



Technical Bulletin
CAFRI/2021/02

Plant Diseases in Agroforestry

A Ready Reckoner

M Ashajyothi, YN Venkatesh, K Rajarajan, AK Handa and A Arunachalam



ICAR-Central Agroforestry Research Institute

Near Pahuj Dam, Gwalior Road, Jhansi 284003, Uttar Pradesh, India





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The document has been prepared fully in academic spirit for educational and ready reckoning purposes so that apt measures are taken to control diseases in agroforestry trees and bamboo. The information in the document is based on primary observations and secondary information from published sources.

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May 10, 2021

Foreword



India became the first country in the world to adopt an agroforestry policy in 2014. The policy aims to improve productivity and environmental sustainability by integrating trees, crops, and livestock into the same plot of land. It was created to counteract limited agricultural productivity due to consistent decreases in the landholdings of farmers, which has been caused by rapid growth of population and agricultural activity dependent on seasonal rainfall. Agroforestry is defined as a land use system which integrate trees, shrubs and/ or animals on farmlands and rural landscapes to enhance productivity, profitability, diversity, and ecosystem sustainability. Such a practice promises the humanity with future food and nutritional security balancing the environmental stability. However, the losses in production due to biotic and abiotic stresses in any farming system are significant due to the climate change, changing production practices and cropping patterns, pathogen shift and injudicious use of agricultural chemicals, loss of soil microbial diversity etc. All these developments if ignored would result in collapse of the system. Unlike, agricultural crops entrepreneurs, agroforestry farming community are left with a very few options with limited practical knowledge on detection, diagnosis, and management of tree diseases both at nursery and field level.

In the absence of any documents for farmers to learn about the tree diseases, this ready reckoner on "Plant Diseases in Agroforestry" to start with, focusing on eight major agroforestry species including sandal, malabar neem, eucalyptus, teak, poplar, Indian rose wood, wattle tree and bamboo that are predominant in the Indian farming systems. This ready reckoner will act as a quick guide to identify the tree-specific diseases and advocate and initiate their management at early stages. Production of quality planting material by containment of diseases at nursery level is more economical, rational, and appropriate way to restrict spread of the initial inoculum. As the nurseries are the gateways for successful plantation programmes, they contribute to the increasing tree cover in the country particularly outside forests. The authors deserve compliments in bringing out this Ready Reckoner at appropriate time that in turn will be useful for farmers, nursery managers, field practitioners and other stakeholders engaged in promoting agroforestry.

(P.K. Chakrabarty)



Preface

The accurate information on plant protection strategies for sustainable production of agroforestry tree species ensure and assure the growers to take up nursery development and/or plantation programmes on large scale. Currently, the information available on tree disease management practices is highly fragmented. This is an attempt to help the nursery managers/tree growers with available literature by making the knowledge on disease management available for them in a more understandable way with pictorial representation to act as guide in quick detection of the problems. As the title suggests, major focus was given on selected plant species that are key in Indian agroforestry systems. This ready reckoner included basic information of major agroforestry species covering their biosystematics, distribution in the world as well as in India, most commonly occurring diseases along with symptomatology and integrated management practices to be followed for each major disease. We are grateful to the authors who reported the disease outbreaks and did research on these important tree species which facilitated this compilation for publication.

We do understand that the usefulness of this ready reckoner will be ultimately decided by the stakeholders. However, the feedback on this effort will help updating the information from a scientific perspective. The information on new diseases outbreak reports, major diseases of economic importance and their management practices will further be extended to other forestry/agroforestry tree species on a continuous basis.

**M Ashajyothi
YN Venkatesh
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AK Handa
A Arunachalam**



Acknowledgement

We are grateful for the financial support provided by the ICAR-Central Agroforestry Research Institute to enable this publication. The information compiled in this document is from various published papers and books. Our effort has been to bring all available information on the agroforestry species to a single document for anyone to have it as a ready reckoner. The first four authors of this document thank Dr. A. Arunachalam, Director, ICAR-Central Agroforestry Research Institute for this concept and guidance to initiate and design this document for the benefit of grassroot level workers involved in tree plantation activities. Some of the figures were adopted from published reports and available literature with proper citation to the respective authors. We also extend our thanks to all the plant pathology scientific fraternity who had generated vast information on tree diseases that were assimilated in this document to provide the basic understanding on major pathological problems of nurseries and plantations in India.



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Indian sandalwood tree (*Santalum album*)

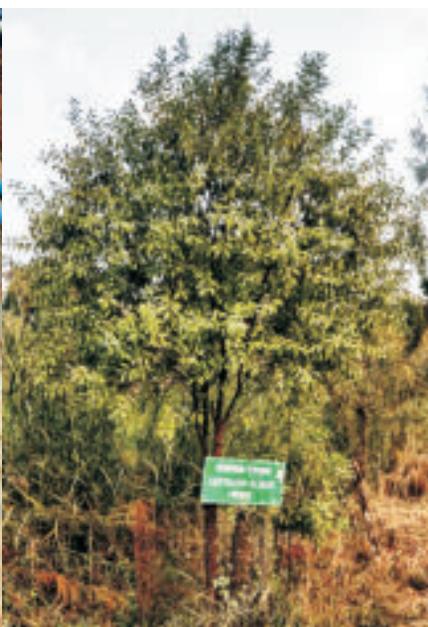
Indian sandalwood tree (*Santalum album*) is well known for its industrial importance due to its aromatic and medicinal properties of the 'santalol' in the oil. Sandal wood oil can either be pressed from the wood or extracted with alcohol or water which is known to relieve fever, used to treat mental disorders, including anxiety, bronchitis, diarrhoea, fatigue, gallbladder problems, high blood pressure, indigestion, insomnia, liver problems, low libido, sore throat, and urinary tract infections. It also has the religious and spiritual significance in India and its neighbouring countries like Sri Lanka, Nepal and Bhutan. The heartwood of sandalwood is also used for making wood crafts, decorative furniture items and bring huge profit to the growers.

