Forestry Commission

Bulletin 100

Honey Fungus

B J W Greig,
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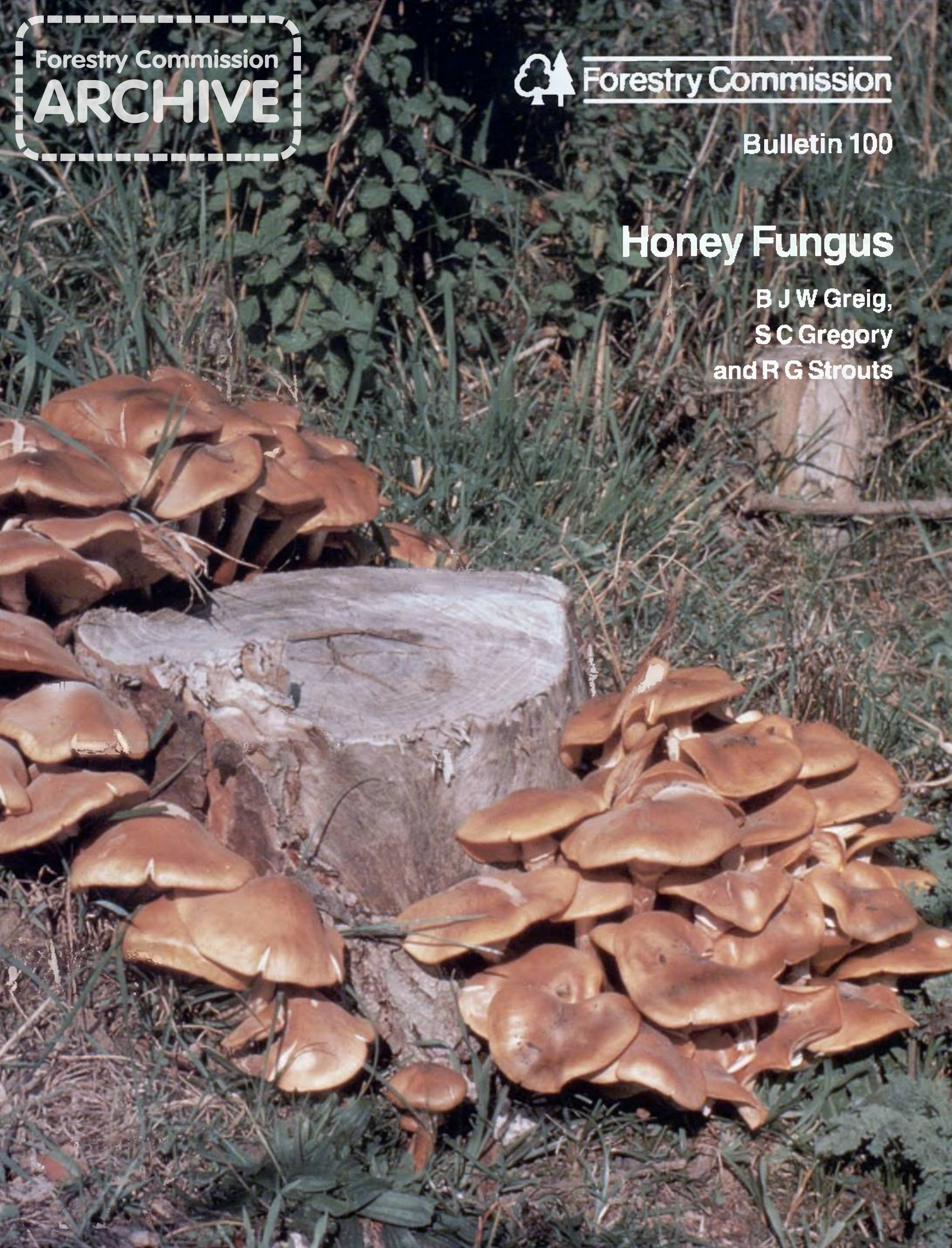

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B.J.W. Greig, S.C. Gregory and R.G. Strouts
Forest Pathologists, Forestry Commission

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Enquiries relating to this publication
should be addressed to:
The Technical Publications Officer,
Forestry Commission, Forest Research Station,
Alice Holt Lodge, Wrecclesham,
Farnham, Surrey GU10 4LH.

