DISEASES of BAMBOOS in ASIA

An Illustrated Manual

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International Network for Bamboo and Rattan
Beijing n Eindhoven n New Delhi

The International Network for Bamboo and Rattan (INBAR) develops, provides and promotes appropriate technologies and other solutions to benefit people and the environment. A world-wide network, it connects governmental and non-governmental organizations and the private sector. INBAR provides leadership, coordination and support for research and development. INBAR's R&D programmes cover natural and cultivated raw materials; genetic resources, processing and utilization; economic and other social aspects; and supporting services. INBAR aims to enhance the quality of life of poor and disadvantaged people in developing countries and to make favourable impacts on forests and degraded environments.

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FOREWORD

Bamboos are considered very hardy plants, although they do, from time to time, suffer devastation from diseases. Bamboos are now increasingly being grown in plantations, and this necessitates increased vigilance against disease attacks, and preparedness for effective and rapid control if the attack occurs.

Recognizing this, the Network Planning Group of the International Network for Bamboo and Rattan (INBAR), at its meeting in Singapore in 1993, placed high priority on gathering available information on diseases of bamboos in Asian countries and the publication of this information in the form of a user-friendly, amply illustrated manual. INBAR entrusted the work to Dr C. Mohanan of the Kerala Forest Research Institute, and through the award of an internship, facilitated the collection of information from various parts of the continent.

We are delighted that this task has now been completed most satisfactorily, thanks to the dedicated work that Dr Mohanan put in. Apart from the national scientists throughout Asia who helped in gathering information necessary for this manual, INBAR also thanks: Dr C.T.S. Nair of FORSPA for his interest in the project; Prof. W. Liese of Germany who contributed greatly to drawing the international community's attention to diseases of bamboos; and Dr E. Boa of the UK who has been particularly helpful to INBAR in this current project in reviewing parts of the draft manual.

We hope that this landmark publication will stimulate further research, especially on the development of appropriate control measures where needed

I.V. Ramanuja Rao
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EXECUTIVE SUMMARY

Bamboos form the backbone of the rural economy of many Asian countries. The bamboo resource base in this region is dwindling at a fast pace because of various biotic and abiotic factors, including pests and diseases. Available information on diseases and disorders of bamboos from different countries in Asia is assembled in this manual. A large portion of the information is from China, India, Japan and Taiwan-China, and only a limited number of records are available from other countries.

About 170 species of bamboos belonging to 26 genera are found affected by various diseases and disorders. A total of 440 fungi, three bacteria, two viruses, one phytoplasma (mycoplasma-like organism) and one bacterium-like organism have been reported to be associated with these diseases and disorders. Only a few diseases are identified as serious ones, affecting culm production as well as stand productivity.

In bamboo nurseries, 13 diseases have been recorded from India, the Philippines and Thailand. Similar problems are likely to occur in other bamboo-growing countries in the region. Most of the diseases are common seedling diseases of other forestry species, with the exception of leaf striping and seedling stunting possibly caused by a virus. Among the nursery diseases, web blight caused by ***Rhizoctonia solani*** is a potentially serious disease that is widespread. ***Dasturella divina,*** which causes leaf rust, and ***Exserohilum*** spp. and ***Bipolaris*** spp., which cause foliage infection, are the other major diseases.

In the warm-humid tropical climate, an occasional

outbreak of any of these diseases is quite possible in bamboo nurseries. Most nursery diseases can usually be controlled by good nursery management practices or prophylactic fungicidal application.

Diseases that affect the rhizome, roots, culm, foliage, branches and minor branches, inflorescence, and seeds have been reported from bamboo stands. Decay and deterioration of culms in stands and storage, caused by an array of fungi, have also been noticed. Among the diseases that affect bamboos in stands, foliage diseases are most common, and about 220 fungi are known to be associated with such infections. Most of the disease records are earlier reports from China, India, Japan and Taiwan-China; and there is a lack of more recent data on foliage diseases from China and Japan. Most foliage diseases are of minor significance; nonetheless, under conducive microclimates, flare-up of certain foliage diseases — such as leaf rust, leaf spot and leaf blight — are often reported. Diseases which are recognized as potentially serious include: culm blight caused by ***Sarocladium oryzae*** in village groves in Bangladesh and in the coastal belts of Orissa state, India; rot of emerging and growing culms caused by ***Fusarium*** spp.; witches'-broom caused by ***Balansia*** spp. in China, India, Japan and Taiwan-China; little leaf disease caused by phytoplasma in the dry tracts of Southern India; culm mosaic caused by bamboo mosaic virus in Taiwan-China; and culm rust caused by ***Stereostratum corticioides*** and top blight of *Phyllostachys* spp. caused by ***Ceratosphaeria phyllostachydis*** in China.

