1. Introduction

Bamboos are vulnerable to various diseases and disorders, which affect them in nurseries, plantations as well as in natural stands. About 170 species of bamboos belonging to 26 genera are reported to be affected by various diseases and disorders (Mohanan, 1997). A total of 440 fungi, three bacteria, two viruses, one phytoplasma (mycoplasma-like organism) and one bacteria-like organism have been reported to be associated with these diseases and disorders (Mohanan and Liese, 1990; Mohanan, 1994abc; 1997, 2004). However, in India, only a few diseases are identified as serious ones, affecting the culm production as well as stand productivity. Limited experience in raising bamboo planting stock together with lack of information on diseases affecting them and their management measures have often resulted in partial to complete failure of bamboo nurseries. Also, diseases affecting emerging and growing culms in plantations, homesteads and in natural stands have adversely affected the bamboo industry, both in rural and urban sectors. Bamboo forms a significant component of the natural vegetation in many states and occurs in tropical evergreen, semi-evergreen, and moist-deciduous forests, sub-tropical hills, and also as southern-moist-bamboo brakes (Mohanan, 1994a). Bamboos have also been raised in pure or mixed with plantations as well as in homesteads and farmlands. Bamboos play a major role in the economy of the states and are used in traditional cottage industries and as raw material for bamboo ply, rayon and paper industries.

2. Diseases in Bamboo Stands and Their Management

Bamboos in natural stands, plantations, homesteads, village groves, etc. are vulnerable to various diseases at their different stages of growth. Newly emerging and growing supple culms are generally susceptible to diseases. Among large number of diseases recorded on bamboos, potential diseases affecting the stand productivity
include rot of emerging and growing culms, bamboo blight, thread blight, witches’ broom, little leaf disease and culm basal rot.

2.1. Rot of Emerging Culms

*Bambusa balcooa, B. bambos, B. polymorpha, B. vulgaris, D. longispathus, D. strictus, Thyrostachys oliveri* are the most severely affected bamboo species. Severe infection and culm mortality were recorded in bamboo stands in high rainfall areas in the Kerala and Karnataka states. The disease manifests as dark brown lesions on the outermost culm sheath of the emerging culm (15-20 cm height), near the soil level (Fig. 2.1.1a). These lesions spread rapidly and cover the entire outer culm sheaths. The infection causes rot of the tender, succulent emerging shoot which becomes discoloured and gives off a strong smell of molasses. The disease affects further development of the culm and causes total decay (Fig. 2.1.1b). *Fusarium moniliforme* var. *intermedium* Neish and Legget is the fungal pathogen associated with the disease. Heavy rainfall during and after the emergence of culm, water logging around the clump, mining, insect activity and poor stand management are the factors favouring the infection. The disease has also been reported in various bamboo species in Bangladesh and Pakistan (Mohanan, 1997).

Cultural control measures, such as removal debris around the clumps before the onset of monsoon, light burning of the debris over the ground, loosening the soil around the clump before the culm emergence, pruning and removal of branches from the basal part of the older culms during the dry period (March-April) are suggested to minimize the disease incidence. To avoid mechanical damage to the emerging culms caused by cattle and other animals, clump tending and cleaning operations are recommended only in well-protected stands. Application of carbendazim (@0.2% a.i.) or mancozeb (@ 0.3% a.i.) is also recommended for managing the disease.

2.2. Rot of Growing Culms

Among several species of bamboos, *B. balcooa, B. bambos, B. polymorpha* and *D. strictus* are the severely affected ones in India. The disease appears as water-soaked brown lesions at the base of culm sheaths where they are attached to the nodes. Injury on culm sheaths and culms at nodal region, made by the sap sucking insect *Purohita cervina* Distant, predisposes the culm to fungal infection. Sap oozes out from the pin-prick wounds made by the insect, and infection develops in and around these wounds and forms large necrotic lesions. The infection often spreads to the entire culm sheath and to the tissues beneath the culm sheath. Severely affected culms cease to grow, become shrivelled, and fall off even before they complete their elongation phase.
Twisting and bending of culms due to severe necrosis on one side of the culm, partial development of branches, breaking of culms at the point of infection, etc. were also noticed. *Fusarium equiseti* Corda (Sacc.) and *Fusarium moniliforme* Sheldon are the fungi associated with the disease. The causal fungi sporulate profusely on the necrotic tissues of the culm internode and culm sheath. Build up of insect (*P. cervina*) population at the culm elongation phase was found responsible for the spread of disease within the individual culm or among the culms and clumps by way of dispersal of fungal spores mechanically. Disease can be managed by taking chemical control measure (spraying insecticide, monocrotophos 0.05% a.i.) against the buildup of the insect (*Purohitia cervina*) population in the bamboo stands during the culm elongation phase and by application of fungicides carbendazim (Bavistin) or mancozeb (Dithane M 45) at 0.2 per cent a.i. on the infected culms.

