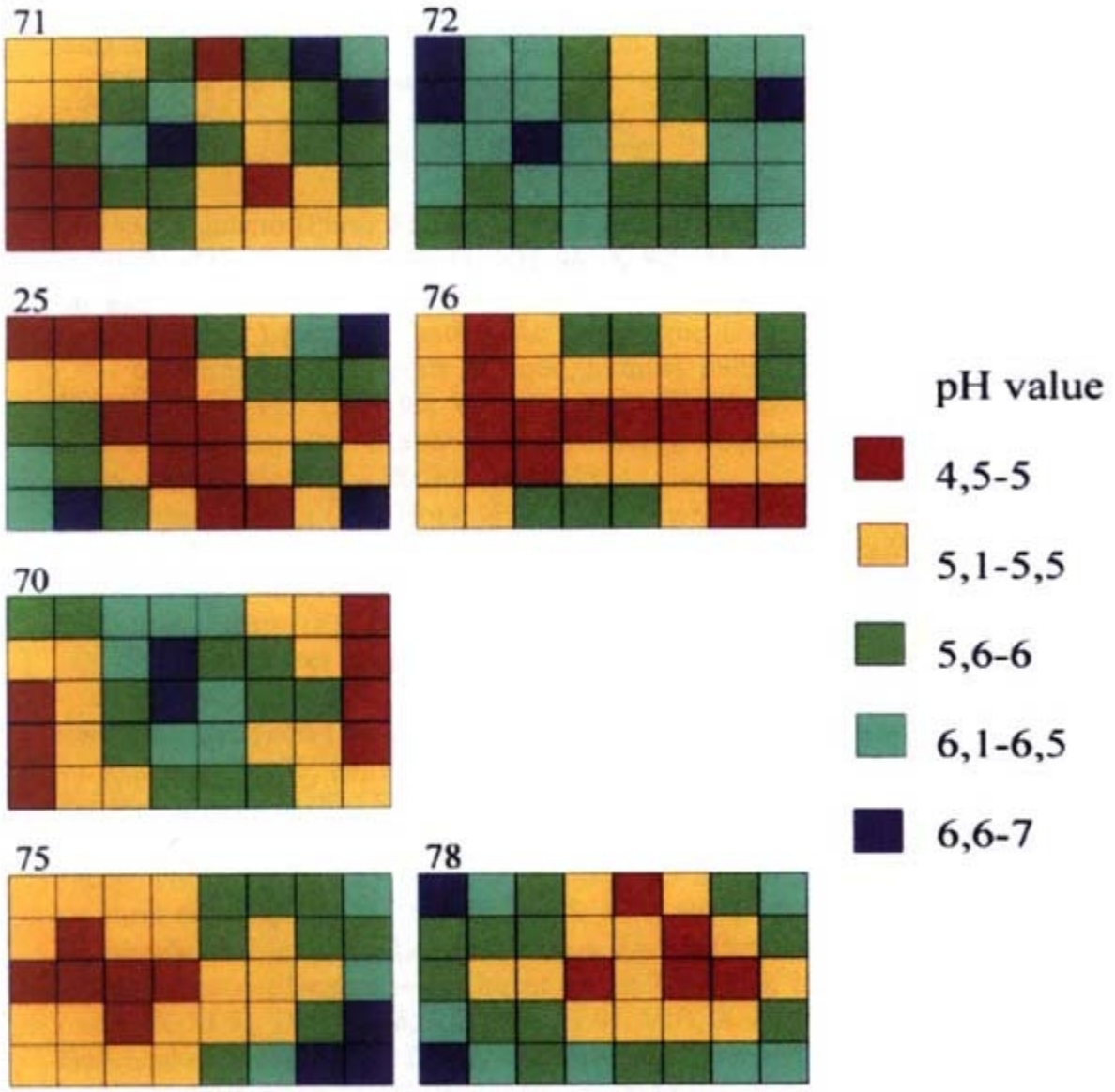

Fig. 5. Soil acidity (pH) in 1995 on the observation plots

Peziza subviolacea Svrček = *P. praetervisa* Dennis – on humus; plot: 70; IX 95; (Mn).

