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CAUSAL AGENTS OF BUTT-ROT IN NORWAY SPRUCE IN SOUTHERN FINLAND

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KUUSEN TYVILAHON AIHEUTTAJAT ETELÄ-SUOMESSA

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A total of 146 spruce-dominated clear-cutting areas and 140 of the sample plots included in the 7th National Forest Inventory were examined during 1974–1978. The micro-organisms causing decay in the Norway spruce (*Picea abies* (L.) Karst.) sample trees were identified. The most common causal agent of butt-rot was *Heterobasidion annosum* (Fr.) Bref. Other fungi causing decay in the spruce trees were *Armillaria mellea* (Vahl.) Quél, *Stereum sanguinolentum* (Alb. & Schw. ex Fr.), *Resinicium bicolor* (Alb. & Schw. ex Fr.) Parm. and *Climacocystis borealis* (Fr.) Kotl. & Pouz. Species of *Ascocoryne* were very often present in the decay. The decay caused by *H. annosum* was considerably more extensive than cases of decay where the fungus was not present.

1. INTRODUCTION

There are a wide range of different organisms involved in the decay of spruce trees. The first pioneer organisms utilize free sugars present in the wood (bacteria, yeasts, non-hymenomycetous fungi). Micro-organisms which are not sensitive to phenolic compounds (*Phialophora*) gradually become dominant. This opens up the way to the phenol-sensitive decay fungi proper, which in most cases are mainly responsible for the decay processes of wood (Shortle and Cowling 1978). The decay fungi also work successively as the decay progresses. The decay organisms involved in the initial phase of decay include *Cylindrobasidium evolvens* (Fr.) Jül. (Huse 1978, Bonnemann 1979, Hallaksela 1984). *Sistotrema brinkmannii* (Bres.) John Erikss. (Bonnemann 1979, Hallaksela 1984), *Heterobasidion annosum* (Fr.) Bref. (Kallio 1965, Kató 1967, Dimitri 1968, Aufsess 1978, Kallio and Tamminen 1974) and *Stereum sanguinolentum* (Alb. & Schw. ex Fr.) Fr. (Bazzigher 1973, Isomäki and Kallio 1974, Bonnemann 1979, Roll-Hansen and Roll-Hansen 1980a) are commonly found as both pioneer species and in advanced cases of decay. Species which occur slightly later include *Resinicium bicolor* (Alb. & Schw. ex Fr.) Parm. (Kató 1967, Basham 1973, Whitney 1978) and *Climacocystis borealis* (Fr.) Kotl. & Pouz. (Kallio 1965, Schönhar 1969). The decay of the wood in old spruce trees is finished off by *Coniophora* and *Merulius* species (Björkman et al. 1964, Norokorpi 1980). In actual fact however, there is no clear dividing line between the different stages of the rot process and a number of different micro-organisms can be present simultaneously. Bacteria and *Ascocoryne* species, for instance, are micro-organisms which are not dependent on the actual stage of the decay process (Basham 1973, Delatour 1976, Norokorpi 1980).

The results of a number of studies have provided us with the following picture of the agents causing decay in Norway spruce (*Picea abies* (L.) Karst.). *Heterobasidion annosum* is the most common micro-organism isolated from butt-rot on spruce in Finland, apart from the northernmost parts of its distribution area (Kallio 1972, Kallio and Norokorpi 1972,

Kallio and Tamminen 1974). The proportion of *H. annosum* in butt-rot is also considerable (40 – 90 %) in West Germany and in France (Kató 1967, Schönhar 1969, Pechmann and Aufsess 1971, Delatour 1976, Siepmann 1982). The proportion of *H. annosum* decreases on moving northwards and the fungus does not occur at all above the Arctic Circle (Laine 1976, Norokorpi 1980). *Armillaria mellea* (Vahl.) Quel. is also a common butt-rot fungus (Schönhar 1969, Kallio and Tamminen 1974). It appears to be more common in Central Europe than in Finland, and more common in southern Finland than in northern Finland (Greig 1962, Björkman et. al 1964, Zycha 1970, Kallio and Norokorpi 1972, Norokorpi 1980). The most important wound decay fungus is *Stereum sanguinolentum* (Alb. & Schw.) ex Fr. (Pawsey 1971, Aufsess 1978, Roll-Hansen and Roll-Hansen 1980a, Norokorpi 1980, Hallaksela 1984). Other micro-organisms which are frequently isolated from decay in spruce are species of *Ascocoryne, Nectria, Ceratocystis* and *Penicillium*, and bacteria (Pechman and Aufsess 1971, Basham 1973, Kallio 1974, Roll-Hansen and Roll-Hansen 1980b, Hallaksela 1984).