1.1 Plant systematics

Kingdom	: Plantae
Clade	: Tracheophytes
Order	: Santalales
Family	: Santalaceae
Genus	: <i>Santalum</i>
Species	: <i>album</i>



Seedling



Sandalwood tree



Foliage

1.2 Distribution

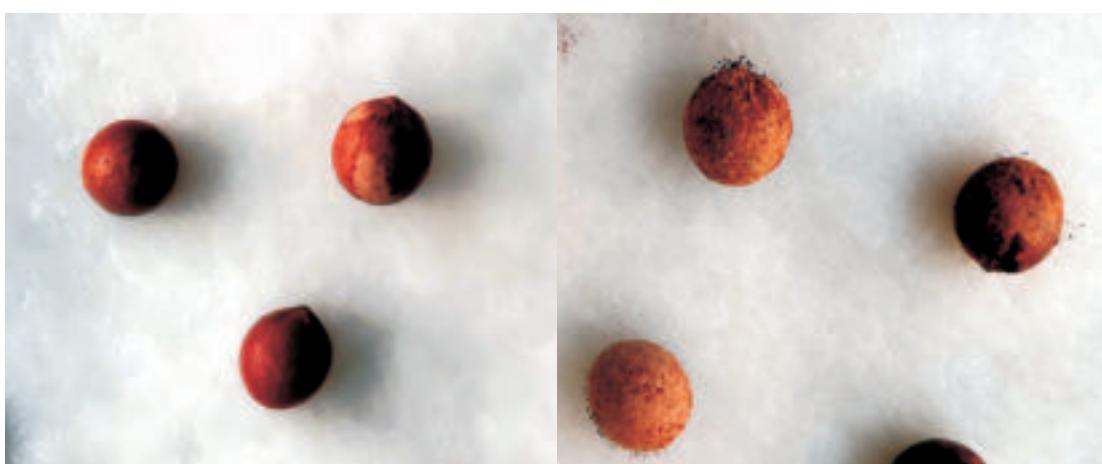
Santalum album is distributed across the Southeast Asian countries like India, Nepal, Indonesia, Sri Lanka, Malaysia, Philippines also in the tropical belt of Australia. In India, commercial plantations as well as natural stands are prevalent in the states of Karnataka, Kerala, Tamil Nadu, and Andhra Pradesh. However, due to over-exploitation, the natural stands of sandalwood trees are now in the verge of extinction and the commercial plantations are now being maintained to meet the industrial demands.

1.3 Common diseases

To fetch maximum returns sandalwood plantations, the species warrants many years including the initial care taken right from seedling stage to main field to ensure the sustainable healthy sandalwood production without pest and disease damage which otherwise severely affect the market value. Reportedly, the sandalwood seeds are affected by various seed borne fungi (*Aspergillus*, *Fusarium*, *Alternaria*) during germination. In nurseries, damage occurs as pre- and post-emergence damping off caused by *Phytophthora* spp. and *Rhizopus* spp. favored by the excess moisture and poor drainage. Later in the seedling stage, fungal wilt infected by the *Fusarium oxysporum* and nematodes bring excessive damage causing mass death of seedlings. In all, these cases controlled watering and good drainage at nursery site will prevent the onset of diseases. Stem canker caused by *Fusarium* spp. has been recently reported from Karnataka. Sandal spike (*Phytoplasma*) transmitted by *Jassus indicus* (leaf hopper) is another menace in sandalwood cultivation.

1.4 Major pathological problems in sandalwood tree

1.4.1 Seed borne fungi (*Aspergillus*, *Fusarium*, *Alternaria*)



Symptoms:

- Web of mycelium observed on surface of seeds
- Lower percentage of seed germination
- Seedling mortality, particularly that emerged from infected seeds



Management:

- Seed should be sun-dried properly before storage
- Seed treatment with *Trichoderma viride* @ 2g/kg seed
- Seed treatment with Captan/Thiram/Carbendazim @ 2 g/kg seed

1.4.2 Powdery mildew (*Pseudoidium santalacearum*)

Symptoms:

- White powdery patches on leaves
- Dusty appearance of the plant
- Reduced growth, small leaves, less branching

Management:

- Seedlings in the nursery should be given adequate spacing and ventilation
- Early morning water spray with high pressure shall wash off the spores of powdery mildew fungus
- Preventive fungicide e.g. wettable sulphur @ 2.5 g/litre at 15 days interval
- Neem oil spray @ 2ml/litre water or Azoxytrobin 23% SC @ 1 ml/litre



Healthy sandal plant



Deformed sandal plant

(Pc: Arun et al. 2012)



Healthy leaves

Diseased leaves

1.4.3 Sandal spike (*Phytoplasma*)

Symptoms:

- Distorted leaves and branches
- Chlorosis, stunting and bushy appearance of the plants with no flowers and fruits
- Death of the plants after 1 or 2 years at young age

Management:

- Using disease-free seedlings
- Removal and disposal of infected plants
- Control vector (leaf hopper) by spraying Imidachloprid 17.8 SL @ 0.5ml/litre
- Tetracycline injection (2-8 g/tree up to 1 year age) to the affected tree trunk

1.4.4 Sandal wilt (*Fusarium oxysporum*)

Symptoms:

- Drooping of leaves, brownish discolouration at the crown region of the seedlings
- Wilting and drying of the seedlings

Management:

- Use disease free seedlings developed from tissue culture if available
- Removal of infected plants and dispose of safely to avoid inoculum spread
- Soil drenching with copper oxy chloride 50% WP @ 2g/litre



Healthy seedling



Wilt infected seedlings

Malabar neem (*Melia dubia*)

Malabar neem (*Melia dubia*) is a promising fast-growing multipurpose tree species known for its excellent timber and fuelwood properties. The wood is mostly used in the plywood industries, matchbox making, packaging materials, musical instruments, and furniture. *Melia* has been screened as an alternative tree species for pulpwood as well. It is highly suitable for agroforestry/farm forestry having a life cycle of 8 to 12 years. Due to its economic importance and special tree characters such as rapid growth rate, stem straightness without profuse branching, less shade effect, the Malabar neem is gaining momentum both in the domestic and global market. With a low maintenance, the species fetches assured income and also, contribute to carbon sequestration and mitigation of climate change impacts.

2.1 Plant systematics

Kingdom : Plantae
 Clade : Tracheophytes
 Order : Sapindales
 Family : Meliaceae
 Genus : *Melia*
 Species : *dubia*



2.2 Distribution

Malabar neem is distributed globally, and it is found in India, Sri Lanka, Malaysia, China and Australia. In India, it is naturally found at an altitude of 600-1800 metre above sea level (m. asl.), especially in the Sikkim, the Himalayas, North Bengal, Assam, Khasi hills, hilly regions of Odisha, Deccan Plateau and the Western Ghats also can be planted successfully in most of the parts of India.



