PART III

Pests of selected forest tree species

Abies grandis

Order and Family: Pinales: Pinaceae
Common names: grand fir; giant fir

NATURAL DISTRIBUTION

Abies grandis is a western North American (both Pacific and Cordilleran) species (Klinka *et al*., 1999). It grows in coastal (maritime) and interior (continental) regions from latitude 39 to 51 °N and at a longitude of 125 to 114 °W. In coastal regions, it grows in southern British Columbia (Canada), in the interior valleys and lowlands of western Washington and Oregon (United States), and in northwestern California (United States). Its range extends to eastern Washington, northern Idaho, western Montana, and northeastern Oregon (Foiles, 1965; Little, 1979). This species is not cultivated as an exotic to any significant extent.

PESTS

Arthropods in indigenous range

The western spruce budworm (*Choristoneura occidentalis*) and Douglas-fir tussock moth (*Orgyia pseudotsugata*) have caused widespread defoliation, top kill and mortality to grand fir. Early-instar larvae of *C. occidentalis* mine and kill the buds, while late-instar larvae are voracious and wasteful feeders, often consuming only parts of needles, chewing them off at their bases. The western balsam bark beetle (*Dryocoetes confusus*) and the fir engraver (*Scolytus ventralis*) are the principal bark beetles. Fir cone moths (*Barbara* spp.), fir cone maggots (*Earomyia* spp.), and several seed chalcids destroy large numbers of grand fir cones and seeds. The balsam woolly adelgid (*Adelges piceae*) is a serious pest of *A. grandis* in western Oregon, Washington and southwestern British Columbia (Furniss and Carolin, 1977). Feeding by this aphid causes twigs to swell or 'gout' at the nodes and the cambium produces wide, irregular annual growth rings consisting of reddish, highly lignified, brittle wood (Harris, 1978).

Diseases in indigenous range

Susceptibility to heart rot and decay is one of the more important factors in the management of *A. grandis*. Indian paint fungus (*Echinodontium tinctorium*) is the most destructive fungus affecting this species in Washington and Oregon (Hepting, 1971), but is rare where rapid growth rates close branch stubs quickly (Etheridge and Craig, 1976). *E. tinctorium* causes a brown stringy rot, but in early stages decay appears as a light-brown or water-soaked stain in the heartwood. Centres of decay are closely related to logging scars, frost cracks, broken tops and other mechanical injuries (Maloy, 1967). *Armillaria* spp. and *Phellinus weirii* are the two most important root-rot fungi (Hepting, 1971).

Acacia mangium

Order and Family: Fabales: Fabaceae
Common names: brown salwood

NATURAL DISTRIBUTION

Acacia mangium is found in northern Queensland, Australia, where it has a very limited distribution in two regions. Most occurrences are in the coastal, tropical lowlands, with small occurrences up to 800 m. It extends through the Western Province of Papua New Guinea into the Indonesian provinces of Irian Jaya and Maluku (Awang and Taylor, 1993).

PESTS

Arthropods and diseases in indigenous range

There are no significant reports.

Arthropods in introduced range

Hutacharern (1992, 1993) lists a wide range of insect pests affecting *A. mangium* and identified a stem borer (*Zeuzera coffeae*), root pests (*Coptotermes curvignathus*) and a shoot and stem girdler (*Sinoxylon* sp.) as serious pests. Insect damage to the wood by carpenter ants (*Camporatus* sp.), termites (*Coptotermes* sp.) and a Cerambycid wood borer (*Xystocera* sp.) has been recorded in localized areas in Sabah, Malaysia.

Pinhole beetles of three species (*Xyleborus perforans*, *X. crassiusculus*, and an unidentified *Xyleborus* sp.) were observed on logs of *A. mangium* during pruning studies in an industrial plantation at Surigao del Sur, Philippines (Braza, 1995). Ho and Maznah (1995) found a total of 21 species of beetles from the family Scolytidae attacking both unseasoned and seasoned *A. mangium* timber.

