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Late Stages of Fungal Succession on Small Beech Sapwood Strips in a Beech Forest Litter*,**

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Synopsis

Eleven small strips of beech sapwood were collected from the litter layer of a beech forest after they had been placed on the litter for 26 months and fungal communities developing in them were investigated. The size of strip (78×5×5 mm) was apparently sufficient for supporting the fungal succession from the initial stage to the latest stage in which some wood-rotting basidiomycetes became dominant. A white rot and a brown rot were dominant in five and two strips respectively, but they never occurred together in any strip. A possible competitive interactions between two rots was suggested. In four strips the smooth progress of the fungal succession seemed to be delayed by the insufficient moisture content of the wood or by the vigorous fluctuation of it, which were caused by the microclimatic conditions surrounding the strips. Common or prominent dematiaceous hyphomycetes mainly colonized the surface of strips, and most of them were well known wood-inhabiting hyphomycetes, especially those of common hardwoods in the cool temperate regions.

Key words: Fungal succession, beech sapwood decay, beech forest litter.

There have been many studies on the fungal succession on felled trees, timber, logs and posts in contact with the soil. They were reviewed by KÄÄRIK (1974) and more recently by LEVEY (1982). They showed that the wood-rotting basidiomycetes normally become dominant in the latest stages of fungal successions on various kinds of wood in various environmental conditions and they are the major cause of decay. However, they also

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recognized that the places of other ecological groups of fungi such as sugar fungi, stainers or soft-rots are not always fixed in the fungal succession associated with the wood decay.

An attempt was made to investigate the fungal succession on the beech sapwood which were placed on the litter layer of a beech forest. The early stages of succession during six months after the placement have been described in detail in the previous paper (OKADA *et al.*, 1984). The following stages of them will be described and discussed in this paper based on the date of fungal communities in the sapwood strips of 26 months after the placement.

Materials and Methods

A sample of 11 strips was collected from the litter layer of *Fagus crenata* forest at Ohbora, Sanada-machi, Nagano Pref., on 18th of July, 1983. It had been placed on the surface of litter layer on 24th of April, 1981 (OKADA *et al.*, 1984), and left there until the present sampling time. So all the strips had been buried in the litter layer. The sample was kept in a new polyethylene bag and immediately carried to the Sugadaira Montane Research Center, University of Tsukuba, for the fungal analysis.

The strips were first put into the tap water of 1000 ml beakers for preliminary washing. Seven of them floated and lay under the water surface (six) or stood in the water (one). These strips were classified into a group (F group). The rest sank and lay on the bottom and were classified into another group (S group). Then they were serially washed and dried on sterilized filter papers for about 24 hrs as the method described in OKADA *et. al.* (1984). After that individual strips were cut into small pieces with sterilized razor blades. The number of pieces per strip varied from 16 to 24 (Table 2). Four pieces to every plate were plated on 1/2 corn meal agar medium. The plates were incubated on the bench of the laboratory and examined at intervals during three months for the isolation or recording of fungi.

Results

Table 1 gives a list of the fungi isolated in this study, showing the frequency of each fungus in the groups of F, S and the whole, respectively. Of the 27 species isolated ten were mucoralean fungi, in which *Mortierella* was rich and widely distributed in the samples.

Eight of fifteen hyphomycetes isolated were dematiaceous and appeared to contribute to the discoloration of the surface of strip from brown to black. Three species of *Trichoderma* occurred but only *T. koningii* was of high frequency. A nematode-trapping *Dactylella* was found in five strips.

Of the 27 species fifteen were common to both strip groups, while eight were restricted within the F group and four within the S group. All the restricted species were rare or of low frequency except *Micromucor isabellinus* which occurred on five strips of the F group. Five species, *Mortierella parvispora, Brachysporium nigrum, T. koningii,* basidiomycete sp. 1, and *M. isabellinus* were common in the F group but infrequent or absent in the S group, while *Chalara* sp. showed a reverse pattern of occurrence.

