1990, 1994a,b) and ***C. andropogonis*** (Zim.) Boedijn (Balakrishnan et al. 1990).

ETIOLOGY

The infection occurs under damp conditions, and infection hyphae of the fungus enter through stomata or injured tissues. Free water on the host surface favours the spread of infection. Under high humidity, the fungus sporulates profusely on the infected host tissue.

CONTROL

The disease is of little importance and control measures are not required.

13 Alternaria Leaf Spot

The leaf spot disease has been reported on *Bambusa bambos* and *Dendrocalamus strictus* in Kerala, India (Mohanan 1994a,b). The infection has been observed on mature leaves, especially those of the lower branches.

SYMPTOMS

Small yellowish brown irregular lesions appear usually near the leaf tip, which later spread to form necrotic spots. Severe infection leads to leaf blight.

CAUSAL ORGANISM

Alternaria alternata (Fr.) Keissler (Mohanan 1990, 1994a,b).

ETIOLOGY

Warm-humid conditions favour the infection. The fungal spores, dispersed through air currents, germinate on the host surface and penetrate through stomata. Fungus sporulates profusely on the necrotic tissues under warm-humid conditions.

CONTROL

Infection is of little importance and control measures are seldom required.

14 Rosenscheldiella Leaf Spot

This leaf spot has been reported on *Ochlandra travancorica* in natural stands in Kerala, India. It was observed during September-October (Mohanan 1994a,b).

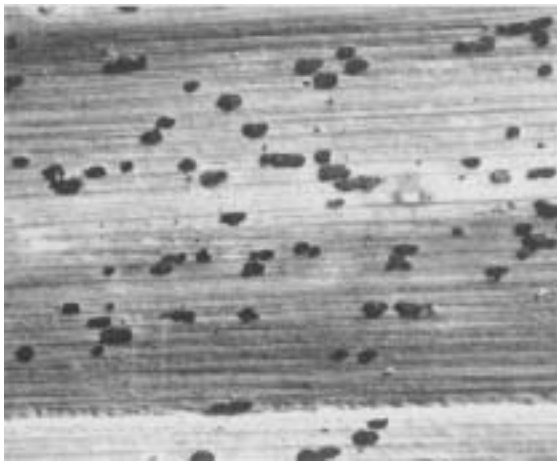

Fig. 93: Fructifications of ***Rosenscheldiella ochlandrae*** on *O. travancorica* leaf

SYMPTOMS

Minute, yellowish brown, linear lesions occur on the mature leaves during September-October. They enlarge to form necrotic, 3-5 mm spots with yellow haloes. Fungal fructifications develop in linear rows in the necrotic spots on the upper surfaces of the leaves (Fig. 93).

CAUSAL ORGANISM

Rosenscheldiella ochlandrae Mohan. (Mohanan 1994b, 1995d).

ETIOLOGY

The etiology of the disease has not been studied.

CONTROL

The disease is of minor importance and control measures are not required.

15 Coccodiella Leaf Spot

Coccodiella Leaf Spot has been reported on *Phyllostachys* sp. in China (Spaulding 1961), on *Phyllostachys* sp., *Sasa* sp. and S*asamorpha purpurascens* Nakai in Japan (Spaulding 1961; Katumoto 1968; Zhu 1989), and on *Ochlandra travancorica* in Kerala, India (Mohanan

Fig. 94: Fructifications of ***Coccodiella ochlandrae*** on *O. travancorica*

1994a,b). In India, the disease was observed on mature leaves of bamboos during September-October.

SYMPTOMS

Yellowish brown, minute lesions appear on the upper surfaces of the leaves, and enlarge to form dark brown linear necrotic spots. Fructifications of the causal fungus develop in the necrotic spots on the lower surface of the leaf (Fig. 94).

CAUSAL ORGANISMS

Coccodiella arundinariae Hara (=***Coccostromopsis arundinariae*** (Hara) Teng) (Spaulding 1961; Zhu 1989) and ***C. ochlandrae*** Mohan. (Mohanan 1994a,b, 1995d).

ETIOLOGY

The etiology of the fungus has not been studied.

CONTROL

The leaf spot is of minor significance and control measures are not required.

