Wood destroying fungi[1]

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INTRODUCTION

These organisms are of outstanding importance to foresters. Their main natural role is the decomposition of woody tissues, involving the destruction of both cellulose and lignin, and some of the breakdown products are eventually incorporated in to the soil in forms available to higher plants. Familiar bracket fungi and some toadstool formers are examples of this group, which includes a number of parasites. In natural and semi-natural forests parasitic activity is restricted since opportunities for infection of standing trees are few and far between. In plantations subject to modern management, by contrast, the scope for parasites is greatly increased, and indeed in some circumstances they constitute a serious threat to timber production. Brief mention will be made here of four fungi which cause loss, and more detailed attention will be given to one other,, *Fomes annosus* which experience has shown to have the greatest potential for destroying conifer wood.

RHIZINA UNDULATA

Strictly speaking this is not a wood destroyer in the sense that only cellulose is attacked, but it is included here because of the interesting first record of its connection with group dying of Sitka spruce (McKay and Clear, 1953) and its importance in Irish plantations. Subsequent research by Murray and Young (1961) demonstrated the relationship between lighting of bonfires and subsequent attack on conifers, as had been reported for younger trees by other workers. In East Angia considerable losses are often sustained amongst replanted conifers or naturally regenerated seedlings on acidic sites where conifer felling, accompanied by bonfire lighting, has recently occurred. It would be prudent to consider the possibility of similar outbreaks occurring in Ireland after clear felling of conifers. If it is impracticable to ban lighting of fires or to resort to mechanical chopping of debris, as is now practised in the flat terrain of East Anglia, delayed planting might be tried. The ascospores of *Rhizina* survive several years in the soil and are stimulated by heat to germinate around the edges of bonfires : subsequent development only occurs if living conifer roots are present in the immediate vicinity (Jalaluddin, 1965). At clear-felled sites *Rhizina* initially invades root systems of conifer stumps, but it would be expected to die out if it experienced

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much delay in acquiring further substrates, such as would be provided by the susceptible roots of young planted conifers. It would appear more difficult to prevent development of group dying in standing spruce, though the severity of such attacks might well diminish with increasing age of the trees. If again fires cannot be banned altogether, methods might be devised to reduce the extent and period of heat received by the underlying soil. Soil disinfection at the bonfire margin might also be attempted, though existing evidence suggests that this approach is not too promising.

STEREUM SANGUINOLENTUM

This fungus by contrast is a wound parasite of standing conifers, especially larches and spruces. In a recent survey of decay developing from extraction damage, Pawsey and Gladman (1965) found it to be by far the commonest cause of decay associated with wounds, and it was also responsible for the fastest rate of decay recorded. Decay was more frequently associated with stem scars than with root scars and it followed fracture of wood tissue more often than mere removal of bark. Wound infection with *Stereum* leads to staining and often later to considerable heart rot, which may extend many feet up the stem. Affected trees cannot pass infection to adjacent healthy ones by means of root contact, so far as is known. *Stereum* is a ubiquitous fungus which colonises freshly cut conifer branches and logs lying on the ground, and also untreated conifer stumps. Sporophores, although to some extent seasonal, are so common that it is virtually impossible to prevent widespread dispersal of spores: control must therefore be aimed at limiting as far as possible the types of wound which favour its establishment.

POLYPORUS SCHWEINITZII

This also causes heart rot of standing conifers such as Sitka spruce and Douglas fir, but unlike the previous species entry to the butt generally occurs from the roots. The mode of initial entry is not known but possibly originates from infected stumps via root contacts. In Britain it is locally prevalent on sites formerly bearing pines or hardwoods; the rot it causes may extend up the stem more rapidly than that produced by *Fomes annosus*. Stem breakage and wind throw often result from its attack. No suggestions can be made as yet about its control, though treatment of freshly cut stumps might be expected to limit any colonisation by wind-borne spores that occurs.