### 2.3. Bamboo Blight

Bamboo blight has been reported in Bangladesh and India. The disease has been recorded as affecting the village groves of *B. balcooa*, *B. bambos*, *B. tulda* and *B. vulgaris* (Gibson, 1975; Rahman, 1978). The disease was first recorded in 1970 by Rahman and Zethner (1971) as a potentially serious problem of village bamboos in Bangladesh. Recently, bamboo blight has also been recorded in *B. nutans* in the coastal belts of Odisha (Gupta *et al.*, 1990; Jamaluddin *et al.*, 1992; Mohanan, 1995b). An average of 94 per cent infection has been recorded in *B. nutans* clumps in Puri, Cuttack, Baleshwar and Ganjam districts in Odisha state. Bamboo blight occurs in well established older clumps, aged more than 8-10 years. Culms which survive the first growing season remain healthy and the spread of the disease between clumps of bamboos is slow. The disease results in a sequential die-back of culms in their first season of growth. Symptoms appear when culms are nearing full growth or shortly after this. The initial symptoms of blight are premature death of culms sheaths and partial collapse of the fragile apical regions. Later, wet rotten patches develop on the internodes, often associated with insect damage. The necrotic patches spread rapidly in the succulent internodes and eventually become confluent. At the same time, symptoms begin to develop in the lower, more fibrous internodes, and spread slowly downwards, resulting in die-back. Epicormic branches from the nodes of the infected culms develop occasionally which also become affected by the disease in due course.

*Sarocladium oryzae* (Sawada) W. Gams and D. Hawks has been reported as the principal fungus associated with the bamboo blight in Bangladesh (Boa and Brady, 1987; Rahman, 1988) and in India (Gupta *et al.*, 1990). *Coniothyrium fuckelii* Sacc., *Fusarium* spp., *Acremonium strictum* W. Gams, *Pteroconium* sp., *Arthrinium* sp. were the other fungi recorded as associated with bamboo blight (Boa and Rahman, 1983).
Etiology of the disease is still poorly understood. As mentioned, various fungal organisms have been found associated with the blighted culms. However, pathogenic connection between a fungus, or a group of fungi, and the blight disease has not been adequately demonstrated. However, *S. oryzae* is considered to be the principal fungus associated with bamboo blight. The fungus perennates in the affected culms, bamboo debris or paddy which act as the source of inoculum. The fungus gets inside the rhizome system before blight is established (Boa and Rahman, 1987). The spores of *S. oryzae* germinate easily in water within a few hours and infect new culms or culm sheaths. Water accumulation in debris, weeds or shrubs around the culms enhances the susceptibility of the culms to infection. High humidity owing to canal irrigation and high temperatures during monsoon favour infection. Poor stand management, conducive climatic and soil factors, and insect attack are responsible for the development of the infection. Mining insects are suspected to help in spreading the disease.

Silvicultural measures recommended to manage the disease include cutting and removing blighted bamboo culms, burning the debris of clumps *in situ* and addition of new soil to clumps. Light surface fire (controlled burning) before the onset of monsoon is suggested for reducing the inoculum potential of the pathogen in the debris or in the top few centimetres of soil. Weeds and bushes around the clumps should be removed as these act as retainers of moisture which helps in initiation of the infection. Offsets for outplanting should not be taken from the blighted clumps. Soil or debris from the infected clumps or nearby areas should not be transferred to healthy clumps. Application of carbendazim combined with mancozeb (carbendazim 0.25% a.i. + mancozeb 0.3% a.i.) or with Fytolan (0.3% a.i.) is recommended. Drenching the soil around the bamboo clumps with copper oxychloride and mancozeb is also desirable to check the disease.

### 2.4. Branch Die-Back

The disease occurs in *B. bambos*, *B. vulgaris* and *D. strictus* stands. Though, the disease severity was low in all the plots surveyed, per cent disease incidence was found high in plantations than natural stands. Culms in young developing clumps were found severely affected by the disease. The disease occurred during September-October and became severe during December-January causing die-back of branches. The infection occurs on branches and on three to five internodes at top of young culm in the form of small greyish magenta coloured linear lesions which later develop into necrotic streaks. Infection occurs on foliage as pale yellowish lesions, later spreading to the entire lamina, resulting in leaf necrosis, withering and subsequent premature defoliation. Infection spreads from the branches to the culm node and internodes downwards (Fig. 2.4.1.). Under high humidity, causal fungus sporulates
on the infected necrotic areas of the culm internodes and branches. Severe infection causes die-back of the branches and culm tip. *Fusarium pallidoroseum* (Cooke) Sacco was the causal agent.