Diseases in introduced range

Diseases of *A. mangium* in plantations in tropical areas of Southeast Asia, the Indian subcontinent and northern Australia have been reviewed by Lenné (1992), Lee (1993) and Old, Lee and Sharma (1997).

Mehrotra *et al*. (1996) describe root and heart rots, their causal agents and potential control measures in plantations of *A. mangium* in West Bengal, India. Root rot of *A. mangium*, caused by *Ganoderma* sp. and *Phellinus* spp., affects young stands in most places where *A. mangium* is now grown. Management options include the physical removal of stumps and woody debris and possible use of fungicides. A yellow, mottled, soft, light heart rot involving a range of wood decay fungi is a potentially serious source of wood degradadation throughout all areas where the species is grown, with 50 percent of trees affected in some stands. Cankers associated with decayed branch stubs and pruning wounds are good indicators of heart rot. Infected trees can continue to grow vigorously to maturity. Management options include adopting silvicultural practices that limit wounds to the stem, including early singling of multistemmed trees, short rotations and selecting provenances for slender branches and single stems.

Other significant diseases include stem cankers involving a range of pathogens, pink disease (*Corticium salmonicolor*) and phyllode rust (*Endoraecium digitatum*).

INVASIVENESS

Acacia mangium could become a weed under certain conditions.

Casuarina equisetifolia

Order and Family: Casuarinales: Casuarinaceae
Common names: coast she-oak; whistling pine; casuarina

NATURAL DISTRIBUTION

Subsp. *equisetifolia* occurs naturally along the tropical coastlines from Northern Queensland and Northern Territory in Australia, throughout the whole Malesian region to the Kra Isthmus of Thailand and adjoining coastal areas of the Andaman Sea in southern Myanmar. Subsp. *incana* has a much narrower distribution extending from the coastlines of central New South Wales to north Queensland in Australia, and in Vanuatu and New Caledonia. Some dispersal of seed, from cones, may be affected by water, ensuring the spread of the species along sea shores. *C. equisetifolia* may form pure stands on the coastal dunes growing over a ground cover of dune grasses and broadleaved herbs, or can be part of a richer association of trees and shrubs collectively termed the Indo-Pacific strand flora (Champion, 1936; Doran and Turnbull, 1997). In Australia, it also grows in narrow belts adjacent to mangrove forests or scattered in open woodlands dominated by eucalypts.

PESTS

Arthropods and diseases in indigenous range

There are no significant reports.

Arthropods in introduced range

C. equisetifolia is a nitrogen-fixing tree of considerable social, economic and environmental importance in many tropical areas of the world. It is widely planted for reclamation of unstable coastal ecosystems in the tropics and subtropics.

Over 50 species of insects are known to feed on the species, but serious pest problems have not occurred. A borer beetle, *Sinoxylon anale*, girdles small stems (about 1 cm in diameter), causing them to break at the point of attack (Pinyopusarerk *et al*., 1996b). Seedlings are susceptible to browsing by rodents, crabs, crickets and grasshoppers. In Puerto Rico casuarina is the host for many insect species from the orders Coleoptera, Hemiptera, Isoptera, Lepidoptera and Orthoptera (Martorell, 1975). In Cuba, insects that damage in plantations include the stem and twig borer *Apate monachus*, leaf cutting ant *Atta insularis*, Australian pine spittle-bug *Clastoptera undulata* and the cottony cushion scale *Icerya purchasi*. In Florida minor damage is caused by the twig girdler *Oncideres cingulata*, the thorn bug *Umbonia crassicornis*, Australian pine spittle bug *C. undulata* and the leaf notcher weevil *Artipus floridanus*.

Diseases in introduced range

The most serious disease threatening *C. equisetifolia* is blister bark disease. Infected trees die rapidly after exhibiting symptoms of foliar wilt and cracking of the bark where blisters develop enclosing a black powdery mass of spores (Bakshi, 1976). Blister bark disease is associated with the fungus *Subramanianospora vesiculosa*. The disease was first reported in Orissa State, India. It has since been recorded in Sri Lanka, from all of the peninsular states of India, and from Mauritius and Indonesia. It has recently been observed in Thailand (Pongpanich, Luangviriyasaeng and Dudzinski, 1996) and Viet Nam (Sharma, 1994).

