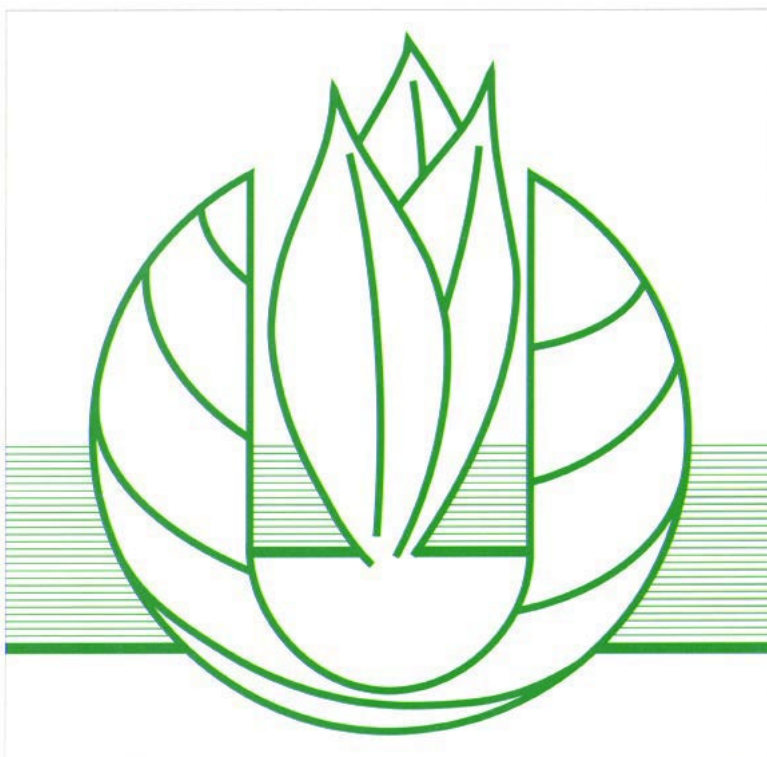
FAO/IPGRI Technical Guidelines for the Safe Movement of Germplasm No. 17

Eucalyptus spp.

edited by **W.M. Ciesla, M. Diekmann and C.A.J. Putter**



in collaboration with the ASEAN Forest Tree Seed Centre

Previously published Technical Guidelines for the Safe Movement of Germplasm

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INTRODUCTION

Collecting, conservation and utilization of plant genetic resources and their global distribution are essential components of international crop and tree improvement programmes.

Inevitably, the movement of germplasm in technical crop improvement programmes involves a risk of accidentally introducing plant pests1 along with the host plant. In particular, plant pests which accompany symptomless host material, such as viruses, pose a special risk. In order to manage this risk, effective testing or indexing procedures are required to ensure that material distributed is free of pests of quarantine concern.

The ever-increasing volume of germplasm exchanged internationally for research purposes, coupled with recent advances in biotechnology, has created a pressing need for crop/tree-specific overviews of the existing knowledge in all disciplines relating to the phytosanitary safety of germplasm transfer. This has prompted FAO and IPGRI to launch a collaborative programme for the safe and expeditious movement of germplasm, reflecting the complementarity of their mandates with regard to the safe movement of germplasm. FAO, as the depository of the International Plant Protection Convention of 1951, has a long-standing mandate to assist its member governments to strengthen their plant quarantine services, while IPGRI's mandate - inter alia - is to further the collecting, conservation and evaluation of germplasm to determine opportunities to use the genetic diversity of useful plants for the benefit of people throughout the world.

The purpose of the joint FAO/IPGRI programme is to generate a series of crop/tree-specific technical guidelines that provide relevant information on disease indexing and other procedures that will help to ensure phytosanitary safety when germplasm is moved internationally. The scope of the recommendations in these guidelines is confined to small, specialized consignments used in technical programmes, e.g. for conservation, research and basic plant breeding programmes.

These technical guidelines are produced by meetings of panels of experts on the crop/ tree concerned, who have been selected in consultation with the relevant specialized institutions and research centres. The experts contribute to the elaboration of the guidelines in their private capacity and do not represent the organizations for whom they work. The guidelines are intended to be the best possible advice to institutions involved in small-scale germplasm exchange for conservation, research and basic plant breeding. FAO, IPGRI and the contributing experts cannot be held responsible for any failures resulting from the application of the present guidelines. By their nature, they reflect the consen-

1 The word `pest' is used in this document as it is defined in the International Plant Protection Convention. It encompasses all harmful biotic agents ranging from viroids to weeds.

sus of the specialists who attended the meeting, based on the best scientific knowledge available at the time of the meeting. The experts who have contributed to this document are listed after this introduction.

The guidelines are written in a short, concise style, in order to keep the volume of the document to a minimum and to facilitate updating. Suggestions for further reading are given at the end, along with references cited in the text (mostly for geographical distribution, media and other scientific information). The guidelines are divided into two parts. The first part makes general and technical recommendations on how best to move eucalyptus germplasm. The second part covers the important pests and diseases of quarantine concern. The information given on a particular pest or disease is not exhaustive but concentrates on those aspects that are most relevant to quarantine.

There are several features of eucalypts which make this genus of trees of particular concern with regard to movement of germplasm. These can be summarized as follows:

- Eucalypts are the most widely grown trees in exotic plantations worldwide. At the end of 1990, there were an estimated 10.06 million ha of eucalypt plantings in the tropics, comprising 23% of all tropical forest plantings (FAO 1993).

- Most species originate in Australia, the 'isolated continent.' Australia is rich in biodiversity and eucalypts dominate the tree cover of areas which receive in excess of 500 mm of annual precipitation.

- Introduction of exotic pests into Australia in the future could severely damage entire ecosystems. The catastrophic damage caused by the root pathogen *Phytophthora cinnamomi* to *Eucalyptus marginata* and other components of native vegetation in Western Australia is an example. Of particular concern are pests which do not currently occur in Australia and appear to have adapted to eucalypts.

- Eucalypts are highly favoured as plantation species in many parts of the world because they are fast growing, easily cultivated and suitable for industrial plantations, agroforestry and community forestry.

- Large quantities of seed are being collected in native stands and are disseminated worldwide.

- Worldwide deployment of eucalypts in tropical, subtropical and, more recently, temperate areas has created a mosaic of suitable host types through which pests can spread.

- There are several examples of major plantation diseases which can severely limit the productivity of eucalypts grown in exotic plantations.

The present guidelines were developed at a meeting held in Bangkok, Thailand from 9-12 October 1995. The meeting was sponsored by the Australian Centre for International Agricultural Research (ACIAR) and hosted by the ASEAN Forest Tree Seed Centre, located in Saraburi, Thailand.

Guideline update

In order to be useful, the guidelines need to be updated when necessary. We ask our readers to kindly bring to our attention any developments that possibly require a review of the guidelines, such as new records, new detection methods, or new control methods. For your convenience, please use the form provided on the last page of this publication.

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GENERAL RECOMMENDATIONS

- Where possible, pest risk analysis should precede the movement of germplasm.
- Germplasm should be obtained directly from the nearest source of healthy material consistent with technical objectives.
- Upon receipt, all material should be kept in isolation from other planting material and planted under conditions conducive to symptom expression of pests of concern.
- Germplasm should undergo testing for presence of pests and appropriate treatment as necessary.
- Germplasm should not be released into the field unless it is confirmed to be pest free. When this is not the case, it should be destroyed.
- Rooted material should be moved *in vitro.*
- All packaging material used in the movement of germplasm should be destroyed.

TECHNICAL RECOMMENDATIONS

Selection of the method of germplasm transfer should meet the technical objectives of the germplasm use such as broadening the genetic base or selecting certain desirable traits (e.g. pest resistance, growth rates, form, etc.).

1. Seed

- Seed storage facilities should be routinely fumigated using a suitable method.
- During extraction of seed in the field, all care should be taken to avoid mixing with soil.
- Seed lots intended for storage or shipment should be cleaned and processed so as to be free from extraneous material, e.g. fragments of leaves and twigs.
- Seed lots should be air dried to less than 6% moisture content and fumigated with aluminium phosphide or carbon dioxide according to manufacturers' recommendations.
- Seed treatment with fungicides may affect seed viability, therefore if treatment is required, it should be done immediately prior to sowing.

- Where pre-shipment fumigation is not required, packaging of seed in laminated bags filled with carbon dioxide is recommended for storage and transport (Mitsuda *et al.* 1973; Shrestha *et al.* 1985; Vercoe, unpublished).

- Seeds should be germinated in a sterilized substrate.

2. *In vitro* material

- *In vitro* material should be derived from healthy sources.

- *In vitro* material should be shipped in sealed, transparent containers and visually inspected before dispatch and immediately upon receipt at destination. Unhealthy and contaminated material should be destroyed.

- When explants must be moved, they should be moved in a sterile medium.

3. Rooted cuttings

- Movement of rooted cuttings is not recommended because there are known pests, such as the rust *Puccinia psidii*, which can cause severe damage to eucalyptus resources should it become established outside of its present range and could easily be transported in this manner. In addition, latent pathogens such as *Botryosphaeria dothidea*, for which there are no practical detection or control methods available, could also be moved via rooted cuttings. Furthermore, root fungi such as *Phytophthora cinnamomi* could be moved on plants which do not express symptoms of infection.

- Where the use of rooted cuttings is needed to meet management objectives, a thorough pest risk analysis should be made prior to shipment and appropriate pest management procedures that are identified as a result of the analysis should be followed.

- In addition to pest management measures identified as a result of the pest risk analysis, tools used for making cuttings (clippers, knives, etc.) should be cleaned and sterilized by dipping in a 0.5-1.0% sodium hypochlorite solution. In addition, cuttings should be taken from trees which show no visible evidence of pest activity.

4. Pollen

- While some eucalyptus germplasm is moved as pollen, there is no information available on pests associated with pollen or practical experience on how to control potential pests associated with pollen.

INTERNATIONAL DISTRIBUTION OF GERMPLASM

- Movement of germplasm should comply with the regulatory requirements of the recipient country.

- A description of tests which have been performed to assess the health of the germplasm should accompany the shipment.

- If germplasm is re-exported, the shipment should be accompanied by copies of the original documents plus additional descriptions of any actions taken during transit which could jeopardize quarantine safety of the consignment.