Scutellinia scutellata (L.: Fr.) Lambotte – on burnt substrate (humus); plots: 76, 70; X 94, X 95; (Tu, P).

BASIDIOMYCETES

Coprinus angulatus (Pers.: Fr.) Fr. – on burnt substrate; plots: 71, 72, 25, 76, 70, 75; IX–X 94, VI–X 95, VII 96, X 97; (M, P, Mn, B, DG).

Faerberia carbonaria (Alb. et Schw.: Fr.) Pouz. = *Geopetalum carbonaria* (Alb. et Schw.: Fr.) Pat. = *Cantharellus carbonarius* (Alb. et Schw.: Fr.) Pers. – on burnt substrate (rests of wood, humus); plots: 71, 72, 25, 76, 75, 78; IX–XI 95, VII, IX-X 96, VII, IX–X 97, X 98, IX 99; (Mn).

Hebeloma antracophilum Maire – on burnt substrate (humus); plots: 76, 70; IX 94, IX–X 95, VIII–IX 96; (Mn, M).

Myxomphalia maura (Fr.) Hora = *Fayodia maura* (Fr.) Sing. = *Omphalina maura* (Fr.) Gill. – on burnt substrate (humus); plots: 71, 72, 25, 76, 70, 75, 78; IX–X 94, IX–XI 95, X 96, IX–XI 97, X 98; (M; D,G).

Pholiota carbonaria (Fr.: Fr.) Sing. = *Ph. highlandensis* (Peck) Smith = Hesler – on burnt pieces of wood; plots: 71, 72, 25, 76, 70, 75, 78; IX–X 94, VI, IX–XI 95, VII–XI 96, VI–VII, X–XI 97, V–X 98; (P, C, DG, Mn, B).

Psathyrella gossypina (Bull.: Fr.) Pears. = Dennis – on burnt wood; plots: 76, 70; IX 94, X 95; (P, Mn).

Psathyrella pennata (Fr.) Sing. – on burnt wood; plots: 72, 25, 70, 78; IX 94, IX-X 95; (To, C, DG, M).

Tephrocybe ambusta (Fr.) Donk = *Lyophyllum ambustum* (Fr.) Sing. – on burnt wood; plots: 25, 76, 70, 75, 78; IX-X 94, IX-X 95; (To, Mn, DG).

Tephrocybe anthracophila (Lasch) Orton = *Lyophyllum anthracophilum* (Lash) M. Lange = Siversten – on burnt wood; 71, 72, 25, 76, 70, 75, 78; IX–X 94, IX-XI 95, IX–XI 96, VII, IX–XI 97, VIII, X 98; (To, Mn, DG, P, B).

Tephrocybe atrata (Fr.: Fr.) Donk = *Lyophyllum atratum* (Fr.: Fr.) Sing. – on burnt wood; plots: 71, 72, 25, 76, 70, 75, 78; IX–X 94, IX–XI 95, XI 96, XI 97, IX–X 98; (Mn).

DISCUSSION

Most research on phoenicoid fungi was carried out on fireplaces (e.g. Moser 1949, Petersen 1970, Turnau 1984, Ginko 1984, Dyląg and Gumińska 1997). Bonfire sites, or fireplaces, are rather small areas affected by a long-lasting fire. In contrast, burnt sites, or burnt grounds, are the areas affected by fire for a short time, but they size can reach hundreds of hectares. The duration and severity of a fire may be variable. In "natural" forest fires, although the surface vegetation may be destroyed, penetration of the fire in to the soil may not be very great – only a few centimetres.

