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Fungal communities in soil beneath Scots pine and their stumps. Effect of fungi on *Heterobasidion annosum* and *Armillaria ostoyae* growth

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K w a ś n a H.: *Fungal communities in soil beneath Scots pine and their stumps. Effect of fungi on Heterobasidion annosum and Armillaria ostoyae growth.* Acta Mycol. 30 (2): 193-205, 1995.

The soil beneath 30-year-old Scots pines, was inhabited by fungi communities which were at least twice as big as communities from the 49-year-old stand. The fungi communities in soil beneath the stumps were much smaller compared to those beneath the live trees and more abundant in the 30- than in the 49--year-old stand. The fungal communities in soil beneath the 30-year-old pines have bigger antagonistic effect on *Heterobasidion annosum* and *Armillaria ostoyae* than those beneath the 49-year-old stand. The decrease in density of fungi and in the frequency of species antagonistic to *H. annosum* and *A. ostoyae* resulted in the decrease of the antagonistic effect on both pathogens in soil beneath pine stumps.

Key words: *Armillaria ostoyae, Heterobasidion annosum, Pinus sylvestris*, roots, soil fungi, stumps.

INTRODUCTION

Root exudates are substances released into surrounding medium by healthy and intact plant roots. Exudates are fractioned into carbohydrates, amino acids/amides, organic acids and about 10 different inorganic ions (S m i t h, 1976). Movement of root exudates from plants to the soil represent an intrasystem nutrient-cycling pathway of unappreciated significance in enhancing the growth of saprophytic and parasitic microorganisms occuring in surrounding soil is considerable. On the basis of differences in germination frequency, J o h a n s s o n et M a r k l u n d (1980) showed that the living roots might have different effects on the activity of their mycobionta.

A number of studies on the mycobionta of soil beneath Scots pine (*Pinus sylvestris*) were undertaken. In contrast very little attention has been paid to the fungal communities occurring in soil surrounding the dead roots of stumps where they are deprived of nutrients. While the occurrence of stumps in forest practice is the natural consequence of thinning and felling, it seems that there was the necessity to fill this gap.

The paper presents the qultitative and quantitative differences in mycobionta in soil beneath the living and dead 2-year-old stump roots of Scots pine. The present work discusses also the antagonistic effect of the soil fungal communities on *Heterobasidion annosum* (Fr.) Bref. and *Armillaria ostoyae* (Romagn.) Herink.

MATERIAL AND METHODS

Individual soil samples were collected beneath five 30- and five 49-year-old Scots pines (September, 1991) and their 2-year-old stumps (September, 1993) in Huta Pusta Forest District (western Poland, 17°10'E, 52°50'N). The representativeness of the results was ensured by sampling in two locations (in each stand) situated 200 m apart. Samples were collected from a depth of 30-50 cm (B-horizon).

Type of soil: area flat, soil brown, leached, slightly loamy deep and fresh stratified with lights, strongly sandy clay. In both stands the main tree species was Scots pine (afforestation: 30-year-old stand – 1.0, 49-year-old one – 0.6) mingled with some single birch and oak. In the 30-year-old stand the soil was covered by *Calamagrostis, Festuca, Poa* and *Rubus*. In the understorey of the 49-year-old stand there were *Betula, Frangula, Padus, Picea, Quercus* and the soil was covered mostly with *Calamagrostis*. The pH at the depth of 30-50 cm in the 30-year-old stand was 4.25 and in the 49-year-old one – 4.15.

In the laboratory individual samples were mixed together and isolation fungi was performed according to Warcup's soil plate method modified by M a ń k a (J o h n s o n et M a ń k a, 1961; M a ń k a, 1964; M a ń k a et S a l m o n o w i c z, 1987). All fungal colonies were considered constituents of communities characteristic of the soil investigated. The fungi were tested for their effect on the growth of *H. annosum* and *A. ostoyae*. The test was performed by the biotic series method according to M a ń k a (1974), on 2 % PDA for *H. annosum* and 2 % malt agar for *A. ostoyae*, using 15 the most frequently occuring species fungi. Individual biotic effect (IBE) after 10 days with *H. annosum* and 20 days with *A. ostoyae* was estimated and general biotic (GBE) and summary biotic effects (SBE) were calculated. *H. annosum* – type P, heteroacryotic culture was isolated from the fruit-body found on young Scots pine tree in Huta Pusta District. Diploid *A. ostoyae* culture was isolated from the basidiome found on *Quercus* stump.