Bacterial wilt, associated with *Ralstonia solanacearum*, causes yellowing foliage and wilting and death has been reported in China and India (Liang and Chen, 1982). Other serious recorded diseases include serious stem cankers and dieback caused by *Phomopsis casuarinae* (Anamorphic Diaporthe), and *Botryosphaeria ribis* and pink disease (*Corticium salmonicolor*) (Pongpanich, Luangviriyasaeng and Dudzinski, 1996). Brown rot caused by *Phellinus noxius* causes tree decline in Taiwan (Chang, 1995).

INVASIVENESS

Casuarina equisetifolia has the potential to become a weed under certain conditions which has been observed in the United States in Hawaii and Florida. It has colonized disturbed native vegetation formations and interfered in the nesting of sea turtles on foreshore dunes (Geary, 1983).

Dalbergia latifolia

Order and Family: Fabales: Fabaceae
Common names: blackwood; Indian rosewood

NATURAL DISTRIBUTION

Dalbergia latifolia is indigenous to south and Southeast Asia. In India it is widely distributed from the sub-Himalayan tract to southern India at altitudes from 0 to 900 m (1350 m in southern India). It is not a gregarious tree and occurs scattered in mixed deciduous forests.

PESTS

Arthropods in indigenous/introduced range

More than 40 species of insects, including defoliators, bark feeders and sap suckers, are known to be associated with living trees of *D. latifolia*. The damage caused by them is insignificant and there is no threat from any of them in the establishment of nurseries or plantations (Beeson, 1941; Mathur and Singh, 1960; Browne, 1968; Troup and Joshi, 1983).

Diseases in indigenous range

Under the humid conditions of Kerala and Karnataka, fungi cause foliage infection of minor importance in nursery seedlings, root suckers and trees in natural stands and plantations (Chiddawar, 1959; Bhat and Hegde, 1991; Sharma, Mohanan and Florence, 1985).

The rust fungi *Uredo sissoo*, *Maravalia achroa* and *M. pterocarpi* have been reported to cause foliage infections in nursery seedlings (Spaulding, 1961; Sharma, Mohanan and Florence, 1985). A *Meliola* sp. causes a sooty mould of seedlings. Root rot of *D. latifolia* caused by *Phellinus gilvus* and *Coriolopsis sanguinaria* are the other minor diseases of the tree, reported from India (Bakshi, 1971, 1976).

Diseases in introduced range

In *D. latifolia*, 13 species of fungi have been reported to cause diseases of nursery seedlings, root suckers and trees in plantations and natural stands. Among them, *Fusarium solani* (Anamorphic *Gibberella*) which causes wilt and dieback of >15-year-old trees, as reported from Indonesia, seems to be economically important (Suharti and Hadi, 1974).

Eucalyptus camaldulensis

Order and Family: Myrtales: Myrtaceae
Common names: river red gum

NATURAL DISTRIBUTION

Eucalyptus camaldulensis is the most widely distributed of all eucalypts. The latitudinal range extends from 12°48' S in the tropical Northern Territory to 38°15' S in cool, temperate Victoria. It occurs throughout inland mainland Australia, typically along water-courses and on flood plains, but occasionally extends to slopes at higher elevations, as in the Mount Lofty Ranges near Adelaide.

PESTS

Arthropods in indigenous range

Insects (e.g. termites and aphids) and rodents may be troublesome in the nursery, and both physical and chemical control measures may be needed.

In Australia, natural stands and plantations of *E. camaldulensis* are affected by many insects and fungi. Leaves are often attacked by leaf chewing insects, particularly of the Chrysomelidae and Curculionidae families (such as *Paropsis* spp., *Chrysophtharta* spp., *Gonipterus* spp., *Oxyops* spp.) (Stone and Bacon, 1995).