Culm blight, culm rust, top blight and culm mosaic are spreading fast in bamboo stands in different countries, and new outbreaks are common, adversely affecting bamboo industries as well as the rural

economy as a whole. Disease management measures in practice in these countries have relied mainly on silvicultural measures and, to a lesser extent, on prophylactic treatment. However, etiology and epidemiology of these diseases are little investigated and control measures often prove inefficient. Hence, a concerted effort is required to develop appropriate measures to check further spread of the disease in stands, as well as to safeguard against the inadvertent introduction of the disease to new areas. Disease management strategies involving both short-term and long-term measures — including broadening the genetic base of bamboos, and the development and introduction of disease-resistant species/provenances — have to be made.

Decay and biodeterioration of culms in storage form an important problem. Natural durability of bamboo culms is very low. A large number of decay and staining fungi have been recorded on bamboos under storage in different countries. The severity of decay and deterioration depends on the duration of storage, the bamboo species, and environmental and storage conditions. Any appropriate storage technique devised to minimize the hazards must consider these aspects. Although effective preservative chemicals and treatment techniques for bamboos are available, more emphasis should be given to develop low-cost, easily available preservatives, and economically viable and environmentally friendly treatment methods.

1. INTRODUCTION

Bamboos are fast-growing, versatile plant species with multiple end-uses. For centuries, bamboos have been closely related to the agriculture, cottage industries, arts, culture and day-to-day life of more than half of the world's population. Recently, bamboos have also entered highly competitive markets in the form of pulp for paper and rayon, parquet, plybamboo and as a canned vegetable. Till recently, bamboos were categorized as minor forest produce or even treated as weeds. With the alarming shrinkage of forest resources and the restrictions imposed on logging from natural stands, emphasis is being placed on raising fast-growing, multipurpose tree species to meet the ever-increasing demand for wood. Bamboo, the world's fastest growing and environment friendly giant grass, has now gained international recognition and priority, leading to its recognition as an important non-timber woody resource. In the afforestation and reforestation programmes of many Asian countries, bamboos have assumed considerable importance to meet industrial and rural requirements, and also as a means of checking soil erosion and conserving soil. Their versatility, rapid growth and many end-uses have made bamboos the backbone of rural economy in many Asian countries.

Bamboos are estimated to comprise about 1 200 species belonging to 75 genera. They have a wide range of distribution from the tropics to the temperate zones and from sea level to elevations of 3 000 to 4 000 m. However, most of the bamboos occur in the warm-humid areas in the tropical and subtropical Asia, South America and Africa (Fig. 1).

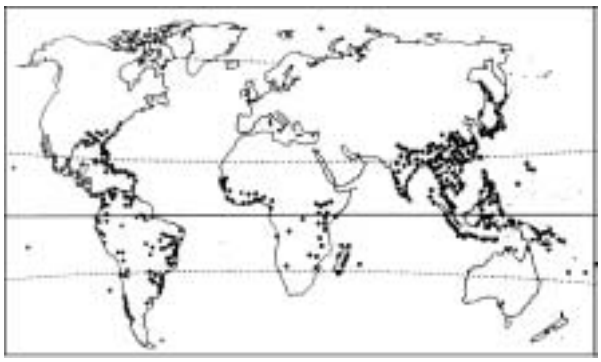

Fig. 1: Geographical distribution of bamboos in the world

Of the three continental regions of bamboo distribution, Asia is the largest with about 18 million ha of land growing more than 800 species and varieties of bamboos belonging to 45 genera (Hsiung 1981, 1991). The economically important bamboos of Asia belong to relatively few species of the following genera: *Bambusa* Schreber, *Cephalostachyum* Munro, *Dendrocalamus* Nees, *Gigantochloa* Kurz ex Munro, *Melocanna* Trin., *Ochlandra* Benth., *Phyllostachys* Sieb. & Zucc., *Schizostachyum* Nees and *Thyrsostachys* Gamble (Table 1).

The productive potential of bamboo stands in most of the bamboo-growing countries in Asia is affected by various biotic and abiotic factors. A large number of diseases have been reported in bamboos from different countries in Asia.