RESULTS

Analysis of the soil samples taken beneath the roots of the 30- and the 49-year-old Scots pines and their 2-year-old stumps revealed the occurrence of 76 fungal species (Table 1-8, 10). The soil under the 30-year-old pines was inhabited by fungi communities which were at least twice as big as those from the 49-year-old stand. The fungi communities in soil beneath the stumps were much smaller, compared to those beneath the live trees, and more abundant in the 30-year-old stand. There were

18-29 fungal species in the examined soils. *Penicillia* and *Mucorales* were the only taxonomic groups sufficiently abundant to warrant specieal consideration. The soil of the 30- and 49-year-old stands was inhabited by 7-9 and 6 *Penicillia* species, respectively. They contributed 53.8-54.2 and 35.6-47.1 % of the total number of isoltaes, respectively. The soil beneath the stumps of the 30- and 49-year-old pines was correspondingly inhabited by 6 and 7-10 species, which comprised 23.3-24.2 and 56.3-68.9 % of the total number of isolates, respectively. The most common species were: *P. adametzii, P. daleae* and *P. janczewskii* and beneath the stumps additionaly *P. spinulosum* and *P. steckii. P. adametzii* did not occur in soil beneath stumps roots of the 30-year-old stand. *Mucorales* amounted to 30.6-32.6 and 21.7--30.3 % of the total number of isolates beneath the living trees and 17.5-31.7 and 4.7-5.5 % beneath the stumps in the 30 - and 49-year-old stands, respectively. Only *Mortierella* species were important with respect to their quantity. The dominating species was *M. vinacea. Oidiodendron* species occurred only in the 49-year old stand. The number of *Trichoderma* isolates increased in soil beneath the stumps to 20.0 % of the total number of isolates (II location) in the 30-year-old stand and to 6.3-11.1 % in the 49-year-old stand (Table 9). Mostly there were: *T. virens* and *T. viride.*

The changes in the density of the four main genera are followed by similar changes in the number of species. The occurrence of particular fungal species in specific habitats is presented in Table 10. Frequency of occurrence of fungal isolates antagonistic to *H. annosum* is given in Table 11.

Table 1

Effects of fungi community from soil beneath the live 30-year-old Scots pines (I location) on *Heterobasidion annosum* and *Armillaria ostoyae* growth

Species	Freq.	*H. annosum*		*A. ostoyae*	
		IBE	GBE	IBE	GBE
Mortierella vinacea Dixon-Stewart	107	-5	-535	+4	+428
Penicillium adametzii Zaleski	96	+20	+1920	+2	+192
Penicillium daleae Zaleski	92	+2	+184	+2	+184
Penicillium janczewskii Zaleski	26	+10	+260	0	0
Pseudogymnoascus roseus Raiłło	23	-3	-69	0	0
Chrysosporium merdarium (Link. ex S. F. Gray) Carm.	15	-3	-45	+1	+15
Aspergillus kanagawaensis Nehira	9	+6	+54	+7	+63
Mortierella nana Linnemann	7	-4	-28	+4	+28
Mortierella gracilis Linnemenn	5	+1	+5	+4	+20
Trichoderma hamatum (Bon.) Bain.	5	+8	+40	+7	+35
Chrysosporium pannorum (Link.) Hughes	4	+2	+8	+1	+4
Penicillium waksmanii Zaleski	4	-5	-20	0	0
Chaetomidium biapiculatum Lodha	3	+1	+3	+3	+9
Humicola grisea Traaen	3	-4	-12	+2	+6
Penicillium spinulosum Thom	3	-5	-15	+5	+15
Summary biotic effect	402		+1750		+999

Other less frequent species: *Absidia cylindrospora* Hagem – 2, *Mortierella turficola* Ling-Young – 2, *Aureobasidium pullulans* (de Bary) – 2, *Zygorhynchus ramanniana* (Moller) Linn.– 1, *Mucor hiemalis* Wehmer – 1, *Penicillium implicatum* Biourge – 1, *Penicillium lanosum* Westling – 1.

Table 2

Effect of fungi community from soil beneath the live 30-year-old Scots pine (II location) on *Heterobasidion annosum* and *Armillaria ostoyae* growth

Species	Freq.	*H. annosum*		*A. ostoyae*	
		IBE	GBE	IBE	GBE
Penicillium dalea Zaleski	175	+2	+350	+2	+350
Mortierella vinacea Dixon-Stewart	160	-4	-640	+4	+640
Penicillium janczewskii Zaleski	63	+10	+630	0	0
Penicillium adametzii Zaleski	27	+22	+594	+2	+54
Pseudogymnoascus roseus Raiłło	18	-3	-54	0	0
Chrysosporium merdarium (Link ex S. F. Gray) Carm.	13	-3	-39	0	0
Aspergillus kaganawaensis Nehira	12	+6	+72	+7	+84
Chrysosporium pannorum (Link) Hughes	10	+2	+20	0	0
Penicillium chrysogenum Thom	6	-6	-36	+4	+24
Trichoderma koningii Oudemans	5	+8	+40	+8	+40
Penicillium waksmanii Zaleski	4	-5	-20	0	0
Trichoderma viride Pers. ex Fr.	4	+8	+32	+7	+28
Mortierella gracilis Linn.	3	+1	+3	+4	+12
Mortierella hygrophila var. *minuta* Linn.	3	0	0	+4	+12
Tolypocladium geodes W. Gams	3	+2	+6	0	0
Summary biotic effect	506		+958		+1244