Front cover: Clumps of toadstools around
a dead elm stump. *(27169)*

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Summary

Honey fungus is one of the commonest root diseases of trees and shrubs in the world. It can kill an enormous range of plants and also causes decay in standing trees. It is rarely a major problem in woodland although it sometimes kills large groups of conifers in young plantations. The disease is more serious in parks, gardens, orchards and arboreta.

In Great Britain, honey fungus consists of five distinct *Armillaria* species which differ in pathogenic ability. A distinctive feature of plants killed by the fungus is the creamy-white sheet of mycelium under the dead bark at their base. *Armillaria* toadstools are also distinctive but too variable to serve to differentiate between the various species. They are found only in the autumn.

The fungus spreads through the soil from infected stumps and trees to healthy trees by means of rhizomorphs and root contact.

Control can be achieved by removing woody material from the ground or by isolating infected areas with physical barriers. Alternatively, replanting can be carried out with species resistant to the disease.

Armillaire

Résumé

L'armillaire est l'une des maladies racinaires des végétaux ligneux les plus répandues dans le monde. Elle entraine le dépérissement de nombreuses espèces de plantes et peut également être à l'origine d'une pourriture de la base du tronc des arbres. Il est rare qu'elle constitue un problème important en forêt, bien qu'elle soit à l'occasion responsable de la mortalité de nombreux plants dans les jeunes plantations. Mais la maladie est beaucoup plus dangereuse dans les parcs, les jardins, les vergers et les arboretums.

Dans La Grande Bretagne, l'armillaire est une espèce collective qui comprend cinq espèces linéennes différant par leures capacités parasitaires. Une caractéristique majeure des plantes tuées par l'armillaire est la présence, sous l'écorce morte de la base du tronc, de palmettes mycéliennes de couleur crème à blanches. Les fructifications sont également très particulières, mais leur variabilité est trop grande pour permettre d'établir une distinction entre toutes les espèces. En outre, elles apparaissent seulement en automne.

L'armillaire se dissémine par le sol; les arbres malades et les souches colonisées contaminent les arbres sains soit par l'intermédiaire des rhizomorphes, soit par contact direct entre racines.

Il est possible de lutter contre la propagation de la maladie en éliminant autant que possible les fragments ligneux dans le sol. La plantation d'espèces tolérantes constitue une autre méthode de lutte envisageable.

Hallimasch

Zusammenfassung

Der Hallimasch gehört zu den wichtigsten und weltweit verbreiteten Wurzelfäulen von Bäumen und Gehölzen, der nahezu sämtliche Baumarten der Laub- und Nadelgehölzer abzutöten vermag.

Der Hallimasch ist zudem auch Urheber einer Wurzel- und Stammfäule in lebenden Bäumen.

Obwohl der Hallimasch selten ein größeres Problem in Waldgebieten darstellt, tritt er manchmal in jungen Anpflanzungen auf, wo er ein Absterben grösserer Nadelbaümgruppen verursacht.

In Grossbritannien, der Armillaria-Komplex umfaßt heute fünf (intersterile) Arten des Hallimaschs, die sich in Ihrer parhogenität merklich unterscheiden.

Als typisches Befallsmerkmal abgestorbener Bäume gelten die zwischen Rinde und Holz in der Stammbasis auftretenden cremig-weißen, fächerartig ausstrahlenden Myzellappen.

Obwohl die Fruchtkörper des Armillaria-Komplexes ein kaum zu übersehendes Kennzeichen darstellen, sind sie zu variabel um bei einer Unterscheidung der verschiedenen Arten behilfich zu sein.

Die Fruchtkörper des Hallimaschs treten ausschließlich im Herbst auf.

Der Hallimasch lebt im Boden in infizierten Stubben von Laub- und Nadelbäumen und verbreitet sich im Boden mittels Rhizomorphen und Wurzelkontakt auf gesunden Bäumen aus.

Die Bekämpfung des Hallimaschs erfolgt durch die Entfernung von im Boden liegenden Holzresten, durch Rodung alter Stubben und indem man infizierte Bereiche durch physikalische Rhizomorphsperren begrenzt.

Als Alternative kann man Baumarten anpflanzen, die gegen einen Hallimasch-Befall wiederstandsfähig sind.

Honey Fungus

B.J.W. Greig, S.C. Gregory and R.G. Strouts, *Pathology Branch, Forestry Commission*

Introduction

Honey fungus is one of the commonest root diseases of trees and shrubs in the world. By killing roots it may kill the plant, or by rotting them it may cause a still living tree to blow over. It can also cause losses in timber by decaying the butts of standing trees. Most woody plants are probably susceptible to the disease to some degree when young and some non-woody plants may also be attacked. Although large trees of some species can be killed, most become more resistant with age. In addition to its pathogenic activities, the fungus lives saprophytically on tree stumps and other buried wood.