Arthropods in introduced range

Where the tree is well adapted outside Australia, it is relatively free from problems. In parts of Africa and Asia, termites affect young trees and must be chemically controlled (Day, Rudgard and Nair, 1994). In Africa, the Australian eucalyptus snout beetle, *Gonipterus scutellatus** (once considered synonymous with *Gonipterus gibberus*), feeds on young shoots but can be controlled biologically. Moribund or newly felled trees may become infested with the Australian stem borer or longicorn beetle, *Phoracantha semipunctata** (Poynton, 1979). The longicorn beetle has caused major damage to plantations of *E. camaldulensis* in parts of North Africa and the Middle East; it is the most important pest of eucalypts in Israel (Mendel, 1987). *E. camaldulensis* was found to be relatively resistant to this pest in southern California, United States, and this was associated with the species drought resistance (Hanks *et al.*, 1995).

Diseases in indigenous range

In the nursery, *E. camaldulensis* is susceptible to a diverse range of fungi causing damping-off, collar rot, and leaf diseases (*Pythium* spp., *Phytophthora* spp., *Rhizoctonia* spp., *Cylindrocladium* spp.).

Diseases in introduced range

Disease is most common where the species is planted off-site, or where inappropriate provenances are used, resulting in stressed trees that are more susceptible to disease than healthy ones. Stem cankers and leaf diseases proliferate where rainfall and humidity are much higher than normally encountered in the natural habitat (e.g. in parts of India; Sharma and Mohanan, 1991). In humid regions of Viet Nam and Thailand, many *E. camaldulensis* plants are defoliated by fungi causing severe reductions in growth rate and deformed crowns and stems. Several pathogens are associated with this disease

in these countries, with *Cylindrocladium quinqueseptatum*, an important causal agent (ACIAR, 1996). The most susceptible provenances suffer mortality and general decline, but some provenances (e.g. Katherine) are little affected, allowing selection and breeding for resistance to the disease.

In Indonesia, prominent leaf spot symptoms on *E. camaldulensis* have been attributed to an unidentified *Mycosphaerella* sp. (Crous and Alfenas, 1995). *Colletotrichum gloeosporioides* (Anamorphic *Glomerella*) has been found responsible for leaf spot and twig blight diseases of young *E. camaldulensis* plantations in Bangladesh, but was controllable by chemical sprays (Begum, 1995).

Eucalyptus robusta

Order and Family: Myrtales: Myrtaceae
Common names: swamp mahogany

NATURAL DISTRIBUTION

Eucalyptus robusta occurs naturally in Australia, within a narrow coastal strip from southern New South Wales (near Nowra) to coastal southeastern Queensland (northwest of Bundaberg). It is also grows on the offshore islands of North Stradbroke, Moreton and Fraser in southeast Queensland. A disjunct population occurs just north of Yeppoon in coastal, central Queensland.

PESTS

Arthropods in indigenous range

In Australia, *E. robusta* is moderately to highly susceptible to insect attack (Marcar *et al.*, 1995). The juvenile foliage is attacked by leaf-blister sawfly (*Phylacteophaga froggatti*) and autumn gum moth (*Mnesampela privata*) while adult foliage is susceptible to lerp (*Cardiaspina* sp.), autumn gum moth, leaf beetle (*Paropsis* spp., *Chrysophtharta* spp.), leaf-blister sawfly, gumtree hoppers (*Eurymela* sp., *Eurymeloides* sp.), scale (*Eriococcus coriaceus*, *Acanthococcus danzigae* (=*E. confusus*) and Christmas beetle (*Anoplognathus* sp.). Older trees under stress by drought are attacked by eucalypt borers (*Phoracantha* spp., *Phoracantha acanthocera* [=*Tryphocaria acanthocera*], *Epithora dorsalis*), and cossid borer (*Endoxyla* spp.). Young trees are susceptible to termites (Ruskin, 1983).

Arthropods in introduced range

The sapwood of sawn timber is prone to attack by *Lyctus* borers (Boland *et al.*, 1984). *E. robusta* wood is susceptible to attack by dry-wood termites in Puerto Rico (Longwood, 1961), while the heartwood of *E. robusta* was only slightly resistant to the Formosan subterranean termite, *Coptotermes formosanus*, in Hawaii (Grace, Ewart and Tome, 1996).