### 2.5. Witches' Broom

The disease is wide-spread in reed bamboo stands in Kerala (Mohanan, 2004). It affects commercially important reed bamboos, viz., *Ochlandra travancorica*, *O. scriptoria* and *O. ebracteata* (Fig. 2.5.1.). The disease incidence varies depending upon the microclimatic conditions in the locality. Very high incidence (24%) was recorded in *O. scriptoria* stands in Periya, where the annual rainfall ranged from 4,000 to 6,500 mm and a high relative humidity (60-90%). The disease was also recorded on grass *Pennisetum polystachion* (L.) Schutles growing in the vicinity of diseased reed bamboo clumps. The disease manifests as development of numerous highly shortened shoots at the nodes of mature culms. These abnormal shoots develop into highly reduced shoots successively from their nodes. The culm sheaths which cover the internodes also become shortened in size and become boat shaped, often with a prominent ligule. Successive development of a large number of thin wiry shoots in tuft from the nodes of the infected culms gives rise to the characteristic appearance of witches' broom. New shoots emerging from the infected rhizome also show pronounced brooming symptoms. Shining black fructifications of the causal fungus develop on the affected shoots after 5-6 months of infection. The fungus associated with the witches' broom disease is *Balansia liniaris* (Rehm.) Diel. The disease has been recorded on different species of bamboo in China, Indonesia, Japan, Taiwan-China and Vietnam (Chen, 1971; Zhu, 1989; Mohanan, 1997, 2004). In China, among different bamboo species affected with the disease, *Phyllostachys viridis*, *P. glauca* McCl. *P. praecox* Chu et Chu, *P. nuda* McCl. *Bambusa multiplex* (Lour.) Raeusch. are important ones. In Indonesia, the disease has been reported on *Gigantochloa apus* Kurz, Gatter (Hassk.) and *G. robusta* Kurz. In Japan, the disease has been recorded on *P. bambusoides* Sieb. Et Zucc., *P. nigra* var. *henonis* Stapf.ex Rendle, *Sasa borealis* var. *pupurascens* and *Sasa* spp. (Shinohara, 1965; Mohanan, 1997). Silvicultural measures to manage the disease include surveying and identifying the diseased clumps in the stands, physically removing and burning the infected culms and witches' brooms. As the disease is systemic, rhizome or culms from diseased clumps should not be used for vegetative propagation.

### 2.6. Little Leaf

This disease affects *D. strictus* in natural as well as cultivated stands in drier tracts, viz., Agaly, Attapady, Goolikadavu, Thakarapady, in Mannarkad Forest Division and Chinnar in Idukki Wildlife Division in the Kerala state (Fig. 2.6.1a.). The disease is
characterized by the development of numerous, highly reduced, abnormal bushy shoots from the nodes of newly emerged culms and culm branches. Foliage develop from these shoots show prominent reduction in size and needle-like appearance. Profuse development of such abnormal shoots from each node of the developing culm and their subsequent growth gives rise to a massive bushy structure around each node. The disease also affects culm elongation; infected culm shows stunted growth. Association of Phytoplasma with the disease was proved by Diene's staining, fluorescence and transmission electron microscopic studies (Fig. 2.6.1b.) and tetracycline therapy (Mohanan, 1994b.). Clump to clump infection was found to be slow and an increase of 6 per cent was recorded at Agaly and 12 per cent at Thakarapady in Kerala over a period of four years. Since, in most bamboos, the process of culm production, elongation and development is completed within six months, and after that only a biological consolidation takes place, it is not worthwhile to control the disease in emerged culms by chemicals or antibiotics. Silvicultural measures to manage the disease include cutting and burning the severely infected culms/clumps and planting disease resistant bamboo species.

2.7. Thread Blight
Thread blight disease affects most bamboo species and the disease appears during monsoon season, subsides and almost disappears during the dry period. *B. bambos, B. vulgaris* and *D. strictus* are the severely affected species. Large water-soaked greyish lesions occur on leaves which advance towards the leaf tip (Fig. 2.7.1a. and b.). Fine silvery white mycelial strands of the causal fungus appear on the lower surface corresponding to the lesions on the foliage. Spread of the disease is mainly through physical contact of the advancing fungal hyphae on the diseased foliage with healthy neighbouring foliage. Diseased foliage stuck closely together by the mycelial weft of the fungus at the leaf margins, tips and bases. Infection causes browning and necrosis, leading to blight of the culm branches, especially foliage. *Botryobasidium salmonicolor* (Berk. and Br.) Venkat. is the fungus associated with the disease. Pruning the diseased branches from the affected clumps and cleaning and burning the debris from the ground around the clumps can minimize the disease incidence.

