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Biodiv. Res. Conserv. 1-2: 102-106, 2006

Interactions among hypogeous fungi and wild boars in the subcontinental pine forest

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Abstract: *Elaphomyces asperulus* Vitt. is the most common hypogeous fungus in the subcontinental Scots pine forest *Peucedano-Pinetum* in Poland. Both conifers comprising the tree stand – *Pinus sylvestris* and *Picea abies* – form ectomycorrhizal associations between their roots and mycelium of *Elaphomyces asperulus*. In good habitat conditions, the fungus produces great number of fruit-bodies. They occur 1-10 cm beneath the soil surface under the moss and humus cover and are easily found by wild boars intensively rooting for food. The paper presents preliminary results of mycological analysis of 61 subplots situated in the *Peucedano-Pinetum* association, 1m^2 each, rooted and unrooted. They indicate the stimulating role of wild boars in the fructification process and spread of spores of *Elaphomyces*.

Key words: *Elaphomyces*, wild boar, *Peucedano-Pinetum* association, rooting, fruit-bodies consumption

1. Introduction

The fruit-bodies of ectomycorrhizal fungi are a well known component of the food of animals. A review of rich American, Australian and European literature shows that fragments of both epigeous and hypogeous fruit-bodies are present in the stomachs as well as excrements of numerous mammal species (Briedermann 1976; Claridge *et al*. 1996; Janda 1958). On the other hand, ectomycorrhizal fungi are associated with forest trees, thus the interrelations between fungi, mammals and trees are also a matter of interest to ecologists (Johnson 1996; Malajczuk *et al*. 1987).

The interest in the composition of the wild boar food in Poland resulted from damage caused by these animals in arable fields. Genov (1981a, 1981b, 1982) carried out the research in a few forest districts in west and northeast Poland, e.g. in the Kurpiowska Forest. He analyzed the content of wild boars' stomachs and their excrements in the years 1975-1977. It appeared that the fruit-bodies of *Elaphomyces* are a considerable part of the wild boar diet.

Eight species of *Elaphomyces* are represented in Poland; the most common are: *E. asperulus* Vitt. associated with pine and spruce, *E. granulatus* Fr. em. Holl. and *E. muricatus* Fr. – associated with deciduous trees (Ławrynowicz 1988, 1989).

In the spring 2004, the large area of the Kurpiowska Forest became a terrain of intensive activity of wild boars. The animals rooted also through the permanent observation plot no. 509, which had been set for the research carried out by the Białowieża Geobotanical Station (Faliński 1966). Preliminary observations of the rooted area in the Czarnia reserve revealed that it was selectively searched by wild boars. Also, the fruit-bodies of *Elaphomyces* and their fragments were found there.

The aims of mycological research were as follows: (*i*) identification of hypogeous fungi in rooted places; (*ii*) evaluation of frequency and abundance of fruit-body production; (*iii*) remarks on the relationship between wild boar activity and fruiting of hypogeous fungi, and its role in forest ecosystems.

2. Study area

The Czarnia reserve is situated in the northwest part of the Kurpiowska Forest (NW Poland). Its borders coincide approximately with the borders of the mesoregion of Kurpiowska Plain. The Plain is covered with fluvioglacial sands which form numerous inland dunes, especially near the watersheds. The Czarnia reserve is a part of the Myszyniec Forest Inspectorate (Ostrołęka Administration Range). It consists of the forest range numbers 131, 132 on the north side of the Myszyniec –

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Chorzela road, and the range numbers 141, 142 and part of 152 on the south side. It is a flat terrain, undulating in places, situated at up to 132 m above sea level (Faliński 1966, 2001).

The Kurpiowska Forest is situated near the south-western limit of spruce subboreal occurrence. The Czarnia reserve protects subcontinental pine forests *Peucedano-Pinetum* with a well developed vertical structure, self-sowing pine and spruce, and complete species composition (*Vaccinium myrtillus, V. vitis-idea, Chimaphila umbellata, Arctostaphylos uva-ursi, Arnica montana*, 4 species of lycopods, rarely *Pulsatilla patens, P. teklae*, numerous lichens). The forest appeared spontaneously on abandoned fields ca. 170-200 years ago. A local fire broke out there around 1950 and the fire marks can be still found on the pine trunks (Faliński 2002).

