

Diseases of exotic *Eucalyptus* and *Pinus* species in Ethiopian plantations

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A SURVEY OF DISEASES OF EXOTIC TREES IN plantations was undertaken in southern and southwestern Ethiopia during 2000 and 2001. Our aim was to ascertain the occurrence and distribution of diseases of major plantation species and to provide a basis for further research. Root, stem and leaf samples were collected from both plantations and trees growing near farms and homesteads in and around Wondo Genet, Munessa Shashemene, Jima, Bedele, Mizan and Menagesha. Armillaria root rot was the most common disease, associated mainly with *Pinus patula*, but also found on *Acacia abyssinica*, *Cordia alliodora* and *Cedrela odorata*. Stem cankers associated with *Botryosphaeria* species were common on *Eucalyptus globulus*, *E. saligna* and *E. citriodora*. Stem canker disease associated with a *Coniothyrium* species was commonly observed on *E. camaldulensis*. Leaf blotch associated with *Mycosphaerella* species was common on *E. globulus* in most areas where this species is planted. In addition, *Sphaeropsis sapinea* on *Pinus* species, cankers associated with *Cytospora* species, and pink disease caused by *Erythricium salmonicolor* on *Eucalyptus*, were also recorded in some plantations. This is the first general evaluation of plantation diseases in Ethiopia and provides a foundation for future planting and disease management strategies, with a view to enhancing commercial timber production.

Introduction

Exotic plantation forestry has been successful and profitable in many tropical and subtropical countries.^{1,2} The timber derived from these plantations is commonly used to produce pulp and paper, viscose and rayon. In addition, wood provides a resource for construction and, in developing countries, is an important fuel.^{2,3}

Wood satisfies 85% of Ethiopia's energy requirements and is used also for construction purposes. Natural forests are, however, diminishing rapidly.⁴ Simultaneously, the demand for forest products is growing apace, necessitating the establishment of plantations of fast-growing trees. Rapidly growing exotic tree species were brought to Ethiopia more than a century ago, with the introduction of *Eucalyptus globulus* in the late 1890s.⁵ Since

then, several other *Eucalyptus* species, as well as *Cupressus*, *Pinus*, *Grevillea* and *Acacia* species, have been widely established in plantations and around farms and homesteads.^{2,5} Plantations now occupy approximately 200 000 ha in the country.⁴

Plantations of exotics have been highly successful in many parts of the world.^{5,6} This is partly attributed to the separation of the trees from their natural enemies. On the other hand, the plantations are established as monocultures in new environments and are exposed to unique suites of pests and diseases. Serious problems of disease have emerged in most countries.⁶

The damaging influence of diseases on exotic plantation forestry in some cases has resulted in the abandonment of some species or their restriction to specific localities. For example, the fast-growing *Pinus radiata* has been replaced in several eastern, central and southern African countries owing to *Dothistroma* needle blight caused by *Dothistroma septospora*.^{7,8} In these countries, *P. radiata* has been substituted by slower growing *P. patula* but in South Africa severe losses of *P. patula* have subsequently occurred through the interaction between hail damage and *Sphaeropsis sapinea*.⁹ Similarly, *Cupressus macrocarpa*, which showed remarkable growth in Kenya and other East African countries, has been given up owing to cypress stem canker caused by *Seiridium cupressi*.^{10,11} As a result, the slow-growing *C. lusitanica* has been introduced as an alternative.^{10,11}

Diseases have also affected *Eucalyptus* species in Africa. For example, *Mycosphaerella* leaf blotch on *E. globulus*, *E. nitens* and *E. maidenii* has reduced plantings of these species.¹² Likewise,

E. fastigata and *E. fraxinoides*, which initially performed well in frost-prone areas of South Africa, have been abandoned because of root disease caused by *Phytophthora cinnamomi*.¹³

Several diseases new to *Eucalyptus*, for example, stem canker caused by *Cryphonectria cubensis*,¹⁴ *Coniothyrium zuluense*,¹⁵ and wilt due to *Ceratocystis fimbriata*,¹⁶ have emerged in recent years. These pathogens not only damage the trees in their exotic habitat, but now also threaten *Eucalyptus* in their areas of origin.^{6,17}

Knowledge of plantation diseases in Ethiopia is limited, although premature tree death is common in the country. Deaths are typically attributed to poor matching of site and species, inadequate forestry management and adverse climatic conditions. The role of biotic factors in tree death is underestimated, poorly understood and has received little attention. We therefore conducted a survey of plantation tree species in southern and southwestern Ethiopia during 2000 and 2001. The objective was specifically to determine the occurrence of diseases of exotic plantation species, to provide a basis for further study and to establish a foundation for disease avoidance. This investigation provides the first detailed overview of plantation tree pathogens in Ethiopia.