ACRONYMS AND DEFINITION OF TERMS AS USED IN THIS PUBLICATION

APPPC
Asia and Pacific Plant Protection Committee

EPPO
European and Mediterranean Plant Protection Organization

FAO
Food and Agriculture Organization of the United Nations

IAPSC
Inter African Phytosanitary Council

IPGRI
International Plant Genetics Resources Institute

Pest Risk Analysis
Pest risk assessment and pest risk management

Pest Risk Assessment
Determination of whether a pest is a quarantine pest and evaluation of its introduction potential

Pest Risk Management
The decision-making process of reducing the risk of introduction of a quarantine pest

Quarantine Pest
A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled

WTO
World Trade Organization

DESCRIPTIONS OF PESTS

Viral Disease

Mosaic

Cause
A spherical virus of approximately 340 to 400 nm diameter with a core of approximately 200 nm diameter (Brzostowski and Grace 1974).

Significance
Incidence of disease is low and does not affect the growth of trees.

Symptoms and signs
Young and old leaves of *E. tereticornis* can show symptoms which consist of white, irregular patches. Diseased plants do not show growth effects except that affected leaves become leathery and thick (Sharma *et al.* 1985).

In *E. citriodora,* infected plants exhibit an intensive red colour at their growing points. Infection results in an increase in the number of axillary buds which ultimately give rise to more branches and cause plants to have a bushy appearance. Fully grown leaves show characteristic mosaic symptoms (Sastry *et al.* 1971).

Hosts
E. tereticornis, E. citriodora (India), *E. macrorhyncha* (Zambia).

Geographical distribution
India (Sastry *et al.* 1971), Zambia (Brzostowski and Grace 1974).

Biology and transmission
Sap transmissible (Sastry *et al.* 1971).

Detection
TMV can be detected by using serological tests, e.g. ELISA.

Treatment
None.

For further reading, see p. 58.

Phytoplasma disease

Little leaf

Cause
A phytoplasma.

Significance
Affects growth, especially of *E. tereticornis* and *E. globulus*. Infected seedlings become weak and most fail to survive. In India, though the disease is widespread, its incidence is low (>1%) in nurseries and plantations.

Symptoms and signs
Infected seedlings show prominent stunting and produce smaller than normal leaves. Leaves also become thin, pale coloured and scaly with narrow lamina (Fig. 1). Apices of affected leaves often show browning. Axillary buds are stimulated and produce abnormal shoots with shortened internodes resulting in a bushy appearance. Infected trees become stunted and sterile and are characterized by chlorotic foliage of reduced size and excessive sprouting. Infected *E. tereticornis* trees become weak, have reduced diameter and height growth and generally die. Infected *E. grandis* have a compact, bushy appearance and shoots easily snap when bent.

Apparent natural recovery or spontaneous remission of the disease is observed in *E. tereticornis* during the dry summer period but symptoms reappear during the rainy season. Natural recovery has not been observed in *E. grandis*, possibly because of the absence of high summer temperatures and the presence of a more even distribution of rainfall at the high elevations where this species is grown.

Fig. 1. Symptom of little leaf disease: thin, pale leaves on abnormal shoots with shortened internodes on *Eucalyptus tereticornis*, 2½ years old. (Dr J.K. Sharma, Kerala Forest Research Institute, Peechi)

Hosts
E. tereticornis, E. grandis, E. globulus and *E. citriodora* (India), and *E. microtheca* (Sudan).

Geographical distribution
India (Sastry *et al.* 1971, Sharma *et al.* 1983), Sudan (Dafalla *et al.* 1986) and China (Zhing *et al.* 1982).

Biology and transmission
Phytoplasmas are pleomorphic bodies, spherical or oval, 92 to 840 µm diameter (Zhing et al. 1982) found in the sieve elements of infected plants. They have DNA strands, ribosome-like granules and a three-layered well-defined unit membrane 10 µm thick (Dafalla *et al.* 1986).

These agents are not transmitted through grafting or dodder, except in the case of little leaf disease of *E. citriodora* reported from Karnataka, India, which is graft transmissible (Ghosh *et al.* 1985, Sastry *et al.* 1971).

Detection
It is possible to detect this phytoplasma reliably in suspect material via electron microscopy and fluorescence staining with fluorochrome, aniline blue and Dienes staining (Hoechst 33258). A DNA-binding fluorochrome gives a negative reaction.

Treatment
No effective method of control is available. The antibiotic tetracycline results in remission of symptoms but does not eliminate the phytoplasma from diseased plants.

For further reading, see p. 58

Bacterial Disease

Bacterial wilt

Cause

Burkholderia solanacearum (Smith) Yabuuchi *et al.*, synonyms: *Bacillus solanacearum* (Smith), *Pseudomonas solanacearum* (Smith). Aerobic, gram-negative, non-fluorescent rod. A full description is given by Saddler (1994). Subspecific classifications for *B. solanacearum* are described in Hayward (1991) and Gillings and Fahy (1993). Eucalypt-infecting strains in South America belong to race 1/biovar 1 and strains in Australia and Asia belong to race 1/biovar 3.

Significance

Losses of up to 17% have been reported in Brazil for 6 to 15-month-old transplants established for plantations on recently cleared areas of native rainforest (Dianese *et al.* 1990). In China, up to 10% losses occurred in young plants/seedlings (Wu and Liang 1988a). *B. solanacearum* is also an EPPO A2 quarantine pest and has quarantine significance for APPPC and IAPSC.

Symptoms and signs

Bacterial wilt can occur on trees up to 3 to 4 years old but is most severe on young plants up to about 18 months old (Fig.2). Symptoms include leaf drop, death of stems and reduced growth rate. Infected trees usually die. Vascular discolouration may occur but is more evident in older stems. Toots die and decay. Bacterial slime is often, although not always, observed in cut stems. No correlation has been observed between the presence of exudation and incidence of wilting.

Fig. 2. Initial symptoms of bacterial wilt on a 6-month-old seedling of *Eucalyptus urophylla*, caused by *Burkholderia solanacearum* (formerly *Pseudomonas solanacearum).* (Dr F.A. Ferreira, Universadade Federal de Vicosa, Vicosa)

Symptom expression is most rapid and dramatic on younger plants. In Brazil, wilt was first seen on 2-month-old transplants and maximum symptom expression occurred within 6 months. All trees with symptoms died within 15 months of transplanting. In China, young seedlings showed a similar pattern of wilt accompanied by root decay and blackish striations within stems. Plants died within 2 to 3 weeks of symptom onset.

In 2 to 4-year-old trees examined in Brazil, root rot and decay, probably linked to attack by secondary organisms, leads to windthrow. Older trees are more susceptible to windthrow and have more extensive rotting of root systems thought to be exacerbated by secondary decay and termite attack.

Hosts

- natural: *E. camaldulensis, E. citriodora, E. grandis, E. leizhou, E. pellita, E. propinqua, E. saligna, E. urophylla* and *E. grandis x urophylla* hybrid.
- experimental: Inoculation trials by Dianese *et al.* (1990) and Wu and Liang (1988a) achieved infection on *E. exserta, E. resinifera, E. tereticornis* and a *E. urophylla x grandis* hybrid. Eucalyptus isolates will also infect *Lycopersicon esculentum, Solanum melongena, Capsicum annum* (Dianese *et al.* 1990) and tobacco (Akiew and Trevorrow 1994). Other race 1 isolates, excluding those biovars from eucalypts, infect diploid bananas, peanuts, olives, ginger and other plants. For a more complete listing of the many plants attacked by *B. solanacearum* see Hayward (1994).

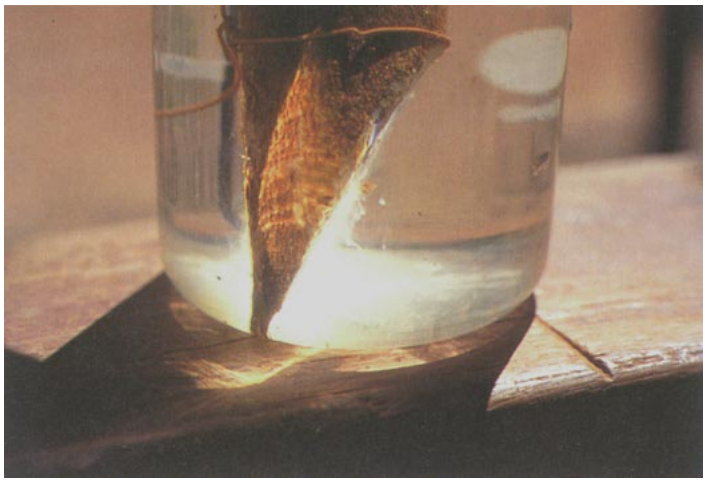


Fig. 3. Streams of *Burkholderia solanacearum* (formerly *Pseudomonas solanacearum)* emerging from a cut stem of *Eucalyptus urophylla* suspended in water. (Dr F.A. Ferreira, Universidade Federal de Vicosa, Vicosa)

Geographical distribution
Bacterial wilt is widespread in tropical, subtropical and warm temperate regions of the world (Smith *et al.* 1992). The disease has been found infecting eucalypts in Australia (Akiew and Trevorrow 1994), Brazil (Dianese *et al.* 1990), China (Wu and Liang 1988a), Taiwan (Wang 1992) and Venezuela (Hodges, pers. comm.).

Biology and transmission
Bacteria generally occur in soil. Survival and maintenance of virulence, based on studies relating to wilt on non-eucalypt hosts, is variable. Its mode of transmission on eucalypts is not known. On other hosts spread occurs by a variety of means, most commonly through movement of cuttings (including latent infections), storage organs, true seed, insect vectors (uncommon) and splash dispersal.

Detection
Streaming of bacterial slime from cut stems suspended in water or exudation from cut surfaces may indicate bacterial wilt (Fig. 3). However, there are reports of exudation without expression of wilt symptoms. More sensitive detection may be possible through the use of the stain Nile Blue A and light microscopy to reveal poly-b-hydroxybutyrate granules present within the bacterium. Selective media, serological and molecular methods are all routinely used to detect *B. solanacearum* and are described in detail by Seal and Elphinstone (1994).

Treatment
There is no known treatment.

For further reading, see pages 58 and 59.

