Woody root and stem rots of living trees

Causal organisms

Several species within the Class Basidiomycotina (Basidiomycetes), which encompasses fungi with sexually-produced spores borne on macroscopic fruiting structures bearing gills, pores or smooth hymenial surfaces. Important pathogens include species of *Armillaria*, *Ganoderma* and *Phellinus,* especially *P. noxius* (Corner) G.H. Cunn. These fungi invade woody roots and can gain access to butts and stems of trees via this route, in addition to infecting above-ground stems and branches. Several other genera can invade stems through wounds and cause heart rots of standing trees. Their importance in eucalypt plantations in South-East Asia, however, is probably slight as rotations are usually less than ten years and heart rots are unlikely to be extensive in such young trees.

Host range

These fungi have very wide host ranges including eucalypts, acacias and other species grown in forestry plantations. *Ganoderma* species are also important pathogens of rubber, oil palm and other plantation species, and *P. noxius* causes brown root rot of many woody hosts throughout the tropics (Ivory 1996).

Known distribution

Armillaria luteobubalina Watling and Kile is the most damaging of the four *Armillaria* species recorded on *Eucalyptus* and *Corymbia* spp. in Australasia (Kile 2000), but this fungus is indigenous to southern and eastern Australia and has not been found on other continents. For the region of interest of this manual, there are records of *Armillaria* spp. causing disease of *Eucalyptus* in Papua New Guinea (Arentz and Simpson 1989) on *E. grandis*, *E. globulus* ssp. *bicostata* and *E. robusta,* and causing death of *E. grandis* on high altitude sites in northern Sumatra (Wingfield unpublished).

Ganoderma species are commonly recorded as root and stem rot pathogens of plantations in South-East Asia (Figs 89–90) and are particularly important in acacia plantations (Old *et al.* 2000). *Ganoderma* spp. have been reported as root rot pathogens of *Eucalyptus* in southern Africa (Masuka and Nyoka 1995), India (Bakshi 1974, 1976), and more widely as agents of heart rot. Kile (2000), however, does not list any such disease records for South-East Asia. *Ganoderma philippii* (Bresad. & P.Henn) Bresad is regarded as a cause of root rot of acacias in Sumatra, Indonesia, where large areas are planted with *A. mangium*. *Ganoderma* root rot is also important on a wide range of crops in Malaysia including rubber, tea cocoa and oil palms (Varghese and Chew 1984). The observation of root rot patches in a plantation of *E. pellita* near Pekanbaru, Sumatra, with *Ganoderma* fruiting on recently-dead trees suggested that this fungus was the cause of *Eucalyptus* deaths (Old personal observation). *Phellinus noxius* is pan-tropical in distribution (Figs 92, 93) and Ivory (1996) lists *Corymbia citriodora* and six *Eucalyptus* species as hosts of this pathogen but these observations were made in Oceania and not South-East Asia.

Symptoms

Root rot is regarded as a major problem for the cultivation of exotic acacia plantations, especially in Indonesia and Malaysia (Lee 1997, 2001) and information on symptoms, pathology, impact and control are provided in Old *et al.* (2000). Outbreaks of rot of woody roots and invasion of eucalypt stems by basidiomycete fungi in South-East Asia are few. Etiology at the plantation and individual tree levels, however, are similar for these pathogens, which often have wide host ranges. The brief description provided below is mainly based on experience with other host/pathogen combinations.

Root rot disease is characterised by expanding patches of dead and dying trees with the most severely affected trees at the centre and trees with early symptoms at the periphery. The foliage of affected trees usually becomes paler green and dull in appearance with reduced leaf size and eventual leaf shedding. Crown dieback commences with flattening of the normally conical apex characteristic of rapidly growing *Eucalyptus,* and death of fine branches. In common with other root diseases, partial crown recovery through the formation of epicormic shoots may be observed, but this will be short-lived and death eventually follows. Gaps are created in the stand and the combination of gaps and root rot predisposes trees to wind-throw.

Root rots of forest trees and plantations can be partly distinguished based on the appearance, especially colour, of infected roots and the fungal structures associated with them. These are: red root disease (associated with *Ganoderma* infection), brown root rot (caused by *P. noxius*) and the less common white root rot.

Roots affected by red root rot are covered by a reddish-brown fungal crust, visible after washing clean of adhering soil. A white mottling pattern is evident on the underside of the infected bark. Although many *Ganoderma* spp.*,* especially when associated with heart rot of large standing live or dead trees form conspicuous fruiting bodies (Figs 89–91), these may be absent from disease foci in fast-grown short-rotation plantations. In other instances fruiting bodies can be found on dead or dying trees near the centre of patches of diseased trees.

Brown root rot is described in detail by Ivory (1996), and this account applies to pathogenic infections of all hosts of *P. noxius*. The most characteristic sign is a thick brown mycelial mantle on the surface of woody roots that often extends to the above-ground stem (Fig. 92). These hyphal mats exude sticky fluid which causes soil particles to adhere. The fungus invades the main stem where it causes a white pocket rot with a characteristic honeycomb appearance (Fig. 93). Although fruiting bodies of *Phellinus* spp. are common on large standing or fallen trees in forests, they are rarely found in exotic plantations.

White root rot caused by *Rigidoporus lignosus* (Klotzsch) Imazeki is a very important disease of plantation crops in tropical South-East Asia, including rubber, oil palm and other crops (Nandris *et al.* 1987). Although a *Rigidoporus* species has been found to be an important decay fungus of mining timbers including *E. tereticornis* (Sharma *et al.* 1988), white root rot does not appear to have been formally reported in eucalypts plantations.

Pathology

Root rot problems in exotic plantations typically occur on sites recently cleared of natural or secondary native forest. The causal fungi rarely cause widespread damage in native forests, disease patches remaining small. Population studies of infected stands have shown that each patch is colonised by a unique clonal genotype (Ivory 1996). Vegetative spread appears to be limited by natural equilibria that are not well understood. Clearing of sites for plantation establishment leaves large stumps and woody root masses that subsequently act as inoculum sources for many years. From these food bases, the root pathogens spread into the newly established plantations and initiate disease foci, which can continue to enlarge throughout the first rotation and possibly into successive rotations. The degree of damage will depend on the susceptibility of the exotic plantation species and the build-up and persistence of the inoculum base in the woody residues and infected trees.

Impacts

The apparently low incidence and minor importance of these pathogens of woody roots in eucalypt plantations in South-East Asia is probably related to the common practice of establishing such plantations on sites which were cleared of native forest many years ago. This situation could change, for example if eucalypts are planted on former rubber, tea, coffee or cacao plantation sites, in response to market trends or to diversify income of rural populations. Under such circumstances red, brown and white root rots could emerge as significant problems for *Eucalyptus* cultivation. These fungi, in common with many related basidiomycetes, have the capacity to invade the heartwood of standing trees and cause decay. As eucalypts are primarily grown, in South-East Asia, on very short rotations, heart rot is not currently a significant issue. If in future *Eucalyptus* is grown for structural uses, then wood decay in standing trees could become important. Measures would then be necessary to achieve the necessary product quality by minimising access of decay fungi to stems through wounds.

Control

No control measures are appropriate as these diseases are seldom reported in *Eucalyptus* plantations. If problems emerge in the future responses should be modelled on experience gained with exotic acacia plantations (Old *et al*. 2000).

References

Arentz, F. and Simpson, J.A. 1989. Root rot diseases of exotic plantation tree species in Papua New Guinea. *In*: Morrison, D.J. (ed). Proceedings of the 7th International IUFRO Conference on Root and Butt Rots, Vernon and Victoria, British Columbia, 1988, 83–91. Forestry Canada, Victoria, British Columbia.

Bakshi, B.K. 1974. Control of root diseases in plantations in reforested stands (with special reference to Khair, Sissoo, *Eucalyptus*, etc.). Indian Forester 100:77–78.