Table 1. Frequency of occurrence of fungi in eleven strips of beech sapwood of 26 months after placement on the litter layer of a beech forest.

Fungal species	Group F* (Max. 7)	Group S** (Max. 4)	Total (Max. 11)
Mortierella humilis Linnemann	6	4	10
M. globulifera Rostrup	5	4	9
M. parvispora Linnemann	6	2	8
Chloridium sp.	5	3	8
Brachysporium nigrum (Link) Hughes	6	1	7
Mucor hiemalis Wehmer	4	3	7
Spadicoides obovata (Cooke & Ellis) Hughes	4	3	7
Trichoderma koningii Oudemans	5	2	7
Basidiomycete sp. 1.	5	1	6
Micromucor ramannianus (Moller) v. Arx	3	3	6
Chalara sp.	1	4	5
Dactylella sp.	2	3	5
Micromucor isabellinus (Oudem.) v. Arx	5	0	5
Haplographium delicatum Berk. & Broome	3	1	4
Trichoderma hamatum (Bonnord.) Bain.	3	1	4
T. polysporum (L. & Pers) Rifai	3	1	4
Basidiomycete sp. 2.	2	0	2
Mortierella gamsii Milko	2	0	2
Penicillium sp.	2	0	2
Spiropes balladynae M. B. Ellis	2	0	2
Selenosporella curvispora MacGarvie	0	2	2
Absidia glauca Hagem	1	0	1
Codinaea sp.	1	0	1
Mortierella minutissima Tieghem	1	0	1
Gliocladium roseum Bainier	0	1	1
Mortierella alpina Pyronel	0	1	1
Verticillium lecanii (Zimm.) Viegas	0	1	1

* The group of strips which floated or stood in the water of beakers.
** The group of strips which sank in the water of beakers.

Tbale 2 shows the distribution of the species within individual strips. The strips of the F group were reclassified into two subgroups (Fw and Fb) based on the difference of dominant basidiomycetes colonizing the inside of the strip. Basidiomycete sp.1, forming abundantly white rhizomorphs on the substrate was dominant in the strips of No. 1, 3, 4, 6, and 7. They were grouped into the Fw group. The pieces of the Fw group had whitish or white-spotted cross sections. On the other hand, basidiomycete sp.2 was dominant in the strips of the Fb group (No. 2 and 5). Many of the pieces of this group had light brown cross sections. The strips of the F group were generally softened by the activities of these

Table 2. Distribution of fungal species within individual strips. Figuers in table indicate percentage frequency of occurrence (approx.) of each species within individual strips.

Strip group	F							S			
Subgroup	Fw					Fb					
Strip No.	1	3	4	6	7	2	5	8	9	10	11
Basidiomycetes											
Basidiomycete sp. 1.	50	100	75	90	78	0	0	0	5	0	0
Basidiomycete sp. 2.	0	0	0	0	0	100	72	0	0	0	0
Dematiaceous hypomycetes											
Brachysporium nigrum	50	22	63	11	16	13	0	0	0	0	0
Spiropes balladynae	13	0	44	0	0	0	0	0	0	0	0
Haprographium delicatum	0	25	13	0	0	0	94	0	0	0	4
Chloridium sp.	0	6	69	15	0	19	17	5	0	6	4
Spadicoides obovata	0	0	0	5	27	19	94	0	11	18	67
Chalara sp.	0	11	0	0	0	0	0	21	21	18	4
Selenosporella curvispora	0	0	0	0	0	0	0	10	0	41	0
Codinaea sp.	13	0	0	0	0	0	0	0	0	0	0
Moniliaceous hyphomycetes											
Trichoderma koningii	19	44	6	0	0	6	6	40	0	0	13
T. hamatum	0	56	0	0	0	6	17	0	16	0	0
T. polysporum	19	0	6	0	0	0	17	0	0	0	21
Dactylella sp.	38	6	0	0	0	0	0	0	26	24	8
Penicillium sp.	0	0	6	0	0	6	0	0	0	0	0
Gliocladium roseum	0	0	0	0	0	0	0	0	5	0	0
Verticillium lecanii	0	0	0	0	0	0	0	10	0	0	0
Mucoratean fungi											
Mortierella humilis	6	0	56	15	21	25	17	30	16	41	33
M. globulifera	38	0	31	5	5	0	17	45	47	6	13
M. parvispora	6	6	6	5	5	0	6	0	5	0	13
Mucor hiemalis	0	6	13	0	0	25	17	5	0	6	4
Micromucor ramannianus	0	0	13	0	0	19	6	10	11	0	4
M. isabellinus	0	0	13	5	5	69	28	0	0	0	0
Mortierella gamsii	0	0	0	0	5	13	0	0	0	0	0
M. alpina	0	0	0	0	0	0	0	10	0	0	0
M. minitussima	0	0	0	0	0	0	6	0	0	0	0
Absidia glauca	0	0	0	0	0	6	0	0	0	0	0
No. of pieces observed	16	18	16	20	18	16	18	20	19	17	24