Fungal diseases

Foliage diseases

Cylindrocladium leaf spot and blight

Cause
Teleomorph: *Calonectria* spp.; anamorphs: *Cylindrocladium ilicicola* (Hawley) Boedijn & Reistma, *C. parasiticum* Crous, Wingfield & Alfenas, *C. pteridis* Wolf, *C. quinqueseptatum* Boedijn & Reistma, *C. scoparium* Morgan, *C. candelabrum* Viegas, *C. theae* (Petch) Subram. and *C. colhouni* Peerally.

Significance
In India and Vietnam, *C. quinqueseptatum* is most damaging. In South America the *C. scoparium/C. candelabrum* complex is most damaging. Other species of *Cylindrocladium* have been associated with leaf spots and blight to various degrees.

Fig. 4. (above) Leaf spots on E. grandis caused by *Cylindrocladium quinqueseptatum.* (Dr F.A. Ferreira, Universidade Federal de Vicosa, Vicosa)

Fig. 5. (right) Irregular necrotic areas surrounded by a light-green halo resulting from coalescing leaf spots of *Cylindrocladium quinqueseptatum.* (Dr F.A. Ferreira, Universidade Federal de Vicosa, Vicosa)

Symptoms and signs
Infections result in leaf spots and shoot blight. Leaf spots range from small, discrete lesions (Fig. 4) to irregular necrotic areas (Fig. 5). Young stems can be infected and girdled (Fig. 6), resulting in shoot blight. Under humid conditions, a white conidial mass develops on dead tissue (Fig. 6). Orange-red perithecia may also be found on necrotic stem tissue.

Hosts
A wide range of *Eucalyptus* spp. and other woody plants.

Geographical distribution
Brazil (Alfenas and Ferriera 1979), India (Sharma and Mohanan 1991), South Africa (Crous and Wingfield 1994), Vietnam (Sharma 1994).

Biology and transmission
The species of *Cylindrocladium* described in this publication occur in soil and litter as mycelia, hyphae, chlamydospores and microsclerotia. They produce conidiophores and conidia and eventually perithecia with ascospores (teleomorph stage). Eucalypt foliage and branches are contaminated with vegetative structures and spores by splashed rain, insects and other microfauna. Two or more months of frequent precipitation and temperatures ranging between 23 and 30°C provide favourable conditions for infection by this group of fungi.

Detection
The pathogens sporulate readily in culture. Conidia are hyaline and septate. On leaf and branch lesions (Fig. 6), sporulation occurs in a moist chamber within 2 to 5 days.

Treatment
None. Infected germplasm should be destroyed.

For further reading, see pages 59 and 60.

Fig. 6. Girdled stem of *E. grandis* with white conidial mass of *Cylindrocladium quinqueseptatum* developing on the dead tissue.
(Dr F.A. Ferreira, Universidade Federal de Vicosa, Vicosa)

Eucalyptus rust

Cause
Puccinia psidii Winter.

Significance
Regarded as the most significant quarantine risk to the cultivation of *Eucalyptus* spp. as well as to related plants. In Brazil it is severely limiting to the growth of highly susceptible species and provenances.

Symptoms and signs
Yellow-golden uredinial pustules on branches and terminal shoots as well as on young sprouts or leaves (Figs. 7,8,9).

Hosts
Potentially all Myrtaceae. In addition to eucalypts, more than 15 genera and 30 species, including guava (Fig. 10), in the family Myrtaceae are reported to be natural hosts (Viegas 1961; Ferreira 1989).

Fig. 7. (left) Young *Eucalyptus* tree with reinfections of the rust *Puccinia psidii.*
(Dr F.A. Ferreira, Universidade Federal de Vicosa, Vicosa)

Fig. 8. (above) Urediniospores of Puccinia *psidii* on young leaves of a *E. grandis* seedling.
(Dr F.A. Ferreira, Universidade Federal de Vicosa, Vicosa)

Geographical distribution
On *Eucalyptus* spp. in Brazil (Ferreira 1989), Taiwan (Wang 1992) and South Africa (Knipscheer and Crous 1990).

Biology and transmission
The rust is seasonal, severity varies according to susceptibility of genetic material and weather conditions. First symptoms appear 2 to 4 days after infection. Sporulation starts 2 to 5 days later with a peak 10 days after infection. Three weeks later, dried pustules and necrosis are observed on the affected organs. Urediniospores survive in dried tissues for 3 weeks at 15.5ºC. Presence of free water (day or night) for more than 3 hours and temperatures of 18 to 23°C are favourable for uredial cycles. Teliospore production is favoured by infections on more mature organs and at temperatures near 25°C. Teliospores have been observed to germinate promptly. Spores are spread by wind and splashed rain (Ferreira 1989).

Detection
Observation of yellow-orange uredinia and urediniospores.

Treatment
No eradicative treatment available.

For further reading see p. 60.

Fig. 9. (above) Yellow-golden uredinia of *Puccinia psidii* on shoot tip of *E. grandis.* (Dr F.A. Ferreira, Universidade Federal de Vicosa, Vicosa)

Fig. 10. (below) Uredinia of *Puccinia psidii* on guava fruits. (Dr F.A. Ferreira, Universidade Federal de Vicosa, Vicosa)

Mycosphaerella leaf spot

Cause

Teleomorph: *Mycosphaerella* spp.; anamorphs: *Colletogloeum, Stagonospora, Stenella, Sonderhenia, Pseudocercospora*. The genus *Mycosphaerella* on eucalypts has not been clearly defined and may actually represent several distinct genera. Of the 17 species described from eucalypt foliage, *M. molleniana* (Thiim.) Lindau and *M. cryptica* (Cooke) Hansf. are the most common and damaging.

Significance

Occurs in most areas where eucalypts are grown in plantations. Also common in native eucalypt forests. Pathogenicity of species ranges from extremely damaging through loss of foliage and growth (Carnegie *et al.* 1994) to minor saprophytes. *E. globulus*, the most widely grown eucalypt in temperate climates, is especially susceptible to damage in summer rainfall areas. This has precluded the planting of this species as well as certain provenances of *E. nitens* in South Africa (Lundquist and Purnell 1987).

Fig. 11. Straw-coloured necrotic areas on leaves of *E. globulus* following infection with *Mycosphaerella* molleniana. (Dr K. Old, CSIRO Division of Forestry, Canberra)

Symptoms and signs
Vary greatly between fungal species and host. M. cryptica infects both juvenile and adult leaves of a wide range of eucalypts. *M. molleniana* attacks only juvenile and intermediate foliage. In severe cases (e.g. infection of *E. globulus* by *M. molleniana* in summer rainfall areas) large, straw-coloured necrotic areas develop (Fig. 11). These bear large numbers of small (100 to 150 mm) pigmented pseudothecia. Teleomorphs are commonly found on leaves and anamorphs are rare or unknown. Juvenile leaves of E. *globulus* infected by *M. molleniana* become crinkled and distorted Ascospores are two-celled with constriction at the septum variable between species. Dimensions of the ascomata, asci and ascospores also vary.

Hosts
Eucalyptus spp.

Geographical distribution
Worldwide wherever eucalypts are grown. Knowledge of the distribution of individual species is incomplete.

Biology and transmission
Disease occurrence is most severe in summer rainfall areas. Seeds may be a means of long-distance spread but seed infection has not been documented.

Detection
Presence of necrotic spots or patches and pseudothecia on leaves and presence of crinkled and distorted foliage.

Treatment
No eradicative treatment available.

For further reading, see pages 60 and 61.

Cryptosporiopsis leaf spot

Cause
Cryptosporiopsis eucalypti Sankaran & Sutton, a recently described Coelomycete (Sankaran *et al.* 1995).

Significance
Infection can result in severe defoliation and dieback of young eucalypt shoots.

Symptoms and signs
Leaves and occasionally twigs are affected. Leaf spots occur on both sides of the leaves and vary in size, shape and colour with or within tree species. Basically, there are four types of lesion patterns: **circular spots** (brownish to blackish brown, discrete, circular or subcircular, 1 to 1.5 cm in diameter, Fig. 12), **large blight spots** (brownish to brown, large spreading necrotic lesions, Fig. 13), **small irregular spots** (grey, brownish to dark brown, sometimes with darker margins, irregular or somewhat angular, discrete, small, up to 0.5 cm in diameter) and **irregular rusty spots** (rusty, rough-surfaced, irregular, discrete or diffuse along veins Fig. 14). Leaf infection can extend to small twigs. Discoloured necrotic lesions with light-coloured fruiting bodies are formed on affected twigs.

Fig. 12. Brownish circular leaf spots caused by *Cryptosporiopsis eucalypti*. (Dr K. Old, CSIRO Division of Forestry, Canberra)

Fruiting bodies are scattered irregularly on the spots and appear as surface pustules. At maturity, they open widely or as a slit. A cream-coloured conidial mass accumulates at the top in high moisture conditions (Fig. 15). The fungus is characterized by having light-coloured, cup-shaped stromatic conidiomata and hyaline, one-celled (rarely two-celled) conidia. Conidia are usually thick-walled, ellipsoid to elongated ellipsoid, measuring 11 to 26 x 4.5 to 10 µm in size. Small, hyaline, thin-walled, ovoid, one-celled microconidia were found in the collection from Australia.

Hosts

- natural: a number of eucalypt species including *E. camaldulensis, E. camphora, E. cinerea, E. cypellocarpa, E. globulus, E. grandis, E. microcorys, E. nicholii, E. nitens, E. nova-anglicae, E. robusta, E. tereticornis* and *E. viminalis.*
- experimental: the fungus induces leaf spots on several additional eucalypts in artificial inoculation tests: *E. amplifolia, E. blakelyi, E. camaldulensis, E. grandis* and *E. tereticornis.*

Geographical distribution

Australia, Brazil, India, Japan, Thailand, Vietnam and USA (Hawaii) (Ferriera 1989; Old and Yuan 1994; Sankaran *et al.* 1995).

