THE SEARCH FOR WILD DRY ROT FUNGUS *(SERPULA LACRYMANS)* IN THE HIMALAYAS

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INTRODUCTION

The dry rot fungus (*Serpula lacrymans*) previously known as *Merulius lacrymans*, is the most important timber decay fungus in buildings in Europe and is of serious concern in Japan and Australia (Singh 1991, 1992 & 1993, Koch 1991, Doi 1983 and Thornton 1991). Not only does the fungus bring about the dramatic decay of timber, but it is able to spread through a building from one timber location to another across non-nutritional surfaces. The fungus has a serious impact on the U.K. housing stock and also causes concern in conservation and preservation of buildings of historic and architectural merit.

The ravages of the dry rot fungus are familiar as is the destruction caused by attempts to eradicate it, including the use of chemicals. The remedial chemical timber treatment not only causes damage to the health of occupants, but also causes concern to the environmental health authorities. The lack of understanding of its biology and ecology has led to this radical treatment, hence considerable damage to the building fabric.

The fungus has occupied a specialised ecological niche in buildings in Europe with its unique biology, and is not known to occur in the wild, except in the Himalayas (Bagchee 1954). The search was made to gather more information about a fungus of great intrinsic scientific interest with a view to understanding its biology, ecology and genetics in the wild. We hope that fundamental scientific knowledge gained through multidisciplinary research should enable us to reach a better understanding of the fungus and to develop safer, more effective and ecological control techniques and strategies.

Recorded outbreaks of *Serpula lacrymans (M. lacrymans)* in India

Bagchee searched the forests of the western Himalayas from 1929 to 1952, and found fruiting bodies of the true dry rot fungus *(S. lacrymans)* on stumps, fallen logs and in buildings (some of them were partially destroyed by fire) (Bagchee, 1954). *Serpula lacrymans* was also observed on stone walls at Jandrighat, Dalhousie (7000 to 8000ft. a.s.l.) and on logs in the forest of Gulmarg, Jammu & Kashmir (1200 to 1300ft. a.s.l.) (Rattan, 1977). The majority of these findings in the forests were made on the stumps and logs of *Picea smithiana, Abies pindrow* and *Pinus griffithii* and in the buildings on *Picea morinda*. The various developmental stages, for example fan shaped mycelium strands and young to mature sporophores were all recorded in the wild (Bagchee, 1954). The fruit bodies of the True dry rot fungus developed in nature under dim light conditions on the lower surface of logs in contact with soil or on the cut surfaces. It was assumed from this that the species in the Himalayas lives in nature, contrary to northern Europe, and from there is introduced into houses either as spores or as mycelium in attacked wood.

Together with *Serpula lacrymans* a number of other wood-destroying fungi were found, e.g. *Fomitopsis rosea*, *Poria carbonia*, *Gloeophyllum subferruginea* and sometimes also *Trichaptum abietinum*.

During the 1992 expedition the herbarium at the Forest Research Institute in Dehra Dun, U.P. India was visited and the dried material of *Serpula lacrymans* (M. lacrymans) studied with kind help of Dr M D Mahrotra, head of the Forest Mycological Laboratory.

Over a period of 23 years the True dry rot fungus was found in the area between Simla and manadi in approximately 13 well-documented instances. Since 1954 no finds have been published from Dehra Dun. According to Dr Sujan Singh (former head of forest pathology) this absence of finds may

be explained by the fact that in the early fifties the forest laboratory at Dehra Dun changed their main research subject from wood-decaying fungi to forest pathology, especially leafspot diseases of living trees in the forest nurseries.

In 1972 the species was found twice, namely on a stone wall at Jandri Ghat, Dalhousie, Himachal Pradesh and on a log of *Abies pindrow* at Ningel Nullah, Gulmarg, Jammu & Kashmir (Rattan, 1977). Both specimens are deposited at the Botanical Department at the University of Chandigarh (Rattan, 1977).

ASSOCIATED FLORA IN HIMALAYAS

Finds of wood-decaying fungi in nature

The expedition in 1992 visited several of the areas on the map. Near Simla the True dry rot fungus was found in a hotel, but only indoors.

At Narkanda, approximately 3000 metres a.s.l., areas with stumps of different ages, namely 5, 10, 15 and 25 years, were searched. During the search *Paxillus panuoides* was found among others. *Paxillus panuoides* causes considerable damage in British buildings, and is also found in nature. Species of Cellar fungus (Coniophora spp.) were also found on newly felled trunks of *Cedrus deodara* and *Picea smithiana*. *Formitopsis rosea* was collected on a fallen log.

