

# Fungal Pathogens in *Pinus* and *Eucalyptus* Seedling Nurseries in South Africa: A Review

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## SYNOPSIS

Fungal diseases are responsible for severe losses of *Pinus* and *Eucalyptus* seedlings in South African forest nurseries. Pathogens such as *Botrytis cinerea*, *Fusarium oxysporum*, *Rhizoctonia solani*, *Phytophthora cinnamomi*, *Cylindrocladium scoparium* and *Colletotrichum* spp. are commonly associated with disease symptoms. Control can be achieved by means of cultural, chemical and biological methods, while ectomycorrhizae could also play an important role in resistance of seedlings to pathogens.

## INTRODUCTION

Forest plantations represent the third largest crop grown in South Africa (Van der Zel, 1989). As the South African forestry industry is based almost exclusively on plantations of exotic tree species (Anonymous, 1984), new afforestation is largely dependant on supplies of transplants raised in nurseries. Factors that reduce the quantity and quality of nursery seedlings may also influence future timber supplies. These factors include various diseases caused by fungi.

Pathogenic fungi are common in forest nurseries. Most of these are variable in host specificity (Anderson *et al.*, 1962; Bloomberg and Lock, 1972; Von Broembsen, 1984a), and responsible for most losses occurring from the time of sowing through to outplanting. Pathogens may inhibit or prevent seed germination, kill seedlings directly, or induce malformation and stunting symptoms, which result in seedling rejection or a lower field survival rate (Peterson and Smith, 1975).

Various disease symptoms of *Pinus* and *Eucalyptus* seedlings are induced by fungi (Darvas *et al.*, 1978; Sharma *et al.*, 1984). The most common of these are damping-off, root rot,

seedling, shoot or web blight, stem cankers and leaf spots. Some virulent pathogens are able to cause more than one symptom, while others that are less virulent, are usually found in association on stressed seedlings.

The aim of this review is to consider the occurrence of pathogens and the diseases they cause in South African forest nurseries. The most important disease-associated fungi and control measures are briefly discussed. The host range, symptoms and conditions favouring disease are provided for each pathogen to assist nursery-growers in diagnosis. Control measures are discussed only in a general sense and are not intended as specific recommendations.

## FUNGI IN SOUTH AFRICAN FOREST SEEDLING NURSERIES

Fungi associated with *Pinus* and *Eucalyptus* spp. in South Africa have previously been listed (Lundquist and Baxter, 1985; Lundquist, 1986, 1987a, 1987b). A number of these fungi are associated with seedling diseases in nurseries (Table 1). The most important pathogens affecting seedlings in South African forestry nurseries are considered below:

TABLE 1. Commonly encountered diseases of *Pinus* and *Eucalyptus* seedlings in South African forest nurseries

Affected Plant Part	Disease Symptoms	Pathogen(s) Involved	Hosts
Roots	Pre-emergence damping-off	<i>Pythium</i> spp.	<i>Pinus patula</i> Schlecth. & Cham; <i>Pinus</i> spp.
	Post-emergence damping-off	<i>Rhizoctonia solani</i> Kühn. <i>Cylindrocladium scoparium</i> Morgan	<i>Pinus</i> spp. <i>Eucalyptus citriodora</i> Hook.; <i>E. grandis</i> Hill: Maid.; <i>E. nitens</i> (Deane et Maid.) Maid.; <i>P. taeda</i> L.; <i>E. tereticornis</i> Sm.; <i>E. tessellaris</i> F. Muell.
		<i>Fusarium oxysporum</i> Schlecht. emend. Snyd. & Hans. <i>Phytophthora cinnamomi</i> Rands	<i>P. palustris</i> Mill.; <i>P. roxburghii</i> Sarg.; <i>P. taeda</i> ; <i>Pinus</i> spp. <i>E. citriodora</i> ; <i>P. elliottii</i> Engelm.; <i>P. halepensis</i> Mill.; <i>P. patula</i> ; <i>P. pinaster</i> Ait; <i>P. radiata</i> D. Don;
		<i>Pythium</i> spp.	<i>Pinus</i> spp. <i>P. patula</i> ; <i>Pinus</i> spp.

the pathogen proceeds to the rest of the plant (Peterson and Smith, 1975). Lesion colour varies with different hosts. In eucalypts, the lesions are water soaked and surrounded by a deep purple fringe. On pines, however, the needles turn brown, inducing a wilt of the shoot tips (Marks *et al.*, 1982). The fungus can also grow from infected germinating seeds into the stem or the roots of seedlings (Baker, 1946).

*B. cinerea* spreads when the airborne conidia are either drawn or blown into nurseries by ventilation fans or wind (Sutherland and Van Eeden, 1980). The fungus can also be introduced into the nursery on infected seed or irrigation water. Grey mould can be seen as a thin grey web of mycelium on infected plant parts (Peterson and Smith, 1975). Tufts of black mycelium and conidia arise from infected tissue bearing clusters of white to grey conidia which are readily detached and dispersed.