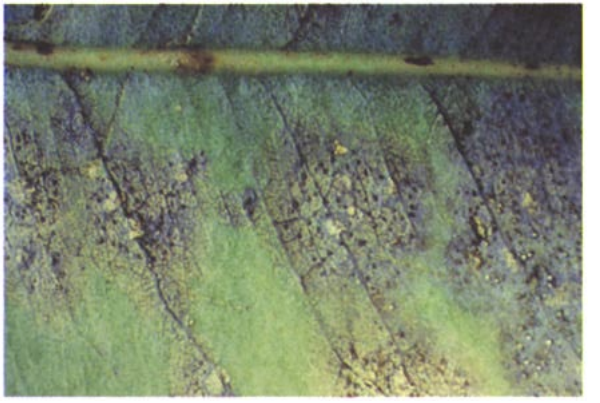


Fig. 13. (left) Brownish large blight spots caused by *Cryptosporiopsis eucalypti.*
(Dr K. Old, CSIRO Division of Forestry, Canberra)

Fig. 14. (above) Irregular, rusty, rough-surfaced leaf spots caused by *Cryptosporiopsis eucalypti.*
(Ms. K. Pongpanich, Royal Forest Department, Bangkok)

Biology and transmission
Little is known about the biology of this pathogen. Growth rates of colonies in culture vary depending on isolates and incubation temperature. The Udon Thani isolate from Thailand, for example, grows faster than the Chacheongsao isolate at the same temperature. Both isolates grow faster at 26°C than at 24°C or 28°C (unpublished data). In inoculation tests, the fungus induced characteristic leaf spots at 24°C 4 to 5 days after inoculation, but did not produce any symptoms at 32°C even 1 month after inoculation.

Infects leaves either through stomata or small mechanical wounds. Symptom development requires about 1 week (more often 4 to 5 days). The disease is most active during monsoons (e.g. in India). Rain and wind are probably the major factors involved in the localized dissemination of the fungus. International spread most probably results from dissemination in seeds or seed chaff but seed infection has not been documented.

Detection
Presence of leaf spots and characteristic fruiting bodies (Fig. 15).

Treatment
No eradicative treatment available.

For further reading, see p. 62.

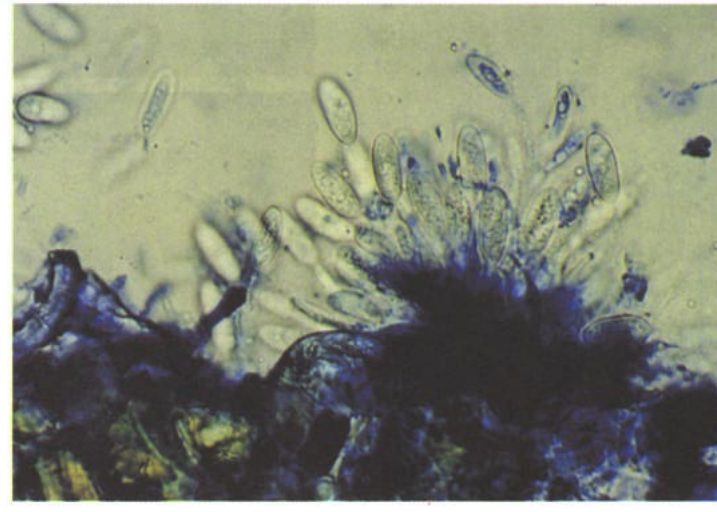


Fig. 15. Conidiomata and conidia of *Cryptosporiopsis eucalypti* in methylen blue stain. (Ms. K. Pongpanich, Royal Forest Department, Bangkok)

Kirramyces leaf spot

Cause

Kirramyces epicoccoides (Cooke & Masee) Walker, Sutton & Pascoe, synonym *Phaeoseptoria eucalypti* (Hansf.) Walker); K. lilianiae Walker, Sutton and Pascal and *K. eucalypti* (Cooke & Massee) Walker, Sutton and Pascal, synonym *Cercospora eucalypti.*

Significance

Causes severe premature defoliation which affects growth and vigour of seedlings.

Symptoms and signs

Infection first appears on mature leaves as purple to brownish-purple amphigenous spots which are characteristically angular and marked by veins, especially on *E. tereticornis* and *E. grandis* (Figs. 16,17). Spots occur on both sides of the leaf, many of which may never become necrotic. Infection gradually progresses upward in the crown and late in the season spots occur on younger leaves and all mature leaves drop.

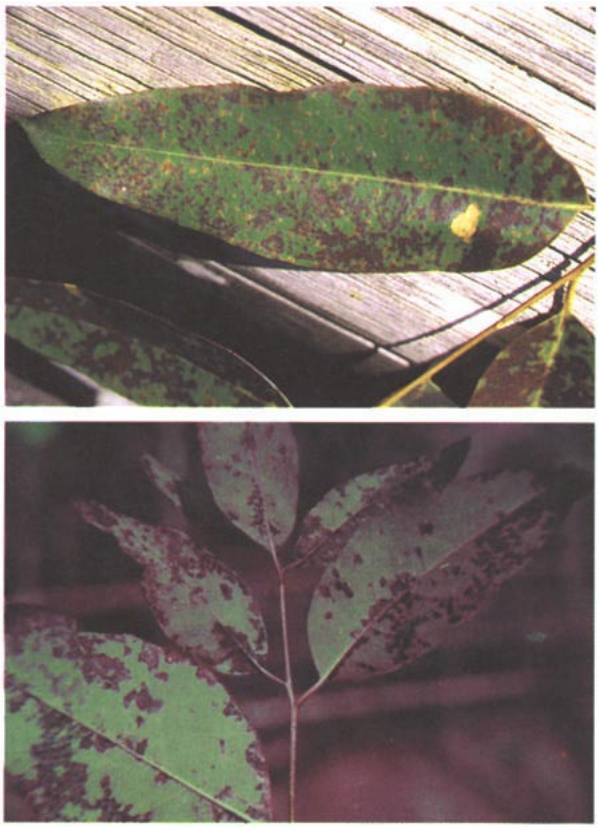


Fig. 16. (above) Purple spots on the upper leaf surface caused by *Phaeoseptoria eucalypti.* (Dr M. Wingfield, University of the Orange Free State, Bloemfontein)

Fig. 17 (right) Purple spots on the lower leaf surface caused by *Phaeoseptoria eucalypti.* (Dr J.K. Sharma, Kerala Forest Research Institute, Peechi)

When leaf spots become necrotic, pycnidia (minute, black fruiting bodies) develop in the leaf tissue, generally more frequently on the abaxial surface (Fig. 18, top left). Pycnidia produce long grey-black tendrils which appear as brownish-black woolly masses, predominantly on the lower leaf surfaces (Fig. 18, bottom left). Rain and dew disperse conidial masses (Fig. 18, right and Fig. 19) from the tendrils and form a black layer over the leaf surface.

Hosts
E. bicostata, E. camaldulensis, E. grandis, E. globulus and *E. tereticornis.*

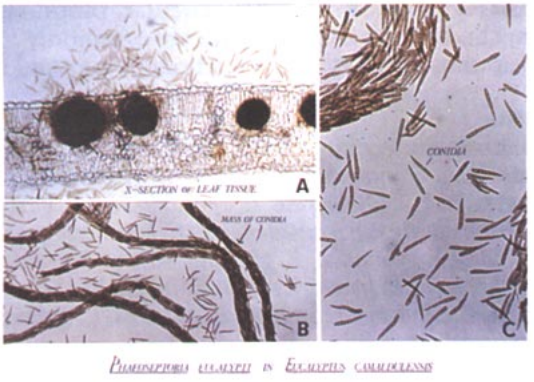
Geographical distribution
K. epicoccoides is found in Africa, Australia, Brazil, India, Japan, Thailand and Vietnam. *K. lilianiae* and *K. eucalypti* are found only in Australia (Sharma and Mohanan 1981; Sharma *et al.* 1985; Walker *et al.* 1992).

Biology and transmission
Dispersal is by air-borne conidia. Warm weather and heavy dew favour infection. Conidia could be distributed on seed.

Detection
Characteristic purple spots on leaves, spore masses (cirri) and conidia (Figs. 18,19).

Treatment
No eradicative treatment is known.

For further reading, see p. 61.



Phaeoseptoria eucalypti in *Eucalyptus camaldulensis*

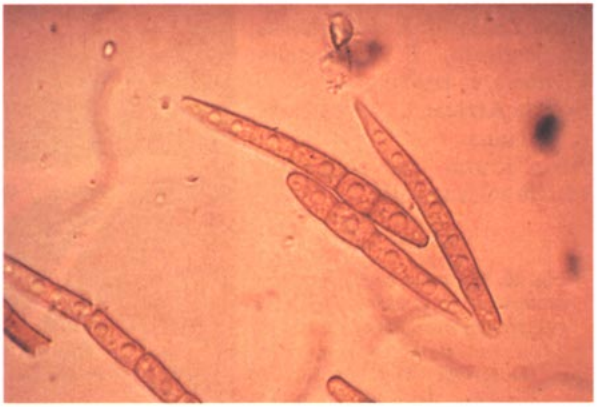


Fig. 18. (above) Pycnidia of *Phaeoseptoria eucalypti* in leaf tissue (top left), long grey-black tendrils (bottom left) and conidia (right). (Ms K. Pongpanich, Royal Forest Department, Bangkok)

Fig. 19. (right) Conidia of *Phaeoseptoria eucalypti.* (Dr M. Wingfield, University of the Orange Free State, Bloemfontein)

Aulographina leaf spot

Cause
Teleomorph: *Aulographina eucalypti* (Cooke & Massee) v. Arx & Müller, synonyms *Aulographium eucalypti* Cooke & Massee, *Lembosiopsis eucalyptina* Cooke & Massee); anamorph: *Thyrinula eucalypti* Petr. & Syd.

Significance
Occurs commonly in natural forests and plantations of many eucalypts in Australia. Causes moderate to severe premature defoliation.

Symptoms and signs
Spots on leaves are amphigenous, typically circular to subcircular, sometimes angular, 2 to 15 mm in diameter, often slightly raised and corky, brown with dark purple margins (Fig. 20). Small, black, circular pimple-like pycnidia and black, elongate, often branched or star-like ascomata are commonly formed on the surface of lesions (Fig. 21). Symptoms also develop on petioles, twigs and sometimes on fruits and bark.