The leaf-eating beetle, *Colaspis favosa*, has reportedly caused serious damage to young seedlings and coppice shoots in Florida; older trees are unaffected (Geary, Meskimen and Franklin, 1983). Coleoptera borers (Brazil) and cockchafers (Viet Nam) are also reported pests of *E. robusta* (see review in Fenton, Roper and Watt, 1977).

Susceptibility of *E. robusta* to the Australian eucalyptus snout beetle, *Gonipterus scutellatus** (once considered synonymous with *Gonipterus gibberus*) has caused a cessation of planting of the species in some parts of southern Africa (Fenton, Roper and Watt, 1977; Poynton, 1979).

Diseases in introduced range

Leaf spots on *E. robusta* in the United States (Hawaii), Brazil, Mauritius and Zimbabwe have been attributed to the fungal pathogens *Harknessia hawaiiensis* (Anamorphic *Wuestneia*), *H. insueta* (Anamorphic *Wuestneia*), *Colletrotrichum gloeosporioides* (Anamorphic *Glomerella*) and *Cylindrocladium ovatum* sp. *novus* (see reviews in Fenton, Roper and Watt, 1977; El-Gholl *et al.*, 1993). In Australia, leaf spots on *E. robusta* have been attributed to *Readeriella mirabilis* (Anamorphic Ascomycetes) (reviewed in Fenton, Roper and Watt, 1977). In the past, the fungus *Cylindrocladium scoparium* (Anamorphic Calonectria) has caused serious seedling

losses in Florida (Durst, 1988), but is now controlled by soil sterilization and sprays. In Puerto Rico, *E. robusta* is susceptible to gummosis and trunk rots caused by *Phaeolus schweinitzii* and *Fomes* sp. (Durst, 1988). Another fungus, *Botryosphaeria ribis*, causes cankers on the trunk (Jacobs, 1981). Susceptibility of *E. robusta* to root rot has also been reported (reviewed in Fenton, Roper and Watt, 1977). In Sao Paulo, Brazil, *E. robusta* has been attacked by the bacterium *Agrobacterium tumefaciens* (formerly *Phytomonas tumifaciens*) (Ruskin, 1983).

Fagus sylvatica

Order and Family: Fagales: Fagaceae
Common names: common beech; European beech

NATURAL DISTRIBUTION

Fagus sylvatica or beech is a deciduous broadleaved tree found in temperate and warm temperate climates of western Eurasia, where it dominates the natural development of forest vegetation (Ellenberg, 1986). The southern limit of the natural distribution of *F. sylvatica* in Europe is from the Pindos Mountains (Greece), the islands of Sicily and Corsica, the Pyrenees, and the Cantabrian Mountains in northern Spain. The western distribution limit is the coast of continental Europe, although beech is indigenous to southern England and southern Scandinavia. The eastern limit is roughly a line from the Baltic Sea to the Black Sea.

PESTS

Beech is less affected by serious diseases than other tree species in western Eurasia. Pathogens can destroy regeneration and individual older beech trees, but no mass destruction on a regional scale has been described (Hartig, 1877; Klimetzek, 1992).

Elateridae larvae, snails (*Agriolima agrestis*, *Arion* spp.), Noctuidae larvae (*Agrotis segetum*) and fungal pathogens of seedlings (*Phytophthora cactorum*, *P. cinnamomi*, *Pythium debaryanum*, *P. ultimum*) cause high mortality (Schwerdtfeger, 1981). Damage in forest nurseries can be mitigated by pesticides.

Arthropods

The larvae of *Cydia fagiglandana* and *Rhynchaenus fagi* can kill 40 percent of beech mast (Veldmann, 1978).

The gall inducing insects *Contarinia fagi* and *Dasyneura fagicola* can destroy buds at bud burst (Schwerdtfeger, 1981). If the terminal bud is injured the tree tends to become forked.

