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Red Band Needle Blight of Pine

INFORMATION NOTE

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SUMMARY

Red band needle blight is an economically important disease affecting a number of coniferous species, in particular pines. It has a world-wide distribution, and since the late 1990s the incidence of the disease in the UK has increased, particularly on Corsican pine (*Pinus nigra* var. *laricio*) in Thetford Forest Park. The disease causes premature needle defoliation, loss in yield and sometimes tree mortality. In other countries where the disease has a significant economic impact, successful methods of control have included good stand management, fungicide application and the use of resistant species.

INTRODUCTION

Red band needle blight, so called because of the symptoms it causes on pine, is an economically important disease with a widespread distribution (Gibson, 1974; Bradshaw *et al.*, 1997). It is caused by the fungus *Mycosphaerella pini*, but is probably better known by the name *Dothistroma pini* (formerly *D. septospora).*

The disease was first observed in the UK in 1954 on nursery stock (Murray and Batko, 1962), but until recently it was only seen very sporadically. The rarity of the disease, coupled with its potential to cause severe damage to certain species of pine, has resulted in its listing under EC plant health legislation as a quarantine organism. This means that if infection by red band needle blight disease is suspected, the Forestry Commission's Plant Health Service must be informed (plant.health@forestry.gsi.gov.uk).

Visible signs of infection by *D. pini* include premature defoliation. Depending on the susceptibility of the host and the extent of infection, the amount of defoliation can be severe as needles of all ages can be affected. The end result is a decrease in the yield and, in some cases, tree mortality. Infected landscape and Christmas trees can be severely disfigured leading to a loss in both aesthetic and commercial value.

HOSTS

Red band needle blight affects many species of conifer, but 2-, 3- and 5-needled pines are the most common hosts. Table 1 shows the range of host species found to be infected by *D. pini*. The majority of this information was obtained from Gadgil (1984) and Ivory (1967). Apart from pines, other coniferous species such as European larch (*Larix decidua*), Norway spruce (*Picea abies*), sitka spruce (*Picea sitchensis*) and Douglas fir (*Pseudotsuga menziesii*) are occasionally susceptible.

In total, over 60 pine species are reported to be prone to infection: radiata pine (*Pinus radiata)*, Austrian pine (*Pinus nigra*) and ponderosa pine (*Pinus ponderosa*) are considered to be the most susceptible, and spreading-leaved pine (*Pinus patula*) the most resistant (Gibson, 1972). The degree of susceptibility to infection by *D. pini* varies widely among different species of the genus *Pinus*, but the susceptibility of particular species of pine to the disease is not always clear. For example, Gadgil (1967) classifies Scots pine (*Pinus sylvestris*) as highly susceptible whereas Peterson (1982) suggests that it is rarely infected. The latter is certainly the UK experience. It seems likely that the susceptibility of a host depends on a wide range of factors including the origin and provenance of a species, as well as site and climatic conditions.

THE PATHOGEN

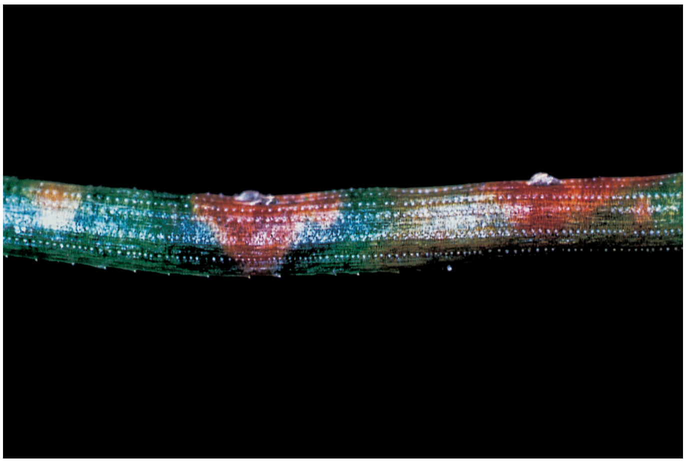
Isolation of the fungus from infected needles is often difficult, but once in culture *D. pini* grows readily, although it is slow growing with optimum temperatures for growth and spore germination at around 20ºC and 22ºC respectively (Karadžić, 1994). On the host, it produces small, dark brown fruiting bodies (acervuli), visible during late spring to summer on attached needles infected in the previous year (Figure 1). The acervuli

Table 1 Tree species susceptible to red band needle blight.