Diseases have been reported on bamboo seedlings in nurseries and clumps in plantations, village groves and natural stands. Decay and deterioration of culms during post-harvest storage and use have also been reported. However, the available information on diseases is widely scattered and often lacking in detail. It has been difficult to make any assessment on the present status of diseases as well as their impact upon bamboo cultivation and culm production in a particular country. Earlier, attempts to collate information on bamboo diseases were made by Boa (1987a) and Mohanan and Liese (1990). This manual gathers information:

- to review existing knowledge of diseases and disorders of bamboos in Asia;

Table 1: Bamboos in Asian countries

Country	Area (10^4 ha)	Genera	Species	Economically important bamboos
Bangladesh	60.00	13	33	*Bambusa balcooa, B. vulgaris, B. nutans, B. tulda, Dendrocalamus strictus, Melocanna baccifera*
Bhutan	*	8	11	*B. nutans, D. hamiltonii, Cephalostachyum* sp.
Cambodia	28.70	*	*	*D. giganteus, Cephalostachyum* sp., *Oxytenanthera* sp.
China	400.00	33	400	*B. textilis, B. pervariabilis, B. blumeana, D. latiflorus, D. strictus, D. giganteus, Phyllostachys pubescens, P. glauca, P. flexuosa, P. nuda, P. bambusoides, P. tanaka*
India	1003.00	23	128	*B. bambos, B. nutans, B. tulda, B. vulgaris, D. hamiltonii, D. strictus, Ochlandra travancorica, M. baccifera*
Indonesia	5.00	14	125	*B. bambos, Gigantochloa apus, G. atter, G. verticillata*
Japan	14.10	13	165	*P. bambusoides, P. edulis, P. nigra, P. reticulata, P. pubescens, Pleioblastus simonii, P. hindsii*
Korea	0.80	10	13	*Phyllostachys reticulata, Pleioblastus* sp.
Laos	9.80	*	*	*G. albociliata, Cephalostachyum* sp., *Thyrsostachys* sp.
Malaysia	3.29	10	50	*G. levis, G. ligulata, G. scortechinii, G. wrayi, Thyrsostachys* sp.
Myanmar	217.00	18	90	*B. polymorpha, B. tulda, B. vulgaris, D. calostachyus, D. giganteus, D. longispathus, O. scriptoria, Cephalostachyum pergracile, Melocanna baccifera, Thyrsostachys siamensis*
Nepal	*	5	30	*Bambusa* sp., *D. strictus, D. hamiltonii*
Pakistan	*	*	*	*B. tulda, D. strictus, D. hamiltonii*
Philippines	0.80	12	55	*B. blumeana, B. vulgaris, D. merrillianus, D. latiflorus, G. aspera, G. levis, Schizostachyum lima, S. lumampao*
Sri Lanka	8.00	7	14	*B. bambos, B. vulgaris, Ochlandra stridula, D. giganteus, D. membranaceus, D. asper, D. strictus*
Taiwan-China	17.56	18	56	*B. oldhamii, D. latiflorus, P. edulis, P. makinoi*
Thailand	100.00	12	50	*B. bambos, B. blumeana, B. longispiculata, B. nana, B. tulda, B. polymorpha, D. hamiltonii, D. membranaceus, D. brandisii, D. strictus, C. pergracile, G. albociliata, G. nigrociliata, G. hasskarliana, G. macrostachys, T. oliveri, T. siamensis*
Vietnam	13.00	15	22	*B. bambos, B. tulda, P. bambusoides*

** Data not available*

- to identify serious disease problems posing threats to the bamboo resource; and
- to identify gaps in knowledge as well as research needs on bamboo diseases/disorders and their management.

This manual presents available information on diseases in nurseries, plantations and natural stands, as well as on decay and deterioration of harvested culms. Available information on distribution of diseases, bamboo species affected, economic losses, associated pathogens, and remedial measures and corrective management practices for economically important diseases are furnished. Potential diseases of bamboos in Asia are also identified.

Sources and Nature of Information

Literature searches were carried out using the TREECD database and by conventional library consultation. Attempts were also made to collect unpublished information by contacting concerned researchers and organizations in the region. Bamboo nurseries and stands in different localities in China, India, the Philippines and Thailand were also visited, and first-hand information on diseases was gathered. However, the present work is heavily dependent on earlier studies by the author (Mohanan 1990, 1994a,b; Mohanan and Liese 1990). Libraries and organizations consulted include: Bamboo Information Centre India, Kerala Forest Research Institute (KFRI), Kerala, India; Indian Council of Forestry Research and Education (ICFRE), Dehra Dun, India; Tropical Forest Research Institute, Jabalpur, India; Institute of Rain and Moist Deciduous Forests, Jorhat, Assam, India; Assam Agricultural University, Jorhat, Assam, India; Botanical Garden,

Calcutta, India; Indian Agricultural Research Institute (IARI), New Delhi, India; International Network for Bamboo and Rattan (INBAR), International Development Research Centre (IDRC), New Delhi, India; Forestry Research Support Programme for Asia-Pacific (FORSPA), Bangkok, Thailand; Bamboo Information Centre China, Institute of Scientech Information, Chinese Academy of Forestry (CAF), China; Nanjing Forestry University, Nanjing, China; Kasetsart University, Bangkok, Thailand; Royal Forest Department, Bangkok, Thailand; Forest Products Research and Development Institute (FPRDI), Los Baños, the Philippines; Ecosystem Research and Development Bureau (ERDB), Los Baños, the Philippines.