Hosts
Commonly associated with many species of *Eucalyptus.*
Americas: *E. punctata, E. saligna, E. globulus.*
Australia: *E. agglomerata, E. approximans, E. baxteri, E. bridgesiana, E. caesia, E. camaldulensis, E. cladocalyx, E. consideniana, E. cypellocarpa, E. dalrympleana, E. delegatensis, E. dives, E. globoidea, E. globulus., E. globulus subsp. bicostata, E. grandis, E. gregsoniana, E. johnstonii, E. lekmannii, E. macrorhyncha, E. niphophila, E. nitens, E. nitida, E. obliqua, E. pauciflora, E. pellita, E. pilularis, E. radiata, E regnans E. sieberi, E. stellulata, E. tetragona, E vimhalis, E. woodwardii.*
Great Britain: *E. coccifera.*
Madagascar: *Eucalyptus* spp.
New Zealand: *E. delegatensis, E. fastigata, E. fraxinoides, E. nitens, E. regnans.*
South Africa: *E. delegatensis, E. globulus.*
Also found on *Angophora costata* in Australia.

Fig. 20. Symptom of *Aulographina eucalypti* on E. *globulus:* circular to subcircular brown leaf spots with dark purple margins. (Dr K. Old, CSIRO Division of Forestry, Canberra)

Geographical distribution
Australia (Marks *et al.* 1982), Brazil (Ferreira 1989), Great Britain (Wall and Keane 1984), Madagascar (Crous and Swart 1995), New Zealand (Dick 1982), South Africa (Crous *et al.* 1989), USA (Hawaii) (Farr *et al.* 1989).

Biology and transmission
A. eucalypti is a biotrophic parasite. Isolation of this fungus directly from surface-sterilized lesion margins is difficult and can only be done through ascospores. The fungus grows very slowly (ca. 2.4 to 5.4 mm/month) and, in culture, sporulation is rarely observed (Wall and Keane 1984). Ascospore release requires relative humidity as high as 98%, with optimum temperature of 15 to 20°C. Symptom development requires about 4 months. Successive rainy days and low temperature (15 to 20°C) predispose trees to infection. Rain and wind-blown spores are the major factors involved in the dispersal of the fungus.

Detection
Characteristic circular corky leaf spot with superficial black, elongate, often branched (or star-like) fungal fruiting structures are readily recognized. The fungus produces clavate, bitunicate asci and hyaline, two-celled ascospores measuring 8 to 14 x 3 to 5 µm.

Treatment
No treatment recommended; destroy germplasm if it is believed to be infected.

For further reading, see p. 62.

Fig. 21. Enlarged lesion caused by *Aulographina eucalypti* with black, elongate, ascomata. (Mr Zi Qing Yuan, CSIRO Division of Forestry, Sandy Bay, Tasmania)

Stem and branch diseases

Botryosphaeria canker

Cause

Various species of *Botryosphaeria* of which B. dothidea (Moug. Fr.) Ces. & deNot. and its anamorph *Fusicoccum aesculi* Corda is the best known and most common. Other species include *B. rhodina* (Cooke) v. Arx and its anamorph *Lasiodiplodia theobromae* (Pat.) Griff & Maubl. (= *Botryodiplodia theobromae* Pat.) and *B. appendiculata* (Yuan and Old).

Significance

Dieback and cankers caused by *B. dothidea* are widespread and cause extensive losses, particularly on susceptible clones in South Africa. The fungus is generally recognized as a stress-associated pathogen. Onset of disease is usually associated with drought, hail damage, wind or frost damage or insect infestation. Has also been shown to commonly exist in asymptomatic tissue as a latent pathogen (Smith *et al.* 1994).

Symptoms and signs

A wide range of symptoms occur. A common manifestation is death of tree tops. This can lead to infection of the pith resulting in a core of discoloured wood surrounded by a healthy sheath of outer wood which often extends throughout the entire length of the tree (Fig. 22). This symptom is common on *E. grandis* clones and often develops after trees have been exposed to hot winds. A similar symptom is found on growing tips of *E. nitens* after 1 to 2-year-old trees have been damaged by late frosts.

Fig. 22. Botryosphaeria canker on growing tip after infection promoted by hot wind damage. (Dr M. Wingfield, University of the Orange Free State, Bloemfontein)

One of the most serious symptoms is the development of stem cankers (Fig. 23). These are most common on trees stressed by drought and are characterized by stem swelling, bark cracks and exudation of copious amounts of black kino (a bleeding exudation high in fatty acid esters.). In severe cases, similar symptoms are found on lateral branches. Stems often break at cankers.

Some trees and clones develop cankers around branch knots. Trees fail to heal at sites of branch abscission and soft pockets of kino develop around the basis of the branches. Kino pockets persist and render trees unacceptable for sawn wood.

Hosts

A wide host range of woody plants including species of Malus, Pistachia and Eucalyptus hosts. Among Eucalyptus spp., *E. camaldulensis, E. globulus, E. grandis, E. nitens, E. macarthurii, E. marginata, E. saligna* and *E. smithii* are recorded hosts and it is likely that other species are also susceptible. Among species extensively propagated in plantations, *E. camaldulensis* appears to be one of the most susceptible: hybrids between this and other species such as *E. grandis* are often highly susceptible. Clones of *E. grandis* appear to differ in their susceptibility to infection.

Fig. 23. Deformed stem after severe infection with *Botryosphaeria dothidea.* (Dr M. Wingfield, University of the Orange Free State, Bloemfontein)

Geographical distribution
Widely distributed. Infections on *Eucalyptus* have been reported in Australia, South Africa and the USA (Barnard *et al.* 1987; Davidson and Tay 1983; Webb 1983). In South Africa it occurs wherever plantations of *Eucalyptus* have been established and is considered to be one of the most important pathogens of these trees (Smith *et al.* 1994).

Biology and transmission
Generally considered to be a wound pathogen. It has, however, also been shown to infect leaves through stomata and will remain latent in these organs. Proliferation and subsequent symptom development occur once the tree is highly stressed or with the onset of senescence. Sporulation occurs on dead tissue and ascospores/conidia are discharged during wet periods.

Detection
Can be detected in infected tissue after incubation in moist conditions where conidia and/or ascospores are produced. Direct isolation on standard culture media is also an effective means of detection. Isolations from surface-sterilized healthy tissue are a reliable means of detecting latent infections.

Treatment
No eradicative treatment available.

For further reading, see p. 62.

Cryphonectria canker

Cause
Cryphonectria cubensis (Bruner) Hodges, synonym *Diaporthe cubensis* Bruner.

Significance
Little information was available on the importance of C. cubensis until 1970 when it was reported to be causing serious cankers on *Eucalyptus* in Surinam. Severe outbreaks of the disease were then reported in various other areas of the world. The disease is a limiting factor in the commercial cultivation of certain species of *Eucalyptus*. Under favourable climatic conditions, infection rates can be as high as 80%. In Brazil (Alfenas et al. 1983) and Surinam (Boerboom and Maas 1970) respectively, 30 and 50% of the stems in plantations of *Eucalyptus* spp. have been reported to be killed by this pathogen.

Symptoms and signs
Basal cankers which can kill young trees during the first 2 years of growth (the most common expression of the disease in South Africa) or result in extensive and longer-lived cankers that extend from the base to breast height and higher on the bole (Fig. 24). Infections are also occasionally observed at the site of branch stubs on the lower bole. Girdled trees wilt and appear to die suddenly in summer during hot dry periods. Susceptible trees which escape death tend to have swollen bases surrounded by cracked bark on which the sexual perithecia (common in various parts of South America) or asexual fruiting structures (pycnidia) of the fungus can easily be seen (Fig. 25). These trees often die as competition between trees increases.

Hosts
Believed to have a wide host range among the Myrtaceae. It has been demonstrated that the fungus originates from clones in Southeast Asia. various species of *Eucalyptus*, including *E. grandis*, *E. saligna*, *E. camaldulensis* and *E. tereticornis*, are highly susceptible. *Eucalyptus urophylla* appears to harbour a high degree of tolerance to infection.

Fig. 24. Severe cracking and swelling at the stem base caused by *Cryphonectria cubensis*.
(Dr M. Wingfield, University of the Orange Free State, Bloemfontein)

Clones and clonal hybrids exhibit substantial variation in susceptibility and considerable success is being experienced in various parts of the world in the selection of disease-tolerant planting stock.

Geographical distribution
Occurs in all major *Eucalyptus* growing areas between 30° north and south of the equator. In Western Australia, it occurs on roots of *E. marginata* (Boerboom and Maas 1970; Conradie *et al.* 1992; Ferreira 1989; Hodges *et al.* 1979; Wingfield *et al.* 1989).

Biology and transmission
Few studies on the biology of *C. cubensis* have been undertaken although it seems that this fungus is similar to the closely related and intensively studied chestnut blight fungus, *C. parasitica.* Infection is through wounds and is favoured by high rainfall (>2000 mm) and humidity throughout the year as well as temperatures which average 23°C or higher. Natural growth cracks at the bases of young trees are apparently the most important infection court. The most common infection propagules appear to differ in different parts of the world with ascospores and conidia being common in South America and asexual conidia predominant in South Africa. Conidia of this fungus are dispersed by rain splash and ascospores by wind.

Detection
Presence of large numbers of perithecia or pycnidia on the canker surface. Perithecia are formed in loose groups with globose bases under the bark surface. Pycnidia produce masses of orange-yellow conidia and are usually superficial on the cankers (Fig. 25). The length of the necks of pycnidia and perithecia is determined by the amount of humidity. Under dry conditions necks of pycnidia barely protrude. These structures are sometimes not present but they can be induced easily by placing small bark pieces in a moist environment for a few days to initiate sporulation.

Treatment
No eradicative treatment available.

For further reading, see pages 62 and 63.

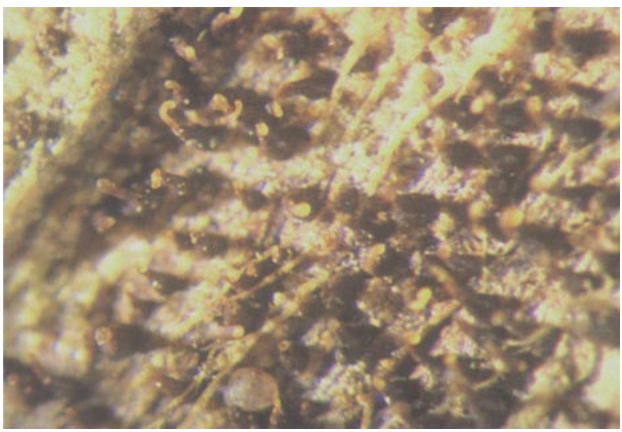


Fig. 25. Asexual fruiting structures (pycnidia) of *Cryphonectria cubensis* on diseased tissue. Note the masses of orange-yellow conidia. (Dr M. Wingfield, University of the Orange Free State, Bloemfontein)

Endothia canker

Cause
Teleomorph: *Endothia gyrosa* (Schw.) Fr.; anamorph: *Endothiella* Sacc.