Materials and methods

Surveys were conducted in April 2000 and in June and September 2001 in southern and southwestern Ethiopia. Collections were made in plantations and on smallholdings around Munessa Shashemene, Wondo Genet, Jima, Mizan Teferi, Bedele, Menagesha and Addis Ababa (Fig. 1, Table 1). Samples from roots, bark, stems, twigs and leaves were collected primarily from *Eucalyptus* and *Pinus* plantations.

Samples were collected from all trees showing symptoms of disease. Affected plant tissue was collected and kept in paper bags for transport to the laboratory. Growth media used to isolate the fungi included 2% malt extract agar (MEA,

Table 1. Climatic conditions and altitude of survey areas.

Locality	Mean annual temperature (°C)	Mean annual rainfall (mm)	Altitude (m a.s.l.)
Bedele	19	1800	2010
Hossana	16	1300	2320
Jima	20	1500	1750
Menagesha	14	1017	2400
Mizan/Aman	24	2200	1350
Munessa Shashemene	19	1200	2140–2600
Woliso	17	1100	2150
Wondo Genet	19	1200	1800–2200

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Fig. 1. Map of Ethiopia showing the plantation areas where surveys were conducted.

Biolab) and MEA supplemented with 100 ppm streptomycin (MEAS) for the isolation of Ascomycetes and Coelomycetes. A selective medium containing benomyl was used for the isolation of Basidiomycetes.¹⁸

In the laboratory, several different techniques were used to isolate disease-causing organisms. These included the transfer of pieces of mycelium or fruiting bodies from diseased plant tissue directly onto the growth medium, incubating symptomatic plant material in moist chambers, as well as inoculating segments of plant parts with disease symptoms onto growth media. All plates were incubated at 25°C to induce fungal growth. To isolate species of *Mycosphaerella*, discs from leaves with disease symptoms were attached to the covers of Petri dishes with the pseudothecia facing downwards, so that spores were released onto MEAS.¹⁹ After 24 hours, ascospore germination was examined under the microscope and single germinating ascospores were transferred to MEA. Microscope slides of each isolate were prepared to determine the germination pattern of the ascospores.

Fungi isolated in this study were identified and representative isolates of the pathogens are maintained in the culture collection of the Forestry and Agricultural Biotechnology Institute, University of Pretoria. Specimens were also deposited in the herbarium of the South African National Fungus Collection, Pretoria (PREM).

Results

Infections recorded during this survey include root diseases, stem cankers and leaf diseases (Table 2). Stem cankers were observed on several *Eucalyptus* species. Disease symptoms include bark cracking, production of copious amounts of kino, stem discoloration and malformation, as well as the production of kino pockets in the xylem (Figs 3, 4).

Armillaria root rot

Armillaria root rot was commonly associated with the death of *P. patula* in

Wondo Genet, Belete and Bedele. The causal fungus, *Armillaria* species (PREM 57377 and 57378), was also isolated from dying *Acacia abyssinica* trees in *Pinus* plantations (Table 2). In addition, *Armillaria* root rot was found in association with dead and dying *Cordia alliodora* and *Cedrella odorata* trees in a research plot near Aman. Symptoms were typical of those known for the disease and included the death of trees in groups, wilting and yellowing of the crowns (Fig. 2A), the occurrence of white mycelial fans between the bark and the wood of symp-