Bakshi, B.K. 1976. Forest pathology: principles and practice in forestry. Forest Research Institute Press, Dehra Dun.

Ivory, M.H. 1996. Diseases of forest trees caused by the pathogen *Phellinus noxius*. *In*: Raychaudhuri, S.P. and Maramarosch, K. (eds). Forest trees and palms, disease and control, 111–133. Oxford and IBH Publishing Co Pty Ltd, New Delhi/Calcutta.

Kile, G.A. 2000. Woody root rots of eucalypts. *In*: Keane, P.J., Kile, G.A., Podger, F.D. and Brown, B.N. (eds). Diseases and pathogens of eucalypts, 293–306. CSIRO, Collingwood, Victoria.

Lee S.S. 1997. Diseases of some tropical plantation species in Malaysia. *In*: Old, K.M., Lee, S.S. and Sharma, J. K. (eds). Diseases of tropical acacias. Proceedings of an International Workshop held at Subanjeriji, (South Sumatra), 28 April–3 May 1996, 53–61. Center for International Forestry Research, Bogor, Indonesia.

Lee, S.S. 2001. The current status of root diseases of *Acacia mangium* Willd. *In*: Flood, J., Bridge, P. and Holderness, M. (eds). *Ganoderma* diseases of perennial crops, 71–80. CABI, Wallingford.

Masuka, A.J. and Nyoka, B.I. 1995. Susceptibility of *Eucalyptus grandis* provenances to a root rot associated with *Ganoderma sculptrutum* in Zimbabwe. European Journal of Forest Pathology 25:65–72.

Nandris, D., Nicole, M. and Geiger, J.P. 1987. Root rot diseases of rubber trees. *Plant Disease* 71: 298–306.

Old, K.M., Lee, S.S., Sharma, J.K. and Yuan, Y. 2000. A manual of diseases of tropical acacias in Australia, South-East Asia and India. Center for International Forestry Research, Bogor, Indonesia. 104p.

Sharma, S.N. Narayanappa, P. and Rao, P.V.K. 1988. Behaviour of preservative treated timber in mining use. Journal of the Timber Development Association of India 34: 23–33.

Varghese, G. and Chew, P.S. 1984. Pathological significance and problems of control of *Ganoderma* spp. parasitic to plantation crops in Malaysia. *In*: Kile, G.A. (ed.) Proceedings of the Sixth International Conference on Root and Butt Rots of Forest Trees, 297–304. Melbourne, Australia. IUFRO Working Party S 2.06.01.

Fig. 89

Fig. 90

Fig. 91

Fig. 92

Fig. 93

Figure 89. *Ganoderma* sp. growing on infected stem of *Acacia auriculiformis*, Sri Lanka

Figure 90. *Ganoderma* fruiting bodies on rainforest tree species, Indonesia

Figure 91. *Ganoderma* sp. on rainforest tree species, Australia

Figure 92. *Phellinus noxius* with spreading brown mycelium which gives the disease the name 'brown root rot'. Photo S.S. Lee.

Figure 93. Stem shown in Fig. 92 with bark removed to show honeycomb appearance of white pocket stem rot. Photo S.S. Lee.

Nursery diseases

Healthy planting stock is a necessary requirement for the success of forest plantations, regardless of the species being grown. The design, construction, operation and maintenance of *Eucalyptus* nurseries in South-East Asia is rapidly changing in pace with the increase in plantation area and the adoption of new technologies, especially clonal forestry. Nursery techniques include simple operations using plastic bags containing seedlings in non-sterile soil, placed on the ground (Fig. 94); facilities with selected trees providing large numbers of cuttings propagated on a large scale (Fig. 95); and enterprises where plantlets, grown under sterile conditions from tissue-cultured mother plants, are propagated. It is expected that companies in South-East Asia will invest in large-scale, highly sophisticated propagation facilities with rigorous control of growth conditions such as are found in Brazil and South Africa (Fig. 96).

It is beyond the scope of this manual to provide detailed recommendations for maintaining *Eucalyptus* seedlings or clonal plantlets in a healthy condition prior to planting out. Comprehensive information on nursery practice in developing countries can be found in Quayle and Gunn (1998) and chapters on nursery diseases and their management can be found in Keane *et al.* (2000). Instead a few general principles will be stated and the main characteristics of commonly-encountered problems, namely damping-off, seedling blights, powdery mildew and their causal pathogens, will be discussed. Although some diseases are primarily associated with propagation of eucalypts, other pathogens span boundaries between nurseries and plantations. Several of these, including *Cylindrocladium* spp., *Phaeophleospora* spp. and *Puccinia psidii*, are dealt with elsewhere in this manual.

Nurseries, from the most basic to the most sophisticated, grow eucalypt seedlings in containers including polythene bags, single plastic tubes or arrays of tubes, which can be moved as single units. The key feature is that the growing medium surrounding the plant roots is separated from that of neighbouring plants. Provided that the growth medium is initially free from soil-borne pathogens, such containers make it possible to ensure that the impact of any chance contamination can be limited to one or a few individual plants. It is essential to have effective hygiene such as sterilisation of tubes, trays or other equipment that may have been contaminated during prior use.

Incubation of plastic bag containers or tubes on bare ground invites contamination with soil-borne organisms and may impede drainage, which inhibits root growth and favours some pathogens. Raising containers above the ground on benches, preferably constructed of sturdy mesh, is good practice and will greatly reduce these risks. If benches are unavailable, containers should be set on beds of freely draining stone chips or gravel, and opportunities taken to replace or partially sterilise this matrix on a systematic basis to reduce the build-up of pathogens.

Airborne contamination of seedlings by pathogenic fungi occurs in even the best-managed nursery. The regular watering and high humidity required for rapid early growth of seedlings, cuttings or tissue-cultured plantlets provide ideal conditions for fungal proliferation. The nursery manager's skills and experience are needed to maintain the balance between these conflicting influences, and to identify the time when any application of fungicide is warranted. Other hygiene measures include ensuring that water supplies are free from water-borne pathogens, and reduction of sources of airborne spores, for example by efficient disposal of diseased or otherwise discarded plant material.

Eucalyptus cuttings are subject to attack by many of the same pathogens that attack seedlings, with the additional problem of maintaining the clonal hedges or other forms of foundation stock in a healthy condition. As propagation inevitably includes wounding of mother plants, strict hygiene is essential when collecting shoots, including cleaning and surface sterilisation of cutting tools. The maintenance of clonal hedges in a juvenile condition can prolong their susceptibility to pathogens, e.g. *Puccinia psidii*. Infection of clone banks by pathogens can reduce their viability and also provides a means for disseminating pathogens to non-infested areas via contaminated planting stock.

References

Keane, P.J., Kile, G.A., Podger, F.D. and Brown, B.N. (eds). 2000. Diseases and pathogens of eucalypts. CSIRO, Collingwood, Victoria. 565p.

Quayle, S. and Gunn, B. 1998. Tree nursery manual for Namibia. Directorate of Forestry, Namibia Australia Forestry Project, CSIRO. Canberra. 109p.

Fig. 94

Fig. 95

Fig. 96

Figure 94. Nursery south of Hue City, central Vietnam. Seedlings being grown in polythene bags placed on the ground

Figure 95. Clonal *Eucalyptus camaldulensis* being raised on a large scale in western Thailand

Figure 96. Advanced tree propagation facility in Sao Paulo State, Brazil. Clonal cuttings being grown under conditions of controlled temperature and humidity

Damping-off

Disease

Damping-off

Causal organisms

The organisms most commonly associated with damping-off in eucalypt nurseries are *Botrytis cinerea* Pers., *Cylindrocladium* spp., *Pythium* spp., *Phytophthora* spp., and *Rhizoctonia solani* Kühn.