Scientific name	Common name	Needle number
Larix decidua Mill.	European larch	
Picea omorika Bolle.	Serbian spruce	
Picea abies (L.) Karst.	Norway spruce	
Picea sitchensis (Bong.) Carr.	Sitka spruce	
Pinus albicaulis Engelm.	White bark pine	5
P. attenuata Lemm.	Knobcone pine	3
P. attenuata (Lemm.) x radiata (D.Don.)	Knobcone & radiata pine	3
P. ayacahuite. Ehrenb.	Mexican white pine	5
P. bungeana Zuccarini	Lacebark pine	3
P. canariensis C.Smith	Canary island pine	3
P. caribœa Morelet	Cuban pine	2–3+
P. cembroides Zuccarini	Mexican nut pine	3 (1,2,4,5)
P. contorta Douglas	Beach pine	2
P. contorta (Douglas) x *banksiana* (Lambert)	Beach pine & Jack pine	2
P. contorta var. *latifolia* S. Watson	Lodgepole pine	2
P. coulteri D.Don	Big-cone pine	3
P. densiflora Siebold and Zuccarini	Red pine of Japan	2
P. devoniana	Michoacan pine	5–6
P. echinata Miller	Short-leaved pine	2 (3–4)
P. echinata x *tæda*	Short-leaved & loblolly pine	2
P. elliottii Engelm. var. *densa* Little and Dorman	Slash pine	2
P. flexilis James	Limber pine	5
P. halepensis Miller	Aleppo pine	2
P. halepensis var. *bruita* (Tenore) Elwes and Henry	Calabrian pine	2
P. jeffreyi Grev. Et Balf.	Jeffrey's pine	3
P. kesiya Royle. ex Gordon	Kesiya pine	5
P. khasya Royle	Khasaya pine	3
P. lambertiana Douglas	Sugar pine	5
P. massoniana Lambert	Masson's pine	2
P. merkusii Jungh. and de Vriese	Tenasserim pine	2
P. montezumae	Rough branched Mexican pine	3–8
P. monticola D. Don	Western white pine	5
P. mugo Turra	Mountain pine	2
P. mugo var. *mughus* (Scopoli) Zenaria		2
P. muricata D. Don	Bishop pine	2
P. muricata var. *cedrosensis* Howell	Cedros pine	2
P. nigra Arnold.	Austrian pine	2
P. nigra laricio	Corsican pine	2
P. occidentalis Swartz		2–3+
P. oocarpa Schiede		3-5
P. palustris Miller	Pitch pine	3
P. patula Schiede	Spreading-leaved pine	3, 4–5
P. pinaster Aiton	Maritime pine	2
P. pinea Linnaeus	Umbrella pine	2
P. ponderosa Laws. (Douglas)	Western yellow pine or ponderosa pine	3
P. pseudostrobus Lindley	False Weymouth pine	3–8
P. pungens Lambert	Hickory pine	2 (3)
P. radiata D. Don	Monteray pine or radiata pine	3
P. radiata var. *binata* Eng.	Guadalupe pine	2
P. resinosa Aiton	Red pine	2
P. roxburghii Sargent	Long-leaved Indian pine	3
P. rudis	Endlicher pine	5
P. sabiniana Douglas	Digger pine	3
P. serotina Michaux	Pond pine	3
P. strobus Linnæus	White or Weymouth pine	5
P. strobus L. var. *chiapensis* Martínez	Chiaplas white pine	5
P. strobiformis	Southwestern white pine	5
P. sylvestris Linnaeus	Scots pine	2
P. tæda Linnaeus	Loblolly pine	3
P. tecunumanii Eguiluz and J.P.Perry		3
P. thunbergiana	Japanese black pine	2
P. thunbergii Parlatore	Black pine	2
P. torreyana Parry	Soledad pine	5
P. wallichiana A.B.Jackson	Bhutan pine	5
Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir	

Figure 1

Small dark brown fruiting bodies of *Dothistroma pini.*



produce asexual spores (conidia) which are exuded in a colourless or white mucilaginous mass. The spore masses disperse in films of water and are disseminated as water droplets fall from the needle surfaces.