16 Cerodothis Leaf Spot

This leaf spot disease has been reported on *Bambusa bambos* stands in Karnataka State (Muthappa 1969), and on *B. bambos, Dendrocalamus strictus* and *Thyrsostachys siamensis* stands in Kerala State (Mohanan, 1994b).

SYMPTOMS

Tiny, pale yellow spots appear on the upper surfaces of leaves. No visible necrotic spots are formed as the disease progresses. The ascocarps of the causal agent cause

Fig. 95: Leaf spot in ***D. strictus*** caused by ***Cerodothis aurea****;* note the yellow microconidia of the fungus

rupturing of the leaf epidermis. At maturity, the ascocarps appear as tiny, golden yellow streaks on the leaves and are arranged in linear rows. Hyaline, spindle-shaped, microconidia of the fungus are also produced in the microconidial locule, which develop close to the margins of the developing ascostroma or are produced separately. The mucilaginous microconidia, pale yellow in colour, are extruded to the leaf surface through a pore formed in the locule. Severe infection affects the photosynthetic activity. Severely infected leaves become yellowish in colour and defoliate prematurely (Fig. 95).

CAUSAL ORGANISM

Cerodothis aurea Muthappa (Muthappa 1969; Mohanan 1994b).

ETIOLOGY

The fungus invades the leaf tissue and the hyaline intracellular mycelium penetrates the mesophyll, spongy parenchyma and vascular bundles. The epidermal cells are not invaded by the fungus. One or two hyphal tips of mycelium in the mesophyll at the corner of bulliform cells of the epidermal layer form tiny hyphal knots. These hyphal knots grow between the epidermis and the mesophyll to form a thin stroma. Microconidial locules develop in the stroma and microconidia are produced. Ascostroma develop very close to the microconidial locule.

CONTROL

The leaf spot is of minor importance and control measures are not required.

17 Leptostroma Leaf Spot

The disease has been reported on *Gigantochloa levis, Bambusa philippinensis* (Gamble) McClure and *Schizostachyum lumampao* in the Philippines (Dayan 1988). The leaf spot disease has also been recorded on *Bambusa blumeana* and *B. vulgaris* stands at Magalang, the Philippines (Mohanan 1995, unpublished observation).

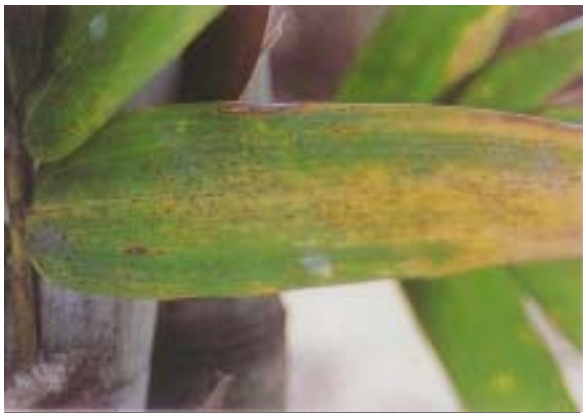

Fig. 96: Leaf spot in *G. levis* caused by ***Leptostroma*** sp.

SYMPTOMS

Yellowish to brown lesions appear on the leaves. Later, dark brown, shining pycnidia develop on the spots. Dehiscence of the pycnidia is by the rupture of epidermal cells, and conidia extrude from the fructification (Fig. 96).

CAUSAL ORGANISM

Leptostroma sp. (Dayan 1988).

18 Eriosporella Leaf Spot

The disease has been reported on *Bambusa* sp., *Bambusa blumeana* (Dayan 1988) and on *Gigantochloa levis, G. aspera* and *Bambusa vulgaris* in the Philippines (Mohanan 1995, unpublished observation).

SYMPTOMS

Small, pale to golden yellow lesions appear on the leaves; later the lesions turn brownish to black, with small pycnidia in the necrotic tissue (Fig. 97).

CAUSAL ORGANISM

Eriosporella calami (Neiss) Hohn. (Dayan 1988).

Fig. 97: Leaf spot in *B. blumeana* caused by ***Eriosporella calami***

Fig. 98: Leaf spot in *S. dullooa* due to ***Fusarium pallidoroseum***

19 Brown Leaf Spot

The disease has been reported on different species of bamboos in natural stands and plantations in India. Brown leaf spot has been recorded on *Melocanna arundina* Kurz and *Schizostachyum dullooa* (Gamble) Majumdar stands in Assam, India (Deka et al. 1990) and on *Bambusa bambos, B. vulgaris, Dendrocalamus strictus* and *Pseudoxytenanthera ritcheyi* stands in Kerala State (Mohanan 1990).