Significance
Generally considered to be opportunistic and favoured by stress (drought or severe defoliation by insects). However, evidence from eucalypt-growing areas, such as South Africa, suggests it is a serious pathogen on clones of various *Eucalyptus* species.

Symptoms and signs
Variable, ranging from superficial cracking of outer bark to deeply sunken cankers with kino. Cankers occur over the entire surface of the bole but are most prominent at the base of trees. Bright orange stromata in which the perithecia are embedded are abundant on the surface of cankers (Figs. 26, 27).

Hosts
Has a wide host range, but primarily known as a pathogen of *Quercus palustris*, causing pin oak blight. Also found inciting disease or inhabiting moribund tissue of *Liquidambar styraciflua, Q. rubra, Q. nigra, Q. phellos* and *Acer saccharinum* in North America. Also known as a canker pathogen of a wide range of eucalypts. Occurs on *E. grandis, E. nitens* and *E. urophylla* and hybrids of *E. grandis* with *E. camaldulensis* and *E. urophylla* in South Africa. Recorded on *E. tereticornis, E. torelliana* and *E. deglupta* in India.

Fig. 26. Bright orange stromata with perithecia of *Endothia gyrosa* on the surface of a canker. (Dr J.K. Sharma, Kerala Forest Research Institute, Peechi)

Geographical distribution
Australia, India, Portugal and South Africa (Old *et al.* 1986; Roane *et al.* 1974; Sharma *et al.* 1985; Walker *et al.* 1985; van der Westhuizen et al. 1993). Fungus apparently is adapted to a wide range of climatic conditions and could occur in other eucalypt-growing areas.

Biology and transmission
Infection is apparently through naturally occurring wounds on the bark associated with branch scars and growth cracks. Transmission can be through both sexual and asexual spores which are both produced abundantly on cankers.

Detection
Perithecia and pycnidia are embedded or sunken in orange stromata or cankers.

Treatment
No eradicative treatment available.

For further reading, see p. 63.

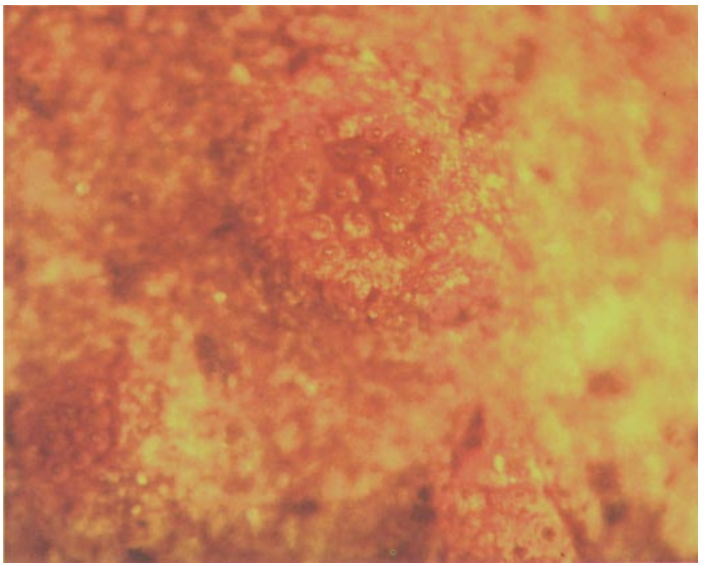


Fig. 27. Close-up of perithecia of *Endothia gyrosa* embedded in stromata.
(Dr M. Wingfield, University of the Orange Free State, Bloemfontein)

Coniothyrium canker

Cause
An apparently undescribed species of *Coniothyrium.* Several *Coniothyrium* spp. have been described as leaf pathogens of *Eucalyptus.* These include *C. eucalypticola* Sutton and *C. ahmadii* Sutton, *C. kallangurence* Sutton & Alcorn, *C. ovatum* Swart and *C. parvum* Swart.

Significance
After first being found in a limited area in Zululand of South Africa in 1991, this disease has spread and has become one of the most serious problems affecting commercial forestry in the Zululand. The disease is not known to occur elsewhere. Considered to be one of the most potentially serious threats to *Eucalyptus.*

Symptoms and signs
Often referred to as 'measles disease'. This is because initial infection occurs on young, green stem tissue (Fig. 28) and gives rise to small discrete dark spots on the bark. On highly susceptible clones, lesions merge to give rise to large patches of dead, black bark which is often cracked and exudes copious amounts of kino. Infection typically occurs at the start of the growing season on young green stem tissue. On susceptible clones, these infections give rise to spindle-shaped swellings on stems of trees (Figs. 29, 30). Cankers occur annually and are interspersed along the stems. In cases of severe infection, epicormic shoots are produced on the stems around the spindle-shaped swellings and the tops of trees begin to die. Lateral branches attain apical dominance but will also become infected, resulting in cessation of height growth.

Fig. 28. Single necrotic spot on green tissue indicative of the early stage of Coniothyrium canker. (Dr M. Wingfield, University of the Orange Free State, Bloemfontein)

Hosts
Initially discovered on a single clone of *E. grandis* in 1991. Has subsequently become widespread and occurs not only on a wide range of *E. grandis* clones, but also on hybrids of this and other species. *E. camaldulensis, E. urophylla, E. tereticornis* and *E. nitens* are also affected.

Geographical distribution
Known only from South Africa. Most severe in the Zululand area, which has a sub-tropical climate. Observed to a lesser extent in other areas of the country (Eastern-Transvaal).

Biology and transmission
Little is known about the biology of the *Coniothyrium* sp. responsible for stem cankers. It has, however, been shown that the small, single-celled spores infect stems directly through the epidermis of the young tissue. Trees appear to be most severely affected in areas of highest rainfall and optimal growth.

Detection
Presence of abundant spores on the surface of necrotic lesions on the stems of diseased trees. Single-celled dematiaceous conidia are produced in pycnidia that form below the surface of the epidermis on diseased tissue.

Treatment
No eradicative treatment known.

Fig. 29. (left) Spindle-shaped swellings on stem of a eucalypt tree typical of advanced stage of Coniothyrium canker. (Dr M. Wingfield, University of the Orange Free State, Bloemfontein)

Fig. 30. (right) Large numbers of necrotic spots on a cankered stem, caused by *Coniothyrium* spp. (Dr M. Wingfield, University of the Orange Free State, Bloemfontein)

Pink disease

Cause
Corticium salmonicolor Berk. & Br.

Significance
Considered to be one of the most important diseases of eucalypts. Trees with repeated infections have reduced height growth due to death of the apical shoot. Severely infected trees are eventually killed. Growth and yield of plantations is reduced.

Symptoms and signs
Infects the main stem and branches of trees 2 to 4 years old. Infected bark forms a depressed canker and develops vertical bark cracks during the dry season (Fig. 31). There is no oozing of kino from the cankers. The terminal shoot above the canker dies when the stem is completely girdled (Fig. 32). Numerous epicormic shoots develop from the healthy part of the stem below the canker. Some shoots near the canker also become infected and are killed. Repeated infections give trees a bushy appearance. Diseased trees may be killed.

Hosts
A wide range of woody plants are hosts including more than 141 species in 104 genera (Sharples 1936). Among eucalypts, *E. alba*, *E. grandis*, *E. kitsoniana* and *E. tereticornis* are known hosts.

Fig. 31. Depressed canker and vertical bark cracks caused by *Corticium salmonicolor*. (Dr) J.K. Sharma, Kerala Forest Research Institute, Peechi)

Geographical distribution
Widely distributed in tropical and subtropical Africa, Asia, Australia, Latin America, New Zealand, South Africa and the West Indies. Eucalypts have been infected in Brazil (Ferreira and Alfenas 1977), Costa Rica (Bazan-de-Segura 1970), India (Seth *et al.* 1978; Sharma *et al.* 1985), South Africa (Wingfield, pers. comm.) and Vietnam (Sharma 1994).

Biology and transmission
The fungus has four distinct forms, known as the **cobweb** (mycelial), **pustule** (mycelial), **necator** (imperfect) and **pink encrustations** (perfect). All forms occur on main stems and branches.

Infection is believed to occur through the lenticels. Dispersal occurs by wind dissemination of the two spore stages and the mycelium.

Detection
Presence of dead apical shoots, epicormic shoots below canker, mycelium and spore stages.

Treatment
No eradicative treatment is known.

For further reading, see pages 63 and 64.

Fig. 32. Terminal shoot death above the canker caused by *Corticium salmonicolor*. (Dr J.K. Sharma, Kerala Forest Research Institute, Peechi)

Seiridium stem canker

Cause
Seiridium eucalypti Nag Raj.

Significance
Associated with eucalypt stem and branch cankers and one of the most pathogenic canker fungi in artificial inoculation tests in Australia (Yuan and Old 1995). Infection can cause severe deformation of stems and branches.

Symptoms and signs
Characteristic lenticular lesions which are normally sunken in the centre with some longitudinal cracking (Fig. 33) and with stem swellings around the lesions (Fig. 34). Some lesions girdle more than half the stem circumference. Branches or stems are killed above the lesions.