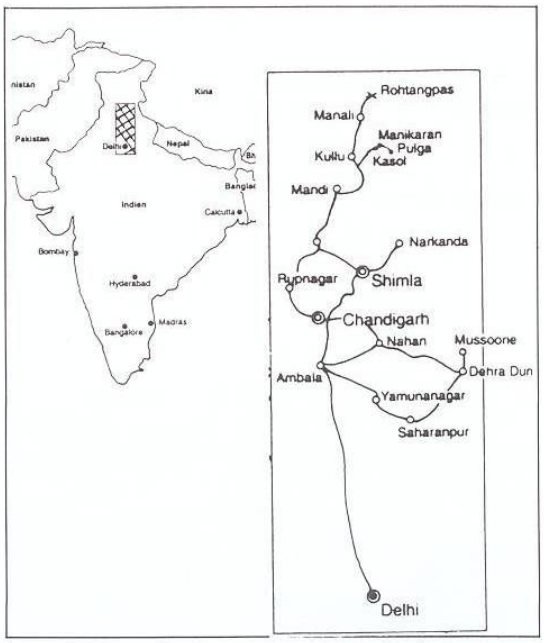
The soil temperature was measured as 20°C and the air temperature was 22°C. We agreed to visit the area again just before returning home, when the temperature had dropped. At Kasol the Spiny dry rot fungus *(Leucogyrophana pinastri)* was found in the open air on piled up trunks of *Cedrus deodara* that had been felled 3-4 years previously.

At Pulga, 3100 metres altitude, Thin-fleshed dry rot fungus *(Serpula himantioides)* was found on fallen trunks of *Picea smithiana* together with Soft dry rot fungus *(Leucogyrophana mollusca)*.

Vegetation in the Himalayas

In Europe spruce, larch and even oak are attacked by (*Serpula lacrymans*). Both sapwood and heart wood is destroyed.

The Himalayas are very varied from a vegetational point of view. Within 100 kilometres the terrain rises from 0 to 5000 metres and the flora changes along this gradient. A comparable journey in Europe would be from North Africa to Denmark, since the mean temperature falls 0.6°C for every 100 metres of ascent in the mountains.



In the tropical climate of the lowland zone you may see rice, bananas and other tropical crops. The rice is grown in the summer months, wheat in winter and vegetables before the next rice crop.

Under subtropical conditions from 300-1500 metres various Citrus species and sweet chestnut *(Castanea sativa)* may be found in cultivation. Among the conifers seen is Long-leaved Pine *(Pinus roxburghii)*, a large, stout native pine.

In the forest of the temperate zone from 1500-2500 metres you may find *Carpinus viminea*, *Populus cilita*, *Rhododendron arboreum* – a species with red flowers that is not hardy in Denmark, *Quercus himalayensis*, *Aesculus indica*, *Buddleja davidii* and Himalayan Cedar *(Cedrus deodara)*.

In the subalpine zone from 2500 metres to the snow limit you will find West Himalayan Spruce *(Picea smithiana)*, Himalayan Silver Fir *(Abies spectabilis*, *Taxus baccata* and *Betula utilis)*.

Under alpine conditions small shrubs and well known plants such as *Gentiana* spp. and Edelweiss may be seen.

REDISCOVERY

The search was made in the western Himalayas (see the map) marked with asterisks.

The True dry rot fungus in the wild

When re-visiting Narkanda at the end of August the soil temperature had dropped to ca. 18°C and after a thorough search of the

Top left: Dry Rot Fruiting body discovered in the Himalayas. Top right: *Schizophyllum*. Middle left: *Leucogyrophana* sp. Middle right: *Gloeophyllum* sp. Bottom left: *Coniophora* sp. on logs; Bottom

Top left: The team with helper on way to Pulga. Top right: View of the forest floor. Middle left: General view overlooking forest; Middle right: Dry rot fruitbody discovered in this area; Bottom left: Herbarium specimen; Bottom right: Dry rot on brickwork at Brighton Pavilion.

stumps and logs previously investigated a fruitbody of the True dry rot fungus *(Serpula lacrymans)* was found. It was situated on the stump of a tree that had fallen 15 years previously.

What connection is there between the True dry rot fungus found in nature in the Himalayas and the one that haunts us in Europe, Asia, America and Australia? Since the True dry rot fungus is found from Kashmir across Himachal Pradesh to Uttar Pradesh, a stretch of several thousand kilometres, it is likely that the fungus was brought from the area by the British and their belongings. How was it able to spread to other continents and why is it, for example, much more common in Holland, Sweden, Germany and Denmark than in its homeland? In order to answer this question we have analysed the different physical chemical and meteorological factors both in the Himalayas and in northern Europe.