SYMPTOMS

Water-soaked lesions occur on the leaf. They later spread and cover the entire lamina, and eventually become brown. Usually the infection occurs only in mature leaves; severe infection causes leaf necrosis and premature defoliation (Fig. 98).

CAUSAL ORGANISMS

Fusarium pallidoroseum (Cooke) Sacc. (Deka et al. 1990; Mohanan 1990) and ***F. semitectum*** Berk. & Rev. (Balakrishnan et al. 1990).

ETIOLOGY

Warm-humid atmospheric conditions favour infection. Airborne fungal spores germinate on the leaf surface and invade the leaf tissues through natural openings or wounds on the surface. Under humid conditions, the fungus sporulates on the necrotic tissue.

CONTROL

The disease is of little importance and control measures are not required.

Culm Sheath Spot

Culm sheath spot has been reported on bamboos in China and India. In China, the disease has been recorded on *Phyllostachys* sp. (Tai 1932). In India, the disease has been recorded on *Bambusa bambos, B. polymorpha, B. vulgaris* and *Dendrocalamus strictus* in Kerala, India (Mohanan 1990, 1994a,b). The spots were observed on culm sheaths of expanding culm internodes during June-July.

SYMPTOMS

Small, brown, spindle-shaped to irregular lesions appear usually at the margins and tips of culm sheaths. The lesions spread to form large 5-12 mm, irregular, necrotic spots with dark brown to purple margins. The infection causes browning and necrosis of sheath margins and tips. Spots and necrosis are more pronounced in sheaths covering the lower 4 to 7 culm internodes.

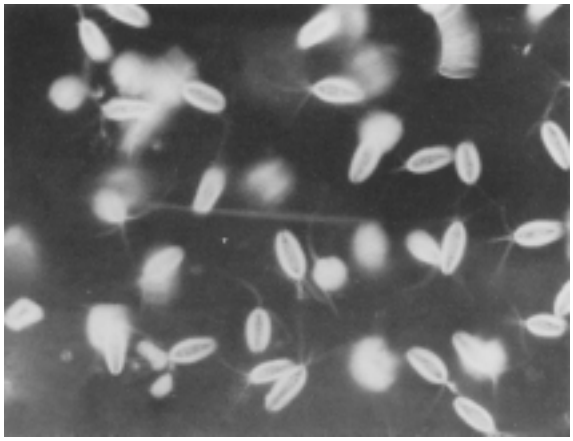

Fig. 99: Conidia of ***Pestalozziella bambusae***

CAUSAL ORGANISMS

Shiraia bambusicola (Tai 1932); and ***Pestalozziella bambusae*** Mohan. (Fig. 99) and ***Sarocladium*** sp. (Mohanan 1994a,b, 1995d).

ETIOLOGY

The causal agents are weak pathogens which enter the host tissue through wounds on the sheath. High humidity and free water on the host surface favour the infection. The causal fungi produce spores in gelatinous masses in the affected tissues. These spores serve as the source of secondary infection and spread of the disease. The disease affects developing culm internodes as well as nodal buds.

CONTROL

Since the culm sheaths fall off after the development of branches from the nodes and the infection does not spread to the culm, the disease is of little importance. Control measures are not required.

Black Mildew

Black mildew is widespread in bamboo stands, especially in humid tropical areas with closed canopy. The disease has been reported on bamboos in China, India, Japan and Thailand. In Japan, the disease has been recorded on *Phyllostachys bambusoides, Phyllostachys* spp., *Sasa senanensis* Rehd. and *Semiarundinaria yashadake* Makino (Spaulding 1961; Zhu 1989). In India, black mildew has been recorded on *Bambusa* sp. (Browne 1968), *Bambusa bambos, Dendrocalamus strictus, Ochlandra travancorica, O. travancorica* var. *hirsuta, O. ebracteata* and *O. scriptoria* (Mohanan 1992, unpublished observation). The incidence of black mildew was recorded as high in humid areas during November-December. Recently, the disease has also been observed on different bamboo species in China and Thailand (Mohanan 1995, unpublished observation).