Greater part of the information collected is from China, India, Japan and Taiwan-China. Only a limited number of disease records are available from Bangladesh, Indonesia, Hong Kong, Malaysia, Pakistan, the Philippines, Singapore, Sri Lanka, Thailand and Vietnam. Little or no information on bamboo disease is available from countries like Bhutan, Cambodia, Korea, Laos, Myanmar, Nepal and Papua New Guinea. Although there are numerous records of bamboo diseases from China, India and Japan, details on their etiology, symptoms, severity, economic importance, control measures, etc. are meagre. Many of the disease records from India are 50-90 years old.

Organization of Information

Information on bamboo diseases and disorders is arranged into four sections. The diseases for which sufficient details are available are presented in Sections 2 and 3. Section 2 documents diseases affecting

bamboo seedlings and planting stocks in nurseries. Section 3 documents information on diseases recorded in bamboo plantations, village groves and natural stands. In Section 4, information on post-harvest decay and deterioration of bamboo culms is presented.

Diseases are arranged on the basis of the plant parts affected, with details on their distribution, incidence and severity, economic importance, bamboo species affected, symptoms, causal organism(s), etiology and control measures. Scientific names of both diseases and hosts are given as they have appeared in the original reports, but when possible and unambiguous, the nomenclature has been corrected. Control measures suggested in the text are taken from the available literature. Where control measures were not available in the literature, the author has suggested possible remedial measures. Summary checklists of host species and pathogens/diseases are provided in Appendices I, II and III. A glossary of technical terms is also furnished.

2. IMPACT OF BAMBOO DISEASES ON THE ECONOMY

The relative importance of different diseases affecting bamboos in the region is difficult to assess because of the general lack of information accompanying the disease records. Similarly, lack of quantitative data on the extent of damage caused to the bamboo stands makes it onerous to evaluate the economic losses resulting from diseases. However, the overall impression is that the impact on economy is limited for most diseases.

A large number of foliage diseases — leaf spots, leaf blight, leaf rust, etc. — of bamboos have been recorded. In general, however, these cause comparatively less damage to bamboo stands than culm diseases.

Diseases affecting the emerging and growing culms are much more serious as they cause extensive damage to bamboo stands. Rot of emerging culms — reported in various bamboo species from Bangladesh, China, India, Pakistan, the Philippines and Thailand — appears to be one reason for the large-scale reduction in culm production. In India, the disease is widespread in natural bamboo stands as well as in bamboo plantations in the southern states. Severe infection and large-scale mortality of emerging culms were recorded in bamboo stands in high-rainfall areas in Kerala state. About 34% mortality of emerging culms was recorded in *Bambusa bambos* natural stands in different locations in Wynad Forest Division of Kerala during 1988-91. In bamboo plantations, mortality of emerging culms ranged from 5.5% to 25.5% during the same period. Usually, very high incidence of disease and mortality occurs in emerging culms of 15-30 cm height. Higher

economic losses have been reported in unmanaged natural stands than in plantations.

Rot of growing culms reported from China and India is another potentially serious disease affecting culm production. In India, the disease has been recorded in different species of bamboos grown in Kerala state, its incidence in different localities varying from 3% to 25% during 1987-91. Young (2-4 years old) clumps of *B. bambos, Dendrocalamus longispathus* and *D. strictus* were found to be the worst affected. The disease lowers the quality as well as the quantity of the culms produced.

Bamboo blight, perhaps the most dreaded disease, has been reported as affecting village groves of *B. bambos, B. balcooa, B. tulda* and *B. vulgaris* throughout Bangladesh, and *B. nutans* in the coastal areas of Orissa state in India. In Bangladesh, the disease was first recorded in 1970 as a potentially serious problem of village bamboos. Losses from the disease have been highest in *B. vulgaris* and the Jawa/Kata Jali variety of *B. tulda.* From 3% to 66% clump infection has been reported in different localities such as Chittagong, Comilla, Dhaka and Rajshahi. Although the disease severely affects the bamboos in village groves and the village farmers in the affected areas experience considerable setbacks, the available data are not adequate to make an overall assessment of the economic losses or of the impact on culm production.