Fig. 33. (left) Lesion with longitudinal cracking caused by *Seiridium eucalypti.* (Mr Zi Qing Yuan, CSIRO Division of Forestry, Sandy Bay, Tasmania)

Fig. 34. (right) Characteristic stem swelling around a lesion caused by *Seiridium eucalypti.* (Mr Zi Qing Yuan, CSIRO Division of Forestry, Sandy Bay, Tasmania)

Subepidermal fungal fruiting bodies (acervuli) are abundant in the area of lesions or on dead parts of branches. They appear as minute, separate, irregularly shaped, black pustules. Pustules are immersed at first and erupt later, exposing a black mass of conidia (Fig. 35). The conidiomata are stromatic-acervuloid, subepidermal. Conidia are six-celled, cylindric-fusoid, straight or slightly curved, bearing-unbranched appendages at both ends, 22.5 to 35 x 5.5 to 10.5 µm in size. The four intermediate cells are barrel-like to short cylindrical, brown to dark brown, thick-walled, smooth. Apical cells are conical, hyaline, thin-walled, bearing apical appendages, which are tubular, flexuous, 7.5 to 22.5 µm long. Basal cells are inversely conical with a truncate base bearing minute marginal frills. The basal appendages are centric or sometimes un-centric (towards the side of conidia) and 1 to 10 µm long.

Hosts

- natural: only on stems of *E. delegatensis* and *E. regnans* and on leaves of *Eucalyptus* spp.
- experimental: in artificial inoculation tests, it causes severe canker symptoms on *E. botryoides, E. cypellocarpa, E. delegatensis, E. grandis, E. maculata* and *E. saligna.*

Geographical distribution

Found so far as a stem canker pathogen only in Tasmania and on a collection of eucalypt leaves from South Australia (Yuan and Old 1995). The relationship between this fungus and the *Seiridium* complex on *Cupressus* spp. needs investigation.

Biology and transmission

Radial growth rate of colonies at 25°C on culture is ca. 3 mm/day. Symptom development requires about 4 to 6 weeks. Method of transmission is not well understood.

Detection

Characteristic cankers and fruiting bodies. Cultures have a distinct pale salmon colour when grown under fluorescent illumination.

Treatment

No eradicative treatment available.

For further reading, see p. 64.

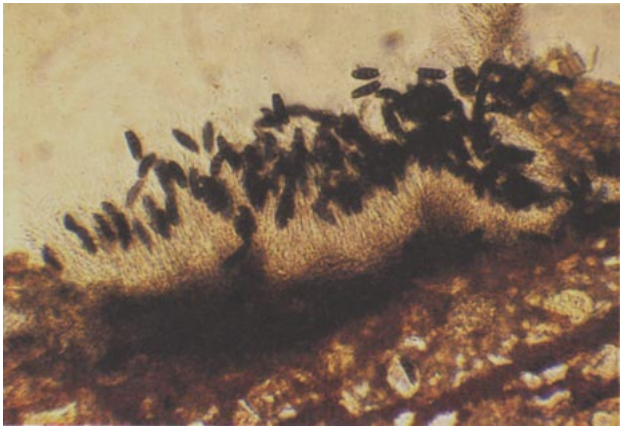


Fig. 35. Acervulus with black masses of conidia of *Seiridium cupressi.* (Mr Zi Qing Yuan, CSIRO Division of Forestry, Sandy Bay, Tasmania)

Fungi associated with seeds and pollen

Seeds

Seeds are the main type of *Eucalyptus* germplasm moved internationally. Seeds can be infected by pathogenic and saprophytic fungi and there is a risk that pathogenic organisms could be introduced to new environments on germplasm. In addition to contamination of seeds, batches of eucalypt seeds often contain chaff (unfertilized ovules) and other fragments of plant material (e.g. leaf debris), which may be colonized by fungi.

Studies of the mycoflora of eucalypt seeds have shown a large number of fungal species associated with seeds (Mittal *et al.* 1990; Mohanan and Sharma 1991; Pongpanich 1990; Sharma and Mohanan 1991; Yuan *et al.* 1990). Although most of these fungi are saprophytes, a number of them are pathogens or potentially pathogenic (see checklist below). Some pathogens may infect seedlings after germination, for example, *Macrophomina phaseolina* (Tassi) Goidanich and *Verticillium albo-atrum* Reinke & Berthold. These common soilborne pathogens were found associated with seeds of *E. grandis* in India (Mohanan and Sharma 1991). Leaf pathogens may also be associated with seeds. In a recent study of seed borne fungi of *E. pellita* in Australia (Yuan *et al.* 1995), several leaf pathogens were found. Notable were Coniella australiensis, a widely recorded leaf pathogen of Eucalyptus spp. in Australia, Thailand and Vietnam (Old and Yuan 1994; Sharma 1994), *Harknessia fumaginea*, a tip blight pathogen of young shoots of Eucalyptus spp. (Sutton 1975), *Pestalotiopsis disseminata* and *P. neglecta* both causing leaf spots of *Eucalyptus* spp. and *Acacia* spp. in Australia, India and Vietnam (Anonymous 1990; Sharma 1994; Yuan 1996) (Table 1).

Pollen

Fungi associated with pollen or floral parts have not been studied to any great degree. Records are limited to a few fungi such as *Ramularia* spp. (Drake 1974), *Colletotrichum* spp. and some yeasts. Capsules containing pollen can be rendered sterile owing to infection by *Ramularia* spp. which grows profusely within capsule chambers and on their surfaces. It seems likely that pollen produced by fertile inflorescences on affected trees could be contaminated with spores of this fungus.

Fungi isolated from stigmata of fertilized ovules by Old (unpublished) include Sporothrix spp. and *Cytospora* spp. Species of both of these genera of fungi have been recorded associated with shoot infections of *Eucalyptus* (Wingfield *et al.* 1993).

There are no records of pests being moved with germplasm in eucalypt pollen. However, viruses of fruit trees and other crops are known to be capable of transmission via pollen (Mink 1992; Childress and Ramsdell 1987). Cherry leaf roll virus has been detected in pollen of birch, *Betula pendula* (Massalski *et al.* 1988). In addition, pollen grains of *Crataegus monogyna* can be contaminated with the fire blight bacterium, *Erwinia amylovora* (Wilson *et al.* 1989) and oil palm by *Fusarium* spp. (Flood *et al.* 1990). There is also evidence for

the transmission of the cadang-cadang viroid of coconut palm via infected pollen (Pacumbaba *et al.* 1994).

Accordingly, it is possible that pathogens and pests of eucalypts could be moved, either borne on floral remnants or as infected pollen. This risk must be assessed when decisions to move pollen between regions or countries are made.

For further reading, see pages 64 and 65.

Table 1. Pathogenic fungi associated with eucalypt seed

Fungus	Host	Country	Reference(s)
Botrydiplodia sp.	*E. grandis*	Uruguay	Mittal *et al.* 1990
Botrytis cinerea	*E. grandis*	India	Mohanan & Sharma 1991
Colletotrichum sp.	*E. citriodora*	India	Sharma & Mohanan 1991
Coniella australiensis	*E. pellita*	Australia	Yuan *et al.* 1995
Curvularia eragrostidis	*E. alba*	Thailand	Pongpanich 1990
	E. pellita	Australia	Yuan *et al.* 1995
Curvularia fallax	*E. pellita*	Australia	Yuan *et al.* 1995
Curvularia inaequalis	*E. citriodora*	India	Mittal *et al.* 1990
Curvularia lunata	*E. camaldulensis, E. grandis, E. tereticornis*	Thailand	Pongpanich 1990
	E. globulus, E. grandis, E, tereticornis	India	Mohanan & Sharma 1991
	E. camaldulensis, E. grandis	Australia	Yuan *et al.* 1990
	E. pellita	Australia	Yuan *et al.* 1995
Curvularia pallescens	*E. alba, E. camaldulensis, E. robusta*	Thailand	Pongpanich 1990
	E. globulus, E. grandis	India	Mohanan & Sharma 1991
Curvularia pubescens	*E. citriodora*	India	Mittal *et al.* 1990
Curvularia senegalensis	*E. camaldulensis, E. nitens*	Australia	Yuan *et al.* 1990
	E. pellita	Australia	Yuan *et al.* 1995
Curvularia verruculosa	*E. grandis*	India	Mohanan & Sharma 1991
Cylindrocladium clavatum	*E. tereticornis*	India	Mohanan & Sharma 1991
Drechslera australiensis	*E. grandis, E. tereticornis*	India	Mohanan & Sharma 1991
	E. pellita	Australia	Yuan *et al.* 1995
Drechslera rostrata	*E. grandis, E. tereticornis*	India	Mohanan & Sharma 1991
Fusarium equiseti	*E. grandis, E. tereticornis*	India	Mohanan & Sharma 1991
	E. deglupta	Philippines	Mittal *et al.* 1990
Fusarium moniliforme	*E. camaldulensis*	Thailand	Pongpanich 1990
	E. grandis, E. tereticornis	India	Mohanan & Sharma 1991
	E. grandis	Uruguay	Mittal *et al.* 1990
Fusarium oxysporum	*E. deglupta*	Thailand	Mittal *et al.* 1990
Fusarium poae	*E. alba*	India	Mohanan & Sharma 1991
Fusarium semitectum	*E. camaldulensis*	India	Mohanan & Sharma 1991
	E. camaldulensis	Egypt	Mittal *et al.* 1990
	E. maideni	Uruguay	Mittal *et al.* 1990
Fusarium solani	*E. citriodora*	India	Mittal *et al.* 1990
Fusarium sp.	*E. camaldulensis*	Australia	Yuan *et al.* 1990
	E. pellita	Australia	Yuan *et al.* 1995
Harknessia fumaginea	*E. pellita*	Australia	Yuan *et al.* 1995
Harknessia hawaiiensis	*E. pellita*	Australia	Yuan *et al.* 1995
Macrophomina phaseolina	*E. grandis, E. tereticornis*	India	Mohanan & Sharma 1991
Macrophomina sp.	*E. camaldulensis*	Thailand	Pongpanich 1990
Pestalotiopsis disseminata	*E. pellita*	Australia	Yuan *et al.* 1995
pestalotiopsis funerea	*E. alba*	India	Mittal *et al.* 1990
	E. grandis	Uruguay	Mittal *et al.* 1990
Pestalotiopsis neglecta	*E. pellita*	Australia	Yuan *et al.* 1995
Phomopsis sp.	*E. citriodora*	India	Mohanan & Sharma 1991
Verticillium albo-atrum	*E. grandis*	India	Mohanan & Sharma 1991
Verticillium sp.	*E. grandis*	Uruguay	Mittal *et al.* 1990

Insects

Many species of insects attack eucalypts in both their natural range and places where they have been introduced. A number of eucalypt-infesting insects are of economic importance and could be moved via transfer of germplasm although the risk is considered to be lower compared with virus diseases, phytoplasmas, bacteria and fungi. Insects which pose the greatest risk of being moved to new locations via germplasm are small insects, especially sap-sucking insects which insert their mouth parts into plant tissue for extended periods. These include members of the insect orders Hemiptera and Homoptera (e.g. aphids, scales, psyllids, lacebugs).