D. pini can also reproduce sexually, generating a second type of spore known as an ascospore. However, for sexual reproduction to take place, two different mating types must be present. In many countries where the disease is widespread (notably New Zealand and Australia) only one mating type of *D. pini* exists, so sexual reproduction never takes place. However the potential to reproduce sexually as well as asexually can have a significant impact on disease spread. Unlike the asexually produced conidia, that have a localised dispersal in water droplets and rain splash, ascospores are wind dispersed and so have the potential to spread much further.

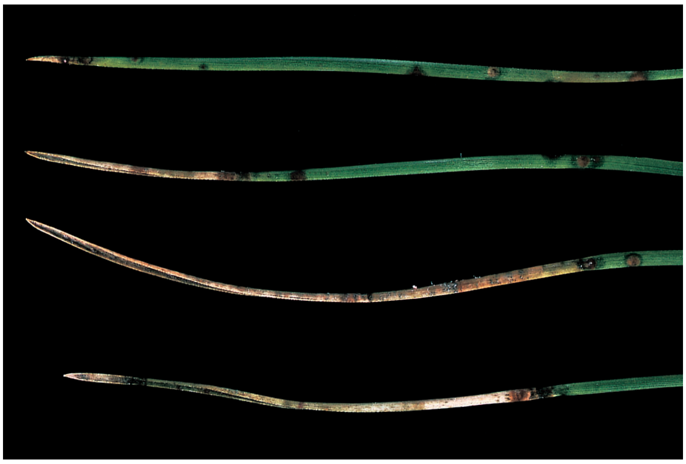
Symptoms and pathogen life cycle

In the UK, May to June appears to be the critical period for infection. Severe episodes of the disease appear to be correlated with wet springs and higher than average rainfall at the time of infection (Evans and Webber, 2002). If spores land on a suitable host, they may germinate on the needle surface and penetrate through the stomata. Moisture is required for germination and successful establishment occurs at temperatures between 12 and 18°C in conditions of high humidity.

Early symptoms on infected needles include yellow bands and tan spots on the live needles, but these signs are short-lived and the bands rapidly turn red (Bulman, 1993) as shown in Figure 2. The red colour remains even when the needle has died (Murray and Batko, 1962). Another

Figure 2

Red banding caused by *Dothistroma pini* on Corsican pine needles.



characteristic symptom is browning at the distal ends of needles while the base remains green (Figure 3). The red banding is not always evident and the needles may have an overall brown or reddish coloration instead, which can easily be confused with symptoms caused by other needle pathogens.

By autumn, symptoms are clearly visible and *D. pini* then overwinters in infected needles and sporulates the following year. Over winter, infected first- and second-year needles remain attached to the tree and are the main sources of inoculum when spores are released the following spring and summer. Conidia can remain viable for several months on retained needles, but once the needles are cast the spores soon die and the pathogen is quickly replaced by competitive fungi which colonise the dead needles.

Figure 3

Characteristic browning at the distal ends of the needles while the base remains green.

In plantations where the disease is active, needle loss in affected trees usually starts at the base of the crown. Foliage of any age can be affected, but infection generally starts with the older needles. In severe cases, lower branches can lose all their needles, and the entire crown is thin with isolated tufts of needles at the branch tips. These remaining needles may become chlorotic, especially on calcareous soils.

Experience with radiata pine has shown that it usually takes several consecutive years of infection before yield is significantly reduced. If infection levels are low, the increment of individual trees is directly proportional to the level of crown infection in terms of percentage symptomatic needles (Van der Pas, 1981; Bulman, 1993). However, once crown infection exceeds 40% the increment loss is >40%, and there is virtually no growth if crown infection is greater than 80% (Gadgil, 1984).

Toxin production

D. pini produces a toxin known as dothistromin (Bradshaw *et al.*, 1997). This is produced after the needles have become infected and it kills cells in advance of the fungal mycelial growth (Partridge, 1998); the toxin also imparts the red coloration to infected needles (Shain and Franich, 1981). Tests have shown that dothistromin can cause chromosome damage in human cells (Bradshaw *et al.*, 2000). This has led to concerns about the health of forest workers exposed to trees heavily infected with red band needle blight. However, Elliot *et al.* (1989) suggest that there is little risk to human health and that working practices can be adopted to minimise any potential hazard, for example, working in dry conditions and wearing cotton clothing which should be washed regularly.

