Research review

Cryphonectria Canker of *Eucalyptus*, an Important Disease in Plantation Forestry in South Africa.

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SYNOPSIS

Cryphonectria cubensis, one of a notorious group of canker pathogens of trees and the cause of a serious disease of *Eucalyptus*, has recently been found in South Africa for the first time. This review provides the first compilation of the literature pertaining to *Cryphonectria* canker and attempts to critically summarise current knowledge of the disease. Specific attention is given to the South African forestry situation and the likely impact that the disease might have in this country. Proposals for future research are also considered.

INTRODUCTION

Cryphonectria cubensis (Bruner) Hodges is one of a notorious group of canker pathogens of trees and causes a serious canker disease of *Eucalyptus* spp. in many tropical areas of the world (Hodges, Alfenas and Ferreira, 1986). This pathogen has severely limited the development of plantations of susceptible *Eucalyptus* spp. in areas where climatic conditions favour disease development (Alfenas, Hubbes and Couto, 1982). The pathogen was recently reported for the first time from South Africa (Wingfield, Swart and Abear, 1989).

The forestry industry in South Africa depends almost exclusively on monocultures of *Pinus*, *Eucalyptus* and *Acacia*. In recent years, the planting of *Eucalyptus* spp. has become increasingly important. The trend towards propagation of clones from cuttings has, therefore, prompted concern for the role that diseases could have on the success of this industry. The discovery of *C. cubensis* in South Africa is thus of considerable concern to the local forestry industry.

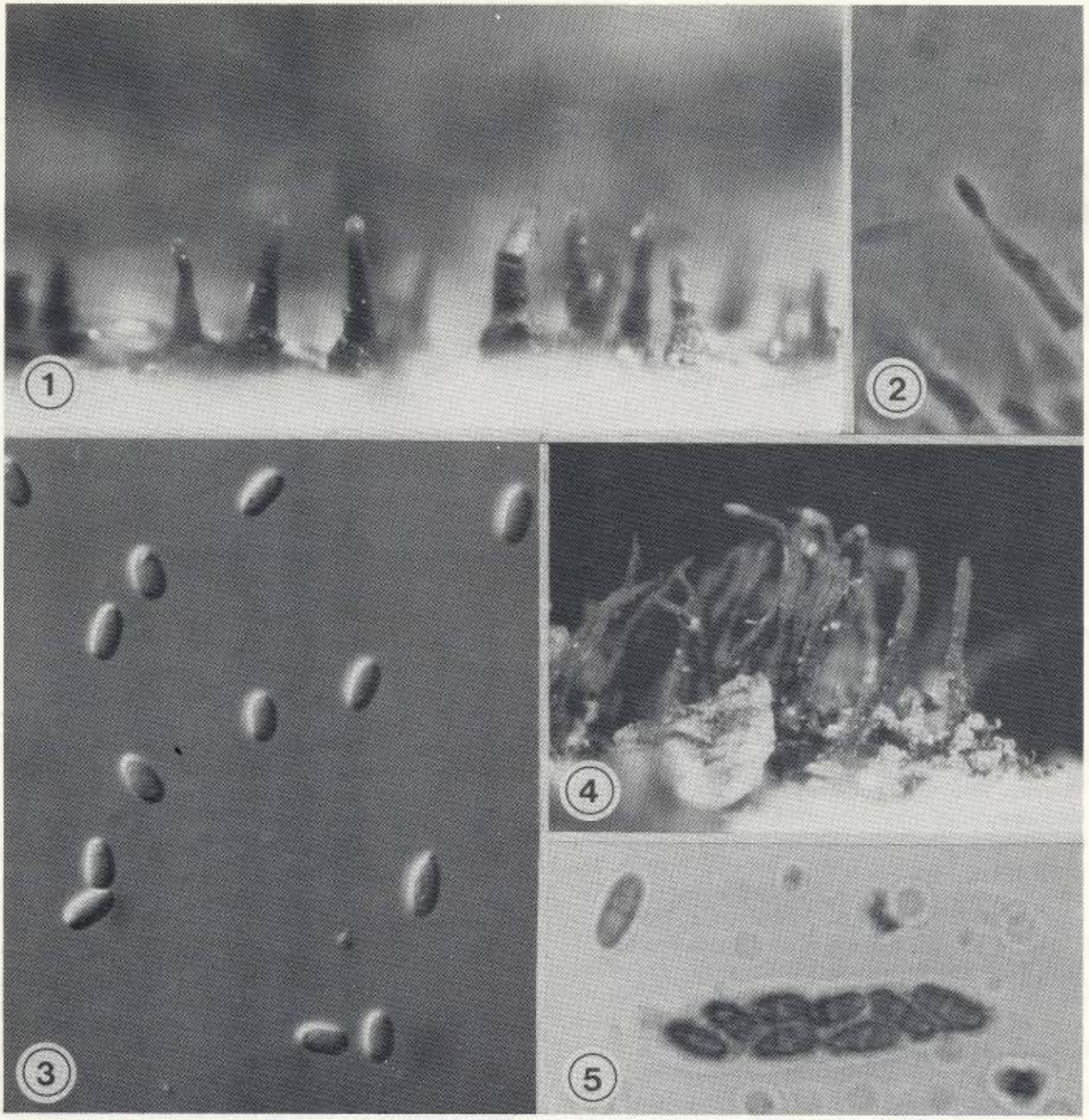
This review outlines past research on *C.cubensis* with a view to identifying areas that require special attention in a future research programme.