Particularly among gardeners, honey fungus has gained a reputation as a devastating disease against which there is little protection. This view is rarely justified, however. Diseased plants cannot be cured but larger ones can nevertheless survive for many years. Spread between plants can often be prevented or inhibited and, while it may be difficult or impossible to eradicate the disease from a site, it can often be reduced to a tolerable level. Furthermore, research in recent years has shown some strains or species of the fungus to be relatively harmless.

In British woodlands, the disease is primarily a problem of young conifer plantations on old woodland sites. Historically, the majority of such sites have been former broadleaved woodland and consequently honey fungus was thought a serious risk to young conifers only on these sites. It is now recognised that the disease can, in fact, also cause appreciable damage on sites with a coniferous or predominantly coniferous history. Killing in conifer plantations can be quite extensive and result in large groups of dead trees. Normally groups stabilise by the time the crops are 10-15 years old but killing does occasionally continue up to maturity (Plate 1).

Plate 1 *Honey fungus killing in a stand of Serbian spruce (*Picea omorika*). The previous crop was oak coppice.* (13875)

Plate 2 *The brown, dead foliage has persisted on this monkey puzzle (*Araucaria araucana*), killed by honey fungus.* (29853)

In woodlands, although the effects of the disease may sometimes be significant, the cost of control measures is rarely, if ever, justified. It is in parks, gardens, orchards and arboreta, where the value of each plant is comparatively high, that honey fungus can be the more serious problem (Plate 2). It is with these situations particularly in mind that this Bulletin is written.

The fungus owes its common name to its honey coloured toadstools (front cover). It is also known as the bootlace or, in the USA, the shoestring fungus from the appearance of the strands (rhizomorphs) by which it spreads through the soil (Plate 3). Until recently honey fungus was usually regarded as one species, *Armillaria mellea*, but the great variability in its toadstools (front cover and Plate 4), rhizomorphs and pathogenicity has led to a more critical examination of its identity, and it is now generally agreed that in Europe 'honey fungus' consists of five distinct species:

- *A. borealis* Marxmüller & Korhonen;
- *A. cepistipes* Velenovsky;
- *A. ostoyae* (Romagnesi) Herink (syn. *A. obscura* (Schaeff.) Bon);
- *A. mellea* (Vahl: Fr.) Kummer;
- *A. gallica* Marxmüller & Romagnesi (syn. *A. lutea* Gillet and *A. bulbosa* (Barla) Kile & Watling).

These species, all of which occur in Britain, differ markedly in pathogenic behaviour.

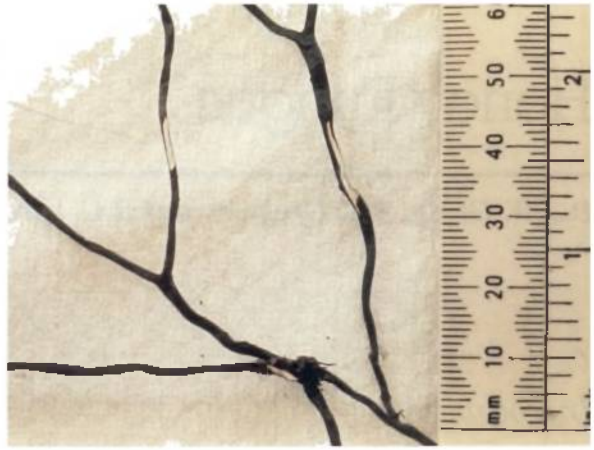

Plate 3 *Rhizomorphs removed from the soil. Note the white core where the outer layer has been cut away.* (30234)

Life history and description of the fungus

Honey fungus exists largely as a mass of microscopically fine threads (hyphae) growing inside the roots and butts of live trees, old stumps, fallen trees, and other woody debris. The fungus derives its nutrition mainly from the woody tissues, resulting in their gradual decay. Beneath the bark of roots and lower parts of the stem the hyphae may be so abundant that they form a clearly visible creamy-white fungal mass (mycelium). Under the bark this appears as a paper-thick, skin-like sheet, often marked with

Plate 4 *A selection of honey fungus toadstools illustrating the wide variation in ratio of cap width to stem length, shape of stem, scaliness of cap and stem, and colour.* (36735, 36865, EK 109)

fan-like striations (Plate 5). Some hyphae aggregate into bootlace-like strands called rhizomorphs which may either grow out into the soil (Plate 3) or develop in a flattened form beneath dead bark (Plate 6). In some species the rhizomorphs are quite tough and elastic but in others they are fragile. They are usually branched, though the pattern varies between species. Old rhizomorphs are almost black but younger ones are reddish brown with a white core and growing tip.