2.8. Foliage Diseases

2.8.1. Leaf rust
Leaf rust of bamboo is widespread and affects almost all the bamboo species in bamboo growing states. *B. bambos, B. vulgaris, B. velltricosa, D. strictus, Oxytenanthera monostigma, Ochlandra travancorica* are the important bamboos
affected with the rust disease (Mohanan, 1997 and 2010). The disease severity rating (DSR) ranged from low (L) to medium (M) and disease severity index (DSI) 0.33-2.00. The rust infection appears as minute pin-head, water-soaked flecks on the adaxial surface of the foliage, where yellowish orange to rust brown linearly arranged urediniosori develop. On the corresponding abaxial surface of the flecks, grayish brown to dark brown lesions with yellowish orange halo forms. Often numerous such lesions develop on a single lamina which later coalesce and spread to entire leaf lamina. Severe infection leads to necrosis of the leaf tissues between the spots. Rust uredinia develop during August-September and continue to produce bright yellowish orange coloured urediniospores till April-May. Rust teliosori develop linearly on the adaxial surface of the leaf either in the degenerating urediniosori or separately during December-January. Severe rust uredinial infection causes abnormal leaf fall even before the development of the teliosori. Dusturella divina (Syd.) Munk. and Khes. is the rust fungus. D. divina has earlier been recorded as having 0-IV stages and of these, 0-I stages on Randia sp. and other two stages on bamboos (Bakshi et al., 1972). Among the rust fungi, D. divina, D. bambusina, Puccinia spp., and Tunicospora bagchi, recorded from bamboos in India. D. divina is the most wide-spread rust fungus in the country (Sujan Singh and Bakshi, 1964; Nema and Mishra, 1965; Bakshi et al., 1972; Mohanan, 1994).

2.8.2. Foliage blight
Most of the bamboo species growing in different states were found affected with the foliage blight B. bambos and D. longispathius and were the severely affected species. Disease severity was low in all bamboo growing areas. Severe foliage blight was also recorded on B. brandisii in several locations. Infection occurs as small water-soaked grayish brown spindle-shaped lesions with pale yellow halo on both young and mature leaves during August-September. The lesions coalesce and form large spreading grayish brown to yellowish brown irregular lesions with dark brown border, often covering the entire leaf lamina (Fig. 2.8.2.1a.). Severe infection causes withering of leaves and defoliation. Bipolaris maydis (Nishikado and Miyake) Shoem. anamorph of Cochliobolus heterostrophus (Dresch.) Dresch. and Bipolaris sp. were identified as the causal agents (Fig. 2.8.2.1b.).

2.8.3. Leaf tip blight
The disease occurs on B. bambusa in natural stands and in plantations. The infection appears as greyish brown linear to spindle-shaped lesions near margin, base and tip of both young and mature leaves. Usually, the leaf tips were found severely affected which led to leaf tip blight. Alternaria alternate (FR.) Keissler was the causal fungus.
2.8.4. Exserohilum leaf spot

This leaf spot disease occurs in most of the bamboo growing areas and affects *B. polymorpha*, *D. longispathius* and *D. strictus*. The leaf spots occur on mature leaves during August-September. Infection manifests as small water-soaked greyish black linear to irregular lesions which later coalesced and spread to the entire leaf lamina; infection causes necrosis, withering and premature defoliation. *Exserohilum rostratum* (Desch.) Leonard and Suggs anamorph of *Setosphaeria rostrata* Leonard and *E. holmii* (Luttr.) V. Arx. anamorph of *Setosphaeria holmii* (Luttr.) Leonard and Suggs are the causal organisms (Fig. 2.8.4.1.). Generally, no marked difference in symptoms was observed in different bamboo species, except in juvenile leaves of *D. longispathius*, where the lesions were olive yellow, spindle-shaped and water-soaked which later spread to entire leaf lamina and became necrotic. *Exserohilum halodes* also causes leaf blight on bamboo species in Karnataka (Bhat et al., 1989).

2.8.5. Zonate leaf spot

The disease affects *B. bambos*, *B. polymorpha*, *D. strictus*, *O. travancorica*, *O. ebracteata*, *Oxytenanthera monostigma* and *T. siamensis* foliage. Infection occurs usually on foliage in the lower branches as minute greyish-brown spots of 2-3 mm across. The spots enlarge to 5-8 mm in dia and become yellowish brown with dark brown margin. The spots spread further and formed reniform, semi-circular to circular greyish brown areas of 5-10 mm in width with dark brown wavy margin around the pale coloured central spot; later, these develop into a large zonate spot of 3-12 mm in dia. depending on the host species affected and climate conditions. *Dactylaria* sp. is the causal agent.

2.8.6. Colletotrichum leaf spot

The disease occurs in almost all the bamboo species raised in different states. The disease manifests as small water-soaked grayish brown lesions on the juvenile and mature leaves. These spots spread and coalesce to form large purple linear to irregular areas which often cover the entire leaf lamina, as in *O. travancorica* or *O. ebracteata*. Infected leaves become pale yellowish and leathery. *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc., anamorph of *Glomerella cingulata* (Stonem.) Spauld. & Schrenk. is the causal agent. *C. gloeosporioides* is a common foliar pathogen affecting large number of forestry and agricultural species. The fungus has earlier been recorded on bamboos from Meghalaya (Deka et al., 1990) and Malaysia (Azmy and Maziah, 1990).