MORPHOLOGICAL CHARACTERISTICS

Pycnidia of *Endothiella* (Sacc.), the anamorph of *Cryphonectria cubensis*, are produced during the rainy season on dead bark surrounding cankers (Florence, Sharma and Mohanan, 1986). They are generally formed singly, but may be fused in groups at the base, which is slightly embedded in the bark. Initially they are light reddish-brown, but later become almost black except for the tip of the neck *(Figure 1)*. Pycnidia are cylindrical to broadly pyriform in shape with an attenuated neck of varying size. They range from 0,4 to 1,2 mm in height and from 0,2 to 0,8 mm in basal diameter (Hodges, Geary and Cordell, 1979). Conidiophores formed on the inner walls of pycnidia, are septate with branches arising just beneath the septum and terminating in phialidic conidiogenous cells. Conidiogenous cells are 3 to 8 um long and about 3 um in diameter at the widest part, narrowing to 1 um or less at the apex (Hodges *et al.*, 1979) *(Figure 2)*. Conidia are hyaline, one-celled, clavate to broadly oval, 2,5 to 4 x 1,8 to 2,2 um *(Figure 3)*, and are extruded under humid conditions in yellow cirri up to 3 mm long (Hodges *et al.*, 1979; Florence *et al., 1986)*.

Perithecia develop during dry periods, either singly or in groups, with their bases immersed in the bark *(Figure 4)*. Perithecial necks vary in length depending on moisture (Hodges *et al.*, 1979). Those formed near ground level where humidity is high may be 10 mm or longer; those formed higher on the trunk may barely extend beyond the bark surface. Initially perithecia are a light brown colour and become dark brown to black with maturity (Sharma, Mohanan and Florence, 1985 b). Asci are clavate, with a thickened apical cap perforated by a narrow canal, 25 to 33 x 5,0 to 6,5 um, and contain eight biseriately arranged ascospores (Hodges, 1980). Ascospores are hyaline, equally two-celled, cylindrical with rounded ends, straight or slighty curved, and 4,4 to 9,5 by 1,9 to 3,0 um *(Figure 5)* (Boerboom and Maas, 1970; Hodges *et al.*, 1979; Florence *et al.*, 1986; Sharma *et al.*, 1985 a & b).

Cryphonectria cubensis grows rapidly on most common culture media. The colonies are yellow-brown and produce small pycnidia with soft walls covered with bright yellow-orange mycelium (Hodges *et al.* 1979). After about 10 days pycnidia turn black and conidia are extruded in a cream coloured mass (Boerboom and Maas, 1970).



FIGURES 1–5. Fruiting bodies, conidia and ascospores of C.cubensis. *FIG. 1. Long-necked pycnidia on the surface if dead bark with conidial masses at their apices. FIGURE 2. Conidiogenous cell and conidium. FIGURE 3. Hyaline, single-celled conidia. FIGURE 4. Long-necked perithecia. FIGURE 5. Two-celled ascospores.*

TAXONOMY OF *CRYPHONECTRIA CUBENSIS*

C. cubensis was originally described in the genus *Endothia* Fries as *E. havanensis* Bruner. This genus includes *Endothia parasitica* (Murr) P.J. & H.W. And., the casusal agent of chestnut blight, which has decimated the American chestnut, *Castanea dentata* (Marsh.) Borkh. (Griffin and Elkins, 1986).