Infections occur when growing rhizomorph tips contact and then penetrate roots or root collars of susceptible live plants. Spread may also take place without rhizomorphs via grafts and contacts between infected and uninfected roots. As well as infecting living trees, the fungus can colonise stumps and trees killed by other agents. All of these food sources serve as foci for further spread and infection.

Honey fungus reproduces by means of microscopic spores produced in the toadstools. These spores are of no importance in the local spread of disease but provide the means by which the fungus can colonise more distant areas.

The toadstools appear only in autumn. They usually arise in clumps but may occur singly. Most often they are to be seen growing clustered around infected stumps or plants (see front cover) but they may also be found growing above infected roots, directly from rhizomorphs in the soil or out of the lower stems of standing, dead trees.

Several other fungi have toadstools similar to those of honey fungus, but it is usually possible to identify honey fungus by taking all the following features into account (see front cover and Plate 4):

Size: though variable, generally from 10-15 cm tall when fully grown, with caps 6-12 cm wide or larger.

Colour: caps and stems a brownish-honey colour; gills cream, sometimes tinged pinkish or yellowish (but degenerating to shades of brown with age, especially in frosty weather).

Stem: encircled by a whitish collar-like ring not far below the cap.

Gills: clearly attached to the stem.

Plate 5 *Bark removed from the base of a dying Sitka spruce (*Picea sitchensis*) to show the underlying white mycelium of honey fungus.* (L. Starling)

Plate 6 *Dead bark removed from a Scots pine (*Pinus sylvestris*) stump to show flattened rhizomorphs beneath.* (37302)

Spores: the spore powder from the gills is whitish, never dark in colour. It is often visible as a pale coating on surfaces beneath the caps (see spore deposit on cap to left of stump in front cover photograph), and can be collected by placing a cap, gills down, on a dark surface for a few hours.

Reliable identification to species level is generally not possible because of the variability amongst toadstools of each honey fungus species.

Although it is now clear that the various species of honey fungus differ in their pathological behaviour, these differences are not fully understood. It is still as well to assume that if any plants have apparently died or are dying from honey fungus, further deaths among susceptible plants in the vicinity are likely. If, however, the only evidence for honey fungus is the appearance of toadstools or the discovery of rhizomorphs, and no infected or ailing plants can be found nearby, action against the fungus may not be called for.

Diagnosis of the disease

The typical effect of honey fungus in gardens is to kill plants in ones or twos over the years. These are often in the vicinity of other plants which have died earlier (Plate 1) or near old infected stumps. In hedges, infection often results in successive deaths of adjacent plants (Plate 7). In plantations, deaths may be widely scattered at

Plate 7 *Leyland cypress hedge (* × Cupressocyparis leylandii*) dying from honey fungus. Notice the spread of infection in both directions (yellowish, dying foliage) from the tree first infected (brown, dead foliage).* (39670)