Insects may attack eucalypt seed before it is shed from the capsule (gum nut) or after it falls to the forest floor. Two species of beetles belonging to the genus *Dryophilodes*, and a small wasp, *Megastigmus* sp., lay their eggs in eucalypt flowers. After hatching, the larvae tunnel into the developing seeds and consume their contents (Elliott and deLittle n.d.). These insects are native to Australia and have the potential of causing seed damage should they be introduced into new locations. Tree pollen and tissue cultures generally are at low risk of infestation by insects (Ivory and Tompsett 1994). Rooted cuttings of eucalypts present the greatest hazard of movement of insects. Examples of insects of eucalypts which have the potential for being moved by rooted cuttings are given in the following sections and in Table 2.

Blue gum psyllid
Ctenarytaina eucalypti (Maskell) (Homoptera: Psyllidae)

Significance
Accidentally introduced into a number of countries where it has caused extensive damage to eucalypt plantings. Presently considered to be the most important forest insect pest in Portugal.

Damage
Distortion, wilting of foliage, mostly at the tips, followed by leaf drop. Dieback of twigs and branches can occur during heavy infestations and young plants may have reduced growth due to foliage loss. Nymphs and adults excrete honeydew which provides a medium for growth of sooty mould. Nymphs exude filaments of a white, waxy secretion or 'lerp' under which they shelter (Fig. 36).

Adults are 1.5 to 2 mm long, with pairs of membranous, greyish-white wings which are held roof-like over the body when the insect is at rest. General body colour is dark purple, but transverse yellow bands occur on the upper and lower surfaces of the abdomen and on the under side of the head and thorax. Nymphs are pale yellow with dark patches of purple (Fig. 37).

Hosts

E. globulus, E. maideni, E. nitens and *E. gunnii* (Elliott and deLittle n.d.).

Geographical distribution

Native to Australia. Accidentally introduced into New Zealand during the late 1800s but now causes little damage (Zondag 1982). More recently, it became established on *E. globulus* and *E. maideni* plantings in Portugal and Spain (Goes 1977). Its occurrence in Burundi, Tanzania and Ethiopia has also been confirmed (CABI 1993).

Biology

Eggs are laid in masses near the developing buds of host plants. Adults and nymphs feed by sucking plant juices. All life stages may be found throughout the year. Adults are strong fliers and nymphs may be dispersed by air currents. This insect could be transmitted via rooted cuttings.

Detection

Presence of insects, waxy filaments or lerps and characteristic damage on new foliage.

Treatment

Destroy infested germplasm.

For further reading, see pages 65 and 66.

Fig. 36. (above) *Eucalyptus* shoot with psyllid colony. (Dr H.Elliot, Forestry Tasmania, Hobart)

Fig. 37. (right) Adults and last-stage nymphs of the blue gum psyllid, *Ctenarytaina eucalypti*, with wax exudate. (CSIRO, Division of Entomology, Canberra; previously published in CSIRO Identification Leaflets No. 12)

Eucalyptus fungus gnat
Bradysia coprophila (Diptera: Sciaridae)

Significance
The most important pest of eucalypt seedlings in southeastern Brazil. Responsible for the loss of millions of seedlings.

Damage
Cuttings fail to sprout and die. There are patches of discolouration on the bark of cuttings underneath which clusters of white, legless larvae can be found (Fig. 38).

Hosts
At present, only *E. urophylla* has been attacked but insects of this family are normally polyphagous.

Geographical distribution
Brazil.

Biology
Eggs are laid under the bark of cuttings and larvae feed in the cambium. Adults (Fig. 39) tend to congregate in organic material in areas where eucalypt seedlings are produced.

Detection
Patches of discolouration on the bark surface of cuttings and colonies of three to five larvae under the discoloured patches.

Treatment
Destroy infested germplasm.

Fig. 38. (above) Larvae of *Bradysia coprophila.* (Dr J.C. Zanuncio, Universidade Federal de Vicosa, Vicosa)

Fig. 39. (right) Adult of *Bradysia coprophila.* (Dr J.C. Zanuncio, Universidade Federal de Vicosa, Vicosa)

Blue gum chalcid
Rhicnopeltella eucalypti Gahan
(Hymenoptera: Chalcidoidea: Eulophidae)

Significance
One of the most important insect pests of *E. globulus* in New Zealand where it has been introduced. Repeated attacks can lead to loss of foliage from terminal branches and, in the case of heavy infestations, large limbs. This may result in tree mortality.

Damage
Formation of galls on twigs and foliage of host plants. Galls on foliage are small 'pimple' galls which are well separated from one another. Young growth has a gnarled appearance following repeated attacks. Twig galls can cause tissues to split and destroy the cambium.

Hosts
E. globulus and other species which have a similar succulent growth.

Geographical distribution
Native to Australia. Introduced into New Zealand where it now occurs wherever suitable host plants occur.

Biology
Adults are small black wasps, 1.0 to 1.5 mm long. Larvae are minute, white, legless grubs which are found within galls on host plants. Larvae pupate within the galls and adults emerge through a hole that they cut to the surface. Egg-laying occurs soon after adult emergence. Eggs are laid in twigs, midribs of leaves or actual leaf blades. There is generally one generation per year but two generations have also been reported in New Zealand. Could be transmitted via cuttings.

Detection
Presence of characteristic galls on twigs.

Treatment
Destroy material which is believed to be infested.

For further reading, see p. 66.

Gum tree scale
Eriococcus coriaceus Maskell (Homoptera: Coccoidea: Eriococcidae)

Significance
Sucks the sap of eucalypts and may cause dieback of branches and even death of trees. Photosynthesis may be affected when leaves are covered with sooty mould growing on the honeydew excreted by the insects. This insect caused severe damage to eucalypt plantings in New Zealand during the early 1900s before biological control agents were introduced (FAO 1979).

Damage
Presence of scale insects and sooty moulds on leaves and twigs (Fig. 40). The female scales are enclosed in a rounded felted sac, 2 to 4 mm long, varying in colour from yellowish to dark brown (Fig. 41). Sacs may be packed so closely together that stems and twigs may be entirely covered for several centimeters.

Hosts
A wide range of *Eucalyptus* species.

Geographical distribution
Native to Australia, introduced and established in New Zealand (Zondag 1977).

Fig. 40. Colonies of gum tree scale, *Eriococcus coriaceus.* (Dr H. Elliot, Forestry Tasmania, Hobart)

Biology
Adult females are wingless, brown in colour, about 1.7 mm long and enclosed in a protective sac. Squashing of adult scales produces a reddish liquid. Each female lays several hundred eggs which hatch into red nymphs or 'crawlers' and emerge through the top of the sac, move over the surface of the tree and can be dispersed by winds over long distances. Nymphs settle on branches or foliage, insert their sucking mouth parts and begin to feed. They also secrete wax threads under which they live. Both nymphs and adults secrete copious amounts of honeydew. A related species is *Eriococcus confisus.*

There are least four generations per year in southern Australia and all stages can be found throughout the year. The number of generations in New Zealand is unknown.

Could be moved on rooted eucalyptus cuttings.

Detection
Presence of scale insects, protective sacs and sooty mould on foliage and twigs.

Treatment
Destroy germplasm suspected to be infested.

For further reading, see p. 66.

Fig. 41. Females of *Eriococcus coriaceus.* (CSIRO, Division of Entomology, Canberra; previously published in CSIRO Identification Leaflets No. 10)

Cottony cushion scale
Icerya purchasi Maskell (Homoptera: Margarodidae)

Significance
Principally a pest of citrus, other fruit trees, tea and coffee. In forestry it is occasionally injurious in nurseries where it causes stunting of seedlings and transplants.

Damage
Insects are easily recognized by their conspicuous, fluted egg sacs which are often more than twice as long as the reddish or yellowish body of the adult.

Hosts
Insect has a wide range of hosts including *Eucalyptus* spp. Other forest species include Acacia spp. (major pest of *A. mearnsii), Cassia spp., Casuarina equisetifolia, C. suberosa, Delonix regia, Juglans regia, Mangifera indica, Morus alba, Pinus radiata, Pinus roxburghii* and *Pseudotsuga menziesii.*

Geographical distribution
Native to Australia where it is of little importance. Now widely distributed in the tropics and milder parts of temperate zones. Reported on *Eucalyptus* spp. in Angola, India and Malawi (Browne 1968; FAO 1979).

Biology and transmission
This insect is a functional hermaphrodite. Each mated individual may produce hundreds of offspring. In southern Europe there are two generations per year with all stages present at the onset of winter. During mild winters there may be five generations in 2 years. In New Zealand, there are two generations a year with overwintering by immature nymphs. This insect could be spread by rooted cuttings.

Detection
Presence of large, conspicuous scale insects on branches.

Treatment
Destroy infested germplasm.

For further reading, see p. 66.

Table 2. Some additional insects of *Eucalyptus* spp. which have the potential of being transmitted via germplasm

Order/Family	Species	Natural range	Areas of introduction	Portion of tree attacked	Economic importance and reference
Hemiptera (true bugs) Miridae	*Helopeltis schoutedeni* Reuter	Tropical East and West Africa	None	Foliage and young shoots	Caused severe damage to eucalypt plantings in the Congo beginning in 1984 (Lavabre 1987)
Homoptera (aphids and scales) Psyllidae	*Blastopsylla occidentalis* Taylor	Australia	California and Hawaii, USA; New Zealand	Foliage and shoots	Undetermined (CABI 1994)
	Cardiaspina squamulata	Australia	None	Foliage	Develops into outbreaks on *E. viminalis* (Elliot and deLittle, n.d.)
Hymenoptera (bees and wasps) Chalcidae	*Megastigmus* spp.	Australia	None	Seeds	Minor seed pests in Australia (Elliot and delittle, n.d.), similar damage reported from Greece (FAO 1979)

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Comments on Technical Guidelines for the Safe Movement of *Eucalyptus* Germplasm

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