2. MATERIAL AND METHODS

A sample of 146 spruce-dominated, clear-cutting areas were examined during the period 1974–1978. The study area was restricted subjectively on the basis of the results of butt-rot studies and the National Forest Inventories. The area was considered to include the vast majority of cases of butt-rot in southern Finland. In addition, 140 of the sample tree plots included in the 7th National Forest Inventory (NFI) were examined. The material and the measuring methods used to depict the decay are described in more detail in Tamminen (1984).

The micro-organisms causing decay in the sample trees in the clear-cutting areas were determined on the basis of 404 spruce trees with butt-rot and 43 trees with wound decay. 185 different-aged (40 to 160-year-old) spruce trees in the 7th National Forest Inventory (NFI) sample tree material were analysed.

Butt-rot was defined as decay which had progressed from the butt of trees which on visual inspection had an otherwise unaffected surface. Wound decay was defined as decay which had spread from stem or root-collar wounds. The micro-organisms in the butt-rot and wound decay were isolated from 5 cm thick sample discs. The trees on the NFI sample plots were studied by taking increment cores at butt height.

Two sample discs were sawn from the butt-rot and wound decay areas and placed immediately in sealed plastic bags. The fungi isolated from one of the disks were grown on malt agar and the bacteria on bacterial medium (Kallio 1973). Conidiophores of *H. annosum* and aerial rhizomorphs of *A. mellea* were examined on the other disc using a stereomicroscope (Hallaksela 1977). In addition, the micro-organisms which had spread the furthest in the rot were isolated from the apex of the colour defect. The sample discs were stored prior to cultivation for 1 to 7 days at −18°C.

3. RESULTS

31. The micro-organisms in the butt-rot trees in the clear-cutting areas

Micro-organisms were isolated from 377 spruces with butt-rot. In addition, *H. annosum* or *A. mellea* were detected on the basis of visual inspection with a stereomicroscope on 23 trees only. A micro-organism was isolated only from the apex of the decay in four of the cases. There were 23 completely sterile cases of trees with a colour defect.

The most common causal agent of butt-rot was *Heterobasidion annosum* (Table 1). *Armillaria mellea* and *Stereum sanguinolentum* which are also known as decay agents, were considerably less common causal agents of butt-rot (Table 1). A few of the spruce trees in the study material were decayed by either *Resinicium bicolor* or *Climacocystis borealis*. *Ascocoryne* species were also very often involved in the decay process . The large number of different species of Deuteromycotina fungi were found, although present in small numbers.

H. annosum was very frequently present at the butt height of the spruce affected by butt-rot from which only one micro-organism was isolated (in 60 % of the trees with butt-rot). This fungus was even more frequently the only apex micro-organism. *S. sanguinolentum* (6 %) and *Ascocoryne* spp. (5 %) were also present as the apex micro-organism in trees where the colour defect had spread extensively. Deuteromycotina fungi do not usually occur alone, but rather together with species of *Ascocoryne* and Basidiomycotina fungi. Only rarely was more than one microbe isolated from the apex of the colour defects.

Although a number of micro-organisms participate in the decay process, the actual combinations of micro-organisms which occur depend on the age of the decay and the isolation method used. Pairs of micro-organisms were isolated fairly frequently (in 25 % of the trees affected by butt-rot) in this study, and in a number of cases even between 3 and 7 microbes were found in the same sample disc. *H. annosum* was one of the micro-organisms in 45 % of the combinations of micro-

Table 1. The decay agents present in spruce stands in southern Finland, and their number and proportion (%) out of the total number of decayed trees. NFI = The 7th National Forest Inventory.
Taulukko 1. Etelä-Suomen kuusikkojen lahonaiheuttajat, niiden lukumäärä ja %-osuudet lahopuiden kokonaismäärästä. VMI = 7. valtakunnan metsien inventointi.