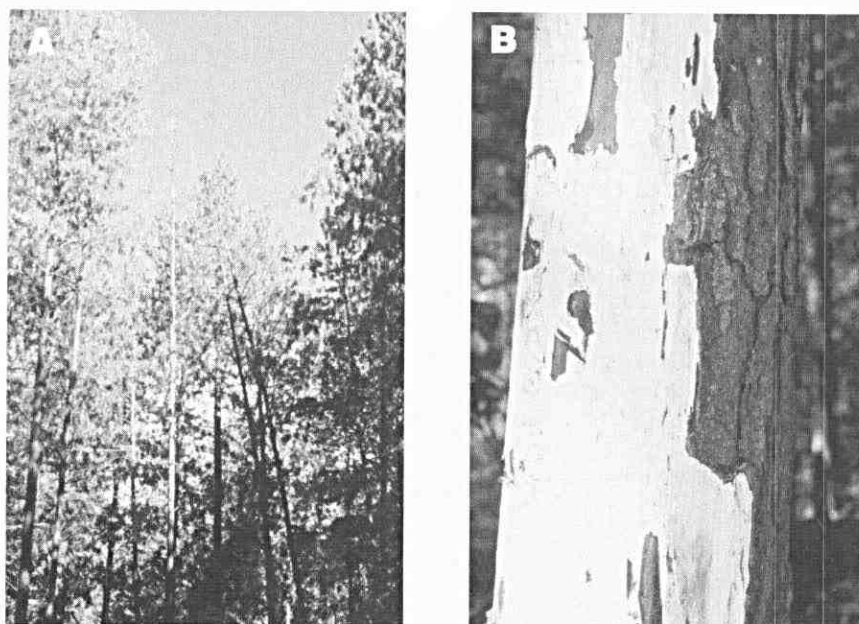


Fig. 2. Symptoms of *Armillaria* root rot on *Pinus* species. A, Group death and crown dieback of *P. patula*; B, white mycelial fan expanding up the stem of an infected tree.

Table 2. Disease samples^a collected from different localities in Ethiopia.

Pathogen	Host	Wondo Genet	Munessa Shashem.	Jima/ Belete	Bedele	Aman/Mizan	Menagesha	Holeta/ Wolmera	Wolliso/ Wolkite	Addis Alem	Hossana/ Endtiber	Pawe
<i>Armillaria</i> sp.	<i>Pinus patula</i>	25	-	2	2	-	-	-	-	-	-	-
	<i>Cordia alliodora</i>	-	-	-	1	-	-	-	-	-	-	-
	<i>Acacia abyssinica</i>	1	-	-	1	-	-	-	-	-	-	-
	<i>Juniperus exelsa</i>	2	-	-	-	-	-	-	5	-	10	-
	<i>Eucalyptus camaldulensis</i>	-	-	20	-	-	-	-	-	-	-	-
<i>Coniothyrium</i> sp.	<i>E. globulus</i>	-	5	-	-	-	5	-	-	-	-	-
	<i>Botryosphaeria</i> sp.	-	-	10	-	-	-	-	-	-	-	-
<i>Sphaeropsis</i> sp.	<i>E. citriodora</i>	3	-	-	-	-	-	-	-	-	-	-
	<i>E. saligna</i>	3	-	-	-	-	-	-	-	-	-	-
	<i>E. grandis</i>	3	-	-	-	-	-	-	-	-	-	-
<i>Mycosphaerella</i> spp.	<i>P. patula</i>	-	20	-	-	-	-	-	-	-	-	-
	<i>E. globulus</i>	3	-	-	3	-	7	-	-	5	-	-
<i>Cytospora</i> sp.	<i>Eucalyptus</i> spp.	10	-	-	-	-	-	-	-	-	20	-
	<i>E. camaldulensis</i>	-	-	-	-	-	-	-	-	-	-	3

^aEach sample was obtained from a different tree.

tomatic trees (Fig. 2B), as well as the presence of rhizomorphs on the bark of infected trees. *Armillaria* root rot was the main cause of death of *P. patula* at Wondo Genet; the damage observed at other plantation sites appeared to be mild at the time of the survey.

Stem canker associated with *Botryosphaeria*

The most common disease observed on *Eucalyptus* species was canker, from which a species of *Botryosphaeria* (PREM 57379, 57380 and 57381) was isolated (Table 2). At Wondo Genet these cankers were found on *E. saligna*, *E. grandis*, *E. citriodora* and *E. globulus*. At Munessa Shashemene, they were observed on *E. globulus*, both on coppice and first-generation stands, as well as on mature *E. saligna* trees. At both sites, stem cracking and kino exudation were observed over the entire length of the stems of affected trees. When the bark was removed from these trees, well-developed kino pockets were visible in the cambium and xylem (Fig. 3C).

