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Culm, foliage, rhizome, root and inflorescence diseases of bamboos in Kerala, India and their management

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Abstract: To strengthen the knowledge base of diseases and disorders affecting the bamboos in nurseries, plantations and natural stands, an in-depth study was carried out. Research plots in bamboo stands were laid out in 25 different localities in the Kerala State and an experimental bamboo nursery was raised at Chandanathodu, Wayanad. Disease indexing was made using standard techniques. Causal agents of diseases were isolated, identified and pathogenicity proved. Histopathological, flourescence and transmission electron microscopic techniques were applied to confirm the association of Phytoplasma with little leaf disease. *In vitro* and *in vivo* screenings of fungicide were made to manage the diseases in nurseries and stands. In bamboo stands, a total of 37 fungi and a phytoplasma were found causing various diseases. Among these, diseases affecting the productivity of the stands include: rot of emerging and growing culms caused by *Fusarium moniliforme* var. *intermedium* and *F. equiseti*, respectively, thread blight caused by *Botryobasidium salmonicolor*, witches' broom and little leaf caused by *Balansia liniaris* and Phytoplasma respectively, and culm basal rot caused by *Amylosporus campbellii*. In bamboo nurseries, web-blight caused by *Rhizoctonia solani*, foliage rust by *Dasturella divina* and seedling stunting and foliage striping by virus (BMoV) are the most potential ones. Diseases in nurseries can be controlled by adopting good nursery management practices or by prophylactic fungicidal applications. In bamboo stands, most of the potential diseases can be managed by cultural measures like mild surface burning, thinning, pruning, *etc.* and by application of fungicides.

Key words: Bamboo diseases, culm rot, witches'broom, little leaf, fungi, phytoplasma, virus, management measures.

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, 1994a, b; 2004; Mohanan and Liese, 1990). However, in India, only a few diseases are identified as serious

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ones, affecting the culm production as well as stand productivity. Limited experience in raising bamboo seedlings 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 as well as in natural stands have adversely affected the bamboo industry, both in rural and modern sectors. In Kerala State, bamboo forms a significant component of the natural vegetation and occurs in tropical evergreen, semi-evergreen, and moist-deciduous forests, sub-tropical hills, and also as southern-moist-bamboo brakes (Mohanan, 1994a). Bamboo has 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 State and they are used in traditional cottage industries as well as raw material for bamboo ply, rayon and paper industries. In this paper, information is provided on the diseases affecting various bamboo species, their incidence, severity and possible management measures.

MATERIALS AND METHODS

Representative plots of 50 x 50 m in bamboo stands in 20 different localities (total 60 plots) and of 20 x 20 m in reed bamboo stands in five different localities in the Kerala State (15 plots) were laid out. The plots were visited at least twice a year, during June-September and December-March and observations on disease incidence and severity were recorded. An experimental bamboo nursery of two species (*Bambusa bambos, Dendrocalamus strictus*) was raised at Chandhanathodu, Wayand, Kerala and studied the nursery diseases and their management. Disease severity in stands and nursery was rated on a numerical scale (0-3) of disease rating index and average severity index of a disease (DSI) was calculated (Mohanan, 1994a).

Infected materials *viz*., seedlings, foliage, culm, culm sheath, branch, rhizome, roots were collected, brought to the laboratory and isolation and identification of causal organisms were made. Pathogenicity tests were carried out employing standard techniques (Mohanan, 1990, 1993a,b;1994a). For studying the little leaf disease caused by phytoplasma, histopathological techniques employing Dienes' staining reaction, fluorescence and transmission electron microscopic (Mohanan, 1994a) techniques were employed. Screening of tetracycline for little leaf disease recovery was also made using Tetracycline-hydrochloride tree injection formula (Pfizer Ltd.). Evaluaton of fungicides for disease management was made *in vitro* and in bamboo nurseries raised at Chandhanathodu and at Kerala Forest Research Institute Peechi campus. A field trial at Thenkodum (Kaliyar Forest Range) was carried out using 18-month-old bamboo planting stock at spacement of 10 x 10 m and studied the disease (rhizome rot caused by *Pythium middletonii*) affecting *B. bambos* at its establishing phase.

RESULTS AND DISCUSSION

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, thread blight, witches' broom, little leaf disease, and culm basal rot.