Other less frequent species: *Penicillium raistrickii* G. Smith – 3, *Absidia cylindrospora* Hagem – 2, *Aureobasidium pullulans* (de Bary) – 1, *Humicola grisea* Traaen – 1, *Penicillium lividum* Westling – 1, *Penicillium pinetorum* Stolk – 1, *Penicillium spinulosum* Thom – 1, *Trichoderma polysporum* (Link: Pers) Rifai – 1, *Zygorhynchus moelleri* Vuill. – 1.

Table 3

Effect of fungi community from soil beneath the live 49-year-old Scots pines (I location) on *Heterobasidion annosum* and *Armillaria ostoyae* growth

Species	Freq.	*H. annosum*		*A. ostoyae*	
		IBE	GBE	IBE	GBE
Mortierella vinacea Dixon-Stewart	50	-5	-250	+4	+200
Penicillium adametzii Zaleski	31	+22	+682	+2	+62
Pseudogymnoascus roseus Raiłło	26	-3	-78	0	0
Penicillium daleae Zaleski	20	+2	+40	+2	+40
Oidiodendron periconioides Morrall	16	-5	-80	0	0
Penicillium janczewskii Zaleski	16	+10	+160	0	0
Oidiodendron tenuissimum (Peck) Hughes	7	-7	-49	0	0
Absidia cylindrospora Hagem	6	+1	+6	+4	+24
Chrysosporium merdarium (Link ex S. F. Gray) Carm.	6	-3	-18	+1	+6
Mortierella gracilis Linnemann	6	0	0	+4	+24
Chloridium virescens var. *chlamydosporum* (Beyma) W. Gams & Hol.-Jech.	5	-4	-20	+3	+15
Trichoderma viride Pers. ex Fr.	5	+8	+40	+7	+35
Penicillium implicatum Biourga	4	+2	+8	+5	+20
Penicillium steckii Zaleski	3	-3	-9	0	0
Acremonium diversisporum (v. Beyma) W. Gams	1	-5	-5	0	0
Summary biotic effect	202		+427		+426

Other less frequent species: *Humicola grisea* Traaen – 1, *Mortierella nana* Linnemann – 1, *Mucor hiemalis* Wehmer – 1, *Oidiodendron griseum* Robak – 1, *Polyscytalum spinulosum* Thom – 1, *Phialophora lsiosphaeriae* W. Gams – 1, *Polyscytallum fecundissimum* Riess. – 1, *Thysanphora penicillioides* (Roum.) Kendrick – 1, *Wardomyces humicola* Hennb. et Barron – 1.

Table 4

Effect of fungi community from soil beneath the live 49-year-old Scots pines (II location) on *Heterobasidion annosum* and *Armillaria ostoyae* growth

Species	Freq.	*H. annosum*		*A. ostoyae*	
		IBE	GBE	IBE	GBE
Penicillium adametzii Zaleski	22	+20	+440	+2	+44
Pseudogymnoascus roseus Raiłło	20	-3	-60	0	0
Mortierella vinacea Dixon-Stewart	19	-5	-95	+4	+76
Penicillium janczewskii Zaleski	14	+10	+140	0	0
Penicillium daleae Zaleski	8	+1	+8	+3	+24
Penicillium chermesinum Biourge	3	-4	-12	+2	+6
Chrysosporium merdarium (Link ex S. F. Gray) Carm.	2	-3	-6	+1	+2
Mucor hiemalis Wehmer	2	+7	+14	+5	+10
Oidiodendron tenuissimum (Peck) Hughes	2	-7	-14	0	0
Penicillium vinaceum Gilman & Abbot	2	0	0	+3	+6
Polyscytalum fecundissimum Riess.	2	-4	-8	+1	+2
Trichosporiella cerebriformis (Vr. et Kl. Nat.) W. Gams	2	-7	-14	0	0
Zygorhynchus moelleri Vuill.	2	+8	+16	+4	+8
Acremonium terricola (Miller et al.) W. Gams	1	-5	-5	0	0
Aspergillus kanagawaensis Nehira	1	+6	+6	+7	+7
Summary biotic effect	102		+410		+185

Other less frequent species: *Chrysosporium pannorum* (Link) Hughes – 1, *Cladosporium sphaerospoermum* Penz – 1, *Humicola grisea* Traaen – 1, *Penicillium spinulosum* Thom – 1.