In the Jima area, *E. citriodora* and *E. saligna* displayed similar disease symptoms. Here the damage was most severe on *E. citriodora* and at least half the trees in the plantation near Jima were symptomatic, but no dead trees were observed at the time of the survey. Large basal cankers were noted on this species. The disease was characterized by black discoloration and cracking of stems, from ground level up to a height of approximately one metre (Fig. 3A). When the bark was removed, the cambium was completely discoloured and soaked with kino. Two or three layers of black lines were visible in the wood, indicating different seasons of infection (Fig. 3B). At Menagesha, symptoms of stem canker were commonly found on coppice stems of *E. globulus*; several coppice stems observed were dead and wilting. A species of *Botryosphaeria* was commonly isolated from symptomatic plant material collected from all sites.

Coniothyrium stem canker

Stems of *E. camaldulensis* trees in the Jiren plantation at Jima and on trees in woodlots between Jima and Woliso, as well as between Wolkite and Sodo (Table 2), were seriously affected by a stem canker disease; this produced extensive stem malformation. Initial symptoms included small discrete lesions on young green bark. Patches of large necrotic lesions developed from these on the stems, branches and twigs (Fig. 4B). A species of *Coniothyrium* (PREM.57382) was

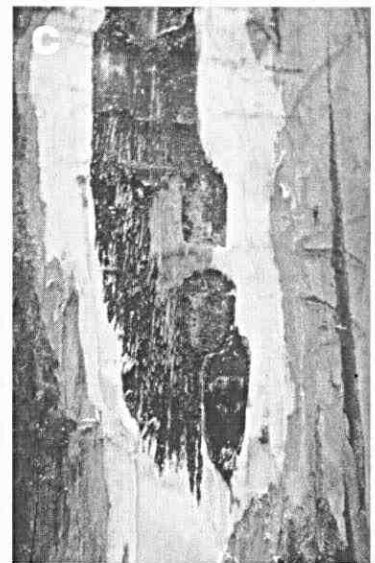
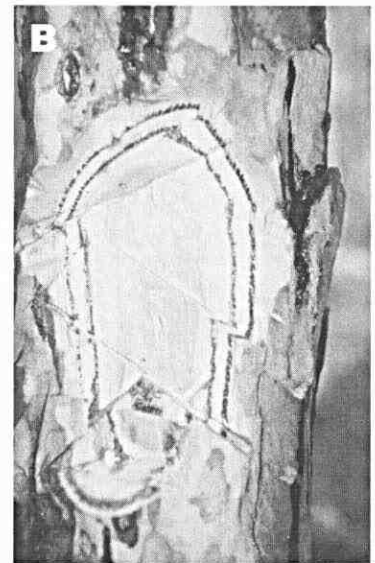


Fig. 3. Disease symptoms associated with *Botryosphaeria* on *Eucalyptus* species. A, Basal canker resulting in the cracking of the stems of *E. citriodora*; B, internal resin zones associated with external cankers on *E. citriodora*; C, wood discoloration on *E. saligna* associated with stem canker.