Host range

Damping-off affects many host species including *Eucalyptus* spp. and is caused by a number of different pathogens sharing the capacity to exist in soils or other media in which seedlings and cuttings are grown. The pathogens can attack seedlings pre- or post-emergence and their impact is greatly heightened by poor nursery practice, especially lack of hygiene and over-watering. All *Eucalyptus* species are potential hosts to damping-off fungi, although susceptibility undoubtedly varies. For example, Podger and Batini (1971), testing seedlings for susceptibility to *P. cinnamomi*, demonstrated that members of the subgenus *Monocalyptus* were generally more susceptible to disease than those classified in the subgenus *Symphyomyrtus*.

Known distribution

Damping-off probably occurs wherever eucalypts are nursery-grown on a large scale. Published information from tropical and subtropical South-East Asia on causal organisms and their etiology is limited, with the exception of the Philippines (Kobayashi and De Guzman 1988, De Guzman *et al*. 1991). Most reports from these latitudes emanate from India (Sharma *et al*. 1984, Sharma and Mohanan 1991), Australia (Brown and Wylie 1991) and Brazil (Ferreira and Muchovej 1991). The few published reports, however, indicate that the pathogens listed above are also responsible for damping-off of eucalypts in Indonesia, Papua New Guinea (Arentz 1991), Thailand (Pongpanich 2002) and Vietnam (Mao 1996).

Symptoms

Damping-off is often separated into pre- and post-emergence phases although the same groups of fungi are usually responsible. The pre-emergence phase results in poor seedling emergence due to killing of the seed before germination or by invasion of seedling radicles and hypocotyls. The post-emergence phase occurs soon after seedling emergence, when succulent hypocotyls and stem tissues are not lignified and are especially vulnerable. Stems become water soaked due to invasion of the tissues and cell maceration, and the plants fall over. This sequence of events typifies infection by *Pythium* species, which are commonly but not exclusively responsible for the disease. Damping-off in its broadest sense includes disease of very young, non-lignified seedlings associated with invasion by any of the above-listed pathogens. *Rhizoctonia* and *Cylindrocladium* and *Botrytis* species are especially notable, due in part to their ready identification to genus by non-specialists, compared to the more difficult *Pythium* and *Phytophthora* species.

Pathology

Damping-off is the most common disease of forest nurseries (Brown and Ferreira 2000). The causal pathogens are soil-borne and are able to grow or survive as dormant propagules in soil, compost and other nursery potting media. These fungi are commonly endemic in nurseries and management is aimed to minimise their effects as far as possible. Seedlings rapidly become resistant to damping-off because of secondary thickening and lignification of stem tissue, but these same fungi can attack either roots or aerial parts and cause seedling blights. *Cylindrocladium* spp. are of particular importance in the tropics and subtropics as seedling blight and leaf blight pathogens. Plants remain susceptible to these latter fungi throughout their time in the nursery and even after out-planting is completed.

Excessive moisture in growing media due to over-watering, high humidity, high seedling density and high organic content of growth media are the main factors contributing to initiation and spread of damping-off by *Pythium* spp. *Rhizoctonia* spp. are less demanding with regard to soil moisture conditions and can cause disease under a broader range of environmental regimes (Vaartaja and Morgan 1961). *Phytophthora* spp., especially *P. cryptogea* and *P. cinnamomi*, are major nursery pathogens in Australasia (Figs 97, 98) and are also associated with tree deaths in plantations and native forests. Old and Dudzinski (2000), however, found few significant reports of nursery diseases attributed to this genus in Asia. An exception is Papua New Guinea, where Arentz (1991) considered *Phytophthora* spp. to be the most serious pathogens in nurseries.

Impacts

Damping-off becomes apparent as irregular patches of dead and dying seedlings, either in seedling trays or arrays of plants pricked out or sown directly into containers. In well-managed, hygienic nurseries, the disease is almost absent. Under conducive environmental conditions, however, the disease can be very serious resulting in high mortality, economic loss and disruption to planting programmes. Once the infection starts, it can spread very quickly and kill a large number of seedlings within a few days.

Vegetative propagation from cuttings of tissue-cultured plantlets is increasingly important in plantation forestry. The term 'damping-off' is not strictly applicable to cuttings, as the stem tissue is somewhat lignified. Nevertheless, similar suites of fungal pathogens thrive in clonal nurseries, and shoot blights caused by *Botrytis cinerea*, *Cylindrocladium* spp. and *Rhizoctonia solani* are major problems.

Control and management

Damping-off can be managed effectively by following appropriate nursery practices (Brown 2000). Ferreira and Muchovej (1991) provide a detailed account of a seedling management system developed in Brazil which reliably controls damping-off and shoot blight. The main features are:

1. use of pathogen-free seed;
2. direct sowing into conical plastic tubes, containing pathogen-free growing media, which are suspended in racks about 1 m above the ground;

3. thinning seedlings to one per tube as soon as possible (before 7 cm in height);
4. use of pathogen-free water;
5. culling seedlings for uniform height with removal of diseased or dead seedlings;
6. when such cultural controls fail to prevent disease, fungicide sprays are applied at intervals of 3–4 days over 14 days, using paired combinations of thiabendazole, captan, benomyl and thiram.

When chemical treatment becomes necessary to control outbreaks of damping-off, drenching with fungicide in place of normal watering has been found to be very effective. An alternative is the use of foliar sprays, the choice of application method being determined by the selected chemical and available facilities. Sharma and Mohanan (1991) investigated a wide range of fungicide combinations for nursery diseases including damping-off and seedling blights. Recommended treatments included combinations of captan, carbendazim, copper oxychloride and quintozene. As the optimum fungicide treatment depends partly on the causal agent, Brown (2000) has listed chemicals suitable for the control of a wide range of fungal pathogens. After fungicidal treatment, control of watering to prevent excessive soil moisture helps to check further spread of the disease.

References

Arentz, F. 1991. Forest nursery diseases in Papua New Guinea. *In*: Sutherland, J.R. and Glover, S.G. (eds). Diseases and insects in forest nurseries. Proceedings of the First Meeting of IUFRO Working Party S2.07-09, Victoria, British Columbia, Canada, 22–30 August 1990, 97–99. Information Report BC-X-331. Forestry Canada, Pacific and Yukon Region, Pacific Forestry Centre, Victoria British Columbia.

Brown, B.N. 2000. Management of disease during eucalypt propagation. *In*: Keane, P.J., Kile, G.A., Podger, F.D. and Brown, B.N. (eds). Diseases and pathogens of eucalypts, 487–517. CSIRO, Collingwood, Victoria.

Brown, B.N. and Ferreira, F.A. 2000. Disease during propagation of eucalypts. *In*: Keane, P.J., Kile, G.A., Podger, F.D. and Brown, B.N. (eds). Diseases and pathogens of eucalypts, 119–151. CSIRO, Collingwood, Victoria.

Brown, B.N. and Wylie, F.R. 1991. Diseases and pests of Australian forest nurseries past and present *In*: Sutherland, J.R. and Glover, S.G. (eds). Diseases and insects in forest nurseries. Proceedings of the First Meeting of IUFRO Working Party S2.07-09, Victoria, British Columbia, Canada, 22–30 August 1990, 3–15. Information Report BC-X-331. Forestry Canada, Pacific and Yukon Region, Pacific Forestry Centre, Victoria British Columbia.

De Guzman, E.D., Militante, E.P. and Lucero, R. 1991. Forest nursery diseases and insects in the Philippines. *In*: Sutherland, J.R. and Glover, S.G. (eds). Diseases and insects in forest nurseries. Proceedings of the First Meeting of IUFRO Working Party S2.07-09, Victoria, British Columbia, Canada, 22–30 August 1990, 101–104. Information Report BC-X-331. Forestry Canada, Pacific and Yukon Region, Pacific Forestry Centre, Victoria British Columbia.