Table 5

Effect of fungi community from soil beneath the 2-year-old stumps made of 30-year-old Scots pines (I location) on *Heterobasidion annosum* and *Armillaria ostoyae* growth

Species	Freq.	*H. annosum*		*A. ostoyae*	
		IBE	GBE	IBE	GBE
Aspergillus kaganawaensis Nehira	41	+6	+246	+7	+287
Mortierella vinacea Dixon-Stewart	20	-5	-100	+4	+80
Penicillium daleae Zaleski	20	+2	+40	+3	+60
Pseudogymnoascus roseus Raiłło	11	-3	-33	0	0
Chrysosporium merdarium (Link ex S. F. Gray) Carm.	6	-3	-18	+1	+6
Exophiala sp.	3	-7	-21	0	0
Penicilium janczewskii Zaleski	3	+10	+30	0	0
Penicillium spinulosum Thom	3	-5	-15	+3	+9
Sporothrix schenckii Hectoen et Perkins	3	-5	-15	+3	+9
Aspergillus versicolor Tiraboschi	2	-5	-10	0	0
Cladosporium herbarum Link: Fr.	1	-5	-5	+2	+2
Coniophora puteana (Schum.: Fries) Karst.	1	0	0	+4	+4
Mortierella gracilis Linnemenn	1	+1	+1	+4	+4
Penicillium steckii Zaleski	1	-3	-3	0	0
Trichoderma viride Pers.: Fr.	1	+7	+7	+7	+7
Summary biotic effect	202		+104		+468

Other less frequent species: *Penicillium clavigerum* Demelius – 1, *P. fellutanum* Biourge – 1, *Tolypocladium goedes* W. Gams – 1.

Table 6

Effect of fungi community from soil beneath the 2-year-old stumps made of 30-year-old Scots pines (II location) on *Heterobasidion annosum* and *Armillaria ostoyae* growth

Species	Freq.	*H. annosum*		*A. ostoyae*	
		IBE	GBE	IBE	GBE
Mortierella vinacea Dixon-Stewart	28	-5	-140	+4	+112
Penicillium daleae Zaleski	17	+2	+34	+2	+34
Trichoderma viride Pers.: Fr.	17	+8	+136	+7	+119
Aureobsidium pullulans (de Bary)	6	-5	-30	+1	+6
Mortierella nana Linnemann	6	-4	-24	+4	+24
Aspergillus kaganawaensis Nehira	5	+6	+30	+7	+35
Penicillium janczewskii Zaleski	5	+10	+50	0	0
Chrysosporium merdarium (Link ex S. F. Gray) Carm.	4	-3	-12	+1	+4
Humicola grisea Traaen	3	-4	-12	+2	+6
Penicillium citrinum Sopp.	3	-2	-6	0	0
Pseudogymnoascus roseus Raiłło	3	-3	-9	0	0
Tolypocladium geodes W. Gams	3	+2	+6	0	0
Trichoderma koningii Oudemans	2	+8	+16	+7	+11
Trichoderma virens (Miller) Giddens et Foster)	2	+8	+16	+7	+14
Trichoderma viride Pers.: Fr.	2	+8	+16	+7	+14
Summary biotic effect	106		+71		+382

Other less frequent species: *Ascomycota* sp. – 1, *Cladosporium spharospermum* Penz. – 1, *Mortierella gracilis* Linnemann – 1, *Mortierella humilis* Linnemann – 1, *Mucor hiemalis* Wehmer – 1, *Penicillium fellutanum* Biourge – 1, *Penicillium islandicum* Sopp. – 1, *Penicillium steckii* Zaleski – 1, *Sporothrix schenckii* Hectoen et Perkins –1, *Torulomyces lagena* Delitsch – 1, *Trichocladium opacum* (Corda) Hughes – 1, *Trichoderma* sp. – 1, *Zygorhynchus moelleri* Vuill. – 1, non-sporulating Sg II 27 – 1.

Table 7

Effect of fungi community from soil beneath the 2-year-old stumps made of 49-year-old Scots pines (I location) on *Heterobasidion annosum* and *Armillaria ostoyae* growth

Species	Freq.	*H. annosum*		*A. ostoyae*	
		IBE	GBE	IBE	GBE
Penicillium adametzii Zaleski	22	+22	+484	+2	+44
Penicillium daleae Zaleski	17	+2	+34	+2	+34
Penicillium janczewskii Zaleski	9	+10	+90	0	0
Penicillium steckii Zaleski	6	-3	-18	0	0
Penicillium spinulosum Thom	5	-5	-25	+5	+25
Trichoderma viride Pers.: Fr.	4	+8	+32	+7	+28
Mortierella vinacea Dixon-Stewart	3	-5	-15	+4	+12
Absidia cylindrospora Hagem	2	+1	+2	+4	+8
Eladia saccula (Dale) G. Smith	2	-3	-6	0	0
Oidiodendron tenuissimum (Peck) Hughes	2	-7	-14	0	0
Penicillium jensenii Zaleski	2	-4	-8	0	0
Polyscytalum fecundissimum Reiss.	2	-4	-8	+2	+4
Trichoderma aureoviride Rifai	2	+8	+16	+7	+14
Trichoderma polysporum (Link.: Pers) Rifai	2	+8	+16	+6	+12
Aspergillus niveus Bloch	1	-5	-5	-1	-1
Summary biotic efect	81		+575		+180