2.8.7. Phoma leaf spot

This disease occurs on *B. bambos* and *D. strictus*. Infection occurs as small pin-head sized brown lesions on the adaxial surface of the leaves. Both the juvenile and mature
Fig. 2.1.1. Rot of emerging culms.

Fig. 2.4.1. Branch dieback in *B. bambos*.

Fig. 2.5.1. Witches' broom in *O. travancorica*.

Fig. 2.6.1. Little leaf disease.

Fig. 2.7.1.a. Thread blight in *O. travancorica* and b. on leaves of *B. polymorpha*.

Fig. 2.8.2.1. a. Foliage blight of *B. bambos* and b. conidiophores and conidia of *B. maydis*.

Fig. 2.8.4.1. Spores of *E. holmii* causing foliage blight in *D. strictus*. 

a. *Bambusa balcooa* culms showing typical symptoms

b. Rot of *B. bambos* culms showing browning and rot of culm sheaths

a. Disease of *D. strictus*

b. Transmission electron micrograph of diseases tissues showing Phytoplasma.
leaves were found affected with the disease. The spots become spindle-shaped and later coalesce to form large irregular spot with greyish white centre and dark brown margin. The spots develop in November-December and the pycnidia of the fungus formed in the necrotic lesions as erumpent structures. Under high humidity, pale pink coloured gelatinous fungal spore mass produced in cirii from the pycnidia. \textit{Phoma sorghina} (Sacc.) Boerma., Dorenbosch and Van Kestteran, \textit{Phoma herbarum} Westend., \textit{Phoma} sp. are the causal fungi.

2.8.8. \textbf{Phomopsis leaf spot}

This leaf spot disease was recorded in \textit{B. bambos}, \textit{D. strictus} and \textit{Thrysostachys} sp. The infection manifests as minute greyish brown water-soaked lesions on the mature leaves which later spread to form circular to irregular spots with dark brown wavy margin. Pycnidia developed in the necrotic tissues during November- December and conidial mass oozed out in yellowish cirii. \textit{Phomopsis} sp. is the causal agent. So far, no \textit{Phomopsis} sp. has been recorded on bamboos from India and pathogen appears to be an undescribed species.

2.8.9. \textbf{Stagonospora leaf spot}

The leaf spot was recorded on \textit{B. bambos} and \textit{D. strictus} in natural stands. The disease affects mature leaves during December-January. The infection appears as dark brown irregular lesions of 3-5 mm diameter which later enlarge and become brownish black necrotic spots. The spots usually develop along the leaf margins. \textit{Stagonospora} sp. was identified as the causal agent.

2.8.10. \textbf{Septoria leaf spot}

The leaf spot was recorded on mature leaves of \textit{Thrysostachys} sp. during December-January. Infection appears as greyish brown lesions of 2-4 mm dia on the upper side of the mature leaves. Pale to dark brown pycnidia develop in the centre of the lesion. \textit{Septoria} sp. is the causal agent.

2.8.11. \textbf{Chaetospermum leaf spot}

The leaf spot was observed on \textit{B. bambos} during August-September, usually on mature leaves of the lower branches. The disease manifests as numerous minute pale yellow lesions arranged linearly on the upper surface of the mature leaves. High humidity and presence of water drops on the leaf surface possibly help in rapid spread of the lesions. Usually, development of large number of such lesions on the leaf imparted yellowish colour to the affected foliage. Yellowish brown minute pycnidia developed in the necrotic areas during October-November. \textit{Chaetospermum carneum} Tassi is the causal agent.
2.8.12. Curvularia leaf spot
The leaf spot was recorded on *Arundinaria* sp., *Ochlandra travancorica*, *O. ebracteata* *O. scriptoria* and *Thyrsostachys* sp. The disease affects only the juvenile foliage of new culms. The leaf spots appear as greyish black irregular lesions on the juvenile expanding foliage, especially those in the lower branches of new culm. The lesions enlarge and cover the entire leaf lamina and become necrotic. *Curvularia lunata* (Wakker) Boedijn, anamorph of *Cochliobolus lunatus* Nelson and Haasis is the causal agent.

2.8.13. Ascochyta leaf spot
The disease was recorded in bamboo plantations and natural stands during November-December. *B. bambos*, *D. strictus* and *Thyrsostachys* sp. were the most affected bamboos. Infection occurs as minute spindle-shaped yellowish brown to brown water-soaked spots on the upper surface of the leaves. Both juvenile and mature leaves were found affected by the disease. Dark brown to black pycnidia develop over the necrotic area from which under high humidity pinkish white spore mass oozed out. Severe infection caused premature defoliation. *Ascochyta* sp. is the causal agent.