Endothia havanensis was originally described in 1916 from Cuba as the cause of a serious disease of *Eucalyptus* spp. (Bruner, 1916). In 1917 Bruner unknowingly described the same organism as *Diaporthe cubensis* Bruner (Hodges, 1980). It was not recorded again until 1970 when it was reported as *E. havanensis* from Surinam (Boerboom and Maas, 1970). Subsequently, Hodges and Reis (1974) also recorded it under the same name from Brazil. It was later shown that the fungus recorded from Brazil and Surinam as *E. havanensis* was the same as *Diaporthe cubensis* (Hodges *et al.*, 1976).

E. eugeniae (Nutman & Roberts) Reid & Booth, is associated with diebak of clove *(Syzygium aromaticum)* (L.) Merr. & Perry and occurs sporadically in all major clove growing areas (Hodges *et al.*, 1986). Data

obtained from morphological comparisons, cultural studies, protein and isoenzyme analyses, and pathogenicity studies show *C. cubensis* and *Endothia eugeniae* to be conspecific (Alfenas, Hodges and Jeng, 1984; Hodges *et al.*, 1986; Micales and Stipes, 1984).

The species epithet *"cubensis"* predates *"eugeniae"* and the correct name of the *Eucalyptus* canker pathogen is thus *Cryphonectria cubensis* (Hodges *et al.*, 1986).

Barr's (1978) monograph of the Diaporthales altered the taxonomy of the genus *Endothia*. Barr separated the species into *Endothia* and *Cryphonectria* and placed these genera in the Gnomoniaceae and Valsaceae, respectively (Roane, 1986). *Endothia* was restricted to those species with diatrypoid stromata, predominantly pseudoparenchymatous tissue, and non-septate, allantoid ascospores. The remaining species were transfered to *Cryphonectria* due to their valsoid stromata, predominantly prosenchymatous tissue, and monoseptate, ovoid to ellipsoid ascospores (Micales and Stipes, 1987). Hodges (1980) transferred *D. cubensis* to *Cryphonectria* as *C. cubensis*.

HOST RANGE AND DISTRIBUTION

C. cubensis has been reported from Cuba (Bruner, 1916), Brazil, Surinam, Trinidad, Florida, Hawaii, Puerto Rico, Western Samoa (Boerboom and Maas, 1970; Hodges, 1980; Hodges *et al.*, 1979), India (Florence *et al., 1986;* Sharma *et al.*, 1985 a & b), North Africa (Gibson, 1981), South Africa (Wingfield *et al.*, 1989), and Hong Kong, Cameroons and Venezuela (Minter cited by Sharma *et al.*, 1985 b). Davidson and Tay (1983)and Old *et al.* (1986) reported *C. havanensis* (as *E. havanensis*) from Australia on *Eucalyptus* spp. based on the *Endothiella* anamorph. There is, however, no firm evidence at present for this conclusion (Walker, Old and Murray, 1985). This indicates that *C. cubensis* is distributed within 30 °N and S of the equator. The distribution is probably determined by the tropical climate apparently needed for growth and spread of the pathogen. The principal countries of occurrence and important eucalypt hots of *C. cubensis* are given in *Table 1*.

Although *Eucalyptus* spp. are the most important hosts of *C. cubensis,* the fungus probably does not occur in Australia, where most of the *Eucalyptus* spp. are indigenous. *Eucalyptus* spp. planted in very isolated locations become infected soon after the introduction of *C. cubensis* (Hodges *et al.*, 1986). This has led to speculation that *C. cubensis* may be a widely distributed fungus which occurs on hosts other than *Eucalyptus*. In Brazil and Indonesia, *C. cubensis* was found on clove trees but did not cause any dieback symptoms and only one or two small cankers were found (Hodges *et al.*, 1986).