Identification of the True dry rot fungus from the Himalayas

The fruitbody from Narkanda measured c. 10 × 6cm, and 16mm thick. It was easily detachable from the substrate.

The trama was gelatinised and greenish skeletal hyphae were found parallel to the substrate, together with L-shaped skeletoid hyphae. The skeletals turned dark blue in Cotton Blue. The spores measured 9-10.5 × 5-5.5μm, and were yellowish brown.

All characters correspond to what is known from finds in Europe, Japan and Australia.

Dispersal of the True dry rot fungus from the Himalayas

In the period 1850-1920 large amounts of timber were exported from the Himalayas, e.g. from Narkanda to England, and the fungal mycelium and spores could easily have been dispersed in this manner (pers. comm. Sujan Singh).

The term 'dry rot' appears to have been used first about 1765 and towards the end of the 18th century decay of timber in buildings became a serious problem (Findlay, 1982). In 1784 dry rot became so serious that the Royal Society of Arts offered a gold medal to cure it and this was won by Mr Batson. Samuel Pepys reported in 1684 and 1686 that rot in ships was an even more serious problem than rot in buildings. Amrose Bowden of the Navy Office in 1815 published that dry rot was due to 'vegetation of the sap excited by the action of heat'. Ramsbottom in his presidential address in 1937 to the Essex field club on 'dry rot in ships', stated that 'foreign timbers were often floated down rivers and then immediately loaded into the confined holds of timber ships, an ideal arrangement for fungal infection; the logs were sometimes covered with fruit bodies' (of fungus) 'before they reach the dockyard'. Dry rot was first validly described in 1781 by Wulfren based on a find from Austria. He named the fungus *Boletus lacrymans*, but it has since then been placed in many different genera. Today we call it *Serpula lacrymans* (Wulf.: Fr.) Schroet.

Since the True dry rot fungus is known from England and Austria before the export of timber from India began, dispersal must have taken place in a different way, e.g. in the form of spores spread by the wind. A fruitbody can produce several billion spores so the probability of wind dispersal is great.

DNA analysis of the fruitbody of the True dry rot fungus found in the Himalayas is in progress at Dundee Institute of Technology (Pers. comm. Dr John Palfreyman) to compare it with isolates from different continents.

The True dry rot fungus in the wild versus in buildings

The True dry rot fungus has been confirmed as living in nature on stumps and fallen logs at an altitude of 3000-5000 metres within the natural distribution area of *Picea smithiana*, *Abies pindrow* and *Pinus griffithii*.

It has been found 13 times in the period 1929-1952, twice in 1972 and has been rediscovered in a single specimen in 1992.

At Wildflower Hall, Simla, Himachal Pradesh, 30km from Narkanda, an attack of the True dry rot fungus was found that in every way corresponds to a European attack of the same species.

It is likely that the True dry rot fungus finds larger amounts of calcium and iron in buildings than in the Himalyan forests. Furthermore the temperature and moisture relations are closer to optimum conditions in buildings, and the competition from other species there is much less than in nature. From being a relatively rare species in the forests of its homeland, the fungus has become a pest of modern buildings, where it may regulate the moisture on its own, has optimal concentrations of calcium and iron, and the low temperature is the same as in the mountains of the Himalayas.

EXPEDITION

Hutton + Rostron Environmental Investigations Ltd organised a multi-national team of biologists to study wood decay fungi in the wild. The team included Dr Jagjit Singh of Hutton + Rostron Environmental Investigations, UK, Dr Jorgen Bech-Anderson and Steen Elborne from Hussvamp Laboratoriet, Denmark, Dr Fred Goldie from the UK and Dr Bryan Walker (Oscar Faber Applied Research) from the UK and Dr Sujan Singh who has had more than 30 years experience of forest pathology throughout India. Dr Singh opened many doors and was an invaluable source of information and delightful companion. Intensive searches of the forests in the extreme north of India were hampered by monsoon rains, landslides and hazards of leeches, scorpions and other large wildlife. The studies ranged into extremely remote areas with steep forest slopes from 4000 to 13500 ft.

The team found the climbing tough and experienced extremes of temperature as they walked from the foothills towards the snowline. 'We became accustomed to being soaked to the skin for most of the time', but the trip has been a total success.

The climate: hot (>40°C) and humid (>95%) in the plains, temperate but rainy and overcast in the hills. Communications in the hills were badly disrupted at this time of year by frequent landslides. Phones out, electricity unreliable. Fortunate only to be trapped once, overnight, by a landslide near Mussoorie. Plunging about on semi-liquid 60° hillslides in heavy rain listening to minor landslides on the road above.