Fig. 100. Black mildew on *B. bambos* due to ***Meliola*** sp.

SYMPTOMS

Cobweb-like to powdery black patches appear on the upper surfaces of mature leaves. As the infection develops, the upper leaf surface becomes densely coated with a black powdery growth of fungal hyphae (Fig. 100). Infection also occurs on leaf sheaths and minor branches. Severe infection reduces effective photosynthetic area of the leaves.

CAUSAL ORGANISMS

Meliola bambusicola Hans. (Browne 1968); ***M. pseudosasae*** Hara (Zhu 1989); ***Meliola*** sp. (Mohanan 1990, 1994a,b); ***M. stomata*** Hara (Zhu 1989); and ***Haraea japonica*** Sacc. et Syd. and ***Asterinella hiugensis*** (Spaulding 1961).

ETIOLOGY

Black mildew fungi are parasites, penetrate the host tissue by means of haustoria that arise from the characteristic superficial hyphopodiate mycelium. High atmospheric humidity and free water on the host surface favour infection and growth of the fungi.

CONTROL

Opening the canopy will reduce the infection.

Sooty Mould

Sooty mould has been reported on different bamboo species in India and Japan. The disease has been recorded on *Bambusa vulgaris, B. bambos, B. polymorpha, D. strictus, D. longispathus, Ochlandra travancorica, O. travancorica* var. *hirsuta, O. scriptoria* and *O. ebracteata* (Mohanan 1994a,b). Recently, severe sooty mould infection has been recorded on *B. blumeana, B. multiplex, B. vulgaris* and *Gigantochloa albociliata* (Munro) Kurz stands in Kanchanburi, Thailand (Mohanan 1995, unpublished observation). Very high incidence of sooty mould was recorded in humid areas during September-December. Extensive growth of the fungus on foliage markedly reduces the effective photosynthetic area of the leaves. Sooty moulds also absorb water readily from the atmosphere and keep the leaf surfaces moist for long periods. This creates a very humid environment within the canopy, allowing the spread of other foliage diseases.

Fig. 101: Sooty mould on *O. travancorica* caused by ***Spiropes scopiformis***

SYMPTOMS

Infection usually appears on the upper leaf surface as a sparse, black network of hyphae or a thin, effuse, black, powdery fungal coating (Fig. 101). The disease also occurs on branches and minor branches. Sooty mould also occurs on the lower surfaces of the leaves.

CAUSAL ORGANISMS

Capnodium sp. and ***Spiropes scopiformis*** (Berk.) M.B. Ellis (Balakrishnan et al. 1990; Mohanan 1990, 1994a,b).

ETIOLOGY

Sooty moulds are saprophytic epiphytes and are not parasitic on their hosts. They normally obtain nourishment from the honeydew secreted by aphids, mealy bugs, scale insects and other sap sucking insects. In cases where insect infestation is absent, the fungi obtain their food from plant leachates, leached into water deposited on the leaf surface by rain, dew or mist. Surface water, together with the insects, are important in dispersing sooty moulds.

Miscellaneous Foliage and Minor Branches Infections

Various fungi that cause infections of minor importance on leaves, minor branches and branches have been reported on different species of bamboos in China, India, Japan, the Philippines and Taiwan-China (Cooke 1892; Sydow and Butler 1906, 1911, 1916; Miyake and Hara 1910, 1913; Rehm 1913, 1914, 1916; Tanaka 1922; Butler and Bisby 1931, 1960; Tai 1931; Teng 1938; Chowdhury 1948; Sprague

Fig. 102 :Shoot malformation in Phyllostachys sp. caused by ***Myriangium*** sp.

Fig. 103 Shoots of Phyliostachys sp. malformed by ***Myriangium*** sp.

1950; Anonymous 1951, 1960; Hino and Katumoto 1955,1958, 1961; Hino 1961;Kapoor and Gill 1961; Nema and Mishra 1965; Anahosur 1970; Rangaswami et al.1970;Singh and Khanna 1970;Ellis 1971,1976; Kar and Maity 1971; sharma 1971; Panwar and Gehlot 1973; Itoi et al. 1978,1979; Kwan 1979; Sutton 1980;Saikia and Sarbhoy 198O, 1982,1985; Mukerji and Bhasin 1986; Dayan 1988; Zhu 1989; Balakrishnan et al. 1990; Deka et al. 199O; Eriksson and Yue 199O;Bilgrami et al. 1991; Mohanan 1992, unpublished observation).