2.8.14. Petrakomyces leaf spot
The leaf spot was recorded during July-September on *Arundinaria* sp., *B. bambos*, *D. strictus*, *O. scriptoria*, *O. ebracteata* and *Thyrsostachys* sp. The disease manifests as pin-head sized brown water-soaked lesions on the foliage, especially those on the lower branches of the culms. The lesions enlarged to form 3-5 mm dia. oval to elliptical dark violet coloured spot with pale yellow halo. Later, the spots appeared as raised black structures bearing pycnidia of the causal fungus. *Petrakomyces indicus* Subram. & Ramakr. is the causal fungus. Earlier, the fungus was recorded on *Bambusa* sp. from Tamil Nadu and Karnataka (Rangaswami *et al.*, 1970).

2.8.15. Rosenscheldiella leaf spot
The leaf spot was recorded on *O. travancorica* in natural stands during September-October. The infection appears as minute yellowish brown linear lesions on the mature leaves which in due course enlarged to form 3-5 mm dia. necrotic spots with yellow halo. The fungal fructifications produced in linear rows over the necrotic area on the upper surface of the leaves. *Rosenscheldiella* sp. is the causal fungus.

2.8.16. Cerodothis leaf spot
The leaf spot was recorded on *B. bambos* and *D. strictus* natural stands and *Thyrsostachys* sp. plantation during December-January. The infection affects both juvenile and mature leaves and manifests as tiny, pale yellow spots on the upper surface of the leaves. No visible necrotic areas were formed as the disease progressed. The
ascocarps of the fungus become erumpent through the ruptured epidermis. At maturity, the ascocarps appeared as tiny golden yellow streaks arranged in linear rows. Hyaline to pale yellow microconidia of the fungus were also produced in the microconidiallocules which developed close to the margin of the developing ascostroma or produced separately. The microconidia extruded as pale to golden yellow masses through a pore formed in the locules. Under warm-humid condition, the entire leaf surface becomes covered with the spore masses. Cerodothis aurea Muthappa is the causal fungus. Severe infection leads to yellowing and drying up of the foliage.

2.8.17. Coccodiella leaf spot
The leaf spot was recorded on mature leaves of O. travancorica during September-October. The infection appears as yellowish brown minute lesions which enlarged to form dark brown linear necrotic spot. Fructifications of the causal fungus developed in the necrotic spot on the lower surface of the leaves. Coccodiella sp. is the causal fungus. The present isolate differs in morphological and cultural characteristics from all the currently known species of Coccodiella recorded from the monocots.

2.8.18. Tar spot
Tar spot was recorded on B. bambos, B. vulgaris, D. strictus, Oxytenanthera monostigma, O. scriptoria, O. travancorica and Thyrsostachys sp. Infection appeared as pin-head sized pale to dark yellowish brown lesions on the abaxial surface of the leaf. The lesions spread and developed into oval to circular spots with dark brown centre and pale yellow margin. Usually, four to six small spots (3-6 mm dia.) appeared on the leaf lamina, as well as on leaf sheath. Ascocarps developed as dark brown to black raised structures in the necrotic spots. Three species of Phyllachora, viz., P. ischaemi Sydow, P. longinaviculata Parbery and P. shiraiana Sydow. were the causal fungi. Among these fungal pathogens, P. ischaemi infects only B. bambos.

2.9. Rhizome, Root and Culm Basal Rot
In bamboos, diseases also affect the rhizome and roots and cause considerable damage in natural stands and plantations. Diseases affecting the rhizome include rhizome bud rot, root rot, decay of rhizome and rot of basal culm. Rhizome bud rot and root rot were recorded in young one year-old B. bambos plantations in Kerala. Pythium middletonii Sparrow is the causal agent and it causes rot of fleshy rhizome buds, roots and tender tissues at the growing points. The disease was recorded in plantations situated in water-logged areas. Culm basal rot caused by Amylosporus campbellii (Berk.) Ryv., was also recorded from different bamboo growing areas.
A. campbellii produces its sporocarps at the base of the affected culms. B. bambos, D. longispathus and D. strictus, are the most susceptible species to A. campbellii. The disease causes white spongy or fibrous rot of the rhizome and basal culm. Since the disease affects the stand establishment, management measures have to be adopted to minimize the fungal infection.