Malabar neem foliage



Malabar neem plantation

(Pc: Jagdish, 2019)

2.3 Common diseases

Malabar neem is at risk in both north and south India due to various biotic problems such as *Melia* decline caused by the association of fungal pathogens, especially *Armillaria fumosa*, *Botryosphaeria* spp., *Fusarium oxysporum*, *Neofusicoccum grevilleae*, *Leptographium* and *Septoria musiva*. Also, fungal wilt incited by the *Fusarium solani* has

been recently reported which destroyed nearly one lakh seedlings in a Forest Nursery at Dehradun. Besides, the root rot disease induced by *Ganoderma* spp. causes death of the whole tree and drastically reduce the market value of wood. Many other fungal associations such as *Phoma* sp., *Fusarium moniliformis*, *Rhizoctonia solani*, *Lasiodiplodia theobromae* and *Pythium* sp. along with nutrient deficiencies and drought and insect pest stress cause severe losses both in nursery and main field.

2.4 Major pathological problems in Malabar neem

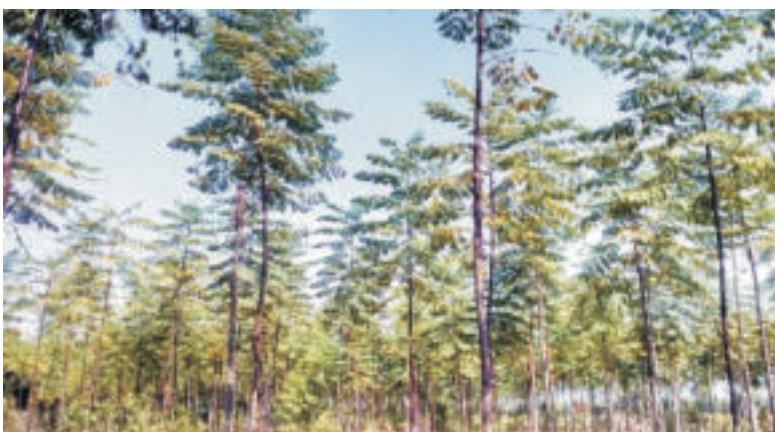
2.4.1 Yellowing (Nutrient deficiency)

Symptoms:

- Yellowing and drying of leaves
- Slow growth leading to thin stem and reduced final wood volume

Management:

- Adopting Integrated Nutrient Management (INM) practices
- Provision of proper irrigation and drainage facility



Healthy 2-year-old Malabar neem



Yellowing of tree crown

2.4.2 Fungal wilt (*Fusarium solani*)

Symptoms:

- Yellowing, drooping, and drying of leaves/branches/whole seedling
- Browning of vascular tissues with no recovery after irrigation
- Death of seedlings



Healthy

Wilt affected seedlings

(Pc: Pandey et al. 2018)

- Placing insect proof nets around nursery
- Drenching soil with copper oxychloride 50% WP @ 2 g/litre in case of severe infection

2.4.3 Decline [(Unknown etiology: Insect+fungal pathogens)]



Healthy Malabar neem trees



Decline syndrome affected dead trees

(Pc: Kumar et al. 2014)

Symptoms:

- Defoliation and stem splitting and bark peeling
- Drying and death of whole trees above 15 years age
- Secondary invaders presence on infected trees (termite, shot hole borers, fungal fruiting bodies)

Management:

- Prevent insect/root damage and / or wounding trees
- Lime coating on tree bases
- Drench soil with copper oxychloride @ 2 g/litre
- Adopting integrated nutrient management (INM) practices

2.4.4 Ganoderma root rot (*Ganoderma lucidum*)

Symptoms:

- Yellowing, wilting, undersized leaves, and dead branches
- Slow growth, and death of lower leaves
- Infected trees easily blow-down during rainstorms or windy periods

Management:

- Adopting good cultural practices: avoid water logging at tree base
- Avoiding damage to tree trunks and roots, even small wounds from mowers and trimmers can initiate infection
- Removal of dead trees, sporophores and safe disposal
- Application of Propiconazole 25% @ 1ml/litre along with irrigation water

- Root feed with tridemorph 75% EC 2ml in 100ml water once in a month for 3 months



Healthy tree stem base

**Fruiting bodies at base
of the infected tree**

Eucalyptus (*Eucalyptus grandis*)

Eucalyptus is a beautiful, tall, evergreen, and majestic tree with rapid growth and adaptability to a variety of ecological conditions. It is a widely cultivated tree species of industrial importance, mainly for paper, pulp, firewood, and timber purpose. The wood is light yellowish-brown colour, moderately durable. The eucalyptus flowers produce abundant pollen and nectar suitable for apiculture. It has also been planted as windbreak and shelter belts along the orchards, pastures, roads, and also for environment conservation purposes such as erosion, salinity control and to reduce atmospheric carbon dioxide levels. Eucalyptus essential oil is used in food, perfumery and pharmaceutical industry, oil possesses a wide spectrum of biological activity including anti-microbial, fungicidal, insecticidal/insect repellent, herbicidal, acaricidal and nematocidal properties.

3.1 Plant systematics

Kingdom : Plantae
 Clade : Angiosperms
 Order : Myrales
 Family : Myrtaceae
 Genus : *Eucalyptus*
 Species : *grandis*



Seedling



Eucalyptus trees



Foliage

3.2 Distribution

Eucalyptus is native to Australia and the genus is represented by around 700 other species that are cultivated throughout the world. It is distributed widely in the tropical and temperate world including the America, Europe, Africa, the Mediterranean Basin, the Middle East, China, and the Indian subcontinent. In India, it was first introduced in the state of Karnataka by Mysore Emperor (Tipu Sultan) and now widely cultivated in Andhra Pradesh, Bihar, Goa, Daman and Deu, Gujarat, Haryana, Kerala, Madhya Pradesh, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh and West Bengal.

3.2 Common diseases

Eucalyptus is attacked by various tree pathogens to cause severe losses at nursery level and also in main field. Stem cankers caused by the fungal species *Corticium salmonicolor* (pink disease); *Chrysoporthe cubensis*; *Amphilogia gyrosa*, *Cytospora eucalypticola*, *Lasiodiplodia theobromae*, *Valsa eucalypti* (valsa canker), *Macrovalsaria megalospora*, *Thyronectria pseudotricha*, *Hysterium angustatum*, *Nattrassa toruloidea* cause major loss to timber quality and quantity. Root rot (*Cylindrocarpon lucidum*), little leaf (*Phytoplasma*) and vascular wilt (*Fusarium oxysporum*) diseases cause death of whole plant and outbreaks of these diseases at nursery level create a fear of failure of entire plantation program. Other diseases like leaf spots (*Phaeoseptoria eucalypti*, *Guignardia citricarpa*) and leaf blight (*Coniella australiensis*) are seasonal.