Ferreira, F.A. and Muchojev, J.J. 1991. Diseases of forest nurseries in Brazil. *In*: Sutherland, J.R. and Glover, S.G. (eds). Diseases and insects in forest nurseries. Proceedings of the First Meeting of IUFRO Working Party S2.07-09, Victoria, British Columbia, Canada, 22–30 August 1990, 17–23. Information Report BC-X-331. Forestry Canada, Pacific and Yukon Region, Pacific Forestry Centre, Victoria British Columbia.

Kobayashi, F.A. and De Guzman, E.D. 1988. Monograph of tree diseases in the Philippines with taxonomic notes on their associated organisms. Bulletin of the Forestry and Forest Products Research Institute 351:99–200.

Mao, T.V. 1996. Impact of diseases in nurseries, plantations and natural stands in Vietnam. *In*: Nair, K.S.S., Sharma J.K. and Varma R.V. (eds). Impact of diseases and insect pests in tropical forests. Proceedings of IUFRO Symposium 23–26 November 1993, 20–27. Kerala Forest Research Institute, Peechi, Kerala.

Old, K.M. and Dudzinski, M.J. 2000. *Phytophthora* in forests and native vegetation in Australasia and eastern Asia. *In*: Hansen, E.M. and Sutton, W. (eds). Phytophthora diseases of forest trees. Proceedings of the First International Meeting on Phytophthoras in Forests and Wildland Ecosystems. Grants Pass, Oregon USA, 30 August–3 September 1999, 14–22. Oregon University Press, Corvallis, Oregon.

Podger, F.D. and Batini, F. 1971. Susceptibility to *Phytophthora cinnamomi* root rot of thirty-six species of *Eucalyptus*. Australian Forest Research 5:9–20.

Pongpanich, K. 2002. Diseases of *Eucalyptus* in Thailand and options for reducing their impact. *In:* Hutacharern, C., Napompeth, B., Allard, G. and Wylie, F.R. (eds). Pest management in tropical forest plantations. Proceedings of the IUFRO/FAO Workshop 25–29 May 1998, Chanthaburi, Thailand, 47–52. FORSPA Publication No 30/2002.

Sharma, J.K. and Mohanan, C. 1991. Epidemiology and control of diseases of *Eucalyptus* caused by *Cylindrocladium* spp. in Kerala. Research Report No. 70. Kerala Forest Research Institute, Peechi, Kerala. 155p.

Sharma, J.K., Mohanan, C. and Florence, E.J.M. 1984. Nursery diseases of *Eucalyptus* in Kerala. European Journal of Forest Pathology 14:77–89.

Vaartaja, O. and Morgan, G.A. 1961. Damping-off etiology especially in forest nurseries. Phytopathology 51:35–42.

Fig. 97

Fig. 98

Figure 97. Asexual fruiting structure (sporangium) of *Phytophthora cinnamomi* which discharges many small motile spores with the ability to spread in irrigation water or in well-watered soil, bar = 20 µm

Figure 98. Sexual spore of *P. cinnamomi*, thick-walled for prolonged survival and with the potential for sexual recombination, although this may be a rare event, bar = 13 µm

Web blight

Disease

Web blight

Causal organism

Rhizoctonia solani Kühn, teleomorph *Thanatephorus cucumeris* (Frank) Donk. (Mordue 1974) is the cause of a particularly damaging seedling blight occurring primarily in humid regions of the tropics. The genus *Rhizoctonia* represents a morphological group, being the mycelial state of several basiomycete fungal genera such as *Thanatephorus* and *Ceratobasidium*. *Rhizoctonia* spp. are characterised by sterile mycelia with rather wide hyphae (Fig. 99) and wide angled branching. The lateral branches are narrowed and septa occur near the junctions with the main axis of the hyphae (Fig. 100). Isolates identified as *R. solani* are pathogenic to plants, have brown or yellow-pigmented hyphae and often form discrete rounded aggregations of hyphae known as sclerotia. The teleomorphs of individual isolates are often not known and are difficult to produce on artificial media.

Host range

Web blight occurs on a wide range of woody and non-woody hosts including *Acacia* spp., *Albizia lebbek*, *Azadirachta indica*, *Eucalyptus* spp., *Paraserianthes falcataria*, *Melia azedarach*, *Ceiba pentandra*, *Lagerstroemia speciosa*, *Cupaniopsis anarcardioides* and species of bamboo.

Known distribution

Although *Rhizoctonia* is distributed worldwide in temperate and tropical regions and is a damaging nursery pathogen, the disease known as web blight is less commonly reported than damping-off and seedling root rot. Most reports of web blight over the last few decades are from southern India (Sharma *et al*. 1984, Sharma and Sankaran 1991, Mohanan 1996) on *Eucalyptus*, *P. falcataria*, *A. indica* and bamboo. The geographical distribution may relate to the high temperatures and humidity of the humid tropics being especially conducive to the extensive proliferation of aerial mycelium characteristic of web blight.

There are reports of severe damage to *Melia azedarach*, *A. indica* and *A. lebbek* and seedlings of several other tree species in Assam in northern India (Mehrotra 1989 a,b). Other reports of web blight are from Florida (McMillan *et al*. 1994) on *C. anacardioides*, from Virginia on woody ornamental plants (Lambe 1982) and from Japan on *Cupressus macrocarpa* (Hoshi *et al*. 1995). Kobayashi and Oniki (1993) reported *R. solani* causing web blight in Indonesia on chrysanthemum, geranium and *Mentha* spp.

Symptoms

The disease is characterised by the growth of aerial mycelium of *R. solani* which proliferates from infested soil or other nursery growing media, to attack the stems, cotyledons and young leaves of densely spaced seedlings. The strands of mycelium are visible to the naked eye or through a hand lens as webs of hyphae, giving the disease its name. Light brown irregularly-shaped sclerotia form on the mycelial web. Infected seedlings develop water-soaked lesions, wilt and die. If appropriate control measures are not adopted the disease spreads rapidly to adjacent healthy seedlings

Pathology and impacts

Rhizoctonia solani is able to grow as a saprophyte in soil or compost. The sclerotia described above are resistant to biodegradation and allow the fungus to survive in the absence of host plants. The pathogen will commonly be present in non-sterile soil or nursery media without causing significant disease. Excessive moisture due to over-watering and shade, however, coupled with high seedling density and high organic content of growth media, create an environment conducive to web blight and epidemics can occur. Re-use of plastic pots or tubes without sterilisation is not recommended as the fungus can survive on contaminated containers. Impacts on seedling production can be severe, as the disease spreads rapidly.

Control and management

Web blight is more likely to be a problem where seed is sown directly into mother beds or germination trays rather than in nursery operations using plastic tubes or poly-pots. In the event of an outbreak, chemical treatment can become necessary for control. Drenching with carbendazim, or Terraclor® (quintozene) applied in place of normal watering, is reported to be effective (Mohanan 1996, Sankaran *et al*. 1996) After treatment, control of watering to prevent excessive soil moisture helps to check further spread of the disease.

References

Hoshi, H., Horie, H., Ishizuka, R. and Sato, S. 1995. Web blight of Monterey cypress is caused by *Rhizoctonia solani*. Proceedings of the Kanto-Tosan Plant Protection Society 42:133–136.

Kobayashi, T. and Oniki, M. 1993. Diagnostic manual for industrial crop diseases in Indonesia. Japan International Cooperation Agency and Research Institute for Spice and Medicinal Crops, Indonesia. 107p.

Lambe, R.C. 1982. Web blight of ornamentals. American Nurseryman 155:105.

McMillan, R.T., Hei, H.V. and Graves, W.R. 1994. First report of web blight caused by *Thanatephorus cucumeris* on *Cupaniopsis anacardioides* in the United States. Plant Disease 78:317.

Mehrotra, M.D. 1989a. Rhizoctonia web blight of *Albizia lebbek* a destructive disease in forest nurseries in India. European Journal of Forest Pathology 19: 382–384.

Mehrotra, M.D. 1989b. Leaf web blight of some hardwood species in Assam and Meghalaya and its control in the nursery. Indian Forester 115:378-384.