### **Colletotrichum spp.**

*Colletotrichum acutatum* Simmonds f.sp. *pineae* Dingley & Gilmour is responsible for terminal crook of *Pinus* spp. (Dingley and Gilmour, 1972). Severe infection was first reported in 1963 by Gilmour from nurseries in New Zealand (Vanner and Gilmour, 1973), and was subsequently also found associated with *P. radiata* seedlings in the southern Cape province of South Africa (Lundquist and Roux, 1984).

Terminal crook, which usually occurs only in the first 12 months of the tree's life, stunts young pine seedlings in nursery beds (Anonymous, 1975). Terminal buds of infected seedlings are killed, or become inverted in a thickened crozier-shaped malformation (Vanner and Gilmour, 1973). This results in severe stunting of the otherwise healthy plant. Infected seedlings are often less than half the height of healthy plants. After several months a sub-terminal shoot usually becomes dominant and top growth resumes. This new leader is, however, not immediately resistant to re-infection. Seedlings become increasingly immune as they gain height (Vanner and Gilmour, 1973).

Nair *et al.* (1983) suggested that seedling infection by *Colletotrichum* is mainly derived from soil-borne inoculum. Large numbers of conidia are washed into the soil during the growing season, surviving for several months as appressoria, pigmented hyphae, or chlamydo-spores in debris.

A second *Colletotrichum* species (*Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc.) is also found in South African forest nurseries (Crous, unpublished). This pathogen causes a wide variety of symptoms, including leaf spot and stem cankers of eucalypt seedlings (Sharma *et al.*, 1984). Although this pathogen occurs more prominently on *Eucalyptus* cuttings, it has also been found infecting leaves of healthy *E. dives*, *E. grandis* and *E. globulus* seedlings. Discrete round light brown lesions that are usually surrounded by a red-purple border, form on leaves. As these lesions spread, the leaves yellow and drop off. Concentric rings of acervuli and yellowish to pinkish conidial masses are often visible (Baxter *et al.*, 1983). Conidia are dispersed via rain-splash and wind. Although the relative importance of *C. gloeosporioides* on *Eucalyptus* seedlings is presently still undetermined, it is regarded as an important pathogen of this host, and occurs in nurseries throughout Natal and the eastern Transvaal (Crous, unpublished).

### **Cylindrocladium spp.**

*Cylindrocladium scoparium* Morgan causes losses to both eucalypt and conifer seedlings locally and in other parts of the world (Peterson and Smith, 1975; Darvas, 1976; Sharma *et al.*, 1984; Lundquist and Baxter, 1985; Crous *et al.*, 1991). Seedlings in nursery beds and containers are damaged in several ways including root rot, damping-off, needle or leaf blight and stem cankers (Hodges and May, 1972; Barnard, 1984; Sharma *et al.*, 1984; Mohanan and Sharma, 1985; Crous *et al.*, 1991). In the case of root rot, seedlings become chlorotic and the needles turn reddish-brown. The fungus initially infects the roots at the root tips and then proceeds towards the crown (Anderson, 1962). Infected roots become necrotic and discoloured, and the cortex is easily removed in advanced stages of rot. In seedlings showing post-emergence damping-off, stems above and below the ground become shrunk, dry and turn black. In the case of needle blight in pine, infected needles turn yellow and later brick red before abscising, while circular, brown leaf-spots, surrounded by a purple to reddish margin are formed on affected eucalypt leaves. Stem cankers on pine seedlings originate at the base of needle fascicles. Brownish, sunken areas gradually enlarge and can girdle the stem, killing the seedling. In eucalypts, infections spread from the lower stem or root collar and eventually kill the seedlings (Barnard, 1984). Under moist conditions *Cylindrocladium* spp. sporulate profusely on infected tissue, creating a whitish film due to abundant conidial production.

*Cylindrocladium* infections are most severe where seedlings are subjected to high humidity and temperature, as well as close spacing (Barnard, 1984). Overhead irrigation and container arrangement may therefore contribute to disease development. Conidia spread by means of wind, splash, soil debris, inter-nursery stock transport and cultural operations (Thies and Patton, 1970). The fungus overwinters as microsclerotia in soil or growing medium, and these propagules can then germinate under favourable environmental conditions (Thies and Patton, 1970).

### **Fusarium spp.**

*Fusarium* spp. have been associated with root disease of *Pinus* seedlings both in South Africa (Doidge, 1950; Darvas, 1976; Lundquist, 1986, 1987a, 1987b) and elsewhere in the world (Bloomberg, 1981). Although Sharma *et al.* (1984) reported *Fusarium* spp. on *Eucalyptus* seedlings in India, they have not been reported on this host in South Africa. *Fusarium* spp. differ in their pathogenicity and host specificity (Bloomberg and Lock, 1972; Darvas *et al.*, 1978). Although some species can induce leaf-spot symptoms (Darvas *et al.*, 1978) or stem cankers (Barnard and Blakeslee, 1980), *Fusarium* spp. are most frequently associated with root diseases such as damping-off and root rot (Peterson and Smith, 1975; Bloomberg, 1981).