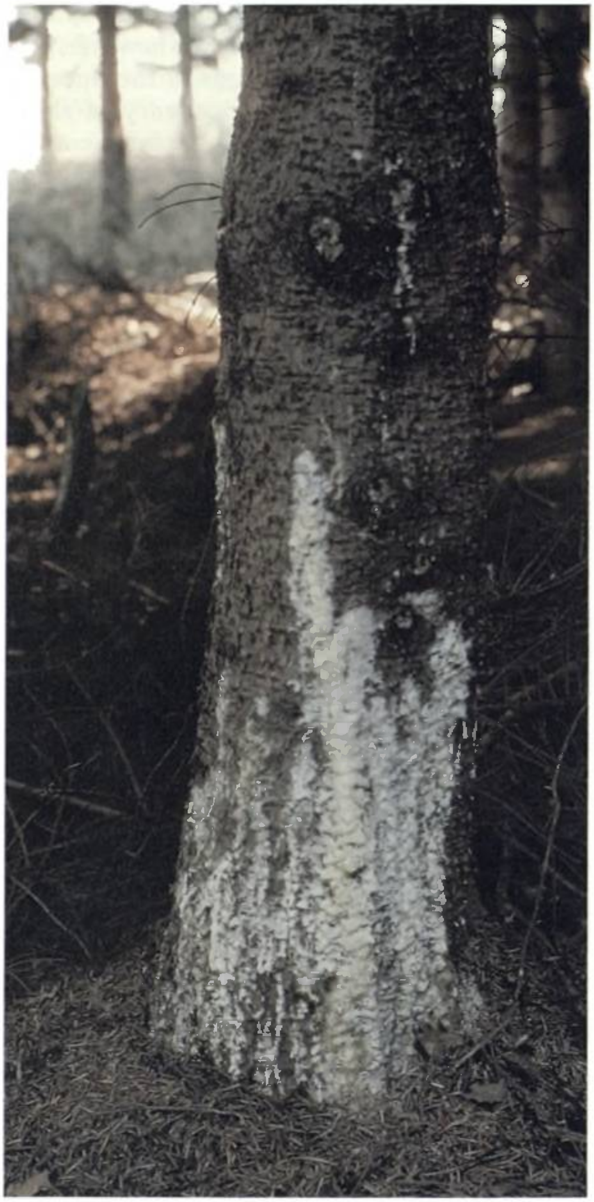

***Plate 8** Resin flow from the stem of a Serbian spruce (*Picea omorika*) infected by honey fungus.* (13608)

first but eventually groups of dead trees usually develop. In young trees and shrubs, the entire foliage may turn brown or wilt and death may appear to be sudden. In older trees, death may follow a gradual dieback and may be preceded by the production of sparse foliage or by an abnormally heavy crop of cones or fruit. As with several other tree root diseases, honey fungus infection may lead to resinous or gummy exudations from the lower part of the stem (Plate 8).

If, within 12 months of planting, a large proportion of plants die, the cause is not likely to be honey fungus.

Plants infected by honey fungus can best be identified from the white or creamy-white sheets of mycelium that develop beneath the bark (Plate 5). Few other fungi produce such coherent and substantial sheets of tissue. If such structures are found under the bark on upper roots and lower main stem of a moribund or recently killed tree, they are unlikely to belong to anything other than honey fungus.

Rhizomorphs are of limited value in the diagnosis of the disease: they may be difficult to find and can be confused with small tree-roots. They can be present under dead bark or in the soil without causing infection. Indeed, the two least pathogenic of the British species, *A. gal-*

***Plate 9** Transverse section through a Norway spruce (*Picea abies*) butt showing the stained wood at an early stage of infection.* (10079)

lica and *A. cepestipes,* produce conspicuous and abundant rhizomorphs, whereas in *A. mellea,* which is probably the most pathogenic, rhizomorphs are usually fragile and hard to find. However, if they occur in association with mycelial sheets, they are a useful aid to identification of honey fungus. Similarly, in autumn toadstools can be helpful in confirming the presence of the fungus on the site but they are not invariably produced.

In diagnosis, account must be taken not only of the presence of the fungus but also of the circumstances and character of the damage. The fungus may be acting as a secondary agent of damage in trees weakened by other means and can also grow saprophytically on trees killed by something else. Consequently death from honey fungus is often not immediately distinguishable from death due to many other agents. The presence of mycelial sheets under the bark of roots or root collar of dying, but not completely dead, plants is probably the best indication of a primary honey fungus attack. Particular care is necessary when Phytophthora root rot* could be involved as honey fungus can very rapidly invade tissues killed by *Phytophthora* and may be found only a few centimetres behind the leading edge of the spreading *Phytophthora* lesion. In these circumstances *Phytophthora* infection can only be confirmed by laboratory tests. Where the diagnosis is in doubt it would be prudent to attempt to eradicate the honey fungus.

The earliest stage of Armillaria butt-rot in conifers is an irregular, pale brown or inky blue-grey patch of stain, usually near the centre of the stem (Plate 9). When the woody tissues have begun to break down visibly, the centre of such a patch is coloured mid- to orange-brown and in the last stages of decay the wood is reduced to a very wet, pale yellow-flecked, stringy rot through which run occasional thin, black sheets of hard fungal tissue (Plate 10). In

*See Arboricultural Leaflet 8 *Phytophthora diseases of trees and shrubs* by R. G. Strouts (1981). HMSO, London.