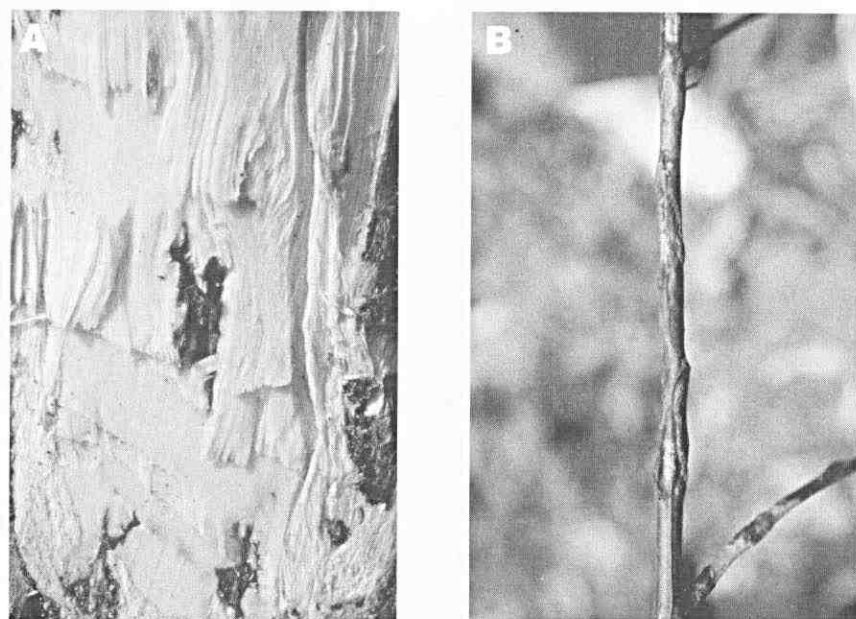


Fig. 4. Coniothyrium canker of *Eucalyptus camaldulensis*. A, Kino pockets; B, infected twig.

consistently found sporulating on the surface of the lesions. Stems were often reddish owing to the exudation of kino from the cracks; the wood of the affected stems contained pitted kino pockets (Fig. 4A). In addition, several of the infected trees produced epicormic shoots. We estimated that at least half the trees in a stand were affected by this pathogen.

Pink disease

Stem samples of diseased *E. camaldulensis* obtained from Pawe in the Benshangul Gumuz region yielded structures typical of the pink disease pathogen, *Erythricium salmonicolor* (= *Corticium salmonicolor*). Characteristic symptoms of pink disease include branch die-back, stem cankers, branch and stem girdling, production of epicormic shoots on the stems, the death of trees, as well as the production of pink mycelial growth on symptomatic plant parts. The fungus produced typical flat/resupinate fruiting structures on the surface of affected stems.

Mycosphaerella leaf blotch (MLB)

Leaf blotch and blight were commonly observed on *E. globulus* wherever this

species occurred (Table 2). The symptoms noted on *E. globulus* were characteristic of those caused by species of *Mycosphaerella* and, in many cases, resulted in defoliation of young trees (Fig. 5). Isolations from leaves with leaf blotch symptoms consistently yielded *Mycosphaerella* (PREM 57386). From the examination of the germination patterns of ascospores, it is clear that in Ethiopia more than one *Mycosphaerella* species is involved in causing leaf blotch on *E. globulus* leaves.

Other fungi

Several other fungi known to be associated with tree disease elsewhere in the world were found in *Pinus* and *Eucalyptus* plantations, although they appeared to be relatively unimportant. For example, *Sphaeropsis sapinea* was isolated from pine cones collected from Wondo Genet and Munessa Shashemene. Species of *Cytospora*, *Fusarium graminearum* and *Cylindrocladium* were also isolated from *Eucalyptus* branches collected from Wondo Genet, Wolkite and Menagesha. *Phaeophleospora eucalypti* was common on *E. camaldulensis* and *E. grandis* leaves, in all areas examined.

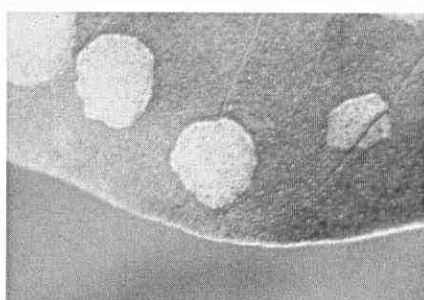


Fig. 5. Leaf spots on *E. globulus* associated with *Mycosphaerella* species.

Discussion

Exotic tree species have been grown in Ethiopian plantations for more than a century. The impact of diseases on plantation development has, however, received little attention. In recent years, premature tree deaths have been common, but were usually attributed to extreme climatic and poor site conditions. Our results show that several well-known fungal pathogens cause considerable damage in exotic plantations.