The trip to Pulga – 12 miles from nearest road, with three partners to take our luggage there was worth remembering. So remote, that they worshipped forest spirits, sacrificed a goat to them while we were there with gangs and drums and the only restaurant included toilet paper as an item on the menu! Presumably for ill prepared hippies who'd reached that far in search of pure hashish.

CONCLUSIONS

A single fruitbody of True dry rot fungus was discovered near Narkanda in the 1992 expedition. The environmental conditions of temperature and humidity in the Himalayas are somewhat similar to the North European building conditions. Sporophores have mainly been found in nature at the interface of soil and log, i.e. the poor ventilation conditions together with dense vegetation undergrowth. The oxalic acid produced during active metabolism can chelate with Iron (Fe) in the Himalayan soil compared with calcium (Ca) in North European buildings. In a further 1993 expedition we are hoping to gain more information on soil ecology and environmental conditions together with isolating the natural antagonistic microorganisms to dry rot fungus. This would enable us to exploit the possibilities of biological control.

It is intended that the fresh collection of the wild strain of dry rot will enable the study of its genetics and biology with a view to understanding its success as a coloniser of buildings in temperate climates, and to further development of chemical-free environmental strategies for its control. It is also hoped to answer the question of how evolutionary and epidemiological processes have led dry rot from being a rare fungus on Himalayan mountainsides to a common and destructive pest species in buildings in the UK and elsewhere.

A research grant has been awarded under the Eureka project to Dr Jagjit Singh, Chief Scientist at Hutton + Rostron Environmental Investigations Ltd in association with the Dundee College of Technology, the Building Research Establishment and the Danish Technological Institute, to extend the understanding of the biology and pathology of dry rot and related fungi.

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APPENDIX

Dry Rot *(Serpula lacrymans)* in Europe

The term dry rot in Britain refers to a type of decay timber in buildings caused by the True dry fot fungus *Serpula lacrymans* (formerly known as *Merulius lacrymans*). The dry rot fungus mostly attacks soft wood and often causes extensive damage. The term dry rot is rather misleading, as moist conditions are required to initiate the growth (a moisture content in timbers of about 20 per cent or more), and optimum growth is continued at about 30 to 40 per cent. Spore germination requires a more precisely favourable microclimate at the wood surface. The fungus has the ability to grow through plaster, brickwork and masonry and even extends a distance of several metres from its food source to attack sound timber using specialised hyphal strands (rhizomorphs). Rhizomorphs are conducting strands formed by the mycelium, and they are able to transport nutrients and water. Rhizomorphs may be up to 6mm in diameter; they are relatively brittle when dry. These characteristics are adaptive to the building environment, and make it one of the fungi which cause most rapid decay as well as being probably the most difficult to eradicate. Conditions of static dampness are particularly favourable to *S. lacrymans;* unlike wet rot fungi, it is able to tolerate fluctuating conditions. Active growth is indicated by silky white sheets or cotton-wool like cushions with patches of lemon yellow or lilac tinges where exposed to light, perhaps covered with tears or water drops in unventilated conditions. This exudation of water is the way fungus responds to the atmospheric relative humidity and is the explanation for the latin name 'lacrymans'. Mycelial strands are white to grey and often subsequently green in colour through development of superficial saprophytic mould growth.

Sporophores generally develop in response to stress, for example unfavourable conditions of temperature, humidity and lack of nutrients. Sporophores are tough, fleshy, pancake and bracket-shaped, varying from an inch (a few cms) to a yard (a metre) or more across. The centre is yellow-ochre when young, darkening to rusty red when mature, owing to spore production. The fruiting body is covered with shallow pores or folds and the margin is white and grey. The appearance of the fruiting body together with distinctive 'mushroom' odour, may be the first indications of an outbreak of dry rot, as fungal growth in buildings is generally concealed.

Wood thoroughly rotted with dry rot fungus, *S. lacrymans,* is light in weight, crumbles under the fingers, is a dull brown colour and has lost its fresh resinous smell. Wood damaged by this fungus has a typical cubical cracking along and across the grain. The dry rot is a type of brown rot, a term relating to the manner in which it destroys the cellulose but leaves the lignin largely unaltered so that the wood acquires a distinctive brown colour and the structural strength is almost entirely lost.

In Northern European countries there are a number of other fungi occupying similar ecological niches to dry rot fungus that occur in houses. These are *Serpula himantioides* (thin-fleshed dry rot fungus), *Leucogyrophana pinastri* (spiny dry rot fungus), *L. pulverulenta* (small dry rot fungus), *L. mollusca* (soft dry rot fungus) and *L. mollis* (membranous dry rot fungus).