Micro-organism *Mikrobi*	Butt-rot *Tyvilaho*		Wound decay *Vauriolaho*		Butt-rot (NFI-sample) *Tyvilaho (VMI-näyte)*	
	No. *kpl*	%	No. *kpl*	%	No. *kpl*	%
Armillaria mellea	31	8				
Climacocystis borealis	6	1				
Heterobasidion annosum	227	56	1	2	60	38
Resinicium bicolor	10	3	1	2	2	1
Stereum sanguinolentum	25	6	15	35	8	5
Ascocoryne spp.	112	28	10	23	11	7
Nectria fuckeliana	7	2	4	9	4	3
Acremonium butyri	10	3				
Acremonium spp.	2	<1			3	2
Aureobasidium pullulans					6	4
Cordata pauciseptata	4	1	1	2	1	1
Graphium spp.	1	1	2	5	1	1
Paecilomyces elegans	5	1			3	2
Penicillium spp.					4	3
Phialophora fastigiata	20	5	5	12		
Phialophora spp.	19	5	1	2	2	1
Rhinocladiella sp.	5	1			1	1
Scytalidium sp.	2	<1			1	1
Unidentified fungi *Tunnistamattomat sienet*	61	15	9	21	29	18
Bacteria – *Bakteerit*	65	16	9	21	16	10
Sterile – *Steriilit*	23	6	4	9	27	17
Number of trees, total *Puita yhteensä, kpl*	404		43		157	

organisms. *Ascocoryne* spp. (in 40 % of the *H. annosum* combinations), in particular, were present together with *H. annosum* in the same decay column. Species of *Ascocoryne* also formed a large number of combinations with other species of Basidiomycotina, Deuteromycotina fungi and bacteria.

311. Effect of the micro-organisms on the decay volume

The diameter and the height of the decay column in the sample trees were measured. These parameters were then used to calculate the volume of the decay in dm^3 (Tamminen 1984). The relationship between these decay parameters and the micro-organisms responsible was tested using one-way analysis of variance and the paired t-test.

The decay caused by *H. annosum* was compared with decay where this fungus was not present, and with decay in which a Basidiomycotina fungus was present together with *H. annosum*. In addition, decay caused by *H. annosum* was compared to decay where *H. annosum* was present together with a Deuteromycotina fungus and/or bacteria.

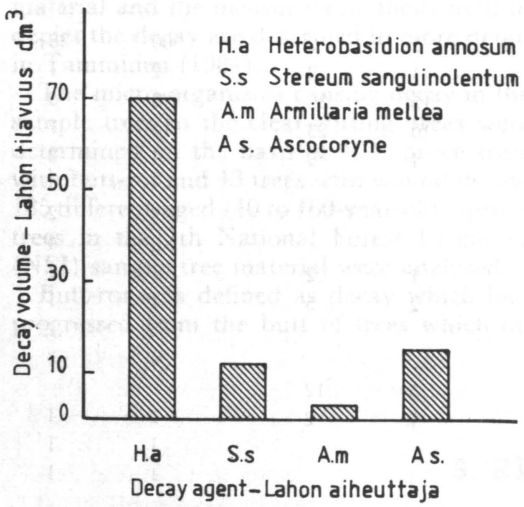

Fig. 1. The volume of butt-rot caused by *Heterobasidion annosum* in comparison to decay caused by *Stereum sanguinolentum, Armillaria mellea* and *Ascocoryne*.

Kuva 1. Heterobasidion annosum tyvilahon tilavuus (dm^3) verrattuna Stereum sanguinolentum, Armillaria mellea ja Ascocoryne lahoihin.

The volume of the decay caused by *H. annosum* was greater, to a statistically highly significant degree (t-value 12.27***), than those in which the fungus was not present. Whether or not *H. annosum* was present alone in the tree or together with some other micro-organism did not have a significant effect on the volume of the decay.

The cases of decay were also classified into four groups according to the causal agent: *H. annosum* decay, *S. sanguinolentum* decay, *A. mellea* decay and *Ascocoryne* spp. decay. These groups were compared using the paired t-test. *H. annosum* was found to cause significantly more extensive cases of decay than the other micro-organisms. The cases of decay with the smallest volumes were those caused by *A. mellea*. The volume of decay caused by *S. sanguinolentum* and *Ascocoryne* spp. did not differ very much from each other (Fig. 1). In point of fact, *Ascocoryne* spp. were isolated both from decay in the initial stages and from decay which had progressed to a fair height.