Root rot caused by a species of *Armillaria* was commonly found in *P. patula* plantations. *Armillaria* species are responsible for root rot on a wide range of tree species worldwide, including exotic and native trees.²⁰ The identification of *Armillaria* root rot from native *Acacia abyssinica*, as well as from *Cedrella odorata* and *Cordia alliodora*, suggests that this disease could be important not only to *P. patula*, but also on other trees, including native species. Further study is needed to determine its role in causing root rot in localities not covered by this survey. Previous investigations have attributed *Armillaria* root rot in Ethiopia to *A. mellea*.²¹⁻²³ Fruiting bodies recovered from our survey, however, did not match the macro-morphological characteristics of *A. mellea*. We are currently pursuing the identification of the species isolated during the surveys.

Botryosphaeria species have a cosmopolitan distribution and are found on many different hosts, including *Eucalyptus*,^{24,25} so it was not surprising to find them in our study. They are considered to be opportunistic wound and stress-related pathogens.^{25,26} Environmental stress, especially drought²⁶ and frost,²⁷ provides conditions conducive to disease development. Species of *Botryosphaeria* are also known as endophytes and are found in healthy plant tissues.²⁸ In some areas the presence of this pathogen seems to have resulted from poor growth of the coppice sprouts of *E. globulus* and it most likely contributed to the failure of coppice development. Regenerating *Eucalyptus* trees by coppicing is widely practised in Ethiopia, and further investigation is needed to determine the association of the stem canker with poor growth and coppice failure. Studies are under way to determine which *Botryosphaeria* species are involved, and to what extent, in causing stem canker on *Eucalyptus* in Ethiopia.

Stem canker associated with a fungus that closely resembles *Coniothyrium zuluense* was the most common stem canker found affecting *E. camaldulensis*. This is the most widely planted species of *Eucalyptus* in Ethiopia and, given the

importance of the disease on these species, clones and hybrids in South Africa, Thailand and Mexico,^{15,29,30} this infection is of considerable concern. *Coniothyrium* canker is considered to be one of the most important threats globally to *Eucalyptus* plantation forestry. This disease not only complicates debarking but also affects tree growth, the quality of sawn timber and, in severe cases, may also result in tree death.^{15,29,30} At present little is known about its occurrence in other *E. camaldulensis*-growing areas of Ethiopia or whether it infects other *Eucalyptus* species. It will, therefore, be important to conduct further surveys for evidence of this disease. A study is currently in progress to confirm the identity of the species of *Coniothyrium* found in Ethiopia and to determine whether it is the same fungus prevalent in South Africa and elsewhere.

Pink disease caused by *Erythricium salmonicolor* is common in the tropics, affecting a wide range of hosts including coffee, rubber, cacao, tea, *Acacia*, *Eucalyptus* and *Podocarpus*.^{31,32} We consider its discovery on *Eucalyptus* in Ethiopia to be important. In South Africa, pink disease has been reported on *E. macarthurii* and *E. cloeziana* in temperate parts of the country.³¹ The damage caused by this disease is of concern for the development of *E. camaldulensis* plantations in Ethiopia and we need to know more about its distribution and host range.

Leaf blotch caused by *Mycosphaerella* is widely distributed and important on *Eucalyptus* species worldwide. It is especially well-known for the defoliation it causes on *E. globulus* and *E. nitens*;^{12,33} its occurrence on *E. globulus* in Ethiopia is significant. Elsewhere in Africa, MLB has been reported from South Africa,³⁴ Uganda,³⁵ Malawi,³⁶ Zimbabwe and Kenya.¹⁰ Twenty-nine species of *Mycosphaerella* have been described in association with leaf blotch of *Eucalyptus*, of which 11 have been recorded on the African continent.³⁷ Nothing is known regarding the diversity, distribution or importance of *Mycosphaerella* in Ethiopia and these matters deserve investigation.

This study has resulted in many new records of *Pinus* and *Eucalyptus* diseases in Ethiopia. It provides a foundation on which to base future surveys and management strategies. In the past, tree deaths have been ascribed to factors such as adverse climatic conditions, poor species selection and inadequate post-planting management. Our study shows that the situation is more complicated and that biotic diseases play an important role in

commercial forestry. These findings suggest that management strategies to reduce the impact of diseases, and facilities to diagnose and monitor them, should be introduced. In addition, most of the pathogens involved require more detailed taxonomic study and pathogenicity tests should be conducted to understand better their role in tree death.

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