In India, large-scale mortality of *B. nutans* owing to blight occurred in 1988 in the coastal areas of Ganjam, Puri and Cuttack in Orissa, causing considerable damage to the village economy. Villagers in these areas earn Rs 3 000 to 5 000 annually from sale of culms in their groves. The infection was so widespread and severe that it threatened to damage all the groves, each

consisting of 50-100 clumps, within a period of 2-3 years. The disease soon reached an epidemic proportion, and about 55-67% of the clumps in Cuttack and Puri Districts were affected. At present, the disease is spreading fast, forcing the desperate village farmers to altogether abandon bamboo cultivation.

Culm brown rot is another disease that affects growing bamboo culms, mainly those of *Phyllostachys viridis* and *P. viridis* f. *hauzeauana.* It was first recorded in 1974 in Nanjing, China, and is at present widespread among *Phyllostachys* stands in Jiangsu and Zhejiang provinces. Disease incidence in different areas ranged from 9% to 17% during 1974-79, with an annual average of 10% culm mortality.

Top blight (also known as withered tip disease or die-back), which occurs in *P. edulis* and *P. heterocycla* stands in China, is another serious disease. It affects the culms of current season, and is widespread in Jiangsu, Zhejiang, Anhui, Jiangxi, Fujian and Shanghai provinces. Top blight caused large-scale mortality of bamboos in 1983. The resultant economic losses were reported to be very high in bamboo stands growing in drought-affected areas and in poor soils with poor growth.

Branch die-back disease is extensive in natural stands and plantations in Kerala, India. Comparatively, the incidence of disease recorded was higher in young (2-3 years old) *B. bambos* in plantations (14-67%) than in natural stands (2-37%) during 1987-91. The disease has been reported as adversely affecting the establishment of young clumps. However, economic losses resulting from it have not been assessed yet.

Witches'-broom disease reported from China, India, Indonesia, Japan, Taiwan-China and Vietnam is considered a potentially serious disease that affects a

large number of bamboo species in the genera *Phyllostachys, Ochlandra, Bambusa, Gigantochloa* and *Sasa.* In China, the disease is widespread in Hunan province, causing 95-100% infection in *Phyllostachys* stands. Although the disease causes malformation of the culms and affects culm production, data on economic losses are not available from any affected countries. In Kerala, India, the disease is fairly extensive in areas where reed bamboo grows, and 6-15% disease incidence was recorded in different localities during 1988-92. Severe infection leads to the production of thin, wiry shoots. Even though no assessment of economic losses are available, the extensive and systemic nature of the infection is expected to adversely affect culm production and stand productivity of reed bamboos in the near future.

Little leaf disease, caused by a phytoplasma (mycoplasma-like organism), reported from the southern states of India is another critical bamboo disease. Severe infection causes the emerging culms to be stunted and deformed, causing clumps to become bushy. In Kerala, very high incidence (90%) of the disease is reported in dry tracts and sandalwood reserves. A survey during 1988-92 recorded 6% to 12.5% increase in the disease occurrence over the four-year period in different localities of the state. Economic losses caused by the disease are very high in dry tracts, where the farmers hardly get any culm from their groves.

Bamboo mosaic disease, caused by the bamboo mosaic virus, has been reported as affecting the two major cultivated species in Taiwan-China — *D. latiflorus* and *B. oldhamii.* The disease is widespread in bamboo-growing areas in Taiwan-China, and 70-82% disease incidence has been reported from different localities. The diseased shoots become hard in texture, their

internal tissue gets discoloured, and their edible and canning quality declines markedly. The disease is reported to be spreading fast because of the large-scale use of vegetative propagules for raising plantations. As the disease affects industries based on the export of edible shoots as well as its canning, the economic losses resulting from the disease are very high.

Culm rust caused by ***Stereostratum corticioides*** poses a major threat to *P. glauca* and *P. meyeri* stands in Jiangsu, Hunan, Zhejiang and Anhui provinces in China. The incidence of rust infection ranged from 30% to 90% in different provinces, and the disease affects the production of edible shoots. Culm rust is reported as causing serious economics losses, and a current major outbreak of the disease in Yangzhong County is destroying about 200 ha of *P. glauca*.

Culm staining and die-back in *B. vulgaris* and *D. longispathus* stands, reported from the Kerala state of India, acts as a limiting factor for the establishment of clumps in plantations, especially in high-rainfall areas. Although 10% to 98% incidence was recorded during 1980-92, the disease has a patchy distribution and economic loss from it is negligible.