ARMILLARIA MELLEA

The all too familiar honey fungus is often present at sites formerly bearing hardwoods, especially oak, and may cause damage if these are replanted with conifers. *Armillaria* is unusual in producing rhizomorphs looking like bootlaces: these permeate the soil and may infect trees at a distance from the food-base, commonly in the form of a hardwood stump. Scattered killing of young conifers often occurs but tends to cease as trees grow older. Butt rot caused by *Armillaria* seldom extends more than a foot or two up the stem, but other fungi causing more serious rot sometimes enter as a result of root killing by the parasites. Although the damage it causes in British plantations is as yet relatively small, we should be unwise to ignore it. Unfortunately control is very difficult, the practice of ring-barking developed in some tropical crops almost certainly being of limited value under temperate conditions. The role of spores, produced mainly in the autumn by the characteristic toadstools, is unsufficiently known but there is evidence that under some conditions they can infect freshly cut stumps (Rishbeth, 1964).

FOMES ANNOSUS

This is another stump and root inhabiting fungus with a very wide distribution. It differs from *Armllaria* not only in having bracket-shaped fruit bodies which can liberate spores throughout the year where winters are mild, but in being unable to infect trees by growing through the soil: local spread is by means of root contacts or grafts. Although characteristic of conifer stumps *Fomes* is sometimes present in those of hardwoods such as birch and ash. Stumps containing the fungus are by far the commonest source of infection of standing trees. Root invasion, where extensive, may lead to outright killing in a variety of conifers, though this is perhaps commonest wth pines. However in the case of susceptible trees, such as larches and spruces, by far the commonest result of root infection is butt rot, and this is the major source of economic loss in many countries. In Sweden losses up to about £90 per acre have been recorded in Norway spruce 60-70 years old, and the total loss for this species is estimated at some four million pounds annually. The forester may also have to reckon with wind blow and loss of increment, and his choice of species for subsequent rotations may be seriously limited by build-up of the fungus.

Operations leading to its establishment

Many aspects of the behaviour of *Fomes* are familiar by now and need not be described here, but it is perhaps worth stressing the variety of forest operations which may lead to its appearance. Felling a conifer stand and then replanting with conifers is one common example. It is not necessary for the previous crop already to have infection, because for instance development of *Fomes* has occurred quite early in a plantation of *Thuja plicata* established directly after felling a healthy crop of European larch. The probable explanation here is that the larch stumps became infected as a result of colonisation by windborne spores. Replanting after destruction of a conifer crop by fire can also lead to appearance of *Fomes* since charred stumps may also be colonised by spores. Attacks occasionally develop at sites formerly bearing broad-leaved trees, especially birch.

On sites devoid of stumps at the time of felling, such as former arable, pasture or moorland, plantations are free from *Fomes* infection in the early years. The first opportunities for such infection arise when trees are cut during weeding or cleaning, or for sale as Christmas trees. Remarkably small stumps may on occasion become infected by *Fomes* in the moist environment provided by stands at the "thicket" stage, when the young trees are specially susceptible to root attack. However by far the most serious opportunities for entry occur during thinning and rack-cutting.

It has been found that brashing wounds on standing conifers sometimes become infected, if the branches removed are still living. With pines killing from such infection is generally confined to heavily suppressed trees though very occasionally a dominant or sub-dominant tree succumbs. Infection through severe brashing wounds has also been recorded for spruce, but wounds caused by extraction are seldom colonised by *Fomes,* apparently. These avenues of infection created by wounds, though worth mention, are far less important than those provided by stumps. The emergence of *Fomes* as a major pathogen is in fact directly related to the increased demand for timber: even in naturally forested countries the damage it causes is increasing, most likely because of intensified felling in accessible areas and exploitation of districts formerly inaccessible.

Spore dispersal and competitive effects

Some idea of the potential risk of stump infection has been obtained by collecting samples of spores from the air at various places and testing them for the presence of *Fomes* (Rishbeth, 1959a). This was done by culturing the samples on freshly cut discs of pine stem, which are highly selective for the fungus. Over a period of about a year nearly 60% of the samples were found to contain viable spores of *Fomes*: they were detected at all the localities chosen, including the Shetland Islands which are nearly 200 miles from the nearest spore source. As might be expected, the largest catches were obtained down wind from major sources such as large areas of infected plantations.