For instance, severe malformation of foliage in different species of Phyllostachys and B. Multiplex caused by ***Myriangium*** sp. Has recently been recorded in Nanjing, China (Mohanan 1995,unpublished observation). The infected foliage shows symptoms similar to those produced by the witches'-broom disease, except for the nature of fungal fructification (Fig.102, 103).

Another minor disease is the leaf and sheath inflection by ***Shiraia bambusicola*** P. Henn. on B. biumeana (Fig. 104). A list of miscellaneous foliage and minor branch infections is given in Appendix IIB. Detailed information is not available on most of these minor diseases.

Fig.104: Leaf and Leaf sheath infection by ***shiraia bambusicola*** on B.blumeana

Infection of Inflorescence and Seeds

Bamboo has a typical inflorescence which consists of one to many spikelets (Fig. 105). Each spikelet is protected by brads called glumes, and contains one to few flowers called florets. Each floret consists of a lemma, a palea, three lodicules (sometimes absent), three or six stamens, and an ovary with one or three stigmas. The fruit of bamboo is mostly a caryopsis which consists of a pericarp enclosing the seed (Fig. 106). Each seed contains endosperm, and an embryo comprising a radicle, a plumule and a scutellum. Fungal infection on inflorescences of bamboos, causing smut and ergot, has been reported from India, Japan and Thailand.

Fig. 105: *Inflorescence of Dendrocalamus hamiltonii*

Smut

Smut affecting the developing seeds in spikelets of bamboo species has been reported from India and Japan. Smut on Bambusa bambos and Bambusa sp. has been reported from Uttar Pradesh, India (Thirumalachar and Pavgi 1952). Severe infection completely replaces the seeds with a fungal spore mass. In Japan, smut affeds Phyllostachys heterocla var. pubescens, Sasa nana Mak. and S. ramosa Mak. et Shib. (Hori 1905; Zhu 1989).

SYMPTOMS

The fungi attack young developing spikelets and often completely replaces the seeds with black fungal spores,

Fig. 106: Developing seeds of Thyrsostachys sp.

causing smut (Fig. 107). Only seeds that are not infected attain maturity, but they also may contain fungal spores. Infected seeds on germination do not produce healthy seedlings.

CAUSAL ORGANISMS

Ustilago shiraiana P. Henn. and ***Tilletia Bambusae*** Thirum. & Pavgi (Mundkur and Thirumalachar 1952; Thirumalachar and Pavgi 1952).

ETIOLOGY

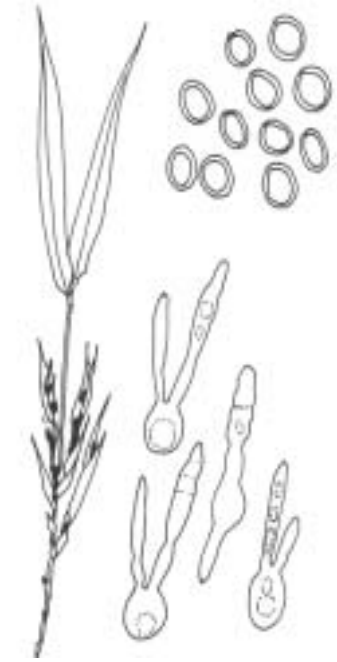

Fig. 107: Symptom of smut in Phyllostachys sp. caused by ***Ustilago shirajana***(source: Zhu 1989)

Smut fungi generally overwinter as chlamydospores (teliospores) on contaminated seed or plant debris, in soil, or as mycelium in the infected kernels or plants. The chlamydospores germinate and produce basidiospores which, upon germriation, either fuse with compatible ones and then infect, or penetrate the tissue and fuse to produce dikaryotic mycelium and typical infection.

CONTROL

Control of smut is possible by planting resistant species and seed treatment. Carboxin, thiabendazole, etaconazole and other systemic fungicides are effective in controlling the smut fungi.

Erogt

Ergot on Phyllostachys spp. has been reported from Japan (Spaulding 1961; Zhu 1989).