By contrast, where branches and litter have been accumulated into bonfires, the centre of the fire may reach very high temperatures, and the temperature of soil surface may reach 500°C (D i x and W e b s t e r 1992). P e t e r s e n (1970) distinguished five layers at bonfire sites: white ash layer, black ash layer – containing charred organic matter, raw humus layer, reddish-grey sand layer and yellow sand layer. Chemical changes associated with severe burning include in pH and an initial increase is followed by differential leaching of salts (e.g. B å å t h 1995). Values as high as pH 9,8 – 10,2 in the white ash layer have been recorded at bonfire sites in Denmark (P e t e r s e n 1970). The first group of fungi which "arising from the ashes" on fireplaces are specialised Ascomycetes, tolerated high pH value (e.g. M o s e r 1949a; P e t r e s e n 1970; Z a k and W i c k l o w 1980; T u r n a u 1984; E g g e r 1982; D i x and W e b s t e r 1992).

The fire in the Jelonka reserve spread quickly over a vast area but was rather superfacial and not long lasting. Some of the places were hardly affected but those were pines and junipers occurred were burned completely. Among post-fire fungi *Basidiomycetes* dominated especially *Pholiota carbonaria* and *Tephrocybe anthracophila.* Typical carbophilous *Ascomycetes* of the genus *Anthracobia* as well as the species characteristic of fireplaces *Geopyxis carbonaria* were not observed; not frequent were also the species of *Peziza.*

The occurrence of phoenicoid *Ascomycetes* is associated with severe physico-chemical changes of the substrates, mainly with an increase in pH value. The pH of burnt area in the Jelonka reserve oscillated between 7 and 4 (Tab. 1); it seemed to have no effect on the occurrence of post-fire *Basidiomycetes.* The limiting factor is rather an access to the carbonised substrate (logs, branches, bark) inhabited by the fungi. They tend to disappear along with a decrease of the substrate amount. *Pholiota carbonaria* and the species of *Tephrocybe* occur exclusively on burnt ground and are classified as anthracobionts (M o s e r 1949a). They are present independently of a climatic region or altitude. Other species, e.g. *Myxomphalia maura,* preferred places affected by fire but they can also appear after other disturbances (P e t e r s e n 1970). Some species, e.g. *Cotylidia undulata, Neotiella hettieri* and *Octospora humosa,* are associated with bryophytes recovering after the fire. The relations can be of a parasitic type – they should be a subject of future studies.

One of the interesting phenomena was an appearance of *Gyromitra esculenta* in the reserve three years after the fire. The species is known to be a mycorrhizal symbiont of pine. The fungus was not observed in the non-disturbed area in the reserve (K a ł u c k a 1999). Similar observation was made by M o s e r (1949 b), who recorded *Morchella esculenta* on burnt area in Austria.

Many researchers, e.g. W i c k l o w (1975, 1988), Z a k and W i c k l o w (1980), E g g e r (1982) as well as T u r n a u (1984), carried out experimental studies on phoenicoid *Ascomycetes.* After mycological observations on the burnt area in the Jelonka reserve laboratory studies on *Basidiomycetes*

Pholiota carbonaria and *Tephrocybe anthracophila* should be undertaken. The question is if the mycelium of these species exists in the habitat and what factors promote their mass occurrence on burnt ground.

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Grzyby wypaleniskowe pożarzyska w rezerwacie Jelonka (Białowieża, Polska NE)

Streszczenie

W latach 1994–1999 na pożarzysku w rezerwacie Jelonka w sąsiedztwie Puszczy Białowieskiej prowadzono badania mikologiczne, na 7 stałych powierzchniach obserwacyjnych, gdzie liczono i oznaczano owocniki każdego gatunku. Zanotowano 250 gatunków makromycetes w tym 16 gatunków występujących na wypaleniskach. W pierwszych latach po pożarze z duża obfitością i frekwencją występowały *Pholiota carbonaria* i *Tephrocybe anthracophila*. W wyniku badań stwierdzono, że obecność spalonego substratu jest czynnikiem limitującym występowanie wypaleniskowych podstawczaków na pożarzysku.