Microorganisms invade bamboo seeds during their different development stages in plant as well as after the seed fall. Seeds are also infected during storage and subsequent handling prior to sowing. Poor quality of seeds in terms of viability and vigour has been the cause of a high degree of failure in nurseries. Few of the seed-borne fungi are also capable of causing seedling diseases in nurseries. Considering the usual flowering and seeding cycle of bamboos, the seeds are so valuable and any losses owing to microbial deterioration is of great concern. Although data on such losses are not available from any of the bamboo-growing countries in the

region, it is evident from some of the disease records that large quantities of bamboo seeds deteriorate at different stages from various microorganisms.

Large quantities of bamboo culms stored in forest depots, mill yards and other storage facilities are decayed and deteriorated by microorganisms. The onslaught on culms is mainly caused by fungi, which include those that cause soft-rot, white-rot, brown-rot and staining. Bacterial degradation of culms also occurs, but is a slow process unlike that caused by fungi. Bamboos used for structural purposes in rural and tribal housing deteriorate within a couple of years, putting heavy pressure on the resource because of the frequent need for replacement. The natural durability of bamboo culms is low and varies from 1 to 36 months, depending on species and environmental conditions. During storage for up to 12 months, 20-25% damage of culms has been reported in India. Decay and deterioration are major problems in bamboo culms stored for making pulp. Decay fungi affect the pulp yield by up to 25% over a storage period of one year, and the pulp strength is reduced by 15-40%. Although data on economic losses owing to culm decay and deterioration are not available, fungal attacks on culms, in general, increase pulping costs because of the increased alkali requirement and higher bleach consumption.

Apart from the infectious diseases, non-infectious diseases — which are caused by abiotic factors — also play a major role in limiting culm production. Severe damage caused by glazed frost has been reported from mainland China and Taiwan-China. About 3 800 ha of *P. pubescens* stands in Qianshan County of Anhui province in China suffered destruction from glazed frost in 1988, causing losses worth 9 million renminbi yuan.

3. DISEASES IN BAMBOO NURSERIES

Bamboos, like many other forest species, are vulnerable to various nursery diseases. Seedlings raised in conventional seedbed nurseries as well as through vegetative propagation methods are equally susceptible to various pathogens. Usually, the nursery stocks have to be maintained for a considerable period of time (6 to 19 months) before planting out (Figs. 2-4).

Fig. 2: Bamboo seedbed nursery (Kerala, India)

Diseases affect the nursery stocks from the time the radicle emerges to the time of planting out, causing considerable damage depending on the prevailing microclimate in the nursery, bamboo species and the virulence of the pathogen. Diseases affecting the nursery stocks have been reported only from India, the Philippines and Thailand. Altogether 13 nursery diseases, caused by 15 fungi and one virus, have been reported on bareroot, container-seedlings and vegetatively propagated planting stocks.

Damping-off

Damping-off is common in bamboo nurseries, causing considerable loss of seedlings. The disease affects seedlings during germination (pre-emergence damping-off) or after germination (post-emergence damping-off), while the seedling tissues are still succulent. Damping-off has been recorded in *Bambusa bambos*

Fig. 3: Bamboo container nursery (Kanchanburi, Thailand)

(L.) Voss (=*Bambusa arundinacea* (Retz.) Willd.), *Dendrocalamus brandisii* (Munro) Kurz, *D. strictus* (Roxb.) Nees and *Thyrsostachys siamensis* Gamble in seedbed nurseries in Kerala, India (Mohanan 1994a,b). The disease was observed in nurseries where high sowing rates of 750 g to 3 kg seeds per standard seedbed (12 x 1 x 2.5 m) were used, and seedbeds were provided with thick shading and profuse watering. The disease severity ranged from low to severe, depending upon the local microclimatic conditions and the nursery cultural practices. A high incidence of the disease, affecting 30% to 40% of the seedlings of *B. bambos,* was reported during 1990 in a nursery at Kulanjithodu (Ranni Forest Division), Kerala, India (Mohanan 1994a).

Fig. 4: Bamboo vegetative propagation nursery (Selangor, Malaysia)

SYMPTOMS

The disease occurs in patches in the seedbeds 7 to 12 days after sowing (Fig. 5). The seed decay and pre-emergence damping-off are characterized by the rotting of well-filled viable seeds and also the newly emerged radicle. Post-emergence damping-off is characterized by the development of water-soaked greyish brown lesions on the emerging plumule near the soil level. The lesions spread and become necrotic, resulting in the collapse of the plumule.

CAUSAL ORGANISMS

Rhizoctonia solani Kuhn state of ***Thanatephorus***

Fig. 5: Damped-off patches in *B. bambos* seedbed

cucumeris (Frank) Donk; ***Fusarium moniliforme*** Sheld.; and ***F. oxysporum*** Schlecht. (Mohanan 1994a,b).