32. The micro-organisms in the wound decay trees in the clear-cutting areas

The most common causal agent of wound decay was *S. sanguinolentum* (Table 1). The other decay fungi were less common. Species of *Ascocoryne* also participated in wound decay. The species of *Ascomycotina* and *Deuteromycotina* were the same as those in the cases of butt-rot, and their proportions were of the same order of magnitude. Bacteria formed the second largest group of micro-organisms in the stem decay cases (Table 1). Apart from one case, bacteria were included in all the combinations of micro-organisms found in wound decay trees (in 14 % of the trees with wound decay).

33. The micro-organisms in the decayed trees in the 7th National Forest Inventory material

Increment cores were taken at butt height from 185 different-aged, spruce sample trees in connection with the 7th National Forest Inventory (NFI). The material included 28 trees which had a number of different wounds. These were excluded from the microbial examination. The micro-organisms in 157 trees suffering from butt-rot were studied.

H. annosum was the most important micro-organism in the increment core samples and in the butt-rot sample discs (Table 1). A lower number of fungi were isolated from the increment core samples. This is presumably due to the greater number (in 17 % of the trees from which increment cores were taken) of sterile samples encountered using the increment core method. The number of sterile samples may also have been affected by the fact that the blade of the increment core sampler was not dried after being flamed with alcohol (sterilization of the blade). The method could be improved if the blade were to be flamed until all the alcohol had burnt away and then allowed to cool down before taking a new increment core. Taking increment cores from the trees is not always successful in the case of small cases of decay. For instance, decay caused by *A. mellea* is usually rather small in size and is easily missed when taking increment cores.

Specimens of *Aureobasidium pullulans* and *Penicillium* spp. were only isolated from trees in the NFI material. The microflora was very similar in the butt-rot trees selected in the clear-cutting areas and in the NFI trees, although the latter material was more representative of the different age classes and also better fulfilled the criteria of a random sample.

4. DISCUSSION

This study again showed that the most important causal agent of butt-rot on spruce in southern Finland is *H. annosum*. This study covered a much wider area and gave a much clearer picture of the real situation in southern Finland (Tamminen 1984) than earlier studies (Kallio and Norokorpi 1972, Kallio and Tamminen 1974).

A. mellea is the second most important decay agent, although in fact it is considerably less common than *H. annosum*. The proportion of *A. mellea* as a decay agent on spruce varies considerably in different parts of the country. *A. mellea* infects the roots of spruce and slowly spreads upwards through the stem (Yde-Andersen 1958, Kallio and Norokorpi 1972). The fungus may remain unnoticed if the decay agent is analysed from the part of the tree stem lying above the felling point. On the other hand, *A. mellea* forms a white layer of mycelia inbetween the wood and the bark, while at the same time *H. annosum* may spread in the internal parts of the stem (Greig 1962, Whitney 1978). If the decay agent is identified on the basis of this white area, then the result will not represent the actual situation (Kallio 1971).

Decay agents which were identified, and which were also encountered more than once in the study, were *Resinicium bicolor* (Alb. & Schw. ex Fr.)(syn. *Odontia bicolor* (Alb. & Schw.) Quél.) and *Climacocystis borealis* (Fr.) Kotl. & Pouz.). In addition to being a decay agent in Finland (Kallio and Tamminen 1974), the former has also been mentioned as a decay agent in Germany (Kató 1967, Schönhar 1969, Pechmann and Aufsess 1971) and in Canada (Basham 1973, Whitney 1978). In actual fact the species of spruce and fir growing in Canada are different. According to the results of the different studies cited in this paper, *R. bicolor* is present as a decay agent in at the most 5 % of cases. The German researchers, Kató (1967) and Schönhar (1969), called this species of fungus by the name *Polyporus abietinus* (Dicks.) Fr. In actual fact it is a question of two different fungi. Both *R. bicolor* and *P. abietinus* develop very similar-looking crystal formations in laboratory cultures, and so it is very difficult to distinguish between them. It is difficult to say in actual fact which of the two fungi has been dealt with in different studies.

The textbooks mention that *Climacocystis borealis* is a decay fungus of old spruces. The sporophores of the fungus can be seen in the autumn on spruce stumps in southern Finland. *C. borealis* was isolated to some extent from cases of spruce decay in this study. Schönhar (1969) is the only other researcher who mentions that it is a decay agent. *C. borealis* has not occurred in studies carried out

in the Nordic Countries (Björkman et. al 1964, Roll-Hansen and Roll-Hansen 1980a). This fungus is either not a very significant decay agent, or else it has not been identified.