Mohanan, C. 1996. Epidemiology and control of rhizoctonia web blight of bamboos. *In*: Nair, K.S.S., Sharma J.K. and Varma R.V. (eds). Impact of diseases and insect pests in tropical forests. Proceedings of IUFRO Symposium 23–26 November 1993, 169–185. Kerala Forest Research Institute, Peechi, Kerala.

Mordue, J.E.M. 1974. *Thanatephorus cucumeris*. CMI Descriptions of Pathogenic Fungi and Bacteria 406. Commonwealth Mycological Institute, Kew, Surrey.

Sankaran, K.V. 1996. Diseases of *Paraserianthes* in Kerala and their possible control measures. *In*: Nair, K.S.S., Sharma J.K. and Varma R.V. (eds). Impact of diseases and insect pests in tropical forests. Proceedings of IUFRO Symposium 23–26 November 1993, 134–142. Kerala Forest Research Institute, Peechi, Kerala.

Sharma. J.K., Mohanan, C. and Florence, E.J.M. 1984. Nursery diseases of *Eucalyptus* in Kerala. European Journal of Forest Pathology 14:77–89.

Sharma, J.K. and Sankaran, K.V. 1991. Epidemiological studies of *Rhizoctonia* web blight of *Albizia falcataria*. Indian Phytopathology 44:201–205.

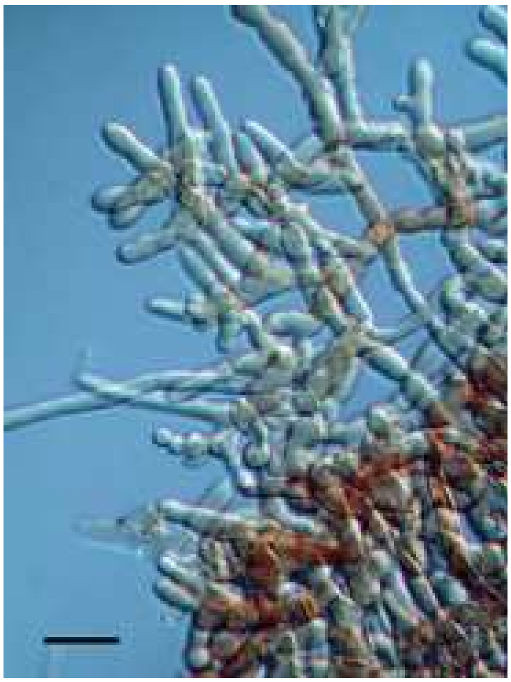

Fig. 99

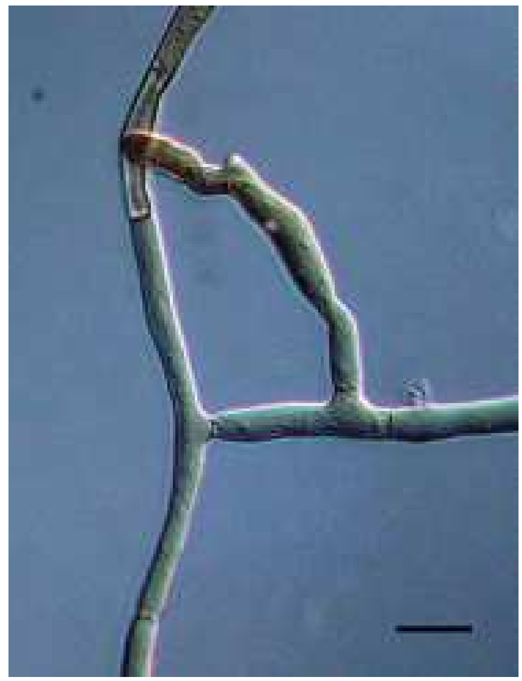

Fig. 100

Figure 99. Stout hyphae of *Rhizoctonia solani*, the cause of web blight, showing characteristic branching and pigmentation, bar = 45 µm

Figure 100. Detail of hypha showing constriction of the branch at the point of right-angle branching, bar = 25 µm

Powdery mildew

Disease

Powdery mildew

Causal organisms

Several species of genera *Erysiphe* and *Sphaerotheca* belonging to the family Erysiphaceae of the order Erysiphales are reported to cause powdery mildews of various eucalypt species.

Due to the absence of the teleomorph stage, powdery mildews on *Eucalyptus* are commonly recorded in various parts of the world as *Oidium* spp., the asexual stages of *Erysiphe* and *Sphaerotheca*. This problem of identification may be resolved in future by DNA sequencing of anamorph collections. Records in which teleomorphs have been associated with powdery mildew on *Eucalyptus* spp. are listed below.

Erysiphe cichoracearum DC. and *Erysiphe polyphaga* Hammarl [= *Erysiphe orontii* Castagne] were found in New Zealand (Boesewinkel 1979, 1981). The former species was also recorded in UK (Gibson 1975) and USA (Gardner and Yarwood 1974, Matheron and Matejka 1992).

Sphaerotheca aphanis (Wallr.) U.Braun [= *S. alchemillae* (Grev.) L.Junell; *Erysiphe alchemillae* Grev.] was reported in New Zealand (Boesewinkel 1979, 1981), *S. macularis* (Wallr.) Jacz. in Germany (Brandenburger 1961) and *S. pannosa* (Wallr.) Lév., the teleomorph of *Oidium eucalypti* Rostr., in Argentina, Australia, Brazil, Denmark, Italy, New Zealand, Poland, Portugal, South Africa and United Kingdom (Grasso 1948, Glasscock and Rosser 1957, Spaulding 1961, Yarwood and Gardner 1972, Gibson 1975, Boesewinkel 1981, Crous *et al*. 1989).

Host range

Powdery mildews have been commonly found on many species of *Eucalyptus*:

Erysiphe cichoracearum on *E. calycogona*, *E. camaldulensis*, *E. campaspe*, *E. cladocalyx*, *E. globulus*, *E. leucoxylon*, *E. leucoxylon* var. *rosea*, *E. microcarpa, E. pauciflora, E. pauciflora* ssp. *niphophila*, *E. platypus*, *E. polyanthemos*, *E. populnea*, *E. porosa*, *E. pulverulenta*, *E. tetragona*, *E. viminalis* and *E. viridis*;

Erysiphe polyphaga on *E. crebra* and *E. moluccana*;

Sphaerotheca aphanis on *E. albens*, *E. cinerea*, *E. crebra*, *E. diversicolor*, *E. grossa, E. megacarpa, E. nutans*, *E. paniculata*, *E. tereticornis* and *E. torquata*;

Sphaerotheca macularis on *E. algeriensis*, *C. citriodora*, *E. cornuta*, *E. diversicolor* and *E. gomphocephala*;

Sphaerotheca pannosa on *E. albens*, *E. camaldulensis*, *E. gunnii*, *E. moluccana*, *E. nitens*, *E. perriniana* and *E. tereticornis*;

Oidium sp. on *E. botryoides*, *E. camaldulensis*, *E. crenulata*, *E. globulus*, *E. globulus* ssp. *maidenii*, *E. gunnii*, *E. muellerana*, *E. perriniana*, *E. tereticornis* and *E. viminalis*.

Known distribution

The disease has been reported on *Eucalyptus* in Argentina, Australia, Brazil, Denmark, Germany, India, Italy, New Zealand, Poland, Portugal, South Africa, UK and USA (Sankaran *et al*. 1995). Formal reports of powdery mildew on *Eucalyptus* spp. in nurseries in South-East Asia are few although Kobayashi (2001) reported that *Oidium* is often prevalent on *Eucalyptus* seedlings in nurseries in the region.

Symptoms

Sphaerotheca pannosa, known as the 'rose mildew' is one of the most common and destructive species causing powdery mildews of a variety of plant hosts. It attacks leaves and young shoots of *Eucalyptus*, producing a thick layer of densely inter-woven white mycelium (Fig. 101) on the surface of leaves and shoots (Crous *et al*. 1989), sometimes causing spotting and malformation of older growth (Gibson 1975, Boesewinkel 1981).