Other less frequent species: *Aspergillus versicolor* Tiraboschi – 1, *Chloridium virescens* var. *chlamydosporum* (Beyma) W. Gams et Hol.-Jech. – 1, *Chrysosporium merdarium* (Link S. F. Gray) Carm. – 1, *Humicola grisea* Traaen – 1, *Penicillium terlikowskii* Zaleski – 1, *Pseudogymnoascus roseus* Raiłło – 1, *Trichocladium opacum* (Corda) Hughes – 1, *Trichoderma atroviride* Karsten – 1, *Trichoderma koningii* Oudemans – 1.

Table 8

Effect of fungi community from soil beneath the 2-year-old stumps made of 49-year-old Scots pines (II location) on *Heterobasidion annosum* and *Armillaria ostoyae* growth

Species	Freq.	*H. annosum*		*A. ostoyae*	
		IBE	GBE	IBE	GBE
Penicillium steckii Zaleski	15	-3	-45	0	0
Penicillium adametzii Zaleski	5	+20	+100	+2	+10
Oidiodendron tenuissium (Peck) Hughes	4	-7	-28	0	0
Penicillium lanosum Westling	4	+1	+4	0	0
Trichoderma viride Pers.: Fr.	4	+8	+32	+7	+28
Oidiodendron chlamydosporicum Morrall	3	-5	-15	0	0
Penicillium daleae Zaleski	3	+2	+6	+2	+6
Penicillium janczewskii Zaleski	3	+10	+30	0	0
Pseudogymnoascus roseus Raiłło	3	-3	-9	0	0
Eladia saccula (Dale) G. Smith	2	-3	-6	0	0
Penicillium waksmanii Zaleski	2	-5	-10	0	0
Torulomyces lagena Delitsch	2	0	0	0	0
Aspergillus carneus (van Tiegh.) Bloch	1	-4	-4	-1	-1
Aspergillus kaganawaensis Nehira	1	+6	+6	+7	+7
Chrysosporium merdarium (Link ex S. F. Gray) Carm	1	-3	-3	+1	+1
Summary biotic effect	53		+58		+51

Other less frequent species: *Chrysosporium pannorum* (Link) Hughes – 1, *Mortierella nana* Linnemann – 1, *Mortierella vinacea* Dixon-Stewart – 1, *Paecilomyces farinosus* (Holm ex S. F. Gray) A. H. S. Brown et G. Smith – 1, *Penicillium lanosum* Westling – 1, *Penicillium spinulosum* Thom – 1, *Penicillium variabile* Sopp. – 1, *Penicillium verruculosum* Peyronel – 1, *Wardomyces humicola* Henneb. et Barron – 1, *Zygorhynchus moelleri* Vuill. – 1, non-sporulating Sg II 9 – 1.

Table 9

Frequency (%) of the most common taxa in soil beneath the roots of 30- and 49-year-old Scots pines and their stumps

Taxa	30-year-old pine				49-year-old pine			
	living roots		stump roots		living roots		stump roots	
	location							
	I	II	I	II	I	II	I	II
Mucorales	30.6	32.6	17.5	31.7	30.3	21.7	5.5	4.7
Oidiodendron	0	0	0	0	11.4	1.9	2.2	10.9
Penicillia	53.8	54.2	24.2	23.3	35.6	41.7	68.9	56.3
Trichoderma spp.	1.2	1.9	0.8	20.0	2.4	0	11.1	6.3
T. virens + *T. viride*	0	0.8	0.8	15.8	2.4	0	4.4	6.3