Peniophora gigantea, a competitor of *Fomes,* was found in no less than 80% of the samples which suggests that the latter may be naturally controlled to some extent. Sampling of pine stumps at various periods after felling showed this to be the case: in East Anglia, for instance, where *Peniophora* is now very abundant it is usual in winter months for pine stumps first to be colonised by both fungi, but *Peniophora* generally gains ascendancy after the first few weeks and thereafter usually becomes dominant. Sporophores of *Peniophora* are much more subject to desiccation than those of *Fomes,* however, so that during spells of dry weather spore production of the former is often greatly reduced. Sampling of stumps has confirmed that this may lead to increased colonization by *Fomes.* In other districts *Peniophora* is as yet relatively uncommon and exerts little control. This is probably because the fungus persists for only three to four years in pine stumps after felling, by contrast with *Fomes* which may survive for decades. In new plantings of pine near land formerly bearing conifers stumps are thus more likely to be colonised by *Fomes* than by *Peniophora* during early thinnings, though later *Peniophora* may increase rapidly through colonisation of branches on the forest floor, much as Ste*reum sanguinolentum* does.

Incidence of infection

Forest surveys in Britain show that *Fomes* has entered young first-rotation conifers established on a wide variety of soils as a result of stump infection (Low and Gladman, 1960). The most serious damage occurs as in other countries, where the soils were previously under cultivation, and especially where they have been limed. The potentiality for root infection in various soil types is not fully known, but though it is considerably lower in some than in others there is enough evidence to suggest that no type is entirely free from risk. The extent to which *Fomes* has developed in some first-rotation Irish stands within 25 years confirms the very general prevalence of the hazard.

Control

Eradication of *Fomes* infection, once established, presents formidable problems and is bound to be very costly; thus here is an outstanding case of prevention being better than cure. Fortunately in the majority of Irish plantations *Fomes* has not yet appeared or has not built up to any great extent. The case for attempting to prevent further stump infection by *Fomes* rests not only on saving timber in the current rotation but on retaining the freedom of choice to plant tree species susceptible to the parasite in the following rotations, if need be. Experience has shown that protection may be achieved by treating freshly cut stumps in various ways (Rishbeth, 1959b, 1963). In choosing between them the necessity for limiting spread of *Fomes* into stumps from any roots already infected at the time of felling must be considered in addition to the need for preventing colonisation of the stump by spores

Stump creosoting was the first method to be suggested, and evidence of its effectiveness was obtained in one set of plots established in Scots pine where, after first thinning, only 3% of treated stumps became infected as compared with 75% of the untreated controls. Six years later the number of trees affected by *Fomes* in these plots (3 and 63 respectively) was clearly related to the proportion of stumps earlier infected. In 1952 stump creosoting was introduced in East Anglia and by about 1960 it was in general use throughout Britain in conifer plantations managed by the Forestry Commission. By this time however it was evident that this treatment had some disadvantages mainly arising from its retarding effect on the entry of saprophytic fungi into stumps. Creosoted stumps tend to remain alive longer than untreated ones, and resulting from the exclusion of saprophytes there is a considerable risk of *Fomes* becoming dominant in stumps of trees already infected at the time of felling. Another consequence of delayed colonisation is that subsequent damage to treated stumps may permit entry of *Fomes*. Again many types of creosote are useless for protecting stumps and even satisfactory types give poor control when applied lightly. But despite the fact that by then something was known about the effects of other chemical treatments on pine stumps, it was decided not to introduce any new method until very extensive testing had been carried out. The advantages of creosoting were considered to outweigh its disadvantages, especially in uninfected or lightly infected stands.