Pathology

Spores of *Oidium* spp. germinate on the surfaces of the leaves producing germ tubes that penetrate the walls of the leaf epidermal cells. The fungus forms absorbing structures known as haustoria through which it obtains nourishment from the host cells. The fungus proliferates over the leaf surfaces, producing abundant conidia (Fig. 102), which result in the powdery white appearance from which the name of the disease is derived. The spores, which are produced successively on specialised hyphae arising from the superficial mycelium (Figs 102, 103), are dispersed by wind to other susceptible hosts, initiating new infections. When the perfect stages are present, small black dots (cleistothecia) are observed immersed in white mycelium layers. The cleistothecia of *Erysiphe* and *Sphaerotheca* have hairlike, unbranched flexuous appendages and contain 1–several asci with eight ascospores.

Impacts

Powdery mildews of *Eucalyptus* rarely occur in plantations, although are commonly encountered in glasshouses and nurseries where they primarily cause leaf distortion and poor growth of seedlings. In Arizona, USA, *Erysiphe cichoracearum* was observed only on young plants of *E. camaldulensis*, *E. cladocalyx*, *E. leucoxylon*, *E. polyanthemos* and *E. viminalis* in greenhouse conditions (Matheron and Matejka 1992). In Tasmania, *Oidium* sp. causes severe nursery problems of susceptible species, such as *E. nitens* and *E. globulus* ssp. *globulus* (Wardlaw and Phillips 1990). In India, powdery mildew causes distortion, necrosis and ultimately leaf fall on eucalypt hybrid seedlings (Sehgal *et al*. 1975).

Control and management

Early recognition and prompt removal of infected plants are important in preventing disease spread and fallen leaves should be destroyed to reduce inoculum potential.

Chemical treatments are seldom necessary, but sometimes the control of powdery mildew relies primarily on the use of fungicides (Wardlaw and Phillips 1990) and can be effected by spraying with a fungicide, such as benomyl, chlorothalonil, triademefon, maneb or zineb (Sehgal *et al*. 1975).

Biological control is an alternative means of management of foliar diseases including powdery mildews, especially in greenhouses. Commercial biocontrol products containing *Trichoderma harzianum* T39, *Ampelomyces quisqualis*, *Bacillus* and *Ulocladium* have been developed for greenhouse crops (Paulitz and Belanger 2001). Foliar sprays with other substances such as JMS Stylet-oil for cucurbit powdery mildew (McGrath and Shishkoff 2000) and nonswelling chlorite mica clay for cucumber powdery mildew (Ehret *et al*. 2001) have been proved to significantly reduce the severity of the disease in greenhouses.

References

Boesewinkel, H.J. 1979. Erysiphaceae of New Zealand. Sydowia 32:13–56.

Boesewinkel, H.J. 1981. A first recording of rose mildew, *Sphaerotheca pannosa,* on three species of *Eucalyptus*. Nova Hedwigia 34:721–730.

Brandenburger, W. 1961. Beobachtungen über das Auftreten einer *Sphaerotheca*-Art an *Eucalyptus*. Sydowia 15:194–196.

Crous, P.W., Knox-Davies, P.S. and Wingfield, M.J. 1989. A summary of fungal leaf pathogens of *Eucalyptus* and the diseases they cause in South Africa. South African Forestry Journal 149:9–16.

Ehret, D.L., Koch, C., Menzies, J. Sholberg, P. and Garland, T. 2001. Foliar sprays of clay reduce the severity of powdery mildew on long English cucumber and wine grapes. Hortscience 36:934–936.

Gardner, M.W. and Yarwood, C.E. 1974. A list of powdery mildews of California. University of California Agriculture Experiment Station Extension Service Leaflet. 30p.

Gibson, I.A.S. 1975. Diseases of forest trees widely planted as exotics in the tropics and Southern Hemisphere. Part I. Important members of the *Myrtaceae, Leguminosae, Verbenaceae* and *Meliaceae*. Mycological Institute and Commonwealth Forestry Institute, Kew and Oxford.

Glasscock, H.H. and Rosser, W.R. 1957. Powdery mildew on *Eucalyptus*. Plant Pathology 7:152.

Grasso, V. 1948. L'oidio dell'eucalipto [*Oidium* of *Eucalyptus*]. Nuovo Giornale Botanico Italiano 55:581–584.

Kobayashi, T. 2001. Diagnostic manual for tree diseases in the Tropics—with some diseases of agroforestry crops. Japanese International Forestry Promotion and Cooperation Center, Tokyo. 178p.

Matheron, M.E. and Matejka, J.C. 1992. Powdery mildew caused by *Erysiphe cichoracearum* on five new *Eucalyptus* hosts in Arizona. Plant Disease 76:1077.

McGrath, M.T. and Shishkoff, N. 2000. Control of cucurbit powdery mildew with JMS Stylet-Oil. Plant Disease 84:989–993.

Paulitz, T.C. and Belanger, R.R. 2001. Biological control in greenhouse systems. Annual Review of Phytopathology 39:103–133.

Sankaran, K.V., Sutton, B.C. and Minter, D.W. 1995. A checklist of fungi recorded on *Eucalyptus*. Mycological Papers 170. CABI Bioscience, Egham, Surrey. 376p.

Sehgal, H.S., Nair, J.M., Nair, J.J. and Stanley, S. 1975. Diseases of *Eucalyptus* in South India. The Southern Forest Rangers College Magazine 51:21–25.

Spaulding, P. 1961. Foreign diseases of forest trees of the world—an annotated list. USDA Agriculture Handbook 197. US Government Printing Office, Washington DC. 361p.

Wardlaw, T. and Phillips, T. 1990. Nursery diseases and their management at the Forestry Commission nursery, Perth. Tasforests 2:21–26.

Yarwood, C.E. and Gardner, M.W. 1972. Powdery mildews favoured by agriculture. Phytopathology 62:799.

Fig. 101

Fig. 102

Figure 101. Powdery mildew on a *Eucalyptus* seedling grown in the greenhouse; the mealy-white appearance is due to production of vast numbers of conidia