Table 10

List of fungal species occurring in soil

beneath:

the living trees: *Acremonium diversisporum* (van Beyma) W. Gams, *Acremonium terricola* (Miller et al.) W. Gams, *Chaetomidium biapiculatum* Lodha, *Fusarium tricinctum* (Corda) Sacc., *Mortierella hygrophila* Linnem. var. *minuta* Linnem., *Mortierella ramanniana* (Moller) Linnem., *Mortierella turficola* Ling-Young., *Oidiodendron griseum* Robak, *Oidiodendron periconioides* Morrall, *Penicillium chermesinum* Biourge, *Penicillium chrysogenum* Thom, *Penicillium implicatum* Biourge, *Penicllium lividum* Westl., *Penicillium pinetorum* Christensen et Backus, *Penicillium raistrickii* G. Sm., *Penicillium vinaceum* Gilman et Abbott, *Phialophora lasiosphaeriae* W. Gams, *Thysanophora penicillioides* (Rouss.) Kendrick, *Trichoderma hamatum* (Bon.). Bain., *Trichosporiella cerebriformis* (de Vries et Kleine-Natrop) W. Gams;

the living trees and stumps: *Absidia cylindrospora* Hagem, *Aspergillus kaganawaensis* Nehira, *Aureobasidium pullulans* (de Bary) Arnaud, *Chloridium virescens* var. *chlamydosporum* (Beyma) W. Gams et Hol.-Jech., *Chrysosporium merdarium* (Link) J. Carm., *Cladosporium sphaerospermum* Penz., *Humicola grisea* Traaen, *Mortierella gracilis* Linnem., *Mortierella nana* Linnem., *Mortierella vinacea* Dixon-Stewart, *Mucor hiemalis* Wehmer, *Oidiodendron tenuissimum* (Peck) S. Hughes, *Penicillium adametzii* Zaleski, *Penicillium daleae* Zaleski, *Penicillium janczewski* Zaleski, *Penicillium lanosum* Westl., *Penicillium spinulosum* Thom, *Penicillium steckii* Zaleski, *Penicillium waksmanii* Zaleski, *Polyscytalum fecundissimum* Reiss., *Pseudogymnoascus roseus* Raiłło, *Tolypocladium geodes* W. Gams, *Trichoderma koningii* Oudem., *Trichoderma polysporum* (Link) Rifai, *Trichoderma viride* Pers., *Wardomyces humicola* Henneb. et Barron, *Zygorhynchus moerelleri* Vuill.;

the stumps: *Aspergillus carneus* (v. Tieghem) Blochwitz, *Aspergillus niveus* Blochwitz, *Aspergillus versicolor* (Vuill.) Tiraboschi, *Cladosporium harbarum* (Pers.) Link, *Coniophora puetana* (Schumacher) Karsten, *Eladia saccula* (Dale) G. Sm., *Exophiala* sp., *Mortierella humilis* Linnem. ex W. Gams, *Oidiodendron chlamydosporicum* Morrall, *Paecilomyces farinosus* (Holmskiold) A. H. S. Brown et G. Sm., *Penicillium citrinum* Thom, *Penicillium clavigerum* Demelius, *Penicillium fellutanum* Biourge, *Penicillium islandicum* Sopp., *Penicillium jensenii* Zaleski, *Penicillium terlikowskii* Zaleski, *Penicillium variabile* Sopp, *Penicillium verruculosum* Peyron., *Sporothrix schenckii* Hectoen et Perkins, *Torulomyces lagena* Detlisch, *Trichocladium opacum* (Corda) S. Hughes, *Trichoderma atroviride* Karsten, *Trichoderma aureoviride* Rifai, *Trichoderma virens* (Miller, Giddens et Foster), *Trichoderma* sp., 2 x non-sporulating fungi.

Table 11

The number and frequency (%) of fungal isolates* from soil surrounding the Scots pine roots and stump roots antagonistic** to *Heterobasidion annosum*

Scots pine	30-year-old pine				49-year-old pine			
	location							
	I		II		I		II	
	absolute	%	absolute	%	absolute	%	absolute	%
roots	240	59.7	302	59.6	82	40.6	49	48.0
stump roots	66	56.4	53	50.0	58	71.6	20	37.7

* – numbers include 15 of the most common species
** – individual biotic effect (IBE) ≥ + 1

The effect (SBE – summary biotic effect) of fungi communities from soil beneath the living pines and their 2-year-old stumps on the growth of *H. annosum* and *A. ostoyae* was calculated.

Taking into consideration *H. annosum* the SBE of fungi in soil under live trees was +1760 and +958 in the 30-year-old stand as well as +427 and +410 in the 49-year-old stand. Two years after cutting of the trees the SBE decreased to +104 and +71 in the 30-year-old stand and changes to +575 and +58 in the 49-year-old stand.

Taking into consideration *A. ostoyae* the SBE of fungi in soil under live trees was +999 and +1244 in the 30-year-old stand as well as +426 and +382 in the 30-year-old stand and to +180 and +51 in the 49-year-old one (Table 1-8).

DISCUSSION

Thinning is a common treatment in Scots pine stands. Despite many commercial and sanitary benefits is effects also the biotic relations in the soil environment of the stand (M a ń k a et al., 1991). Partly they are due to the changes in fungal communities which are influenced by a multiplicity of factors, i.e., chemical changes of substrate, microclimate, microfungal and microfaunal associates. The present study was undertaken to obtain data on the quantitative and qualitative composition of filamentous fungi communities and their role in soil surrounding the stump roots in two pine stands: 30- and 49-year-old ones, two years after thinning.