Rot of emerging culms

Bambusa bambos, B. balcooa, B. polymorpha, B. vulgaris, D. longispathus, D. strictus, Thyrsostachys oliveri are the most severely affected bamboos. Severe infection and culm mortality were recorded in bamboo stands in high rainfall areas in the State (Table 1). The disease manifests as dark brown lesions on the outermost culm sheath of the emerging culm (15-20 cm height), near the soil level. 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. 1a,b). *Fusarium moniliforme* var. *intermedium* Neish & 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, India, and Pakistan (Mohanan, 1997).

Table 1. Incidence of rot of emerging culms in bamboo stands

Bamboo species	Locality	No. of clumps observed	Per cent disease incidence			
			Yr1	Yr2	Yr3	Yr4
BB	Nilambur	102	-	5.5 (109)	4.03 (124)	6.04 (149)
BB	Kollathirumedu	67	-	12.6 (127)	13.5 (156)	8.6 (140)
BB	Ezhattumugam	59	-	12.6 (119)	12.3 (146)	14.9 (148)
BB	Palappilly	60	-	10.4 (125)	11.1 (144)	10.2 (167)
BB	Irumpupalam	64	6.8 (132)	11.9 (151)	15.1 (172)	14.0 (200)
TO	Mundoor	96	3.8 (317)	3.3 (340)	4.1 (362)	4.4 (294)
BBL	Nilambur	4	6.6 (15)	5.3 (19)	4.5 (22)	8.7 (23)
BP	Nilambur	4	10.0 (20)	13.04 (23)	12.0 (25)	9.5 (21)
BV	Nilambur	19	5.3 (76)	2.9 (102)	2.06 (97)	2.4 (82)
DL	Nilambur	12	7.3 (96)	8.08 (99)	11.6 (112)	16.6 (74)
DS	Nadukani	43	25.5 (153)	18.2 (159)	14.7 (136)	18.0 (128)
TO	Mundoor	96	3.8 (317)	3.3 (340)	4.1 (362)	4.4 (294)

* BB: *Bambusa bambos*; BBL: *B. balcooa*; BP: *B. polymorpha*; BV: *B. vulgaris*; DL: *Dendrocalamus longispathus*; DS: *D. strictus*; TO: *Thyrsostachys oliveri*; -: observations not recorded; Figures in parenthesis are total number of newly emerged culms

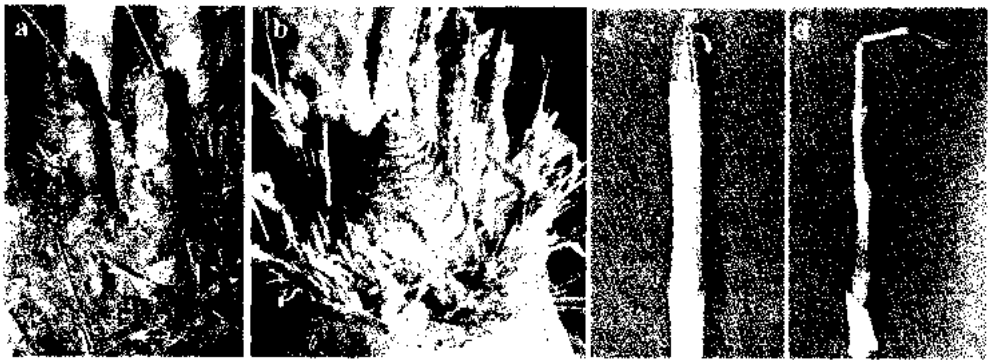

Figure 1. Rot of emerging and growing culms of bamboos; a: emerging culms of *B. balcooa* showing typical symptoms, b: close up of emerging culm of *B. bambos* showing browning and rot of culm sheaths and unexpanded culm internodes, c.d: rot of growing culms of *B. polymorpha*..

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.

Rot of growing culms

Among several species of bamboos studied, *B. bambos, B. balcooa, B. polymorpha* and *D. strictus* are the severely affected ones (Table 2). 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 *Purohitha 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 shriveled, 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 (Fig. 1c.d). *Fusarium equiseti* Corda (Sacc.) and *F. 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