Several insect species (e.g. *Operophtera fagata*, *Ennomos quercinaria*, *Rhynchaenus fagi*, *Dasychira pudibunda*) can completely defoliate beech stands, but as attacks do not occur until well after foliage has developed, the main effect of them is a reduction in annual increment and fruit production, rather than long-term damage (Schwerdtfeger, 1981). Protection from biotic damage can be undertaken using chemical pesticides, but these are only used in nurseries.

Diseases

Germinative capacity can be reduced by infection of beech nuts with the pathogen *Thanatephorus cucumeris* (Dubbel, 1992). Fungal infections and staining of fruits can be prevented by use of nets to harvest beech nuts (Dubbel, 1989; Burschel and Huss, 1987).

Generally the most serious and mortal diseases of beech affect the stem. Beech bark disease is the only serious disease of beech in Europe. This complex disease can be widely observed and appears to be chronic on a local to regional scale. It tends to occur on trees previously subjected to stress due to prolonged drought (or other causes): a minute sap-sucking insect, the felted beech coccus (*Cryptococcus fagisuga*), attacks the tree, followed by infection of the pathogenic fungus *Nectria coccinea*. The combined attack of insect and fungus can result in tree death due to moisture stress. In some cases, the succession of secondary pathogens may include wood-boring insects

(*Xyloterus domesticus*) and *Hylecoetus dermestoides* and, finally, white rot (*Fomes fomentarius*, *Fomitopsis pinicola*, *Polyporus* spp.) (Lunderstadt, 1992; Schwerdtfeger, 1981). Protection against biotic damage can be achieved by the immediate removal, through felling, of infected trees.

Gmelina arborea

Order and Family: Lamiales: Verbenaceae
Common names: candahar; gamhar; gumhar

NATURAL DISTRIBUTION

Gmelina arborea is indigenous to India, Pakistan, Bangladesh, Myanmar, Sri Lanka, Thailand, the Lao People's Democratic Republic, Cambodia, Viet Nam, and Yunnan and Guangxi provinces in China (Troup, 1921; Moldenke, 1977; Greaves, 1981; Gupta, 1993; Luna, 1996). It is found in deciduous forest and moist deciduous forest, but also sometimes occurs in evergreen and *Shorea robusta* forests. It is seldom found above 1200 m altitude in the Himalayan region (Troup, 1921), but it has been observed above 1500 m in the Sri Lankan moist forests (Greaves, 1981).

PESTS

Severe pest and disease problems are frequent in plantations within the natural distribution of *G. arborea* and have even led to the failure of plantations (Homfray, 1937; Allsop, 1945).

Arthropods in indigenous range

Insect pests that are common in *G. arborea* plantations within the natural distribution area are stem borers, leaf defoliators and leaf or shoot cutters. Stem borers include *Dihammus cervinus* (Beeson, 1961) in India and Myanmar; leaf defoliators include larvae of *Calopepla leayana* in Assam, Bengal and Myanmar (Ahmed and Sen, 1990), and nymphs and adults of *Tingis beesoni* in India and Myanmar (Greaves, 1981). Dieback is caused by shoot cutters such as the larvae of *Alcidodes ludificator* (=*gmelinae*) in Assam, Bengal and Myanmar (Greaves, 1981).

Arthropods in introduced range

Although *G. arborea* planted outside its natural range suffers similar pest problems, on the whole these are less serious. Leaf defoliators on seedlings and in mature stands are very common. In Nigeria alone, Roberts (1969) noted that defoliators such as *Apophylia nigricollis*, *Zonocerus variegates* and *Achaea lienardi* are common in plantations. In the Philippines, defoliators such as *Chrysodeixis chalcites*, *Acherontia lachesis*, *Ozola minor* and *Attacus* spp. are common in nurseries and plantations (Lapis and Bautista, 1977; Lapis and Genil, 1979). In Latin America, leaf-cutting ants (*Atta* spp.) are a major problem for stem quality and growth of plantations (Greaves, 1981). In Malaysia, a beehole borer, *Duomitus ceramicus* is a damaging insect pest (Ahmad Said, 1989). Chey (1996) reported that *Coptotermes curvignathus*, a termite pest that severely damages *G. arborea* plantations in Malaysia, can be controlled by the application of the termiticide chlorpyrifos. See also records of other insect pests in Browne (1968).