The soil surrounding roots of the 49-year-old pines was inhabited by much smaller fungi communities than the soil in the 30-year-old stand (Tables 1-4). Moreover the soil beneath the stumps was inhabited by a smaller fungi populations than the roots of living trees and stumps, 20 species occurring only in soil beneath the live trees and 28 species only in soil beneath stumps (Table 10). The mycobionta from the soil surrounding the stump roots seems to be a bit more varied. In both stands the mycobiontas have very much in common, thus 1– species of *Chrysosporium merdarium*, *Mortiella vincea, Penicillium daleae, P. janczewskii, Pseudogymnoascus roseus* are the dominant organisms in soil surrounding the roots of live trees and the stumps, 2 – the frequency of *Mucorales* decreases in soil beneath the stumps, 3 – the frequency of *M. vinacea, P. roseus* decreases and of *Trichoderma viride* increases in soil beneath the stumps, 4 – the frequency of *Penicillium adametzii, P. daleae* and *P. janczewskii* decreases in soil beneath the stumps in most cases. Only *Penicillia* behave differently: their frequency decreases in soil beneath the stumps in the 30-year-old stand and increases in the 49-year-old stand.

The decrease in size of fungi communities in soil beneath the stumps may be indication of the big influence of the active root exudates on fungal colonization what supports the findings of R o v i r a (1965). As the nutrients become depleted many fungal isolates die out which is in accordance with P u g h (1980). It seems that mostly density and only to some extent, the diversity of fungi communities can be affected. The number of fungal species in soil beneath stumps is often higher which is in accordance with several studies that have detected an increase in the number of species through the early stages of fungal degradation of the single substrates (see: Christensen, 1981). The soil beneath the roots was inhabited mostly by the same species which occurred on the surface of the roots (Kwaśna, unpubl.). Additionally *Aspergillus carneus, Eladia saccula, Oidiodendron periconioides, Polyscylatum fecundissimum* and *Wardomyces humicola* occurred exclusively in soil. They are presumably very efficient in using the substrates which may be in subnormal concentrations or have the great ability to utilize the compounds unavaiable to members of other groups of fungi.

The data obtained may indicate the correlation between soil fungi communities and physical environmental factors, mainly temperature and moisture which seem to vary in both stands due to the different afforestation rate. The environmental conditions of both stands are indicated by the presence of particular fungal species. It was proved, that favourable moisture conditions and newly available organic substrates stimulate the fungal growth and account for the higher density of soil fungi (Christensen, 1969; Ciborska et Zadara, 1974). In the 30-year-old stand, the dense canopy reduces the solar radiation which decreases the soil temperature and increases its moisture. Additionally, higher nutrient supply account for the higher density of fungi. The occurrence or the higher frequency of fungi with bigger water requirements, i.e.: *Mucorales* in soil beneath the living trees, *Aureobasidium pullulans* and *Ch. pannorum* in younger stand, indicate the higher moisture of those habitats. The nutrient preferences of mentioned fungi for the litter (Wicklow et Whittingham, 1974) should, however, also be taken into account. *Oidiodendron* species prefer more humid conditions as well. The present studies, however, did not confirm this. The increase in density of *P. adametzii, P. janczewskii* and *P. terlikowskii*, which are common in drier conditions (Gochenaur et Backus, 1967) and the increase in number of *Aspergillus* species characteristic for the warmer climates, in soil beneath the stump roots, particularly of the older stand indicate the stronger sun insolation and the higher temperature of those areas. The higher frequency of melanic fungi with darkly pigmented mycelium and greater ability to withstand the effects of ultraviolet light, i.e: *Chloridium virescens* var. *chlamydosporum, E. saccula, Exophiala* sp., *Humicola grisea, Oidiodendron* spp., *P. fecundissimum, Sporothrix schenckii, Tolypocladium geodes, Torulomyces lagena* and *W. humicola* in soil beneath the stumps and of the older stand supports this supposition. The results are in accordance with the findings of Gochenaur et Wittingham (1967), who showed that the members of *Dematiaceae* are more common at sites poorer in organic matter.

The occurrence of *A. pullulans* and *Cladosporium herbarum* as well a species of *Mucorales, Trichoderma* and *Basidiomycetes* such as *Coniophora puteana* in soil beneath stumps of the 30-year-old stand, indicates the occurence of organic matter with varied level of decomposition. The first two species are common primary saprophytes while the three latter are characteristic of the final stage in the fungal succession on *Pinus sylvestris* debris (Kendrick et Burges, 1962). The low frequency of *Mucorales* and high density of *Penicillia* occurring in soil beneath the stumps in 49-year-old stand indicates the higher rate of decomposition of plant debris. According to H u d s o n (1968), *Penicillia* belong to the "soil inhabitants" and are characteristic of the final stage in succession of fungi.