Table 2. Incidence of rot of growing culms in bamboo stands

Bamboo species	Locality	No. of clumps observed	Per cent disease incidence			
			Year 1	Year 2	Year 3	Year 4
BB	Nilambur	102	-	11.0 (109)	6.5 (124)	3.4 (149)
BB	Kollathirumedu	67	-	8.6 (127)	7.7 (156)	6.4 (140)
BB	Ezhattumugam	59	-	10.4 (119)	7.3 (146)	5.9 (148)
BB	Palappilly	60	-	11.2 (125)	11.8 (144)	7.2 (167)
BB	Irumpupalam	64	12.1 (132)	7.3 (151)	5.2 (172)	3.0 (200)
TO	Mundoor	96	3.8 (317)	2.4 (340)	2.5 (362)	2.4 (294)
BBL	Nilambur	4	-	4.5 (19)	-	9.0 (23)
BP	Nilambur	4	25.0 (20)	13.0 (17)	8.0 (19)	4.8 (21)
DL	Nilambur	12	5.2 (96)	6.3 (99)	15.2 (112)	17.6 (74)
DS	Nilambur	11	18.4 (38)	20.0 (40)	18.9 (37)	8.8 (45)
DS	Nadukani	43	5.9 (153)	4.4 (159)	4.4 (136)	6.3 (128)
TO	Mundoor	96	3.8 (317)	2.4 (340)	2.5 (362)	2.4 (294)

* BB: *Bambusa bambos*; BBL: *B. balcooa*; BP: *B. polymorpha*; DL: *Dendrocalamus longispathus*; DS: *D. strictus*; TO: *Thyrsostachys oliveri*; -: observations not recorded; Figures in parenthesis are total number of newly emerged culms

control measure (spraying insecticide, Monocrotophos 0.05% a.i.) against the build-up of the insect (*Purohita 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.

Branch die-back

The disease occurs in *B. bambos, D. strictus* and *B. vulgaris* 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 grayish 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. Under high humidity, causal fungus sporulated 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) Sacc. was the causal agent.

Witches' broom

The disease is wide-spread in reed bamboo stands in the State (Mohanan, 2004). It affects commercially important reed bamboos *viz*., *Ochlandra travancorica. O. scriptoria* and *O. ebracteata*. 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 4000 to 6500 mm and a high relative humidity (60-90%) (Table 3). The disease was also recorded on grass *Pennisetum polystachyon* (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 (Fig. 2). 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, India, 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. *B.*

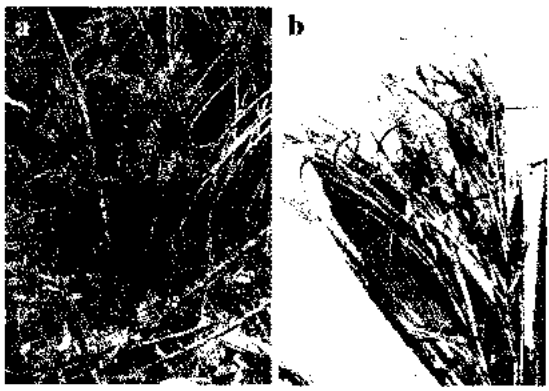

Figure 2. *O. travancorica* clump showing witches' broom infection, b: Ascocarps of *B. linearis* developed on the affected shoots.

Table 3. Incidence and severity of witches' broom disease in *Ochlandra* species

Bamboo species	Locality	Year 1		Year 2		Year 3		Year 4	
		DI	DS	DI	DS	DI	DS	DI	DS
OS	Periya	21.9	L	24.7	L	24.7	L	-	-
OS	Vazhachal	9.8	L	11.5	L	11.5	L	14.8	L
OT	Kollathirumedu	8.6	L	9.3	L	10.0	L	10.7	L
OT	Pachakkanam	7.7	L	8.3	L	9.0	L	9.6	L
OE	Kottoor	6.0	L	7.7	L	8.6	L	9.4	L

* OS: *Ochlandra scriptoria*; OT: *O. travancorica*; OE; *O. ebracteata*; -: Observations not recorded due to mast flowering; L: low.

multiplex (Lour.) Raeusch. are important ones. In Indonesia, the disease has been reported on *Gigantochloa apus* Kurz, *G. atter* (Hassk.) and *G. robusta* Kurz. In Japan, the disease has been recorded on *Phyllostachys 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.

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 State. 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 (Fig. 3).

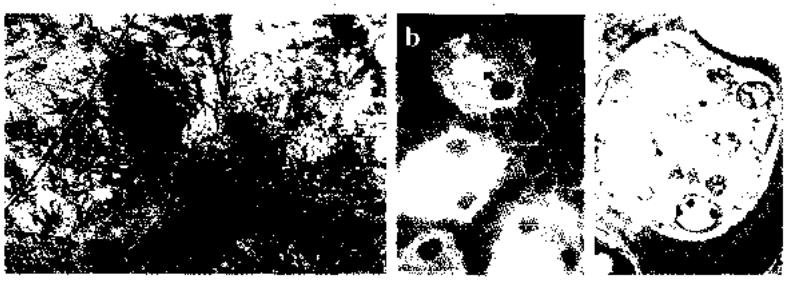

Figure 3. Little leaf disease of *D. strictus*; b: aniline blue staining reaction of diseased tissues showing yellowish green fluorescent spots in the phloem tissue; c: transmission electron micrograph of diseased tissue showing phytoplasma (MLO) in the phloem sieve cells (19200 x)

Association of Phytoplasma with the disease was proved by Diene's staining, fluorescence and transmission electron mycroscopic studies 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 over a period of four years (Table 4).