3. Material and methods

Three permanent observation plots were established in the reserve starting from 1980, 1.1 ha (220 x 50 m) each, divided into 10 x 10 m squares (Faliński 2001). Mycological research was carried out in plot no. 509, in 61 small plots (1 m^2) with different plant cover and dominating moss species: *Pleurozium schreberi, Dicranum polysetum* and *Hylocomium splendens*. Plots rooted and unrooted by wild boar were established close to each other (Fig. 1).

Subsequent layers of mosses and humus had been removed until mineral soil was exposed. There, among the roots of pine and spruce, hypogeous fungi of the *Elaphomyces* genus occur. The fruit-bodies of these fungi lie in the soil, enclosed in a crust consisting of hyphae, ends of living roots and dead organic matter. All fruit-bodies were counted (numbers indicated in Table 1).The following developmental phases were distinguished: p – peas (< 5 mm in diameter); y – young (> 5 mm in diameter); m – mature, with spores; o – old, with incomplete peridium, but still keeping shape; f – morphological fragments (macroscopic); t – traces, dark coloured soil rich in spores.

4. Results and discussion

Taxonomical analysis of hypogeous fruit-bodies and their fragments collected in May 2004 in the rooted places confirmed that *Elaphomyces asperulus* Vitt. is a common fungus producing numerous carpophores in spring there. This species (sub nominee *E. granulatus*) was also found by Genov (1982).

Mycological analysis of 61 subplots: 27 rooted and 33 unrooted ones, revealed that, in the period of long-lasting drought with only few scant showers, fruit-bodies of fungi were found mostly in the rooted places. The results shown in Table 1 indicate *Elaphomyces asperulus* as dominant species. In two subplots *E. muricatus* was also found among the roots of *Vaccinium myrtillus* but the species could have been associated with solitary growing trees of *Betula pendula*. A number of fruit-bodies infected by *Elaphomyces* parasite – *Cordyceps ophioglossoides* were found; this may result from the weaker state of *E. asperulus* in the period of unfavorable weather conditions.

Fig. 1. Professor J. B. Faliński documenting an unrooted plot with one fruit-body of *Elaphomyces asperulus* Fot. M. Ławrynowicz

Three waves of young fruit-body production can be recorded during the year: in spring, summer and autumn. Usually, also three generations of fruit-bodies can be found in the soil: young, mature and old. During the periods of increased soil moisture old carpophores rot and decompose secreting a strong, unpleasant smell. This smell is recognized by animals, e.g. wild boars, which root around and find also fresh, juicy fruit-bodies of young, maturing and ripe fungi. Some observations of rooted places indicate that wild boars find fruit-bodies of hypogeous fungi by chance while rooting the soil for another kind of food.

A significant difference could be noticed in the fruit-body number in the particular subplots. As a rule, the fruit-bodies occurred in the rooted subplots (up to 27 specimens in one subplot) while they were absent in the unrooted ones.

The vegetative period in the year 2004 was exceptionally dry in Poland. In the area of the Kurpiowska Forest, only a few short-lasting showers appeared. In such

Table 1. Presence of hypogeous fungi in rooted (R) and unrooted (U) subplots in the plot no. 502 in the Czarnia reserve (18-21 August, 2004)