Considering the specificity of infection by *Heterobasidion annosum* and *Armillaria ostoyae*, greater interest has been devoted to the roots and root surface fungi and their anagonistic properties (J o h a n s s o n et M a r k l u n d, 1980). Studies on soil fungi communities examined for the presence of competing microorganisms and their suppressiveness toward *H. annosum* and *A. ostoyae* were carried out by M a ń k a et al. (1991, 1993). The reason for this is the presence of *H. annosum* in soil in the form of basidio- and conidiospores (S i e m p a n n, 1974) and of *A. ostoyae* in the form of rhizomorphs. Both, organic residues (N y k v i s t, 1962, 1963) as well as root exudates and leaches of the soil mycobionta and thus can change the R o v i r a, 1965) can effect the composition of the soil mycobionta and thus can change danger both pathogens. Conidiospores of *H. annosum* are even more susceptible to the fungistatic metabolites produced by soil fungi, than is the growing mycelium, and all fungal isolates inhibiting pathogen's mycelial growth also check the germination of its conidia (J o h a n s s o n et M a r k l u n d, 1980). With increasing distance from the root surface the specific effect of root exudates is diluted and influenced by the litter or the deeper, mineral layers of soil.

The fungal communities in soil beneath the 30-year-old pines have bigger antagonistic effect on *H. annosum* and *A. ostoyae* than those beneath the 49-year-old stand. The decrease in density of fungal communities and in the frequency of species antagonistic to *H. annosum* and *A. ostoyae*, which can be expressed by the decreased Summary Biotic Effect (SBE) values, indicate that in the 30- and 49-year-old forests the mycobionta in soil surrounding the 2-year-old stump roots have smaller antagonistic effect on both pathogens compared to the mycobionta in soil surrounding the roots of living trees. The decrease of SBE values was very distinct in the 30-year-old stand and the situation is very similar to that observed on the surface (rhizoplane and rhizosphere fungi) of the stump roots (K w a ś n a, unpubl.). In the case of the 49-year-old stand the decrease was much lower and even the increase in SBE value in case of *H. annosum* was observed. These findings are in contradiction with the earlier results of M a ń k a et al. (1991, 1993), who stated than in intensively thinned and in extremely intensively thinned 13- and 16-year-old Scots pine stands, 3 and 5 years later, the soil fungi communities from suppressed the growth of *H. annosum* and *A. ostoyae* much more than the communities from the neglected (not thinned at all) or thinned in the routine way stands. In both cases the increase in suppressiveness was partly due to the increase both, in size of fungi communities and population of *Trichoderma* species. In the present study the decrease in size of fungal community and only small increase in *Trichoderma* population were observed in both locations of two stands. The reason for this is presumably due to changes in the supply of organic matter. The soil samples were collected from the B-horizon which was at the depth of 15-30 cm, while M a ń k a et al. (1991, 1993) took the samples from the soil at the depth of 5-15 cm which was rich in plant remains and needle litter residues being decomposed mostly by *Trichoderma* species (Millar, 1974). The sufficient amounts of carbon in the upper layer allow the continuous growth of soil fungi, while in the absence of the sufficient amount of organic substrates only a limited number of fungi is able to grow deeper in the soil (Pugh, 1980).

The present studies as well as the earlier findings of Kwaśna (unpubl.) are in contradiction with results of Johansson et Marklund (1980), who showed that the species antagonistic to *H. annosum* were relatively more frequent in the forest rhizoplane and rhizosphere samples than in the root free soil. It seems that these fungi occur in similar proportions in both the root surface soil and the root free soil.

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Zbiorowiska grzybów glebowych spod sosny zwyczajnej i jej pniaków. Ich efekt na wzrost *Heterobasidion annosum* i *Armillaria ostoyae*

S t r e s z c z e n i e

Gleba spod 30-letniego drzewostanu sosnowego zasiedlona była przez zbiorowika grzybów co najmniej 2 razy liczniejsze niż w drzewostanie 49-letnim. Zbiorowiska grzybowe w glebie spod pniaków sosnowych były uboższe od tych spod żywych drzew. Zbiorowiska grzybów glebowych spod 30-letniego drzewostanu sosnowego dzialaly silniej antagonistycznie w stosunku do *H. annosum* i *A. ostoyae* niż zbiorowiska z drzewostanu 49-letniego. Spadek liczebności grzybów oraz liczby gatunków anatgonistycznych w stosunku do obu patogenów spowodował spadek aktywności anatagonistycznej zbiorowisk grzybowych w glebie spod pniaków.