The study in hand lends support to earlier claims than *S. sanguinolentum* is the most common causal agent of wound decay throughout the world (Pawsey 1971, Isomäki and Kallio 1974, Bonnemann 1979, Roll-Hansen and Roll-Hansen 1979, Norokorpi 1980). Another species of *Stereum, S. areolatum* (Fr.), is mentioned in German studies only. This is a significant wound decay agent of spruce under German conditions (Pechmann and Aufsess 1971, Bonnemann 1979).

Apart from *Ascocoryne* (Basham 1973, Roll-Hansen and Roll-Hansen 1979), *Phialophora* (Shortle and Cowling 1978) and bacteria (Kallio 1974, Hallaksela 1984), the significance of other micro-organisms has not been investigated. The lists of fungi present in the results of different papers depend on the researcher's own knowledge of fungi and on his perseverance. The most important decay agents proper are known, but the way in which different micro-organisms affect each other in the decay process has not yet been studied.

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Total of 34 references

SELOSTE

KUUSEN TYVILAHON AIHEUTTAJAT ETELÄ-SUOMESSA

Vuosina 1974–1978 tutkittiin 146 kuusivaltaista avohakkuuleimikkoa ja 140 koealaa valtakunnan metsien 7. inventoinnin koepuualoista. Aineisto ja lahoa kuvaavat mittausmenetelmät on esitetty tarkemmin Tammisen (1984) julkaisussa.

Avohakkuuleimikoiden näytepuista tutkittiin lahon aiheuttaneet mikro-organismit 404:stä tyvilaho- ja 43 vauriolahokuusesta. Valtakunnan metsien 7. inventoinnin (VMI) näytepuista analysoitiin 185 eri-ikäistä kuusta (40–160 vuotta).

Tyvilahoksi määritettiin laho, joka oli edennyt silminhavaittavasti tervepintaisessa puussa tyveltä lähtien. Vauriolahoksi määritettiin laho, joka eteni runko- tai juurenniskavioituksesta. Tyvi- ja vauriolahojen mikro-organismit eristettiin n. 5 cm paksuisista näytekiekoista. VMI-koealojen puista tutkittiin puiden tyviltä kairatut lastunäytteet.

Yleisin tyvilahon aiheuttaja oli juurikääpä (*Heterobasidion annosum* (Fr.) Bref.)(taulukko 1). Myöskin lahottajina tunnetut mesisieni (*Armillaria mellea* (Vahl.) Quél.) ja verinahakka (*Stereum sanguinolentum* Alb. & Schw. ex Fr.) olivat huomattavasti harvinaisempia tyvilahon aiheuttajia (taulukko 1). Muutama tutkimusaineiston kuusista oli joko *Resinicium bicolor* (Alb. & Schw. ex Fr.) Parm. -tai *Climacocystis borealis* (Fr.) Kotl. & Pouz. -sienen lahottama. Lahotapahtumassa oli hyvin usein mukana *Ascocoryne* -lajeja (taulukko 1). Lajisto oli huomattavan samanlainen valituissa tyvilahopuissa ja VMI-puissa, vaikka jälkimmäinen materiaali oli ikärakenteeltaan laajempi ja otannaltaan satunnaisempi (taulukko 1).

Yleisin vauriolahon aiheuttaja oli *S. sanguinolentum* (taulukko 1). Muut lahottajasienet olivat harvinaisempia. *Ascocoryne* -lajit osallistuvat myös vauriolahoon. Bakteerit muodostivat toiseksi suurimman mikrobiryhmän vauriolahoissa.

Lahot ryhmitettiin myös lahonaiheuttajan mukaan neljään ryhmään, *H. annosum-*, *S. sanguinolentum-*, *A. mellea-* sekä *Ascocoryne* spp. -lahot. Eri aiheuttajien lahomääriä verrattiin pareittain t-testillä. Näistä sienistä oli *H. annosum* merkittävästi suurimpien lahojen aiheuttaja. Kooltaan pienimmät lahot olivat *A. mellean* aiheuttamia. *S. sanguinolentum* ja *Ascocoryne* -lahot eivät paljon eronneet kooltaan toisistaan (kuva 1). Tosin *Ascocoryne* -lajeja eristettiin sekä alkuvaiheen lahoista että melko korkealle edenneistä lahoista.