3.4 Major pathological problems in *Eucalyptus*

3.4.1 Pre- and Post-emergence damping off (*Phytophthora* spp.)



Healthy seedlings



Damping off affected seedlings

(Pc: Simamora et al. 2017)

Symptoms:

- Poor seedling emergence due to killing of the seed before germination or by invasion of seedling radicles and hypocotyls

- Stems become water soaked due to tissue invasion and cell maceration
- Plants fall over leading to the death of plants in patches

Management:

- Use of pathogen-free propagating material
- Proper ventilation and adequate drainage facility at nursery site
- Soil solarisation of the potting mixture before use
- Soil fumigation with formalin
- Soil drenching with copper oxychloride 50% WP @ 2g/litre
- Drench the soil with fosetyl aluminum 80% WP @ 20-50g/20 litre water

3.4.2 Web blight (*Rhizoctonia solani*)



Healthy Nilgiri leaf

Blight affected foliage

(Pc: old et al. 2003)

Symptoms:

- Water-soaked lesions in the plant, necrosis and blightening of leaves
- Heavy defoliation
- Wilting and subsequent death of the seedlings/ young plantations
- Web of mycelium at the infection site

Management:

- Soil solarisation of potting mixture before use
- Sterilization of plastic pots/ tubes
- Soil fumigation with formalin
- Soil drenching with copper oxychloride 50% WP @ 2g/litre
- Spray Propiconazole @ 25% EC 1 ml/litre in severely infected nurseries

3.4.3 Bacterial wilt (*Ralstonia solanacearum*)



Healthy wood logs

Wilt affected plants and wood

(Pc: old et al. 2003)

Symptoms:

- Infected seedlings and plants show drooping and drying of leaves with out yellowing
- Young plants die showing no recovery even after irrigation
- Wilt affected wood shows profuse oozing of bacteria from the cut surface

Management:

- Soil solarisation of potting mixture before use

- Sterilization of plastic pots and planting tools
- Removal and disposal of heavily infected plants
- Soil drenching with plantamycin 100mg/litre and copper oxychloride 50% WP @ 2g/litre around tree base

3.4.4 Pink disease/stem canker (*Corticium salmonicolor*)

Symptoms:

- Web of mycelium on the stem and depression at the infected region
- Vertical bark splitting and stem girdling
- Stem above infected area show die-back in seedlings
- Bushy appearance of the tree due to apical shoot damage

Management:

- Avoid wounding
- Use canker resistant planting material
- Application of bordeaux paste (10%) on the cut surface of stumps
- Soil drench with COC 50% WP @ 20g in 10 litres water around tree base



Healthy Tree Trunk

Damaged stem with pink canker disease

(Pc: Old et al. 2003)

Teak (*Tectona grandis*)

Teak is one of the fast-growing tree species suitable for agroforestry which gained momentum due to its pleasant appearance, superior timber quality and more importantly timber durability. The superior qualitative properties of teak incited itself as one of the potential commercial tree species globally. Besides, teak has the potential to tolerate termite attack and wood-decaying fungi which are the characteristic features owing to its demand worldwide used as furniture, shipbuilding and decorative components. Besides, teak provides several beneficial ecosystem services such as carbon sequestration, stand structural diversity to maintain environmental biodiversity, beautification across the roadside/as ornamental outside forest areas, shade provision, windbreak, soil microfauna diversity and microbial density subsequently maintain soil fertility, water conservation through runoff control.

4.1 Plant systematics

Kingdom : Plantae
 Clade : Tracheophytes
 Order : Lamiales
 Family : Lamiaceae
 Genus : *Tectona*
 Species : *grandis*



Teak trees



Teak foliage

4.2 Distribution

Tectona grandis L. (Teak) considered as one of the world's premier hardwood species which is primarily distributed throughout India, Myanmar, Thailand, Nigeria, and Brazil. The teak plantation also naturalized in Java, Indonesia, where it was probably introduced about 400 to 600 years ago. Teak has been introduced in different parts of the world outside its natural occurrence in South-east Asia, Pacific, East and West Africa, the Caribbean, South America, and Central America regions. In India, teak forests cover an area of 11.4 M ha.

4.3 Common diseases

Teak saplings are prone to fungal and bacterial diseases and mature wood slightly shows resistance, however. The teak associated fungal pathogens include *Olivia* sp., *Rhizoctonia* sp., *Alternaria* sp., *Cercospora* sp. *Phomopsis* sp., *Fusarium* sp., *Phytophthora* sp. etc. Among various diseases reported, foliar diseases mainly leaf rust, leaf blight and leaf spot are the most common ones in many areas. Also, root rot, stem canker, heart rot, powdery mildew and vascular wilt diseases do impact its economic importance. The root rot disease of teak caused by *Rigidoporus lignosus* becoming endemic in countries like Nigeria. Recently, a new brown leaf spot disease of teak caused by *Alternaria alternata* reported from China. Pathogens like *Rhizopus stolonifera*, *Botryodiplodia theobromae* and *Aspergillus niger* were also found to cause disease in teak plantations. Leaf rust of teak has been reportedly spreading to many new areas from Brazil, Australia, and Africa. *Pseudomonas tectonae* causing seedling wilt in teak became the important bacterial disease of concern along with the new teak bacterial leaf spot caused by *Xanthomonas fuscans* from Brazil. For the first time, Tomato Chlorosis Virus was reported to be infecting teak in association with insect vector whitefly (*Bemisia tabaci*) in Brazil.