Plate 10 *The butt of a Norway spruce showing advanced decay caused by honey fungus.* (19200)

broadleaves too, advanced decay is generally wet and stringy with black sheets, but is whitish or yellowish in colour. A characteristic of honey fungus butt-rot is that, while decay may be severe at ground level, it rarely extends more than 50 cm up the stem of conifers (Plate 11), although it may occasionally be more extensive in broadleaves.

***Plate 11** Decay and stain in the butt of a Norway spruce (longitudinal section).* (30589)

Susceptibility and resistance

An enormous range of woody and other plant species are susceptible in some degree to honey fungus. However, the resistance to killing of trees increases notably with age and a few species seem to be virtually immune.

When plants are stressed, by drought or insect defoliation for example, they become less resistant to the disease. As a result, not only is infection of healthy roots more likely to occur but the pathogen may also be enabled to advance further in already infected roots. Stressed trees may therefore be killed by infections that would be contained by the defences of a healthy host.

Since there have been few comparative trials, there is little experimental evidence on which to base assessments of relative susceptibility among ornamental plants. The rankings given here depend heavily, therefore, on the frequency of recorded cases on each host. In view of the difficulties of diagnosis outlined earlier, and the fact that the differences between honey fungus species were not taken into account until recently, such records are not completely reliable. Moreover rankings derived from them are subject to distortion by such extraneous factors as the frequency of the host and regional bias in the recording system.

These limitations mean that only broad categories of relative susceptibility can be distinguished.

Table 1 lists plants that appear highly *susceptible* and are frequently killed at any age.

Table 1. Trees and shrubs ***susceptible*** to Armillaria

Maple	*Acer* (except *A. negundo*)
Monkey puzzle	*Araucaria araucana*
Birch	*Betula*
Cedar	*Cedrus*
Cypress	*Chamaecyparis lawsoniana* and × *Cupressocyparis leylandii*
Japanese cedar	*Cryptomeria japonica*
Walnut	*Juglans* (except *J. hindsii*)
Privet	*Ligustrum*
Apple	*Malus*
Spruce	*Picea*
Pine	*Pinus*
Cherry and plum	*Prunus* (except *P. laurocerasus* and *P. spinosa*)
Rhododendron and azalea	*Rhododendron*
Willow	*Salix*
Wellingtonia	*Sequoiadendron giganteum*
Lilac	*Syringa*
Western red cedar	*Thuja plicata*
Western hemlock	*Tsuga heterophylla*
Elm	*Ulmus*

Observations and records indicate that the trees and shrubs listed in Table 2 are *resistant* enough to the disease to make their planting in an infected area reasonably likely to succeed. There are likely to be many others that are equally resistant but information on them is insufficient for their inclusion in this list.

Table 2. Trees and shrubs ***resistant*** to *Armillaria*.

European, grand and noble fir	*Abies alba, A. grandis, A. procera*
Tree of heaven	*Ailanthus altissima*
*Box elder	**Acer negundo*
The bamboos	*Arundinaria* and other genera
Box	*Buxus sempervirens*
Incense cedar	*Calocedrus decurrens*
Hornbeam	*Carpinus betulus*
Clematis	*Clematis*
Indian bean tree	*Catalpa bignonioides*
Venetian sumach, smoke tree	*Cotinus coggygria*
Thorns, including hawthorn	*Crataegus*
Elaeagnus	*Elaeagnus*
Beech	*Fagus sylvatica*
Ash	*Fraxinus excelsior*
Ivy	*Hedera helix*
Holly	*Ilex aquifolium*
*Californian black walnut	**Juglans hindsii*
Larch	*Larix*
Sweet gum	*Liquidambar styraciflua*
Lonicera	*Lonicera nitida*
Mahonia	*Mahonia*
Southern beech	*Nothofagus*
London plane	*Platanus* × *hispanica*
'Laurel' (i.e. cherry laurel)	*Prunus laurocerasus*
Blackthorn, sloe	*Prunus spinosa*
Douglas fir	*Pseudotsuga menziesii*
Oak	*Quercus*
Stag's-horn sumach	*Rhus typhina*
Locust tree, false acacia	*Robinia pseudoacacia*
Elder	*Sambucus nigra*
Tamarisk	*Tamarix*
*Yew	**Taxus baccata*
Lime	*Tilia*

*These seem to be virtually immune.