Succ. No.	No. of subplot	Type of subplot	Trees and other species	Dominating mosses	Humus layer [cm]	Colour of mineral soil	Fungi	Developmental phases
1	0	R	*Ps, Pa*	*Dp, Hs*	6	gray	*Ea*	- 1y 5m - - t
2	32	U	*Ps*	*Hs*	6	gray	.	.
3	50	U	*Ps, Pa*	*Dp*	6	gray	.	.
4	89	U	*Ps*	*Dp*	6	gray	*Ea*	- - 1m - - t
5	89	R	*Ps*	*Dp*	8	gray	*Ea*	- 1y 4m 2o f t
6	88	U	*Ps, Pa*	*Dp*	6	gray	.	.
7	50	U	*Ps*	*Hs*	6	gray	.	.
8	51	U	*Ps*	*Lg*	6	gray	.	.
9	32	U	*Ps, Pa*	*Pls*	6	gray	*Ea*	- 1y - - - t
10	21	R	*Ps*	*Dp*	6	gray, brown	*Ea*	- 15y - - f -
11	21	U	*Ps*	*Dp*	7	gray	.	.
12	61	R	*Ps*	*Pls*	3	gray, brown	*Ea*	- - - 1o - t
13	61	R	*Ps*	*Pls*	8	gray	.	.
14	83	R	*Ps, Pa*	*Pls*	4	gray	*Ea*	- 1y 3m 1o - -
15	83	U	*Ps, Pa*	*Pls*	6	gray	.	.
16	104	R	*Ps, Pa*	*Dp*	6	gray	*Ea, Co*	- - 2m 1o - -
17	104	U	*Ps, Pa*	*Dp*	6	gray	*Ea, Co, Em*	- 2y 1m - - -
18	107	U	*Ps, Pa*	*Pls*	6	gray	.	.
19	107	R	*Ps, Pa*	*Pls*	4	gray, brown	*Ea*	- 2y - 1o - -
20	106	R	*Ps*	*Dp*	4	gray, brown	*Ea, Co*	1p 1y - 8o - -
21	106	U	*Ps*	*Dp*	10.5	gray	.	.
22	108	R	*Ps, Pa, Vm*	*Hs*	8	gray	*Ea*	- 10y 5m - - -
23	108	U	*Ps, Pa*	*Hs*	7	gray	.	.
24	127	R	*Ps, Vvi*	*Pls*	9	gray	*Ea*	- 1y 2m 2o - -
25	127	U	*Ps, Pa, Vvi*	*Pls*	8	gray	*Ea*	t
26	128	R	*Ps, Vm*	*Pls*	10.5	gray	*Ea*	- 1y 3m 7o - -
27	128	U	*Ps, Vm*	*Pls*	12	gray	*Ea*	- - 5m - - -
28	109	R	*Ps, Vvi*	*Dp, Pls*	6	gray	*Ea* (4 infected), *Co* (8 specimens)	- 5y 1m - - -
29	109	U	*Ps, Vvi*	*Pls, Dp*	5	gray	.	.
30	130	R	*Ps, Vvi, Vm*	*Pls*	8	gray	*Ea*	- 3y 2m 2o f t
31	130	U	*Ps, Vvi, Vm*	*Pls*	8	gray	*Em*	- - 3m - - -
32	150	R	*Ps, Pa*	*Pls*	8.5	gray	*Ea*	4p 1y 1m - f t
33	150	U	*Ps, Vvi, Vm*	*Pls*	7	gray	*Em*	1p - - - - -
34	110	R	*Ps*	*Dp*	6.5	gray	*Ea*	1p 3y 8m - - -
35	110	U	*0*	*Dp*	9.5	gray	.	.
36	49	R	*0*	*Dp*	7	gray	*Ea,* traces of *Co*	- 2y 2m - - -
37	49	U	*0*	*Dp*	8	gray	.	.
38	48	U	*Ps, Pa*	*Pls*	8	gray	*Ea*	- - 1m - f t
39	48	R	*0*	*Pls*	6.5	gray	*Ea*	- - 2m - - t
40	91	R	*0*	*Dp*	6	yellow, gray	*Ea*	- - 7m - f -
41	91	U	*0*	*Dp*	5	yellow, gray	.	- - - - - t
42	113	R	*Ps*	*Dp, Pls*	5	yellow, gray	*Ea*	- 1y 1m 1o - -
43	113	U	*0*	*Pls*	7.5	gray	.	.
44	54	U	*Ps, Vvi*	*Dp*	13	gray, yellow	.	.
45	54	R	*Ps*	*Dp*	4	gray, yellow	*Ea*	3p - 5m - f t
46	54a	R	*Ps*	*Pls*	7	gray, yellow	*Ea*	- - 27m - - -
47	54a	U	*0*	*Pls*	12	gray, yellow	.	.
48	75	U	*Ps, Vm, Df*	*Pls*	5	gray	.	.
49	75	R	*Ps, Vm*	*Pls*	4	gray	*Ea*	- 1y 4m - - t
50	94	U	*Ps*	*Pls*	11	gray	.	.
51	94	R	*Ps*	*Pls*	5	gray	*Ea*	10p 1y - 1o - -
52	95	R	*Ps*	*Pls*	5	gray, yellow	*Ea*	- - 9m 1o t f
53	95	U	*Ps*	*Pls*	14	gray	.	.
54	115	R	*Ps, Vm*	*Dp*	4	gray	*Ea*	- - 4m - f t
55	115	U	*Ps, Vvi*	*Dp*	5	gray	.	.
56	99	U	*Ps*	*Pls*	8	gray	.	.
57	99	R	*Ps*	*Pls*	5	gray, yellow	*Ea*	- - 5m - - -
58	119	U	*Ps*	*Dp*	8	gray	.	.
59	119	R	*Ps, Vvi*	*Dp*	6	gray	*Ea*	3p - 8m - f t
60	93	U	*Ps, Vm*	*Pls*	11	gray	.	.
61	93	R	*Ps, Vm*	*Pls*	4	gray	*Ea*	4p 2y 9m - - -