4.4 Major pathological problems in Teak

4.4.1 Leaf rust (*Olivea tectonae*)

Symptoms:

- Infected leaves show small angular brown to grey necrotic lesions on the upper surface
- Lesions coalesce to form larger necrotic areas
- Yellowish orange powdery pustules on the upper leaf surface of the necrotic areas



Healthy teak leaves



Leaf rust infection
on lower leaf surface
(Pc: Osorio et al. 2019)

Management:

- Spatial deployment of resistant teak germplasm
- Burning the infected seedlings
- Regular weeding and adopting clean cultivation practices
- Pruning and thinning in younger plantations
- Less usage of sprinkler irrigation
- Spray neem oil (2ml/litre) as protectant
- Spray azoxystrobin 23% SC (1ml/litre) at recommended dose in infected nursery

4.4.2 Teak rots (*Ganoderma spp.*, *Fomes spp.*, *Phellinus spp.*)

Symptoms:

- Yellowing of leaves, wilting and defoliation
- Disease occurs in patches in nursery beds especially during seedling stage
- Affected trees produce dark rusty brown velvety band of fungal mycelium develops at the collar butt region, followed by typical die-back basal root rot
- Bark depression at the root collar
- Selective decay in the fiber cells, ray cells to induce degradation, delignification and creating erosion channels in the wood, swollen boles, branch stubs, dead branches are indicators heart rots



Healthy teak trees



Rot affected trees

(Pc: Mohd Farid et al. 2005; Wahounou et al. 2017)

Management:

- High temperature and drought areas for nursery preparation should be avoided
- Transplanting in polyethylene bags and regular watering can revert the diseased condition
- Infected and dead saplings must be disposed safely as the pathogen is soil-borne and can sustain in soils for longer duration
- Preventing wounds or injuries caused by fire or other biotic interference can protect plants from disease
- The wound needs to be treated with Bordeaux paste for preventing the entry of rot fungi
- Since many rot causing pathogens are soil borne, it is suggested to do soil drenching with Thiophanate methyl (0.5 ml/litre) and Dithane M-45 (2g/litre) for 10 x 1 metre bed, fytolan (2 ml/litre) and Hexaconazole 5% EC (1.5 ml/litre) spray with 10-15 days interval can check the spread in severely affected nurseries

4.4.3 Leaf spot and blight

Symptoms:

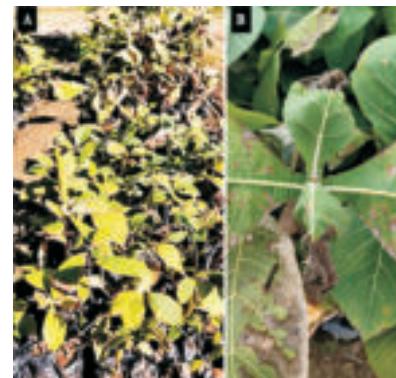
- Pre- and post-emergence mortality in nurseries
- Infected foliage produces dark brown necrotic spots usually in the leaf margin, base of the petiole or in the leaf tips
- Later spots will fuse to form larger necrotic areas and spread entire leaf lamina
- Infected leaves show upward curling and may brittle and finally wither



Healthy leaves

Management:

- Site selected for raising saplings must be elevated with proper ventilation along with sanitation and appropriate drainage
- Avoid excess urea application
- Avoid sprinkler irrigation
- Arrange saplings in rows with proper spacing in the nurseries
- Spray neem oil (2ml/litre) as protectant
- Spray mancozeb (2g/litre) in infected nursery
- Spray Propiconazole 25% EC 1 ml/litre in severely infected nurseries



Leaf spot and blight effect in teak nursery

4.4.4 Teak powdery mildew (*Uncinula tectonae*)



Healthy teak leaves



Powdery patches on teak leaves

(Pc: Parthasarathy)

Symptoms:

- Small patches of whitish powdery masses on the upper surface of teak leaves with corresponding chlorotic lesions on the lower surface
- White powdery patches turn brown to black at later stage

Management:

- Proper sanitation around the trees before the rains
- Sulphur dusting is proven to be effective
- Neem leaf extract/neem oil 2ml/litre spray during morning hours to inhibit the disease spread
- Spray Azoxystrobin 23% SC @ 1 ml/litre

4.4.5 Stem canker (*Corticium salmonicolor/Fusarium solani*)

Symptoms:

- Cobweb stage: a layer of vegetative mycelium (under wet conditions)
- Nectar stage: orange spore structures develop
- Pink encrustation stage: cankers will be covered in pinkish fruiting structures
- Sunken areas on main stem and branch cankers, bark swelling and splitting symptoms also appear in later stage
- Die back of terminal shoot; in severe cases, the plants die too.



Healthy teak trunks



Stem canker on teak plants



(Pc: Business.qld.gov.in)

Management:

- Application of contact fungicide Bordeaux mixture (10%) and systemic fungicide tridemorph 75 EC @ 5 ml/10 litres of water
- Soil drench with copper oxychloride 50% WP @ 20g in 10 litres water around the tree base

4.4.6 Teak wilt (Fungal and Bacterial)



Healthy teak wood
(cross section)



Brown discolouration in teak wood

(Pc: Borges et al. 2018)

Symptoms:

- Leaf yellowing, premature leaf-fall, leaf abscission, whole plant wilting, plant collapse followed by death are common symptoms (wilting without leaf yellowing bacterial wilt)
- Upon splitting the stems of infected saplings show brownish discolouration of vascular tissue spreading in both directions
- On the cross sections of tree trunk, black darkening of heartwood and sapwood can be clearly seen

Management:

- Use disease-free planting material
- Avoid wounding on roots that facilitates pathogen entry
- The soil at the site of the infected plants should be drenched with Plantamycin 100 mg (a.i.)/copperoxychloride 50% WP @ 2g/litre

4.4.7 Phanerogamic parasite

Symptoms:

- Found on trunk, branches and aerial roots of trees
- Major teak pest of teak in Kerala Nilambur region with total failure of the plantation

Management:

- Mechanical removal of the parasite by lopping of the infested branches as practiced in Kerala
- Tree injection of selective herbicides



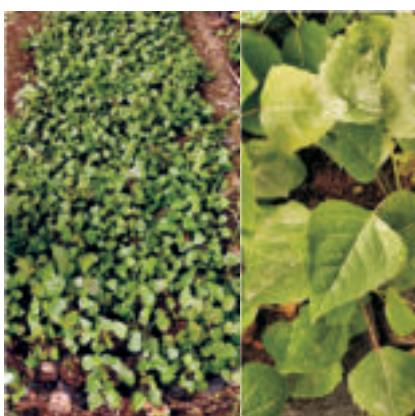
Parasitic plants on teak

Poplar (*Populus deltoides*)

Populus deltoides also known as eastern cottonwood tree is a large and dioecious tree that grows up to 20-60 metres. *Populus deltoides* is the most popular exotic species among other 13 poplar species present in India. Poplars are the most preferred tree species due to its wood quality and its cultivation largely benefit the growers with high net returns. Indian Council of Forestry Research and Education (ICFRE) emphasized poplar cultivation and it has extended poplar through agroforestry to Vaishali District of Bihar; annual returns from *Populus deltoides* cultivation have been estimated to be 250,000 Indian rupees per hectare per year. Wood produced from poplar trees can be used for manufacturing quality plywood, match sticks and paper. Poplar cultivation certainly reduced the pressure on natural forests for wood with all its ecological and environmental benefits, besides generating employment opportunities.