ETIOLOGY

The seed or the emerging seedling tissue is infected either by spores or vegetative hyphae present in the soil or on the seeds. Infection of the host tissue results in the enzymatic degradation of the host cell wall and the death of host tissue. This appears as water soaking, browning or shrivelling of the stem tissue at soil level and collapse of the seedlings. Most damping-off fungi cause disease only at the seedling stage; as seedlings grow and the tissue becomes lignified, they become more resistant to infection. Factors influencing the severity of damping-off include soil moisture, temperature, soil pH, host vigour, host density and inoculum density. Conditions that favour damping-off by one fungus species may not be favourable for another fungus. Damping-off by ***Rhizoctonia solani*** is most severe at high moisture levels, which favour the mycelial growth, while ***Fusarium*** sp. grow best in dry soil. The seeds of species that germinate quickly and seedlings that grow fast possibly sustain less damage from damping-off as compared with slower emerging and slower growing species. However, in the case of bamboos, the seeds in general germinate quickly and the seedlings grow rapidly.

CONTROL

The best means to control damping-off is by preventing pathogenic fungi from entering the seedbed. Damping-off can be avoided by adopting proper

nursery cultural practices. Excessive watering and shading should be avoided.

Low sowing rate — 500 g seeds per standard seedbed — is preferable to prevent the build up of conditions conducive to the spread of the pathogen (Mohanan 1994a). Pre-sowing seed treatment (overnight soaking of bamboo seeds in water), which possibly reduces the spermoplane microflora, and subterranean exposure of the seeds prior to germination also help minimize the incidence of damping-off.

Seedbed soil solarization and seed dressing with fungicides — such as Thiram 75 WP (@2 g/kg), Captan 75 WP (@2 g/kg) — and seed coating with spores of antagonistic fungi — such as ***Trichoderma harzianum*** Rifai and ***T. viride*** Pers. ex Fr. — are the other measures suggested to minimize the disease incidence (Mohanan 1994a).

Seedling Spear-rot

Seedling spear-rot has been observed in *Bambusa bambos* and *Dendrocalamus strictus* nurseries in Kerala, India (Mohanan 1994a,b). The disease was sporadic and its overall severity was low. However, in 1991, a disease outbreak was recorded in nurseries where seeds were sown densely (3 kg seeds per standard bed), and the seedbeds were covered with a thick layer (>0.5 cm) of soil and were insufficiently watered.

SYMPTOMS

Small irregular water-soaked lesions on emerging spear-like plumules appear near the soil level or at the pointed apical portion. The lesions coalesce and spread rapidly from the base to the apex or from the tip downwards, covering the entire plumule, which subsequently becomes necrotic. The infected plumules fail to grow

further and dry up in due course. Disease occurs in patches in seedbeds within 2-5 days of emergence; the advanced stage of infection can easily be detected, because the patches of infected seedlings show a burnt-up appearance.

CAUSAL ORGANISM

Rhizoctonia solani Kuhn state of ***Thanatephorus cucumeris*** (Frank) Donk. (Mohanan 1994a,b).

ETIOLOGY

Rhizoctonia solani, the mycelial state of ***T. cucumeris,*** is a soil-borne pathogen which occurs as a collective species or a species complex made up of divergent populations. The fungus invades tissues of emerging plumules and arrests their further growth by gradual disintegration of the affected tissues. A longer period of subterranean exposure of the emerging plumule owing to a thick layer of soil over the broadcast seeds, along with high soil temperature and lack of sufficient water, are the possible factors enhancing infection by ***R. solani***.

CONTROL

Symptom-wise, the disease appears to be an extension of damping-off, probably delayed by unfavourable soil conditions. The incidence of spear-rot can be minimized by proper nursery management practices, such as regulated watering of the seedbeds and the adoption of good sowing techniques.

Seedling Wilt

Seedling wilt of bamboos has been observed in *Bambusa bambos* and *Dendrocalamus strictus* bareroot as well as container nurseries in Kerala, India (Mohanan 1994a,b). The disease affected seedlings that were

Fig. 6: Seedling wilt of *B. bambos* caused by ***R. solani****;* note the development of epicormic roots

20-40 days old, and the disease severity recorded from most of the nurseries was low.

SYMPTOMS

Initially, the infection occurs as water-soaked, greyish brown lesions on the seedling stem near ground level. The infection spreads upwards and causes lesions on leaf sheath, basal leaves and stem; the juvenile leaves are found free from infection. The infected areas on the stem become dark brown in colour and necrotic, which later coalesce and become constricted. Affected seedlings show symptoms of physiological wilting. Owing to loss of turgidity, the seedlings show rolling up of the entire foliage from about 11 AM onwards, especially those which receive direct sunlight and less water. Bending and breaking up of the seedling stem occur at the constricted area and epicormic roots often develop from the lower portion of the cankered area (Fig. 6).