TABLE 1. Geographical distribution and major Eucalyptus *hosts of* Cryphonectria cubensis

COUNTRY	HOST	CAUSAL ORGANISM	REFERENCES
AFRICA	*Eucalyptus urophylla* S.T. Blake	*Cryphonectria cubensis*	Gibson, 1980.
AUSTRALIA	*E.marginata* Donn ex Sm.	*Endothia havanensis*	Davidson & Tay, 1983. Old *et al.*, 1986.
	E. calophylla R. Br.	*E. havanensis*	Davidson & Tay, 1983.
BRAZIL	*E.saligna* Sm.	*C.cubensis*	Hodges *et al.*, 1976. Hodges, 1980.
	E.maculata Hook.	..	..
	E.angulosa Schau.	..	Hodges, 1980.
	E.botryoides Sm.	..	..
	E.camaldulensis Dehnh.	..	..
	E.citriodora Hook.	..	..
	E.grandis Hill ex Maid.	..	..
	E. longifolia Link & Otto	..	..
	E.microcorys F. Muell.	..	..
	E.paniculata Sm.	..	..
	E.pilularis Sm.	..	..
	E.propinqua Deane & Maid.	..	..
	E.robusta SM.	..	..
	E.tereticornis Sm.	..	..
	E.trabutii Vilmorin	..	..
	E.urophylla	..	..
CUBA	*E.botryoides*	*E.havanensis*	Bruner, 1916.
	E.rostrata Schlecht.	..	..
	E.microphylla Willd.	..	..
	E.robusta	..	..
	E.occidentalis Endl.	..	..
	E.botryoides	*C.cubensis*	Bruner cited by Sharma *et al., 1985b.*
	E.rostrata	..	..
	E.microphylla	..	..
	E.robusta	..	..
	E.occidentalis	..	..

SOUTH AFRICA	*E.grandis*	*C.cubensis*	Wingfield *et al.*, 1989.
SOUTH AMERICA			
SURINAM	*E.grandis*	*E.havanensis*	Boerboom & Maas, 1970
	E.saligna	..	..
	E.citriodora	..	..
	E.grandis	*C.cubensis*	Hodges, 1980.
	E.saligna	..	..
	E.maculata	..	..
NORTH AMERICA			
FLORIDA	*E.grandis*	*Diaporthe cubensis*	Hodges *et al.*, 1979.
	E.grandis	*C.cubensis*	Hodges, 1980.
	E.camaldulensis	..	..
PUERTO RICO	*E.urophylla*	*D.cubensis*	Hodges *et al.*, 1979.
	E.deglupta B1.	..	..
HAWAII	*E.deglupta*	*C.cubensis*	Hodges, 1980
	E.grandis	..	..
	E.saligna	..	..
	E.saligna	*D.cubensis*	Hodges *et al.*, 1979.
INDIA	*E.grandis*	*C.cubensis*	Florence *et al.*, 1986; Sharma *et al.*, 1985 a & b.
	E.tereticornis	..	..
	E.citriodora	..	Sharma *et al.*, 1985 a & b.
	E.torelliana F.Muell	..	..
	E.deglupta	..	..
	E.saligna	..	Sharma *et al.*, 1985 b.
	E.brassiana S.T. Blake	..	..
	E.camaldulensis	..	..
	E.pellita F.Muell	..	..
	E.cloeziana F. Muell		
TRINIDAD	*E.saligna*	*C.cubensis*	Hodges, 1980
WESTERN SAMOA	*E.saligna*	*C.cubensis*	Hodges, 1980.

It is necessary to consider the origin of *C. cubensis* recently discovered in South Africa. Although the introduction of plant material to this country is strictly controlled, the pathogen could have been acidentally introduced. Although there is no firm evidence, it is possible that the pathogen is seedborn. The fungus could also have originated from native Myrtaceae. Studies are therefore needed to compare local isolates with those from other parts of the world as this may shed light on the origin of *C, cubensis* in South Africa.

Isoenzyme and protein patterns have demonstrated the genetic relationships among the *C. cubensis* isolates, with variable degrees of pathogenicity (Alfenas, Jeng and Hubbes, 1984). Variation in virulence of isolates of *C. cubensis* on *Eucalyptus pellita* has been shown to coincide with differences in isoenzyme patterns among African, Brazilian and Hawaiian isolates. Isolates with the same degree of virulence to other *Eucalyptus* spp. also appear to show the same isoenzyme patterns (Alfenas *et al.*, 1983).