5.1 Plant systematics

Kingdom : Plantae
 Clade : Rosids
 Order : Malpighiales
 Family : Salicaceae
 Genus : *Populus*
 Species : *deltoides*



Seedlings

Foliage

Poplar trees

(Pc: apnikheti.com)

5.2 Distribution

Poplar is native to Northern America and distributed throughout the central, eastern, and western United States also present in Canada and Mexico. Nearly seven decades

back poplar got to the Indian sub-continent and so far, 13 of its species have been introduced in various parts of the country. However, there are six species of poplars, viz., *Populus ciliata*, *P. alba*, *P. euphratica*, *P. gamblii*, *P. jacquemontii* var. *glauca* and *P. rotundifolia* are believed to be indigenous to India.

5.3 Common diseases

Intensive cultivation of poplar hybrids in the modern times made to succumb the poplar to various pest and diseases. Among all, fungal diseases are of major concern in poplar cultivation. Diseases like leaf spots (*Myrotheicum roridum*, *Cercospora populina*, *Phaeoisariopsis* sp., *Drechslera maydis*, *Alternaria* spp., *Phyllosticta* spp.); root rot caused by *Rosellinia necatrix* *Armillaria* spp. and *Botryodiplodia* spp.; bark necrosis caused by *Discosporium populeum* and cankers incited by *Cytospora* spp., *Hypoxyylon* spp. are the most common fungal diseases. Bacterial canker caused by *Pseudomonas rimaefaciens* and *Xanthomonas populi*, and rusts caused by *Melampsora* species are other important, but lesser-known diseases on poplar in India

5.4 Major pathological problems in cottonwood

5.4.1 Leafspots caused by *Myrotheicum roridum*, *Marssonina* spp., *Cercospora populina*, *Phaeoisariopsis* sp., *Drechslera maydis*, *Alternaria* spp. and *Phyllosticta* spp.



Healthy seedlings

Marssonina leaf spot

Septoria leaf spot

(Pc: W.R. Jacob)

Symptoms:

- Leaf spots and blights at nursery level
- Dark brown to light-brown irregular spots with or without grey centre and yellow halo on the leaves
- The spots coalesce to form larger necrotic areas and give blighted appearance
- The spots may further get extend to the leaf petioles, stem, and floral parts

All these result in the reduction of leaf chlorophyll and affect the overall photosynthetic ability of the plants

Management:

- Initial sanitation practices before nursery establishment are crucial
- Planting material must be disease-free
- Potting medium should be properly sun-dried
- Adequate irrigation and drainage at nursery site
- If infection is noticed, stop sprinkler irrigation
- As a preventive measure, neem oil could be sprayed at 2ml/litre
- In severe cases, spray Thiophanate methyl @ 0.5g/litre at 10days interval twice

5.4.2 Root rot or butt rot (*Rosellinia necatrix*, *Armillaria*)



Healthy poplar tree



Leaf scorching



Armillaria rot

(Pc: <https://www.missouribotanicalgarden.org/>)



Heart rot

(Pc: alamy.com)

Symptoms:

- Bark scaling, bark discoloration at the crown region
- Presence of strands of white mycelium under bark and around tree as long strands
- Presence of fruiting bodies or honey coloured mushroom like structures at the base of the tree
- Leaf scorching, branch drying initiation in single big branches
- Rotting of heart wood at the centre of timber cross section

Management:

- Avoid injuries to the tree base/ roots/stem
- Maintain tree vigour by managing insect pests in the vicinity
- Early removal and disposal of dead trees
- Soil application of *Trichoderma harzianum* 2.5 kg/ha with 50 kg well-decomposed farmyard manure (FYM)

**5.4.3 Canker (*Cytospora* spp., *Hypoxyylon* spp., *Fusarium* spp., *Nectria* spp.)
Bacterial canker (*Xanthomonas populi*)**



Healthy stem

Canker lesions on stem

(Pc: T.H. Filer)

Symptoms:

- Necrotic sunken spots on stem
- Black water-soaked sunken lesions in case of bacterial canker
- Irregular broken areas on stem with targeted ring like spots and swellings
- Darkened inner bark
- Stem pitting and splitting

Management:

- Use of canker-resistant clones
- Avoid injuries to the tree stem
- Removal of the infected portion with sterile knife dipped in 70% alcohol
- Application of Bordeaux paste (10%) on the cut surface and wounds

Wattle tree (*Acacia nilotica*)

Acacias are also called wattle tree or kikar that grows up to 5-20 metre height with a dense spheric crown, dark brown to black coloured stems and branches, fissured bark, grey-pinkish slash, exude a reddish low-quality gum. The tree has thin, straight, light, grey spines in axillary pairs, usually in 3 to 12 pairs, 5-7.5 cm long in young trees, the same is absent in mature tree. Acacia species are economically important and are widely planted globally for the most attractive timber, tannin, firewood and fodder. The timber is preferred for agricultural implements and musical instruments. Black wattle tree bark has been supporting the tanning industries of several countries, and also supply tannins for production of waterproof adhesives. Traditionally, the seeds of some acacia species are ground into flour and used as food supplement as well in Australia. The seeds contain as much as 25% more protein than cereals, and they store well for long periods due to the hard seed coats, also the acacia gum is edible.

6.1 Plant systematics

Kingdom : Plantae
 Class : Rosids
 Order : Fabales
 Family : Fabaceae
 Genus : *Acacia*
 Species : *nilotica/senegal*

6.2 Distribution



Acacia being a large genus with more than 1000 species distributed throughout the Australia, parts of Asia, Africa, Europe and the Americas. This tree genus present in all terrestrial habitats, including alpine settings, rainforests, woodlands, grasslands, coastal dunes and deserts. In drier woodlands or forests, they are an important component and in Australia they are second most spread forests after eucalypts. India is native to few species of acacia and this tree has a wide presence in almost all Indian states.