basidiomycetes.

No strips had prominent interior colonizers and became considerably soft in the S group. The common dematiaceous hyphomycetes colonizing mainly the surafce of the strip were also various among strips. For examples, in the surface of No. 4 strip *B. nigrum* and *Chloridium* sp. were widely distributed, followed by *Spiropes balladynae*, while *Haprographium delicatum* and *Spadicoides obovata* were common in No. 7 strip. In addition, *B. nigrum* and *Selenosporella curvispora* were prominent in No. 1 and No. 10 strips, respectively. In another strips there were no common dematiaceous hyphomycetes, though all the strips were colonized by two or more dematiaceous hyphomycetes. Among the species of moniliaceous hyphomycetes *Trichoderma* species were prominent in No. 3 and 8 strips.

Discussion

In their reviews both KÄÄRIK (1974) and LEVEY (1982) showed that the wood-rotting basidiomycetes normally become dominant in the latest stages of fungal succession on the wood and they are the major cause of decay, though the kind of woody substrate studied or the given environmental conditions surrouding the decaying wood was very various among the studies reviewed. In this study seven strips of the F group had a fungal communitiy in which some basidiomycetes were dominant colonizers (Table 2). All such strips were soft and considerably lost their weight, which appeared to be largely caused by these dominants. These results showed that the size of test strips used for this study (75×5×5 mm) were enough to support the fungal succession from the pioneer stages to later or the latest one, frequently called the climax mycofloral stage (LEVEY, 1982).

Two species of wood-rotting basidiomycetes were isolated from the strips of the F group. Basidiomycete sp.1 occurred in five strips and basidiomycete sp.2 in two strips, but they never occurred togather in any strip (Table 2). Many pieces of the strips in which basidiomycete sp.1 was dominant had whitish or white-spotted cross sections. So the fungus appeared to be a white rot which can destroy both the hollocellulose and lignin in the wood. Basidiomycete sp.2 appeared to be a brown rot because many pieces of the strips colonized by this fungus had light brown cross sections. The brown rots can utilize only the hollocellulose, leaving the lignin of the wood. Basidiomycete sp.1 was also isolated from a piece of No. 9 strip of the S group (Table 2), but the fungus occurred on only a small white spot of one cross section. These results suggest some competitive interactions between two wood rots found in this study. In fact, only one wood rod occuured in every strip of the F group.

No wood-rotting basidiomycetes were found in all the pieces of strips of the S group except one piece of No. 9 strip as mentioned above (Table 2). The dominant taxonomic groups were mucoralean fungi and hyphomycetes in the fungal communities of these strips (Table 1). It is generally recognized that the mucoralean fungi are the sugar fungi (GARRETT, 1951) which can not utilize cellulose and lignin. On the other hand, some hyphomycetes can become the cause of breakdown of the wood and are called as the soft-rot fungi (SAVORY, 1954 a, b). It is believed that some hyphomycetes isolated in this study are the soft-rot fungus. However, the strips of the S group did not become so soft and the cross sections of them were mostly brown, appearing not to be considerably discolored.