SYMPTOMS AND DAMAGE

Infected trees *(Figure 6)* initially have elongated sunken areas on their bark, either at the base or up to a metre above ground level (Boerboom and Maas, 1970; Florence *et al.*, 1986; Sharma *et al.*, 1985 a) *(Figure 7)*. The tissue underneath the depressed bark is brown and apparently dead. The bark later splits around the infected area.

Gummosis is generally observed on cankers (Boerboom and Maas, 1970; Florence *et al.*, 1986; Sharma *et al.*, 1985 a) and is usually associated with older cankers. Gummosis in *Eucalyptus* spp. is due to injury of the cambium, resulting in the formation of kino ducts (Bakshi, 1972). The ruby coloured kino is usually washed off during the rain and imparts a distinct colour to diseased tissue (Boerboom and Maas, 1970; Sharma *et al.*, 1985 a). Although gummosis is fairly common in *E.grandis*, it has not been observed in *E.tereticornis* (Sharma *et al.*, 1985 a).

Infected trees react by forming callus around the site of infection, leading to bulging of the outer layer of bark. This layer is eventually shed resulting in a canker. On certain trees, infected outer bark may be sloughed off before the cambium is killed. On others, typical cankers are produced as the cambium is killed (Hodges *et al.*, 1979). During this stage, a sectorial dark brown discolouration *(Figure 8)* may be observed in a cross-section of the bole (Boerboom and Maas, 1970).

Multiple cankers are occasionally found on trunks and become confluent to form long cankerous areas (Sharma *et al.* 1985 a). The cankers usually develop above ground level but occasionally at the base. Large above-ground and basal cankers are responsible for the mortality of trees due to complete girdling of the phloem (Sharma *et al.*, 1985 a).

On diseased stumps, fewer sprouted clumps develop and multiple coppice shoots may vary from a few to as many as 34, as compared to between 6 and 15 on healthy ones. Because of the large number of shoots per clump in diseased stumps, shoots remain stunted and weak in comparison to those on healthy stumps (Sharma *et al.*, 1985 b).

Basal cankers reduce the sprouting of stumps by

FIGURES 6–9. Symptoms of Cryphonectria *canker on E. grandis. FIGURE 6. Dead tree showing retention of leaves. FIGURE 7. Dark, discoloured cambium at the base of infected tree. FIGURE 8. Section through a three-year-old tree 12 months after inoculation with* C. cubensis *at three points. FIGURE 9. Dying coppice growth at the base of a tree felled after infection with* C. cubensis.

about 10 to 20 % in Brazil (Hodges and Reis, 1974). Although the frequency of basal cankers is less in Kerala, about 35 % of diseased stumps (indicated by gummosis) fail to produce coppice shoots (Sharma *et al.*, 1985). If such stumps coppice at all, shoots usually develop near ground level. Excessive gummosis kills the outer bark tissues as do cankers which result in stumps failing to sprout (Sharma *et al.*, 1985 a & b). In such cases, even though the mortality is only 3 %, the impact of the disease is far greater on the coppice crop of the second rotation *(Figure 9)*. It is possible that the loss of additional trees through lack of sprouting may reduce stocking for succeeding rotations below an acceptable economic level.

DISPERSAL AND INFECTION

The distribution of Cryphonectria canker is probably determined by humid conditions needed for the growth and spread of the pathogen. The incidence of cankers in plantations varies greatly depending upon *Eucalyptus* spp. and climatic conditions prevailing in an area (Florence *et al.*, 1986). The disease is favoured by high rainfall (2 000 – 2 400 mm/a), high elevation and temperatures above 23 °C (Florence *et al.*, 1986; Sharma *et al., 1985b)*.

In Brazil, C. cubensis causes heavy losses in areas where high rainfall occurs throughout the year, and temperatures average 23 °C or higher (Hodges *et al.*, 1979). Infection rates under such conditions sometimes reach 80 % with 20 % mortality after three years. In cooler or drier areas of Brazil, infection rates are much lower as is the extent of canker development (Hodges *et al.*, 1979). The spatial distribution and severity of the pathogen in *Eucalyptus* plantations in Kerala also appears to be related to climatic conditions (Sharma *et al.*, 1985 a). High rainfall areas in Kerala, where the average temperature ranges from 20 to 25 °C, are possibly the most ideal places for the occurrence of *C. cubensis* (Florence *et al.*, 1986).