Diseases in indigenous range

Fungal attacks are less prevalent, but can cause damage to *G. arborea* stands. Bagchee (1952) recorded a leaf spot leading to defoliation caused by a *Gnomonia* sp. A species of *Poria* attacks *G. arborea* in India and Bangladash during waterlogging (Bagchee, 1952, 1953). A powdery mildew, *Phyllactinia guttata*, attacks leaves but does not seriously affect the whole tree.

Diseases in introduced range

Outside the natural distribution of *G. arborea*, fungal diseases are mainly root diseases found in Africa and Latin America. Root diseases of nursery seedlings are normally caused by *Gibberella fujikuroi* in Gambia and *Athelia rolfsii* in Sierra Leone, Gambia and Nigeria (Gibson, 1975). *Thanatephorus cucumeris*, *Chaetophoma* sp. (Anamorphic Ascomycetes), *Polyporus* sp. and *Armillaria mellea** are also causal agents of root diseases in Nigeria and Cote d'Ivoire (Gibson, 1975). In Amazonia, *Ceratocystis fimbriata*, which is an important pathogen of rubber, mango, coffee and cocoa, also infected *G. arborea*; the vectors of the fungus are insects of the genera *Scolytus* and *Platypus* (Muchovej, Albuquerque and Ribeiro, 1978). In Malaysia, diseases such as leaf spot, collar-rot and wilt have been identified, caused respectively by the fungi *Colletotrichum gloeosporioides* (Anamorphic *Glomerella*), *Thanatephorus cucumeris* (Anamorphic *Ceratobasidium*) and *Pythium* spp. Treatments to overcome these diseases are prescribed by Maziah and Norani (1988). Stem rot and anthracnose are common seedling diseases in Malaysia, although these can be controlled (Lee and Goh, 1989).

Juglans nigra

Order and Family: Juglandales: Juglandaceae
Common names: black walnut

NATURAL DISTRIBUTION

The natural range of *Juglans nigra* covers much of the eastern United States and into Lower Canada. Baker (1921) divided the range of *J. nigra* into botanical, primary commercial and secondary commercial ranges.

PESTS

Arthropods in indigenous range

A range of insects occur on *J. nigra* in its natural range; some cause quality loss through retarding form and others are recognized as important causes of growth loss. Schlesinger and Funk (1977) consider the major threats to growing *J. nigra* in the United States are walnut caterpillar, bud borers, casebearers and anthracnose.

Walnut caterpillar (*Datana integerrima*) is regarded as the most destructive leaf-feeding insect that occurs on *J. nigra* (Linit and Stamps, 1997), but the damage is considered minor as most feeding occurs late in the growing season (Marshall, 1989).

Fall webworm (*Hyphantria cunea*) is another common *J. nigra* defoliator that forms a web over branches about mid-July (Weber, 1988). As with walnut caterpillar, damage is usually at the end of the growing season (Marshall, 1989).

Walnut shoot moth (*Acrobasis demotella*) is considered the most destructive shoot borer on *J. nigra* (Linit and Stamps, 1997). Females deposit single eggs on the underside of leaves in early summer; these overwinter at the base of buds and emerge to bore into the elongating shoot at bud swell, destroying the shoot. Rink *et al*. (1991) concluded that *Acrobasis* infestation appeared to be a problem primarily on young trees <2.5 m in height, but there was no evidence for genetic resistance to *Acrobasis* infestation in *J. nigra*.

Ambrosia beetles (*Xylosandrus germanus*) develop galleries in the stem and the larvae feed on fungi growing in the gallery. They usually attack slower growing trees less than 3 m tall (van Sambeek and Schlesinger, 1988).