These facts suggest that the colonization of hyphomycetes appeared to restrict largely the surface of the strip and not to invade the inside of the strip deeply. It is one posibility that these strips accidentally came out from the litter and dried, so that they did not keep constantly their moisture contents at the level enough to support the growth of basidiomycetes in these strips. Therefore, the fungal communities of these strips appeared to be in the earlier seral stages than those of the F group in this succession. Probably the wood-rotting basidiomycetes may colonize and become dominant in these strips if the strips were left in the litter, passing through a transitional stage of fungal community like as that observed in No. 9 strip (Table 2).

Common dematiaceous hyphomycetes in this sample included common species on rotten wood of various hardwoods, especially those of deciduous trees common in the cool temperate regions of the northern hemisphere, (Ellis, 1971; Ellis and Ellis, 1985), viz. *Brachysporium nigrum* (No. 1 and 4), *Haprographium delicatum* (No. 7), *Spadicoides obovata* (No. 7), *Selenosporella curvispora* and *Chloridium* sp. (No. 4). These results suggest that the cool temperate climatic conditions of this region may influence considerably on the species composition of would-be colonizer on the wood. On the other hand, the dominant hyphomycetes varied with strips. This suggests that the dominant interior wood rots had not a great influence on the species composition of the surface mycoflora.

The results of the present study and those in the previous paper (OKADA *et al.*, 1984) will enable us to suppose a fungal succession associated with the decay of the strips of beech sapwood on/in the litter of a beech forest as follows. From the late April to the early Oct., 1981, the strips were lying on the surface of the litter so that the moisture content of the strip might vary vigorously. During this period, many species of fungi (about 60 spp. in this habitat) colonized the strips. Common primary saprophytes (HUDSON, 1968) represented by *Cladosporium cladosporioides* in this habitat first colonized the strips and became dominant. Most of them might arrive at the strips as air-borne conidia. They were followed by a overlapping wave of saprophytic fungi represented by many dematiaceous hyphomycetes such as *Xenosporium indicum* (OKADA *et al*, 1984). Most of them appeared to be the native fungi of litter and gradually spread over on the surface of the strips. Many soil fungi such as *Trichoderma* spp. or mucoralean fungi colonized the strips very early after the setting of strips and gradually increased the species diversity with the time. In the mid-October the beech trees shed their leaves with which the strips were covered. Some primary saprophytes, probably those inhabiting newly fallen leaves appeared to colonize again the strips, for the mycoflora of the sample collected in May, 1982 was very similar to that of the same month of 1981 in the species composition (OKADA, unpublished data). Soon the ground was covered with snow and as it was until April of 1982.

The major peak of colonization of wood-rotting basidiomycetes found in this study appeared to occurr in the summer of 1982. They invaded the inside of strips and became dominant in seven strips. However, they could not colonize or colonized but failed to survive in the four strips. The true reasons for these absence of wood rots are uncertain. The moisture content of wood may play an important role for this absence or lack of basidiomycetes in these strips. These strips were again covered with fallen leaves of 1982 and would be colonized by some wood-rotting basidiomycetes during the summer season of 1983, if they were left in the litter.

CLUBBE (cited in LEVEY, 1982) reported that the major first colonists on the wood in contact with the ground are typical soil fungi such as *Fusarium and Penicillium* etc. In this study the major initial colonizers were common primary saprophytes like as those on most nonwoody plant remains (HUDSON, 1968). Placing the test strips on the surface of the litter may keep the strips away from the rapid colonization of typical soil fungi. Except for this difference the succession described here is very similar to the general succession on the wood in contact with the soil (KÄÄRIK, 1974; LEVEY, 1982). The wave pattern of saprophytes in this succession is also the familier one in the fungal succession on nonwoody plant debris above the ground such as fallen leaves of various trees (HUDSON, 1968).

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