Figure 102. Barrel-shaped conidia of powdery mildew, bar = 10 μm

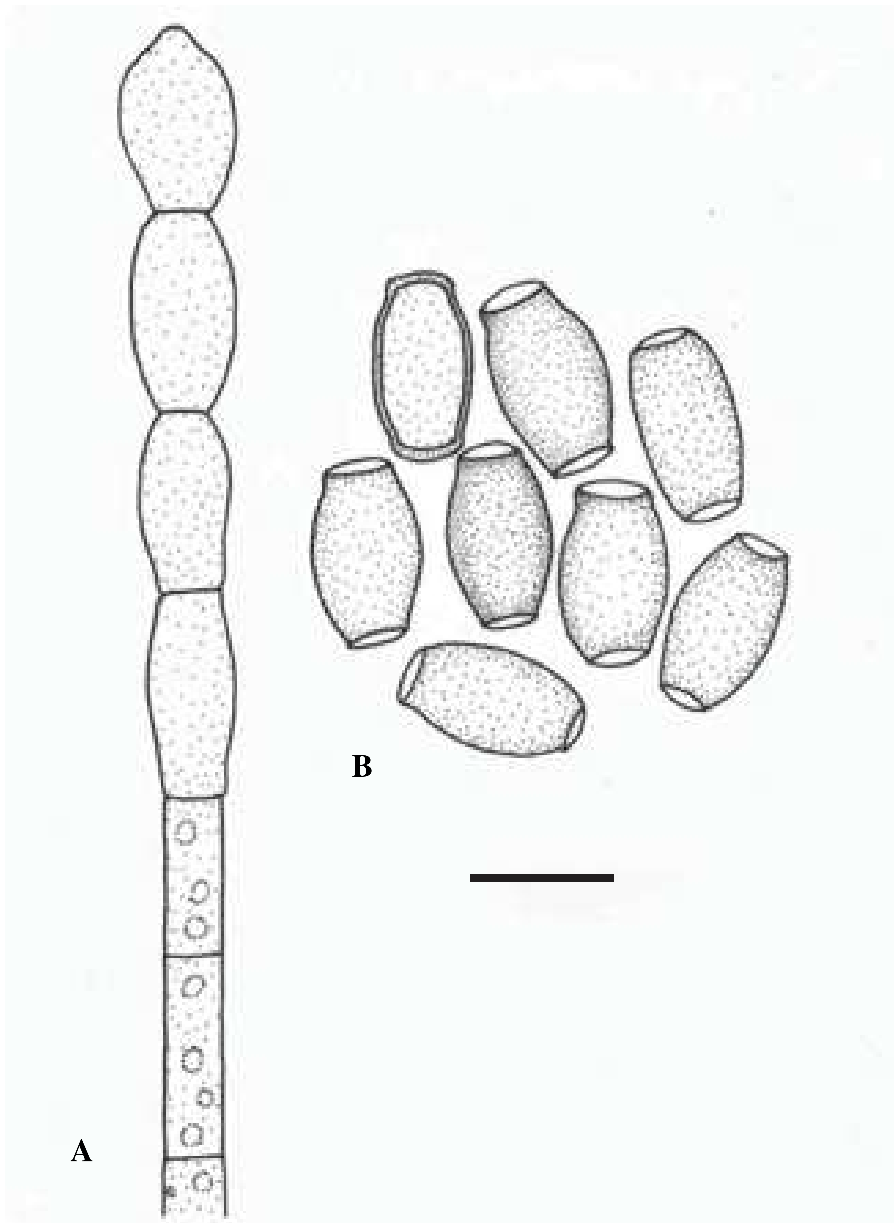

Figure 103. *Oidium* sp.: A. conidia in chain; B. conidia. Bar = 15 µm for A and B.

Eucalyptus rust

Disease

Eucalyptus rust, guava rust

Causal organism

Puccinia psidii Winter

Known distribution

South America, mainly east of the Andes, including northern-most Argentina, Uruguay, Paraguay, Brazil, Venezuela, Ecuador and Columbia. Also present in Central America and the Caribbean, including Cuba, Dominican Republic, Jamaica, Puerto Rico, Trinidad and Florida (Coutinho *et al*. 1998). This fungus is not known to occur in Africa, Australasia, Oceania or Asia and must be regarded as a dangerous exotic pathogen in countries where *Eucalyptus* and other Myrtaceae are grown or constitute native vegetation.

Host range

All genera within the family Myrtaceae are potentially susceptible to this rust, but information on the host range is incomplete. In addition to *Eucalyptus*, 9 genera and more than 30 species of Myrtaceae are recorded hosts of *P. psidii* (Laundon and Waterston 1965, Burnett and Schubert 1985, Ferreira 1989, Coutinho *et al*. 1998). Recent unpublished research by Zauza *et al*. has revealed further hosts of *P. psidii* and has identified resistant species within most genera. Susceptible genera include several which are well represented in Australian native vegetation, e.g. *Angophora*, *Callistemon*, *Corymbia*, *Eucalyptus*, *Kunzea*, *Melaleuca*, *Syzygium* and *Syncarpia*. Of particular importance are plantation and fruit trees including guava, cloves and other *Syzygium* species, *Melaleuca* spp., *Myrciaria jaboticaba* and *Pimenta dioica* (allspice). Evidence of host specialisation exists within the pathogen, so isolates from one host genus may or may not infect other genera within Myrtaceae (Ferreira 1989). Old *et al*. (2003) described a disease severity scale for artificially inoculated eucalypt seedlings, developed by Alfenas and coworkers (unpublished). Almost 100 seedlots comprising 30 species of *Eucalyptus* and *Corymbia* have been screened for rust susceptibility. *Eucalyptus grandis* (Queensland), *E. camaldulensis* var. *obtusa* (Northern Territory) and *E. cloeziana* were among the most susceptible, whereas seedlots of *E. alba, E. paniculata, E. pellita, E. tereticornis*, *E. resinifera*, *E. brassiana* and *C. tessellaris* had high proportions (> 70%) of resistant plants.

Symptoms

Egg-yellow uredinia develop on juvenile leaves of host plants (Fig. 104). Older pustules contain both single celled urediniospores and two-celled, stalked teliospores. The rust attacks both foliage and young green shoots on which cankers are formed, with rupture of the epidermis and phloem. The presence of these cankers can cause stem distortion and crowns of badly affected trees become stunted and multi-stemmed (Figs 105, 106). The fungus also attacks fruits of susceptible species such as guava (Fig. 107), *Myrciaria jaboticaba* (Fig. 108), and *Syzygium jambos*, which are often found in Brazil in gardens in the vicinity of *Eucalyptus* plantations and act as reservoirs of inoculum. On these hosts the fungus fruits prolifically.

Pathology

Puccinia psidii is an autoecious rust, both sexual and vegetative sporulation occurring on the same host. Urediniospores and teliospores form on the same lesions, but teliospores are rarely found on *Eucalyptus* hosts. The pathology of the rust is well described in Coutinho *et al*. (1998) along with other aspects of the biology of the fungus and epidemiology of disease. Disease spread results from airborne urediniospores alighting on leaf surfaces and germinating during darkness and conditions of leaf wetness at temperatures of 15–25°C. Rust lesions then become visible 2–4 days later. Unusually, for a rust pathogen, penetration of the host epidermis occurs directly rather than through stomata. Penetration of mature leaves is generally unsuccessful and this is consistent with the observation that, on *Eucalyptus*, trees less than two years old are susceptible to disease. Coppice shoots of older trees are, however, vulnerable to infection due to their juvenile foliage.

Disease impacts

Disease impacts are difficult to predict across the range of crop species and natural vegetation that is potentially susceptible to attack by this pathogen. For example, in the 1930s an industry in Jamaica based on extracting essential oils from pimento was forced to close only two years after *P. psidii* was first reported (Maclachlan 1938). For *Eucalyptus* in Brazil, impacts are generally small where resistant clones are selected from the *E. grandis* x *E. urophylla* hybrids that are extensively grown as short-rotation crops for pulp and paper mills. A significant proportion of the plantation estate, however, is grown from seed and outbreaks of rust may occur on a scale that needs to be managed. The impacts of rust are particularly important during propagation of cuttings in clonal nurseries, as juvenile foliage can be very susceptible to infection.

Control and management

Control can be readily achieved by use of species with a high or moderate level of resistance to rust and by selection within hybrid progeny for resistant clones. This approach has been highly successful in Brazil where rust-resistant selections within pure *E. grandis* and *E. grandis* x *E. urophylla* hybrids have been readily identified. If, for commercial reasons, seedlings are used on a significant scale to establish plantations, clonal seed orchards containing resistant trees have been found to be a viable option (Alfenas personal communication). Seed for planting in known high rust-hazard areas can be collected from trees homozygous for dominant resistant genes, thus ensuring a rust-resistant plantation. Experience from agriculture suggests that it is unwise to rely on on a single, or few major genes for resistance to rust diseases. Fungicides are available that will control rust effectively (Coutinho *et al.* 1998). These include the protectant fungicide mancozeb and the systemic fungicides triademenol and triforine. Fungicide application is most appropriate, however, in nurseries and clonal hedge plantings, and is not generally practised in plantations. In most instances susceptible planting stock is best discarded in favour of resistant trees.