Rhizome bud rot can be managed by using healthy planting stock, as well as by improving the cultural and management practices in the plantations. During the dismantling of seedbeds and pulling out the bare root seedlings for planting, care should be taken to avoid causing injuries to seedling rhizome. Storage and transportation of planting stocks should be done under hygienic conditions. Planting in water-logged areas should be avoided. To manage the culm basal rot caused by A. campbellii, removal of the sporocarps of the decay fungus from the affected bamboo clumps, burning of dead rhizome and roots of diseased culms are suggested to manage and minimize the further spread of the rhizome and basal rot. Silvicultural measure like isolation trenches may prove effective in containing the disease in between the trenches, thus, preventing its spread. However, trenching and isolation of the diseased clumps will be difficult under flood irrigation. Fungicidal treatments (Copper oxychloride @ 3% a.i., 3 to 4 application at weekly interval) and soil working around the clumps will help in checking the development of the rhizomorphs of the fungus and, thereby, disease incidence and severity. Severely affected clumps should be cut, and rhizome dug out and burnt on the spot as a sanitary measure.

2.10. Culm Staining and Die-Back
The disease was recorded in seven to ten years old clumps of B. vulgaris and D. longispathus. In B. vulgaris, disease incidence ranges from 10 to 98 per cent, while in D. longispathus disease severity was low and per cent infection ranges from 7 to 8. Infection was found to be predisposed by injury caused by hispine beetle Estigmena chinensis Hope on the new culms. Beetle bore holes were observed on almost all the nodes of the affected culms as well as branches. Pale purple to dark brown linear lesions developed around each bore hole which later spread to the entire culm internode and became necrotic. Raised black fructifications of the causal fungus developed on the affected internodes during September-October. Infection also spreads to the branches. The discolouration of the culm internodes, necrosis and die-back of culms started from the distal end towards the base of the culms. Apiospora bambusae is the causal fungus. The affected culms and branches were found completely covered with black fructifications of the fungus.
2.11. Infection of Inflorescence and Seed

Fungi and bacteria invade the bamboo seeds during their different developmental stages on the plant as well as after the seed fall. Microorganisms affect the developing fruits, invade the seeds and, thus, reduce the amount of healthy seeds. A total of 42 fungi belonging to 23 genera and two bacteria have been recorded on seeds of bamboo from India (Mohanan, 1997). Among these Bipolaris sp., Exserohilum sp., Fusarium pallidoroseum, Drechslera sp., Phomopsis sp., etc. are the important seed-borne fungi that cause seedling infection in bamboo nursery. Earlier, a large number of fungi have been reported on bamboo seeds from Thailand (Pongpanich and Chalermpongse, 1986). Bamboo seeds are usually collected from the forest floor, where they are open to attack by fungi and bacteria. Under such circumstances, the seed quality deteriorates before and after the seed collection. The period during which seeds are liable to infection by microorganisms can be greatly reduced if seed collection is done immediately after the seed fall. The cleaned seeds should be stored in air-tight containers under reduced temperature and moisture content. Fungicidal seed treatment (Mancozeb, Ceresan D, Hexathir WP, Vitavax WP @ 4 g/kg seeds) is suggested for maintaining the quality of the seeds under short-term storage.

3. Bamboo Nursery Diseases and Their Management

Planting stock raised in conventional seedbed nurseries, in root trainers as well as through vegetative propagation methods are equally susceptible to various pathogens. Diseases affect the nursery stock right from the time of emergence of radicle to the time of planting out, causing considerable damage depending upon the prevailing microclimatic conditions in the nursery, bamboo species and the virulence of the pathogens.

3.1. Damping-Off

The diseases is common in seedbed nurseries which affects the emerging seedlings during germination (pre-emergence damping-off) or after germination (post-emergence damping-off), while the seedling tissues are still succulent. The disease occurs in patches in the seedbeds 7 to 12 days after sowing. The disease is characterized by the rotting of seeds and also the radicle. Post-emergence damping-off is characterized by development of water-soaked brown lesions on the emerging plumule near the soil level and collapse of the affected plumule in due course. Fusarium moniliforme Sheld, F. oxysporum Schlecht, Rhizoctonia solani Kuhn are the fungal pathogens associated with the disease. The disease can be managed by adopting proper nursery cultural practices; excessive watering and shade over the nursery beds should be avoided. Seed dressing with fungicides such as Thiram 75 WP or Captan and 50 per cent WP (@ 2 g/kg of seeds) is effective in controlling the disease. Application of fungicide like carboxin (Vitavax) @ 0.1 per cent a.i. in the affected nursery beds can...
also control the disease. Low sowing rate, i.e., 500 g seeds (*B. bambos* and *D. strictus*) per standard seedbed (12 x 1 x 0.3 m) is preferable to prevent the build up of conditions conducive to the spread of the disease.