ORIGINS AND DISTRIBUTION

The origins of the pathogen are unclear. Ivory (1994) suggested that *D. pini* has been found to be indigenous to pine forests in Nepal, and it may be endemic in the Himalayas. Alternatively, it has been suggested that it originated in South America in high altitude rain forest (Evans, 1984).

The disease was first described in eastern Europe in 1911 (Gibson, 1974), and early reports described the fungus both in Europe and the USA prior to the 1920s, although it was not recognised as a serious pathogen until the 1960s (Bradshaw *et al.*, 2000). *D. pini* is now distributed worldwide, and has been reported in at least 45 countries including those listed in Table 2 (Ivory, 1994). Spread of the pathogen between countries is believed to be mainly through diseased planting stock (Ivory, 1967).

Table 2

Distribution of red band needle blight disease (after Ivory, 1994).

Continent	Countries
Africa	Ethiopia, Kenya, Swaziland, South Africa, Malawi, Uganda, Tanzania, Zambia, Zimbabwe
North America	Canada, USA, Mexico
South America	Argentina, Brazil, Chile, Ecuador, Guatemala, Jamaica, Peru, Uruguay
Asia	Brunei, India, Japan, Nepal, Philippines, Sri Lanka
Europe	Austria, France, Germany, Italy, Portugal, Serbia, Slovakia, Spain, Soviet Georgia, Rumania, Yugoslavia
Australia/Oceania	Australia (New South Wales and Victoria), New Zealand (North and South Island)

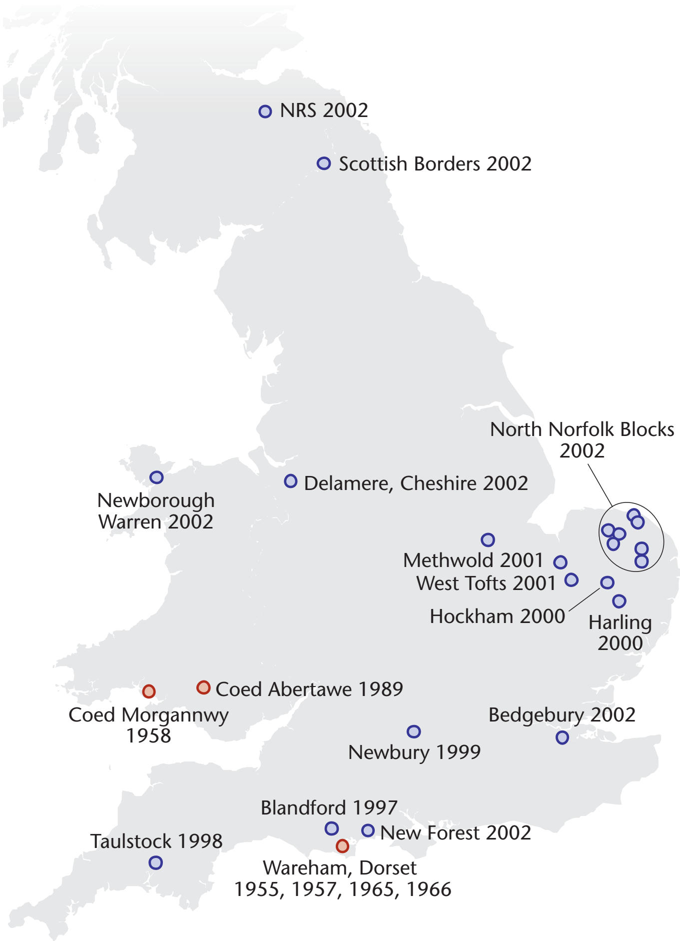
D. pini is present throughout Europe and the disease is particularly well documented in France. The disease was first identified in France in 1966 on Austrian pine, and since the late 1980s and early 1990s there has been an upsurge in severity and distribution (Villebonne and Maugard, 1999).

Red band needle blight in the UK

Following the first record of red band needle blight in the UK in 1954 (Murray and Batko, 1962), the Disease Diagnostic & Advisory Service of Pathology Branch, Forest Research kept records of any reported disease outbreaks. Initially, in the 1950s and 1960s the disease was only seen on young plants of Corsican pine and ponderosa pine at Wareham Nursery in Dorset. However, in the late 1990s it became much more widespread and in 2003 we have seen the most significant occurrence in the UK over the past 40 years. *D. pini* has caused widespread damage to Corsican pine in Thetford Forest Park and has been found in several other locations on the same host (see Figure 4 and Evans and Webber, 2002). The distribution of the disease is governed by the presence of susceptible species, which in the UK is mainly Corsican pine. Prior to the recent outbreaks (between 1997 and 2002), the last recorded case was in 1989 in South Wales. In contrast to the earlier cases in nurseries, the more recent cases have been on trees between 10 and 30 years old.