Incursion pathways

Puccinia psidii is recognised as an extremely dangerous pathogen as it has originated in a continent where *Eucalyptus* is grown widely but is not indigenous (Ciesla *et al*. 1996). *Eucalyptus* spp. are widely planted as exotics in countries, including South-East Asia, where the climates should be suitable for rust epidemics to occur. Australia is at particular risk as *Eucalyptus* and other Myrtaceae dominate much of the native vegetation. In several regions of South-East Asia, in addition to Myrtaceae in native vegetation, there are many important fruit, oil and spice crops which would be susceptible to disease, e.g. *Psidium guajava*, *Melaleuca cajuputi* and *Syzygium aromaticum*. The most dangerous pathway for spread of the pathogen to new regions of the world is by germplasm, including rooted cuttings and other vegetatively propagated trees, seed and pollen. Recent research using a highly sensitive PCR-based DNA diagnostic method (Langrell *et al*. 2003) has detected rust spores in many seed and pollen samples from commercial sources in Brazil. Spores were also detected on clothing, footwear, camera bags and other field equipment exposed to contamination from rust-affected plantations.

References

Burnett, H.C. and Schubert T.S. 1985. *Puccinia psidii* on allspice and related plants. Plant Pathology Circular 271. Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Florida.

Ciesla, W.M., Diekmann, M. and Putter, C.A.J. 1996. *Eucalyptus* spp. Technical Guidelines for the Safe Movement of Germplasm 17. FAO/IPGRI, Rome. 66p.

Coutinho, T.A., Wingfield, M.J., Alfenas, A.C. and Crous, P.W. 1998. Eucalyptus rust: a disease with the potential for serious international implications. Plant Disease 82:819–825.

Ferreira, F.A. 1989. Patologia Florestal-Principais Doenças Florestais no Brasil. Sociedada de Investigações Florestais, Viçosa. P. 129–152.

Langrell, S.R.H., Tommerup, I.C., Zauza, E.A.V. and Alfenas, A.C. 2003. PCR based detection of *Puccinia psidii* from contaminated *Eucalyptus* germplasm—implications for global biosecurity and safeguarding commercial resources. Proceedings of the 8th International Congress of Plant Pathology, Christchurch New Zealand, February 2003. Vol. 2:51.

Laundon, G.F. and Waterston, J.M. 1965. *Puccinia psidii*. CMI Descriptions of Plant Pathogenic Fungi and Bacteria 56. Commonwealth Mycological Institute, Kew.

Maclachlan, J.D. 1938. A rust of the pimento tree in Jamaica. Phytopathology 28:157–169.

Old, K.M., Alfenas, A.C. and Tommerup, I.C. 2003. Guava rust in Brazil, a threat to *Eucalyptus*. Proceedings of the 8th International Congress of Plant Pathology, Christchurch, New Zealand, February 2003. Vol. 1:80.

Fig. 104

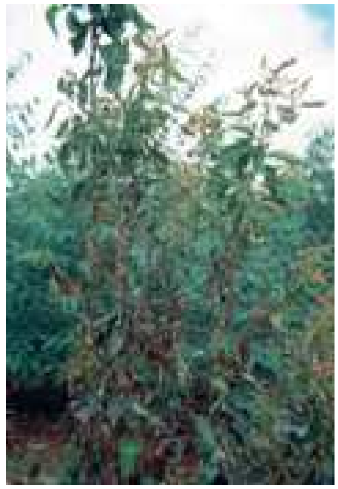

Fig. 105

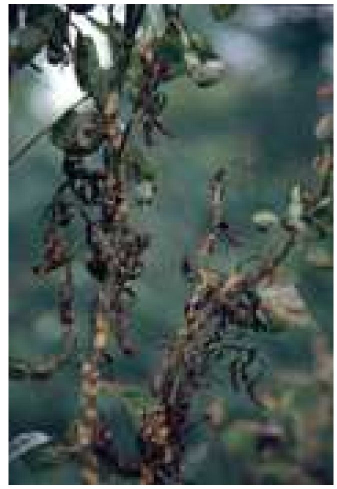

Fig. 106

Fig. 107

Fig. 108

Figure 104. Egg-yellow spores of *Puccinia psidii* produced on a juvenile leaf of *Eucalyptus grandis*
Figure 105. *E. grandis* heavily infected by rust; note stunting of foliage
Figure 106. Detail of infected stems showing stem lesions and shrivelled leaves
Figure 107. Guava fruit infected by *P. psidii*
Figure 108. *Myrciaria jaboticaba* infected by *P. psidii*

Glossary of terms

Acervulus (plural acervuli), a saucer-shaped fruiting structure embedded in host tissue and bearing conidia

Allantoid, slightly curved with rounded ends (sausage shaped)

Anamorph, the asexual (imperfect) form of a fungus

Annular, ring-like

Anthracnose, a group of plant diseases characterised by the formation of discrete necrotic spots on young shoots and foliage

Ascospore, a spore produced inside a sac-shaped **ascus** resulting from meiotic cell division, characteristic of fungi classified in the **Ascomycetes**

Autoecious (applied to rusts), completing life cycle on one host

Basidiospore, a propagative spore formed after meiosis by a basidiomycete

Capitate, having a well-formed head

Chlamydospore, an asexual spore produced primarily as a survival structure (rather than for dissemination), originating from a pre-existing cell by the formation of a thickened inner cell wall layer

Clamp connection, a hyphal swelling that is found between adjacent cells in many Basidiomycete fungi. The connection forms during cell division and is a way of maintaining the ratio of nuclei of differing genetic origin within fungal mycelia

Cleistothecium, a closed fruiting body without a defined opening, containing ascospores formed by powdery mildews

Conidium (plural conidia), a specialised non motile asexual spore produced on a **conidiophore**, typically for dissemination purposes

Conidioma, (plural conidiomata), a specialised conidium-bearing structure now used widely for all such fruiting structures, e.g. acervulus, pycnidium

Etiology, the science of the causes of diseases

Hymenium, the spore-bearing layer of a basidiomycete fruiting body

Kino, polyphenolic substances produced by eucalypts in response to cell damage

Hyphopodium, a short hyphal branch of one or two cells in extent

Microconidium, the smaller conidium produced by a fungus that also forms macroconidia

Necrosis, the death of plant cells, often resulting in tissue becoming dark in colour

Perithecium, subglobose or flask-shaped fruiting structure, containing asci and ascospores, formed by many ascomycete fungi

Pseudothecium, a stromatic fruiting body formed by some ascomycete fungi. Asci are formed within chambers lacking distinct walls (**locules**)

Phialide, a specialised cell, often borne on a conidiophore, which generates a succession of conidia in basipetal succession without any increase in its own length

Pycnidium (plural pycnidia), a flask-shaped fruiting structure embedded in host tissue containing conidiophores and conidia

Rhizomorph, a root-like aggregation of fungal hyphae with a well defined apical meristem, formed by some basidiomycete tree pathogens and decomposer fungi for spreading through soils and along root surfaces

Sclerotium (plural sclerotia), a firm mass of fungal hyphae, often round in shape, not containing spores but often able to survive in the absence of host tissue and germinate when conditions are favourable for infection

Septum (plural septa), cross walls present in fungal hyphae and spores of many species

Seta (plural setae), sterile hair-like hyphae which often project from spore bearing structures and are useful in classification

Sporangium (plural sporangia), a structure formed by many algae and fungi within which spores are formed asexually by nuclear division and protoplasmic cleavage of the contents. The spores may be motile (zoospores) or non-motile. Sporangia may be borne on **sporangiophores**

Stroma (plural stromata), a mass of vegetative **stromatic** hyphae within or on which spores of fruiting bodies are formed

Teleomorph, the sexual (perfect) form of a fungus

Teliospore, a resting or over-wintering rust spore

Thallus, the vegetative body of fungi

Urediniospore, repeating, vegetative rust spores formed rapidly during epidemic disease

Vesicle, a sac-shaped structure which may be the swollen apex of a conidiophore or a sterile hypha as in *Cylindrocladium*

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This manual represents an outcome of 10 years of work by the authors in South-East Asia. It focuses on the main diseases and pathogens of eucalypts found in the region and will assist in disease diagnosis. Summaries of published work on the pathogens and recommendations for their control are provided.

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