By contrast with creosote, which barely affects the selectivity of underlying wood tissues for *Fomes*, many other treatments rapidly kill them. Ammonium sulphamate, applied as a 20% aqueous solution, has this effect and allows a wide range of fungi to become established because it is not especially toxic to them. Competition from other fungi near the cut surface is nearly always sufficient to exclude *Fomes*. Two disadvantages of this treatment, however, are the high cost of the sulphamate and the slight hazard to surrounding trees where root grafts occur, since this tissue poison is very effectively translocated. Other chemicals such as disodium octaborate, also applied as a 20% solution, not only kill wood tissues rapidly but are toxic to fungi: wood-destroyers are excluded until leaching by rain reduces the boron concentration to a tolerable level. By this time other fungi have colonised the wood sufficiently to prevent entry of *Fomes*. This treatment suffers from other drawbacks, namely that the octaborate tends to come out of solution in very cold weather and that, like urea, it does not favour development of organisms sufficiently competitive towards *Fomes* in any roots already infected. It is therefore unsuitable for use in areas where the parasite is already very prevalent but it has found some application elsewhere.

The most promising chemical protectant found as a result of further research at Cambridge is sodium nitrite (Punter, 1964). In subsequent trials set up by the Research branch of the British Forestry Commission in Scots pine, European larch and Sitka spruce, 10% and 20% solutions gave almost equally good results: a mean 0.4% stumps were infected by *Fomes* as compared with 20% in the controls. In Britain sodium nitrite is rapidly replacing creosote for conifers other than pines and it is also being used on Norway spruce stumps in southern Sweden.

Research into chemical treatments of pine stumps showed that their effectiveness in preventing spread of *Fomes* into the body of a stump from roots already infected depends largely on the extent to which *Peniophora* is favoured. It seemed reasonable, therefore, to test direct inoculation of stump surfaces with this fungus. As previously mentioned,, *Peniophora* exerts some natural control over stump infection by *Fomes* but is unreliable because the extent of its spore production varies greatly with locality and with weather. Experiments showed that inoculation with oidia (asexual spores, produced in culture) gives excellent protection at the cut surface: for example with pine stumps of about 8 in. diameter an application of 10,000 viable spores is probably adequate to control the largest dosage of *Fomes* spores likely to occur naturally. Growth of *Fomes* from any tissues infected at the time of felling tends to be checked and the parasite is even replaced to some extent. Whether such a method is practicable of course depends on the availability of a suitable Peniophora inoculum, and this problem has been resolved by using a concentrated source of spores in tablet form. This type of protection is now employed in East Anglian pine plantations and it is expected in due course to become general in other pine areas. So far it has only proved possible to use *Peniophora* for pine stumps, and research is proceeding in the hope of developing a suitable inoculation method for stumps of other conifers, especially Sitka spruce.

Experience has shown that the effectiveness of stump treatments often declines rapidly if they are delayed after felling. Especially with pines, resin may flow from the cut surface so fast that this is effectively sealed within a few minutes. Emphasis has therefore repeatedly been laid on immediate application, and in practice this is achieved by pouring the appropriate solution or suspension from a spouted can and distributing it over the cut suface by brush. A water-soluble dye is added to ensure that stumps are not missed. The cost of treating stumps is about 30/- per acre, equivalent in Britain to some 3% of the income derived from sale of thinnings from young plantations.

Several other methods have been suggested for reducing loss from *Fomes,* such as planting mixtures of conifers and hardwoods in order to reduce root contacts between susceptible species. Wide spacing and delayed thinning are other possibilities, and these are being tested in long-term experiments. Eventually we shall need to know much more about techniques for re-establishing conifers at sites where *Fomes* is very prevalent, and here again experiments set up by the Research branch of the British Forestry Commission may well yield useful information. At the present time in Ireland, however, the obvious need is to prevent as far as possible any further inroads by *Fomes,* and available methods of stump protection such as inoculation with *Peniophora* for pines and treatment with sodium nitrite for other conifers seem well suited to this purpose. Since a large proportion of first-rotation stands are at early stage of development, a fine opportunity exists for preserving them from serious damage.

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