There are some striking differences between the epidemiology of the disease in Brazil and in Kerala (Sharma *et al.*, 1985a). In Brazil the pathogen infects trees of susceptible species as young as five months old. Conversely in Kerala the earliest recorded symptom on *E. grandis* have been on two to three-year-old trees. In Brazil, the principal symptoms are basal cankers whereas in Kerala most of the cankers are found above the ground. It is not known whether these differences are related to *Eucalyptus* species planted, to different strains of the pathogen, or to the influence of edaphic and microclimatic conditions.

The potential for serious damage to *Eucalyptus* spp. is small in southern Florida (Hodges *et al.*, 1979). The summer rainy season in Florida lasts for about four months, the winter is cool, and spring and fall, although hot, are usually dry. The climate of the Hawaiian islands offers ideal conditions for disease development. *Eucalyptus* plantings in Puerto Rico are frequently located in areas with extended periods of high rainfall and moderate temperatures throughtout the year where *C. cubensis* can be a potential hazard to susceptible *Eucalyptus* spp. (Hodges *et al.*, 1979).

Differences in the epidemiology of Cryphonectria canker in various parts of the world could provide clues to the potential damage the disease can cause in South African plantations. Although the pathogen has to date only been recorded in Natal, it is possible that the disease could spread to other parts of the country. Further studies are therefore needed to determine the distribution of *C. cubensis* in this country.

HOST SUSCEPTIBILITY

Variation in resistance to Cryphonectria canker exists within and among *Eucalyptus* spp. (Alfenas *et al.*, 1982). In Brazil, *E. saligna* and *E. maculata* are highly susceptible; *E. grandis, E. propinqua* and *E. tereticornis* are moderately resistant; and *E. citriodora, E. torelliana* and *E. urophylla* are highly resistant (Hodges *et al.*, 1979). Provenances of *E. grandis* vary considerably in their relative susceptibility. *E. deglupta* and *E. urophylla* are highly resistant to *C. cubensis* and would be excellent choices for planting in high hazard areas (Hodges *et al.*, 1979).

There is considerable inter- and intraspecific variation in susceptibility to the fungus. Disease incidence and mortality of *E. grandis* in Kerala (2,5 %) is far lower when compared to Brazil (30 %). This may reflect differences in provenances of *E. grandis* which vary in their relative susceptibility, or to the low virulence of the pathogen. *E. citriodora, E. torelliana* and *E. deglupta* are highly resistant in Brazil and moderately susceptible under Kerala conditions (Sharma *et al.*, 1985a).

The threat of *C. cubensis* to South African forestry is dependant on the suceptibility of *Eucalyptus* spp. planted. *E. grandis*, which is extensively planted in South Africa is highly suspectible in other parts of the world (Hodges *et al*, 1979). It is therefore important for the South African forest industry not to plant clones susceptibe to *C. cubensis* in areas where this pathogen is likely to be problematic. For this reason, clones and hybrids should be screened for susceptibility to the pathogen.

CONTROL

As an immediate measure to check the further spread of canker, chemical control could be attempted. This may, however, not be economical for a crop such as *Eucalyptus* which has a very low return (Sharma *et al*, 1985b).

Currently, the use of resistant or less susceptible species is the only means of reducing losses from the disease (Alfenas *et al.*, 1983). The long term control of disease in a forestry crop is possible either by field selection or breeding for resistance. In Brazil, stable resistance to Cryphonectria canker has already been obtained by intensive field selection followed by vegetative propagation (Sharma *et al*, 1985). A first step in

this direction for South African forestry is to screen *Eucalyptus* clones, hybrids and species.

SUMMARY

1. *Eucalyptus* canker caused by *C. cubensis* has resulted in extensive losses in plantation forestry in various parts of the world. Its recent discovery in South Africa should thus be considered important.
2. At this stage the distribution of *C. cubensis* in South Africa is unknown. Field surveys are therefore urgently required in order to evaluate the potential impact of the pathogen.
3. The extensive planting in South Africa of *E. grandis* which is highly susceptible to the disease is cause for concern. However, clonal resistance could reduce potential losses. Emphasis should be given to screening species, hybrids and clones.

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