6.3 Common diseases

Seeds of acacia are prone to damage by seed borne fungi like *Fusarium avenaceum* and *Aspergillus* spp. and the seed treatment with captan (2g/kg seed) will save from the damage. Foliar diseases such as leaf rust (*Ravenelia taslimii*), powdery mildew (*Erysiphe acaciae*), and leafspots (*Septogloœum acacia*; *Curvularia lunata*) mostly threaten the nurseries. Mature trees are commonly attacked by rot causing fungi such as *Fomes badius* (trunk rot); *Fusarium pallidoroseum* (root rot); *Ganoderma lucidum*; *Polyporus gilvus* (butt rot).

6.4 Major pathological problems in acacia

6.4.1 Acacia mortality (*Fusarium solani* and *Ganoderma lucidum*; insect pest attack, Water logging and drought conditions)



Healthy tree



Mortality in *Acacia*

Symptoms:

- Stag head appearance of the tree canopy due to severe defoliation
- Root rot and blackening of feeder roots
- Discoloration of vascular tissue of the roots
- Presence of bracket fungi fruiting bodies at the tree base
- Presence of insect pests and signs of damage caused by the termites and borers

Management:

- Use of quality planting material
- Preventing the seedlings from prolonged water logging and/or drought
- Removal of fruiting bodies if any from infected trees to avoid the disease spread
- Avoid wounds and cuts to the roots/stem
- Application of 10% Bordeaux paste to the cut surfaces (1 kg lime + 1 kg CuSO₄ + 10 litres of water)
- Application of lime paste to the tree base to avoid secondary infections
- Root feed with tridemorph 75% EC 2ml in 100 ml water once in a month for 3 months

6.4.2 Acacia rust (*Ravenelia acaciae-arabicae*)



Healthy foliage



Rust pustules in *Acacia nilotica*

(Dhileepan et al. 2013)

Symptoms:

- Rusty brown pustules on leaves, stems and floral parts
- Malformation and hypertrophy on leaf rachis, pods and the stem
- Large conspicuous galls in severe stages induced by the aecial stage of the fungus

Management:

- Use of rust-resistant planting material is the best method to prevent the losses
- Avoid sprinkler irrigation at the advent of disease in the nursery
- Removal of infected seedlings and carefully burial underneath soil
- Azoxystrobin 23% EC @ 1ml/litre spray is recommended dosage if the infection is severe

Indian Rose Wood (*Dalbergia sissoo*)

Dalbergia sissoo (shisham/rosewood) is tall, deciduous tree grows upto 25 metres and is as an important agroforestry species known for its timber quality and demand. Shisham wood is extraordinarily strong, close grained, durable, ornamental and is used for various purposes including furniture, panelling, ornamental work, agricultural implements, gun carriages, etc. It has been exported to various countries in the Europe and elsewhere under the name of rosewood/bombay block wood owing to the rich colour, smoothness and after finish to the furniture made up of rose wood. The leaves and young shoots are readily grazed by the animals, used as fodder, especially during the winter season. Shisham also has reputation for its medicinal properties used in treating skin diseases, blood diseases, syphilis, stomach problems, and as an expectorant, etc. Besides, traditionally the fruit extract is under use as molluscide to inhibit freshwater snail problem. This species is having high significance to use in riverbank reforestation programs in tropical and subtropical climatic regions.

7.1 Plant systematics

Kingdom : Plantae
 Class : Rosids
 Order : Fabales
 Family : Fabaceae
 Genus : *Dalbergia*
 Species : *sissoo*



(Pc: Rajesh Srivastava)

7.2 Distribution

Dalbergia sissoo (shisham/rosewood) is widely cultivated in tropical and subtropical regions of Asia and Africa. It grows naturally in India and Iran along the riverbanks above 200 m elevation, and it has a range up to 1400 m asl. It is believed native to the foothills of the Himalayas ranging from Afghanistan to Bihar, India. In India, shisham is mostly grown in the states of Kashmir, Assam, Bengal, Sikkim, Uttar Pradesh also present in central and southern India.

7.3 Common diseases

The major biological threat to shisham comes from fungal and insect damage. Many diseases have been reported to cause huge losses in its cultivation. Irreversible damage is caused during seedling stage by root rot caused by *Rhizoctonia solani* and wilt by *Fusarium oxysporum* f. sp. *dalbergiae*. Regular irrigation and protection from grazing wounds provide adequate assistance at this stage. Leaf spots (*Cercospora sissoo*;

Phyllosticta sissoo; Myrothecium roridum; Alternaria alternata); Black leaf spot (Phyllachlora dalbergiae) disease, powdery mildew (*Phyllactinia dalbergiae*), canker (*Phoma nivea; Hypoxylon investians*) are commonly observed in the nurseries as well as in the foliage of a few mature plants. Root rot/trunk rot caused by *Ganoderma lucidum*, root/butt rot (*Phellinus gilvus*) causes death of whole plant; the rotted trees are prone to fall during windy rains.



Shisham seedlings in the seed bed

(Pc: Rajesh Srivastava)



Healthy foliage

Shisham mortality is a complex problem since 1995 to 2005; under mono-cultivation plots of *Dalbergia* spp. it is still a major issue of concern. The cause of shisham mortality established with huge research efforts and close observation from many years as the fungi (*Fusarium oxysporum* and *Ganoderma lucidum*) being primary damage-causing factor and insect pests (termite attack, borers, defoliators and hoppers) as the secondary ones.



Healthy trees



Dead shisham tree

7.4 Major pathological problems in shisham

7.4.1 Shisham mortality (*Fusarium oxysporum* and *Ganoderma lucidum*; termite attack, borers, defoliators and hoppers)

Symptoms:

- Defoliation of entire tree and/or the tree is left with leafless branches
- Slow drying of leaves, branches and whole tree with die back symptoms
- Presence of fruiting bodies of mycelium at the tree base
- Stem splitting and bark shredding with gummy black secretion under bark
- Signs of secondary infection such as termite and borer attack
- Die back of standing (normally within 3 to 4 years of infection)

Management:

- Use of resistant germplasm for large scale plantations
- Avoid waterlogging near the tree base
- Sandy soils/light textures soils are preferable for planting with good drainage
- Avoid wounds and cuts to the roots/stem
- Application of 10% Bordeaux paste to the cut surfaces (1kg lime+1 kg CuSO₄+10 litres of water)
- Application of lime paste to the tree base to prevent entry of termites and other secondary insects/pathogens
- Root feed with tridemorph 75% EC 2ml in 100ml water once in a month for 3 months