For forestry plantations, it is useful to make the distinction that conifers (with the exception of *Abies* and *Pseudotsuga*) are generally more susceptible than broadleaves. In lowland coniferous plantations, use of broadleaves, especially oak or beech, may be a worthwhile option in large gaps left by disease.

Many species, even those rarely killed such as oak, are occasionally rendered liable to windthrow by honey fungus root- or butt-rot, especially when they have developed into large specimen trees. In forests, groups of even quite young trees may be windthrown (Plate 12).

Because of its limited vertical extent, the butt-rot caused by honey fungus is of minor importance in forestry. Spruces are particularly susceptible, and western hemlock, western red cedar and Lawson cypress are also frequently decayed. Decay in other forest species is rare, occurring only in occasional old trees. Little is known about the susceptibility of ornamental trees to butt-rot.

***Plate 12** A live Norway spruce windblown because honey fungus had decayed the roots.* (27188)

Control

In British woods and plantations control measures are rarely justified (see page 2). In other situations the most effective means of controlling the disease is to remove all sources of infection from the site. This normally means removing infected stumps and plants though it is worth bearing in mind that other buried wood, fence posts for example, can sometimes harbour the disease. There is no simple way of removing stumps; methods which claim to burn, dissolve or rot them away are ineffective. Small stumps can be dug out by hand, but larger ones require the help of jacks, winches or excavators. It should be noted that it is usually far easier to uproot a tree by using its stem as a lever than to cut it down to the ground first and then to excavate the stump. More detailed information is given in Arboricultural Leaflet 7 *Removal of tree stumps* by K. W. Wilson (1981); HMSO, London. Stumps which cannot be dug out can, if access allows, be chipped or ground out with a machine designed for the purpose. Large unchipped pieces, particularly of the roots, often remain. These should be dug out if possible. Once the infected material has been dealt with, it is probably safe to replant immediately.

The fungus may be present as rhizomorphs or minor root infections among trees and shrubs even where there is no sign of disease above ground. Therefore, if woody plants are removed for any reason, it is better to uproot them than to leave stumps in which the fungus could build up and become a greater threat to surrounding plants.

The efficacy of these methods depends entirely on the thoroughness with which infected material is removed or destroyed: the larger and the more numerous the remaining fragments, the greater and more prolonged the risk of reinfection. The mixture of chips and soil which remains after stump chipping probably constitutes little danger as a honey fungus source but if it is not removed, replanting should be delayed for 12 months or until no rhizomorphs can be found in the mixture. If larger buried fragments of root remain after chipping or excavation, a longer delay before replanting is desirable. Trees or shrubs planted 30 yards or more from a source of infection are unlikely to be at risk.

Some chemicals can kill the fungus in the soil and to an extent in stumps. However, they are either too dangerous or too unreliable to recommend at present.

If, because of their extent or location, sources of infection cannot be removed, it may be possible to prevent rhizomorphs from extending into planted areas by creating a physical barrier to their spread or by severing them periodically from their food supply. Such methods have not been tested adequately but the following procedures should be effective if the source of infection can be clearly defined.

It may be possible to separate the source of infection from the area to be protected by burying a sheet of heavy gauge PVC, polythene or other durable plastic material vertically between the two. The sheet should extend from just above the ground to at least 45 cm (18 inches) downwards, more in deep, porous soil. In siting the sheet, bear in mind that rhizomorphs radiate in all directions from infected wood, that large roots extend some distance from trees and stumps, and that rhizomorphs may turn down and pass under too shallow a barrier.

Alternatively, rhizomorphs may be severed from their food supply by digging over a protective strip of ground (of any convenient width) as deeply as possible, several times during the year. In shallow soils it may be sufficient to insert a spade periodically all along a line between the source and the area at risk. These operations must continue until the stump has rotted away or the source of infection is removed. In some situations it may be convenient to maintain a ditch along a similar line and to dig over the bottom periodically.

Normally it is not possible to save infected plants once symptoms show in the crown. Excision of the infected parts of a root system has been known to work with small shrubs but, in practice, by the time symptoms are noticed above the ground it is too late for such remedies.

If neither stump removal nor prevention of rhizomorph spread is possible, the only alternative is to leave stumps and infected trees where they are, accepting the inevitable losses, and to replant gradually with resistant species. Sometimes it may be possible to redesign a garden so that, for example, the affected area is occupied by a lawn, annual vegetables or other non-susceptible plants while the susceptible shrubbery or orchard is confined to a disease-free part of the garden.

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