CAUSAL ORGANISM

Rhizoctonia solani Kuhn state of ***Thanatephorus cucumeris*** belonging to anastomosis group AG2-2IV (Mohanan 1994a).

ETIOLOGY

Rhizoctonia solani invades the root and stem tissues of seedling and causes disintegration of the affected tissues; foliage is rarely affected. This indicates the specificity of the fungus on the host tissues. Wilting is due to the partial breakdown of the conductive tissues of the seedlings. Specificity among the pathogen strains in the population, or even within the strain, has been reported to cause infection of aerial parts and underground tissues.

CONTROL

Since seedling damage is usually low, control measures are seldom required. Drenching affected patches with fungicide (Carboxin, 0.2% a.i.) can control the disease (Mohanan 1994b).

Seedling Web Blight

Web blight of bamboo seedlings has been reported from India and the Philippines. In the Philippines, the disease has been reported as 'sheath blight' in *Bambusa blumeana* J.A. & J.H. Schultes seedlings in Iloilo (Dayan 1988). In India, the disease was recorded in 23 seedbed nurseries in 15 localities in Kerala during 1987-1992 (Mohanan 1994a,b). The disease affected 20 to 30-day-old *Bambusa bambos, Dendrocalamus strictus, D. brandisii* and *Thyrsostachys siamensis* seedlings. Severity and spread of the infection largely depended on the local microclimatic conditions and the cultural practices adopted in the nursery. The overall disease severity index (DSI) ranged from 1.04 to 1.25 (max. 4) and disease severity rating (DSR) was medium. Usually, the disease continues until the microclimatic conditions in the nursery are favourable for the growth and development of the fungus (90-120 days). Severe infection affects the availability of transplanting stocks.

SYMPTOMS

Infection appears as water-soaked lesions on seedling stem near the soil level. Later, it spreads rapidly affecting the entire shoot, except one or two juvenile leaves. Infected stem and foliage become discoloured, greyish brown to dark brown, within 2-5 days of infection. Leaf necrosis is initiated either from the leaf tip and proceeding towards base of the leaf, or from the leaf

Fig. 7: Diseased *B. bambos* seedlings with mycelial webs of causal fungus

Fig. 8: A portion of the severely affected *B. bambos* seedbed

margins towards midrib. The disease usually occurs in small patches of 5-10 seedlings in the seedbed, and the patches increase in size under favourable microclimatic conditions (Figs. 7, 8).

The infected patches in the seedbed merge and form large disease patches of up to 30 cm in diameter. Infected foliage shows shades of greyish brown, purplish grey and pastel green discolouration which later turn into necrotic areas. Complete necrosis often leads to withering of the foliage. Under high humidity, especially during the early morning hours, fungal mycelium, which arises from the soil, grows epiphytically over the affected seedlings. Yellowish brown sclerotia of the fungus develop on the decayed basal foliage and stem. The basidial stage of the fungus also appears on the basal part of the stem of the affected seedlings (Figs. 9, 10).

The diseased seedlings are killed outright within 10-20 days of infection, leaving large circular to irregular patches of dried-up seedlings in the seedbeds.

CAUSAL ORGANISM

Rhizoctonia solani mycelial state of ***Thanatephorus cucumeris*** belonging to different anastomosis groups — AG1-IA, AG1-IC, AG2-2IV (Fig. 11) (Mohanan 1994a).

Fig. 9: Sclerotia of ***R. solani*** on decaying seedling tissues

Fig. 10: Basidial stage of ***R. solani*** on the stem of diseased seedlings

Fig. 11: ***R. solani*** bamboo isolates belonging to different anastomosis groups

ETIOLOGY

The fungus mycelium penetrates the stem and leaf tissues. The infection spreads very rapidly within the seedlings through fast-growing mycelial strands. Spread of disease between seedlings is mainly through physical contact of diseased foliage with healthy neighbouring seedlings. The fungus produces sclerotial as well as basidial stages which serve as inoculum for secondary infection. Heavy and incessant rain for a couple of days followed by overcast weather for 5-6 days form ideal conditions for the disease to become severe. Factors conducive to the incidence and spread of the diseases are high density of seedlings, thick shading over seedbeds and free water on seedlings.

CONTROL

Disease management measures suggested for the web blight of bamboo seedlings include sanitation, modification of nursery cultural practices and use of fungicide (Mohanan 1993a, 1994a,b). Solarization of seedbeds and treatment of seed and seedbed with antagonists like ***Trichoderma harzianum*** and ***T. viride*** are also recommended for reducing disease incidence (Mohanan 1994a,