Explanations: *Ps – Pinus sylvestris, Pa – Picea abies, Vm – Vaccinium myrtillus, Vvi – Vaccinium vitis-idaea, Ds – Deschampsia flexuosa, Dp – Dicranum polysetum, Hs – Hylocomium splendens, Lg – Leucobryum glaucum, Pls – Pleurozium schreberi, Ea – Elaphomyces asperulus, Em – Elaphomyces muricatus, Co – Cordyceps ophioglossum,* p – peas of fruitbodies, y – young, m – mature, o – old, f – fragments, t – traces conditions, all the scant water was captured in the moss layer, leaving the humus and mineral soil dry; the mycelium had no access to water. However, in the subplots rooted by wild boars, the upper layers of moss and humus were disconnected and mixed with mineral soil. In such places the rainfall had a chance to reach mycelium which resulted in production of fruit-bodies.

Genov (1982) noticed that „*the places where the boars furrowed were correlated with the places of occurrence of the fructifications… The intensity of furrowing was correlated with the abundance of fructifications in the forest…*".

It should be concluded that the rooting activity of wild boars favors the development of *Elaphomyces*. Stripping the layers of mosses and humus off the mineral soil improves moisture conditions for the mycelium. Moreover, the consumption of carpophores contributes to the dispersal of spores (Blaschke & Baumler 1989; Briedermann 1968; Génard *et al.* 1986; Groot Bruindernik & Hazebroek 1996).

5. Conclusions

The subcontinental pine forest *Peucedano-Pinetum* offers good habitat conditions for development of the fruit-bodies of *Elaphomyces asperulus*.

Simultaneous occurrence of three generations of *Elaphomyces* as immature, mature, and falling apart carpophores have been found.

The lack of water turned out to be a factor limiting the formation and development of fruit-bodies. The water is easily absorbed by the moss layer and hardly soaks through the humus to reach the underlying mycelium.

Elaphomyces asperulus is readily eaten by wild boar. The animals can smell rotting carpophores and actively root for them. They tear the layers of mosses and humus, and uncover the fruitbodies level. Then the rain can reach the mycelium directly.

The quantitative observations in 61 subplots (unrooted and rooted) revealed the significant prevalence of carpophores.

Mycological observations in wild boar-rooted sites provide interesting data for understanding the plant-fungus-animal relationships in the forest ecosystem.

In consequence, rooting activity of wild boars positively influences development of ectomycorrhizal hypogeous fungi, and thus indirectly affects associated trees – the most significant components of this ecosystem.

Acknowledgements. We are grateful to A. Wiktoruk for her assistance during field studies.

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