### 3.2. Web Blight

The disease occurs in high humid areas and affects 20-to 30-day-old bamboo seedlings. *B. bambos*, *D. strictus* and *D. brandisii* are the most susceptible species; severe infection affects the availability of transplanting stocks (Mohanann, 1993a, b; 2000). Infection occurs as water-soaked lesions on seedlings stem near the soil level and later spreads rapidly affecting the entire shoot, except one or two juvenile leaves. The infected seedling stem and foliage become discoloured and necrotic. Under high humidity, mycelia of the causal fungus (*R. solani*), arise from the soil and grow epiphytically over the affected seedlings. Yellowish brown sclerotia and basidial stage of the fungus (*Thanatephorus cucumeris* (Frank) Donk) also develop on the decayed basal foliage and stem. The disease occurs in patches and the affected seedlings are killed outright within 10-20 days of infection, leaving large circular to irregular patches of dried-up seedlings in the seedbed. *R. solani* Kuhn belonging to different anastomosis groups (Mohanann, 1994a) is the causal fungus. The disease can be controlled lowering the sowing rate (500 g seeds per standard seed beds) and also by lowering the watering regime (120 l per standard beds) in the nursery. Fungicidal application (Carboxin 0.2% a.i.) after seven and 21 days of seedling emergence is recommended for managing the disease.

### 3.3. Leaf Rust

The disease affects most bamboo species viz., *B. bambos*, *D. strictus*, *D. brandisii*, *Oxytenanthera monostigma*, *Ochlandra travancorica*, *Thrysostachys siamensis*, etc. of these, *B. bambos* and *D. strictus* are the most susceptible species. Severe infection causes necrosis and withering of affected foliage and die-back of seedlings. *Dusturella divina* is the rust fungus which also affects the bamboos in stands. Application of fungicide like Plantavax (0.01% a.i.) or dusting with sulphur-based fungicides can control the disease. The disease can also be controlled by avoiding shade over the nursery beds, lowering the sowing rate (500 g seeds per standard seed beds) and also by lowering the watering regime (120 l per standard beds) in the nursery. Fungicidal application (Carboxin 0.2% a.i.) after seven and 21 days of seedling emergence is recommended for managing the disease.

### 3.4. Seedling Leaf Blight and Leaf Spots

Incidence and severity of the diseases depend on the bamboo species, causal agent and nursery practices. Different fungi, viz., *Exserohilum rostratum*, *E. holmii*, *Bipolaris maydis* (Nishikado and Miyake) Shoem., *B. urochloae* (Putterilll) Shoem., *Bipolaris
sp., *Dactylaria* sp., *Alternaria alternata* (Fr.) Keissler, *Curvularia pallescens* anamorph state of *Cochliobolus pallescens* (Tsuda and Veyama) Sivan., and *Colletotrichum gloeosporioides* are responsible for causing foliage infections in nursery seedlings. Most bamboo species are susceptible to these diseases. In general, application of fungicides like Dithane M 45 (mancozeb) @ 0.2 per cent a.i. or Bavistin (carbendazim) @ 0.1 per cent a.i. can control the diseases in nurseries.

### 3.5. Seedling Leaf Striping and Stunting

The disease caused by a virus (possibly BMoV) occurred in one-year-old *B. bambos* seedlings. Pale yellowish to greenish white stripes occur on both young and mature leaves. Often the individual stripes merge together and the leaves become greenish white and leathery. Affected seedlings show stunted growth, and their stem becomes thin, fragile, pendulous and easily breakable. New shoots developed from the rhizome also show similar disease symptoms. Usually, the viruses that cause leaf striping, seedling stunting and mosaic diseases are transmitted mechanically, through seeds or vegetative propagules. In bamboo nurseries, disease may be transmitted through seeds; planting stock from the diseased nurseries should be subjected to thorough screening and seedlings exhibiting mild disease symptoms should be discarded. Earlier, viral disease caused by BMoV affecting foliage and developing culms of *D. latiflorus* Munro and *B. oldhamii* Munro has been reported in Taiwan-China (Chen, 1985; Lin *et al.*, 1993; Mohanan, 1997). Strict quarantine measures against the movement of infected planting materials from the diseased areas should be followed to safeguard against incidence and spread of the disease.

### 4. Conclusion

In bamboo stands, rot of emerging and growing culms, bamboo blight, thread blight, witches’ broom, little leaf, culm basal rot are the potential diseases affecting the stand productivity. The disease incidence, spread and severity depend on prevailing microclimatic conditions as well as stand management practices. A close monitoring of the stands, especially during the culm emergence and elongation period is warranted to adopt appropriate control measures and, thereby, reducing the impact of the diseases. Most of the diseases can be controlled by adopting appropriate cultural measures before the onset of monsoon or by prophylactic fungicidal treatments. The nursery diseases can be managed by following good nursery management practices like regulation of shade, water regime as well as reducing sowing density in the case of bamboos raised in conventional nursery. Application of appropriate fungicides at appropriate dosage is also required to combat the disease outbreak. More importance should be given for selection of bamboo species suitable for the locality and also selection of planting materials prepared from disease free clumps/areas.
References