Figure 4

Outbreaks of red band needle blight in the UK. Red indicates early cases and blue the recent cases.



MANAGEMENT AND CONTROL

It has been suggested that red band needle blight is most damaging and prevalent where host species are planted out of their natural range. For instance, the disease is absent from natural stands of radiata pine in California but is present on the same species growing further up the coast of western North America which is out of its natural range (Gibson, 1972).

Infection depends on several factors: the period of needle wetness, temperature, and the quantity of spores available for infection (Bulman, 1993). The age of the host has a strong influence, and young trees tend to be more commonly attacked compared to older trees. The disease is seldom detected in young seedlings in nurseries even though the pathogen does infect older transplants (Peterson, 1982). Fast growing radiata pine in the Southern Hemisphere tends to be most susceptible up to age 10–15 years. In Europe, Corsican pine can be affected at any age, but is believed to be most susceptible between the age of 15–30 years, especially if the height exceeds 10 metres (Villebonne and Maugard, 1999).

Chemical control

Copper fungicides have been used to control red band needle blight for many years. In New Zealand, Australia and Chile, chemical control is applied routinely via aerial applications of fungicide spray such as copper sulphate or copper oxychloride (Gadgil, 1984). The correct timing for fungicide application is essential: if two applications are used one is applied just prior to needle emergence and one shortly after emergence (Funk, 1985).

Disease resistance and breeding programmes

Even within hosts that are usually considered to be susceptible, disease resistant varieties have been identified. These include varieties of Austrian pine from Yugoslavia and ponderosa pine found in the Rocky Mountains of the USA (Partridge, 1998). Alternatively, species of pine which are considered to be fairly disease resistant, for example Scots pine, can be used as replacement species.

Resistance to the disease in radiata pine is controlled by several genes and has a moderately high level of heritability. A breeding programme in New Zealand has produced families and hybrids of radiata pine that are highly promising in terms of disease resistance. However, it is worth noting that a tree breeding programme is less likely to be successful if the population of *D. pini* is able to reproduce sexually and generate genetic diversity (Hirst *et al*., 1999) in contrast to the clonal population that currently exists in New Zealand (Bradshaw *et al*., 2000).

Stand manipulation

Red band needle blight is believed to be particularly severe in dense, unthinned stands of pine (Wilcox, 1982). Late thinning or a dense understorey of shrubs may keep humidity levels high at the base of the crown and favour development of the pathogen (Villebonne and Maugard, 1999). Pruning trees will improve the airflow within a stand and make the microclimate less favourable to disease (Gadgil, 1984).

CONCLUSIONS

It is unclear why there has been an increase in the incidence of red band needle blight in the UK over the past 4–5 years. However, springs during the period 1999–2002 have been wet in southern England, with an average precipitation of 272 mm compared with an average of 167 mm for the March–May period over the time range 1961–1990 (M. Broadmeadow, unpublished data). A period of 10 hours or more of needle wetness is usually required for successful infection by *D. pini* (Gadgil, 1984; Bulman, 1993). The increased rainfall levels coupled with a trend towards warmer springs, may have optimised conditions for spore dispersal and infection by *D. pini*. Such conditions may become more prevalent in the UK over the next 20 years if current trends in climate change continue.

The increased frequency of the disease may also indicate a change in the behaviour of the pathogen, possibly as a result of increased genotypic diversity if *D. pini* is now able to reproduce sexually as well as asexually. During the earlier disease outbreaks in the UK it was assumed that only a single mating type of the fungus was present and *D. pini* only reproduced asexually, but this may no longer be the case. It is an issue that needs to be investigated, not only because it would increase variation in the pathogen, but also because the sexually produced spores (ascospores) are reported to be wind dispersed and therefore capable of long distance dissemination (Gibson, 1972).

Control methods in countries where the disease causes significant economic impact rely on good stand management, use of resistant or alternative species and fungicide application. Combinations of these methods have proved very effective at controlling red band needle blight.

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