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 (*B. bambos*).

Table 4. Incidence and severity of little leaf disease in *D. strictus*

Locality	Year 1		Year 2		Year 3		Year 4	
	DI	DS	DI	DS	DI	DS	DI	DS
Agaly	64.0	L	64.0	L	67.2	L	70.2	L
Thakarapady	77.5	L	87.5	L	85.5	L	90.0	L
Goolikadavu	59.37	L	59.4	L	59.4	L	68.8	L
Chinnar	9.3	L	9.3	L	9.3	L	11.6	L

* DI: Disease incidence (%); DS: Disease severity; L: low.

Thread blight

Thread blight disease affects most bamboo species and the disease appears during monsoons, subsides and almost disappears during the dry period. *B. vulgaris, B. bambos* and *D. strictus* are the severely affected species (Table 5). Large water-soaked greyish lesions occur on leaves which advance towards the leaf tip. Fine silvery white mycelial strands of the causal fungus appear on the lower surface corresponding to the lesions on the foliage (Fig. 4a,b). 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, the foliage. *Botryobasidium salmonicolor* (Berk. & 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.

Foliage diseases

Leaf rust: Leaf rust of bamboo is widespread and affects almost all the bamboo species in the State. *B. bambos, B. vulgaris, B. ventricosa, D. strictus, Oxytenanthera*

Figure 4. Thread blight and foliage blight; a: mycelial weft of *B. salmonicolor* on culms of *O. travancorica*; b: on leaves of *B. polymorpha*; c: foliage blight of *B. bambos*; d: conidiophores and conidia of *Bipolaris maydis* (440 x).

Petrakomyces leaf spot: The leaf spot was recorded during July- September on *B. bambos, D. strictus, Arundinaria* sp., *Thyrsostachys* sp., *O. scriptoria,* and *O. ebracteata.* 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 (Fig.5c). Earlier, the fungus was recorded on *Bambusa* sp. from Tamil Nadu and Karnataka (Rangaswami *et al.*,1970).

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.

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 microconidial locules 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 (Fig. 6b). Severe infection leads to yellowing and drying up of the foliage.

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.

Tar spot: Tar spot was recorded on B. *bambos, B. vulgaris, D. strictus, O. monostigma, Thyrsostachys* sp., *O. scriptoria* and *O. travancorica.* 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. longinaviculata* Parbery, *P. shiraiana* Sydow., *P. ischaemi* Sydow. were identified as the casual fungi. Among these, *P. ischaemi* was recorded only from *B. bambos*.

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 the State. *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 (Fig. 6d). *B. bambos, D. strictus, D. longispathus* are the most susceptible species to *A. campbellii* (Fig. 10). 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 bareroot 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.

Culm staining and die-back

The disease was recorded in 7 to-10-year-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 (Fig. 6c). The affected culms and branches were found completely covered with black fructifications of the fungus.

Infection of inflorescence and seeds

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 bamoo 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 temperatures 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.

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.

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 &% 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, 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.

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 (Mohanan, 1993a; 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. *Rhizoctonia solani* Kuhn belonging to different anastomosis groups (Mohanan, 1994a) is the causal fungus.

The disease can 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 7 and 21 days of seedling emergence is recommended for managing the disease.

Leaf rust

The disease affects most bamboo species *viz., B. bambos, D. strictus, D. brandisii, Oxytenanthera monostigma, Ochlandra travancorica, Thyrsostachys 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. *D. 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.

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 rostratm, E. holmii, Bipolaris maydis* (Nishikado & Miyake) Shoem., *B. urochloae* (Putterilll) Shoem., *Bipolaris* sp., *Dactylaria* sp., *Alternaria alternata* (Fr.) Keissler, *Curvularia pallescens* anamorph state of *Cochliobolus pallescens* (Tsuda & Veyama) Sivan., and *C. 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.

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.

CONCLUSIONS

In bamboo stands, rot of emerging and growing culms, 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. 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.

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