7.4.2 Stem canker (*Phoma nivea*; *Hypoxyylon investians*)



Branch cankers



Stem pitting

Symptoms:

- Bark splitting and shredding
- Stem pitting is prominent with groove formation
- Branches broke off leaving significant mark on main stem
- Reddish black gummy exudation at the cankerous growth

Management:

- Avoid wounding
- Use canker-resistant planting material
- Remove cankers with sterile knife and apply bordeaux paste (10%) on cut surface
- Soil drench with copper oxychloride 50% WP @ 20g in 10 litres water around tree base

7.4.3 Rootrot (*Ganoderma lucidum*; *Phellinus gilvus*)



Healthy tree base

Diseased tree base with fruiting bodies

Symptoms:

- Severe defoliation and lateral root damage
- Stag head appearance of the affected trees
- White rot in the sapwood
- Presence of mushroom like fruiting bodies of bracket fungus at the tree base
- Drying and death of trees and do not recover even after watering

Management:

- Quick removal and disposal of fallen trees
- Drench the soil with copper oxychloride 50% WP @ 2 g/litre
- Removal of entire old root system before replanting
- Soil can be replaced with fresh soil collected from healthy plantations

7.4.4 Leaf spots and blights (*Cercospora sissoo*; *Phyllosticta sissoo*; *Myrothecium roridum*; *Alternaria alternata*; *Phyllachlora dalbergiae*)



Healthy foliage



Curvularia leaf spot

(PC: Sharma et al. 2012)

Symptoms:

- Leaf spots and blights are most common diseases in shisham nurseries
- Necrotic light greyish to dark brown small spots appear on leaves
- Spots may coalesce to enlarge in size and spread entire leaf lamina
- In many cases, spots start from leaf margins and extend towards petiole with prominent margin
- In severe stages, the entire leaf become blighted and defoliation starts in mature trees

Management:

- Isolation of infected seedlings from the healthy ones
- Removal and safe disposal of infected leaves
- Avoid sprinkler irrigation
- Spraying Benomyl 150% WP @ 0.3g per litre in case of severe infection

Bamboo (*Dendrocalamus strictus*)

Bamboo is the king of the grasses family and called as poor man's timber for its unique and special qualities. It is one of the fastest growing plants, also registered as "Green Gold" of the 21st century. Today, bamboo is a renewable and versatile resource with high strength and low weight hence bamboo based industrial activities have great and wide scope for income and employment generation in rural and semi urban areas of the country. Traditionally, it has been used in construction of houses, live fence, food, fuel, and material used for making agricultural implements and other purposes. In the recent years, it has been using for pulp and paper industry, construction and engineering materials, traps, weapons, rafts, towers, cages, etc. Apart from these uses' bamboo provides ecosystem services and tackle global climate change by releasing 35 percent more oxygen than other plants to the environment and sequesters 20 percent carbon dioxide from the environment. Evidently, plantation of bamboo species in urban and semi-urban could dramatically improve air quality with the release of more oxygen and sequestering more carbon dioxide.

8.1 Plant systematics

Kingdom :	Plantae
Class :	Liliopsida
Order :	Poales
Family :	Poaceae
Genus :	<i>Dendrocalamus</i>
Species :	<i>strictus</i>



Bamboo saplings



Bamboo



Foliage

8.2 Distribution

Globally, there are 87 genera having approximately 1500 species of bamboo. It grows mostly in humid tropical, sub-tropical and warm temperate regions. In India, bamboo is grown in almost all states, but are abundant in the humid tropics of northeast India and Kerala.

8.3 Common diseases

Reportedly, bamboo is affected by nearly 440 fungi, three bacteria, two viruses, one phytoplasma (mycoplasma-like organism) and one bacteria-like organism which all cause diseases and disorders. Many a time's complete failure of plantation programmes due to the disease outbreaks in the nursery stock is evident due to infections. Culm rot (*Fusarium equiseti*), bamboo blight (*Sarocladium oryzae*, *Coniothyrium fuckelii* Sacc., *Fusarium* spp., *Acremonium strictum* W. Gams, *Pteroconium* sp., *Arthrinium* sp.), branch die back (*Fusarium pallidoroseum*), witche's broom (*Balansia liniaris*), little leaf (*Phytoplasma*), leaf rust (*Dusturella divina*), leaf tip blight (*Alternaria alternata*), leaf spots (*Exserohilum* sp.; *Colletotrichum* spp.; *Dactylaria* spp.) are some of the most commonly occurring and economically important diseases reported in the bamboo species in India.

8.4 Major pathological problems in bamboo

8.4.1 Bamboo thread blight (*Botryobasidium salmonicolor*)



Healthy bamboo leaves



Blight infected bamboo leaves

Symptoms:

- Large water-soaked greyish lesions appear on mature leaves
- Fungal mycelial threads observed on corresponding lower surface of the infected leaves
- Lesions spread from leaf tips and even reach to the culms

Management:

- Pruning of the diseased branches
- Cleaning and burning of the infected foliage

8.4.2 Bamboo culm rot (*Fusarium moniliforme*)

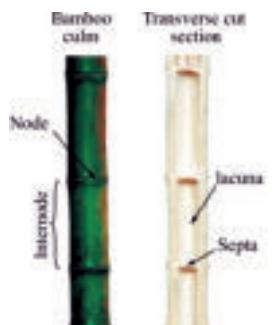
Symptoms:

- Dark brown water-soaked lesions on culms and culm sheath
- Rotting of emerging tender shoot along with strong sour smell

Management:

- Remove the debris surrounding shoots before monsoon
- Avoid insect damage and water logging
- In severe cases, spray carbendazim @ 2 g/litre

8.4.3 Little leaf (*Phytoplasma*)



Healthy bamboo culm
(Pc: Tarun Gangwar)



Rotten bamboo culms
(Pc: C. Mohanan)



Healthy bamboo



Phytoplasma infected bamboo

(Pc: Amit Yadav)

Symptoms:

- Numerous, small and dense needle like leaves and abnormal shoots emerge from nodes
- Bushy appearance of the whole branch around nodes
- Stunted growth of the culms, internodes and whole plant

Management:

- Cutting and burning of the severely infected culms and nodes

8.4.4 Fire damage (*non-pathological*)



Healthy bamboo



Fire damage on young bamboo plant

Symptoms:

- Burning and drying of leaves, stem and branches
- Dried plants quickly catch fire and may provoke forest fires under natural conditions

Management:

- Avoid fire during winters and summers near to the trees



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