*Fusarium oxysporum* Schlecht. emend. Snyder & Hans. is the most common species that has been associated with conifer seedling death. It is most active at temperatures of 25 to 35 °C (Bloomberg, 1981) with low to moderate soil moisture conditions (Kraft and Roberts, 1969). Disease is initiated when chlamydo-spores in the soil infect the roots and ramify through the root system, causing lesions in cortical and vas-

is prevented by providing sufficient water and thus reducing stress (Kraft and Roberts, 1969), while root rot associated with *Pythium* and *Phytophthora* spp. is controlled by improving seedbed drainage (Peterson and Smith, 1975). Irrigation water (Von Broembsen, 1984b) and seed (Singh and Mittal, 1989) are well known sources of inoculum, while the growth medium used may also introduce pathogens into nurseries. Well established sanitation procedures are therefore necessary for the exclusion of these pathogens.

The main purpose of chemical control is the prevention of the disease before it becomes established. This can be achieved either by protecting plants with a chemical barrier or by eradicating the pathogen by means of soil fumigation. Pathogens have been treated successfully with fungicides such as captan (Donald and Lundquist, 1988) and benomyl (Barnard, 1984), and fumigants such as methyl bromide (Bloomberg, 1965; Enebak *et al.*, 1990) and chloropicrin (Rowan, 1981). Leary *et al.* (1982) showed that significant differences exist among treatments which depend on factors such as seedling and pathogen species, as well as the method and concentration of applications. A disadvantage of chemical control is that advantageous rhizosphere micro-organisms are killed, affording the pathogens the advantage during a second infection phase (Trappe *et al.*, 1984). The continuous use of a systemic fungicide without alternating with contact treatments can also result in pathogen resistance to the chemical (Alfenas *et al.* 1988).

Biological control of forestry seedling pathogens has been applied to a limited extent and with little success in the past (Kelly, 1976; Huang and Kuhlman, 1991). Pine bark medium commonly used in South African forestry nurseries (Viljoen *et al.*, 1991) has fungicidal properties due to microbial activity (Hoitink, 1980; Nelson and Hoitink, 1983; Nelson *et al.*, 1983) and could be useful in reducing the effect of seedling pathogens. We therefore have reason to believe that the establishment and maintenance of a threshold population of advantageous micro-organisms could be effective in reducing disease in forestry nurseries.

Pathogen suppression can act either directly on the pathogen through antagonism (antibiosis, competition and mycoparasitism) or through the intermediate agency of the host. In the latter case, the host is inoculated with a nonpathogenic or mildly virulent fungus that reduces symptom expression when the host is subsequently infected by a virulent pathogen (Baker, 1968). Micro-organisms best known as biocontrol agents include bacteria such as *Bacillus* spp., *Pseudomonas* spp. and *Agrobacterium* spp. (Weller, 1988) and fungi such as *Trichoderma* spp. and *Gliocladium* spp. (Chet and Baker, 1981; Baker, 1987). Biological control is most effective where only a short protection period is required such as in damping-off diseases. A disease such as *Fusarium* root rot would be considerably more difficult to control in this way, since infection occurs throughout the season.

The importance of ectotrophic mycorrhizae in the establishment and protection of tree seedlings, and for their growth and development, is well known. Marx and Bryan (1975) have, for instance, shown that inoculation of *P. taeda* seedlings with selected ectomycorrhizal fungi stimulated twice as much dry matter production as in seedlings with naturally occurring ectomycorrhizal fungi. Infected seedlings are protected from pathogenic fungi (Zak, 1964; Marx, 1969;

Marais and Kotze, 1976) through the formation of a physical barrier, the production of antibiotics and the utilisation of root exudates which could otherwise attract pathogens. The improvement in survival and growth of pine seedlings in USA forest nurseries after the selection and introduction of certain mycorrhizal fungi (Marx, 1980; Marx *et al.*, 1984) suggests that South African forest nurseries could benefit by applying similar practices.

## CONCLUSION

Nurseries suffer severe losses due to fungal diseases in South Africa (Donald and Von Broembsen, 1977; Lundquist and Foreman, 1986) and elsewhere in the world (Thies and Patton, 1970). These losses do not only have immediate economic implications, but tend to increase the backlog in the establishment of forests. Despite this fact, very little research has been directed towards nursery diseases in South Africa.

Successful disease management depends on an adequate knowledge of the pathogen and host, as well as good nursery practices. Well conceived disease control programmes are therefore necessary to prevent or reduce losses. The identification of pathogens and the implementation of effective cultural practices by nursery-growers to reduce diseases are becoming essential. Furthermore, sensible utilisation of available sources must be considered in controlling pathogens. In this respect, soil or other growth media used in seedbeds or containers can play an important role in seedling health. The mycoflora including mycorrhizae and biocontrol fungi present in these media can determine the survival of the young plants.

Successful nurseries are critical to the future of the South African forestry industry. Given their importance, considerably more attention should be dedicated to reducing losses due to disease.

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