Black walnut curculio (*Conotrachelus retentus*) develops in the nuts of *J. nigra*. The female deposits an egg within the developing nut and as the larva feeds, the nut is dropped prematurely; its abundance is determined by the availability of nuts during the previous year (Linit and Stamps, 1997).

Diseases in indigenous range

Walnut anthracnose (*Gnomonia leptostyla*) is a fungus which causes premature leaf drop, resulting in growth loss and reduction in quantity and quality of nut crops. Wet weather in which the foliage is covered with moisture for prolonged periods makes the disease more severe (Kessler, 1988). Field and glasshouse trials have shown that fertilization enhanced resistance to walnut anthracnose and delayed premature defoliation (Neely, 1981, 1986). Incidence of walnut anthracnose can also vary with seed source (Funk *et al*., 1983), while interactions occur with selecting for growth and/or resistance.

Cankers are caused by fungi that enter the tree through unprotected wounds, small injuries, or leaf scars. Cankers lasting more than a year (perennial or target cankers) are caused by a *Nectria* fungus (*Neonectria galligena*) (Kessler, 1988). Studies of canker

incidence and effect found that tree growth rate was 30 percent less for trees with cankers than for healthy trees (Thomas and Hart, 1986), and that soil texture, rooting depth and drainage features were not significant to disease incidence but some surface geology and topographic features were (Thomas and Hart, 1986).

Walnut black line disease, caused by the walnut strain of the cherry leaf roll nepovirus (CLRV), causes fatal necrosis of the graft union between susceptible, infected scions of Persian walnut (*Juglans regia*) and hypersensitive, resistant rootstocks. *J. regia* is tolerant whereas *J. hindsii* (a hybrid of *J. hindsii* and *J. regia*) is hypersensitive. Dosba *et al*. (1990) report CLRV was found in many cultivars of *J. regia* and always detected in *J. regia*/*J. nigra* showing black line, but the distribution of the virus was irregular; virus progression inside the tree was slow. Seed and pollen transmission were also demonstrated. It was concluded that the rootstocks belonging to *J. nigra*, *J. major, J. sieboldiana*, nom. illeg. and various interspecific hybrids did not multiply the virus.

Diseases in introduced range

Bacterial blight is considered one of the most serious diseases affecting the genus *Juglans* in Italy. Artificial inoculations with *Xanthomonas arboricola* pv. *juglandis* were performed in an open field nursery by spraying seedlings of *Juglans* species and hybrids. None of the tested bacterial strains multiplied in the leaves of *J. nigra*. This confirms the results obtained in field tests. *J. regia* was the most susceptible among the walnut species tested (Belisario *et al*., 1999).

Belisario and Corazza (1996) reported from Italy that *Corticium rolfsii* was isolated from diseased walnuts (*J. regia*) and *J. nigra* seedlings in the field in 1995. *J. nigra* seedlings were more susceptible than *J. regia* seedlings. This was the first report of *C. rolfsii* on *J. regia* and *J. hindsii* and its first record on *Juglans* in Europe.

Belisario (1996) report that blight (caused by *Xanthomonas arboricola* pv. *juglandis*) was the major disease of *J. regia* in Italy, causing severe damage in both nurseries and plantations. Anthracnose (caused by *Gnomonia leptostyla*) was damaging only in plantations, where it affected both walnut species. Copper treatments were effective against the two diseases. Other diseases were present but most of these were opportunistic pathogens and infections could be prevented by growing walnut trees under suitable cultural and environmental conditions (Belisario, 1996). Luisi and Campanile (1993) also implicated environmental factors, suggesting that *Sphaeropsis camarosporium* caused the most severe symptoms in areas with low soil fertility, with prolonged spring and summer drought, and in neglected plantations.

Khaya ivorensis

Order and Family: Sapindales: Meliaceae
Common names: African mahogany

NATURAL DISTRIBUTION

Khaya ivorensis occurs in West Africa mostly in Cote d'Ivoire, Ghana, Togo, Benin and Nigeria.

PESTS

Arthropods in indigenous range

The larvae of *Hypsipyla robusta** feed on the soft tissue inside the terminal stem. In heavy infestations as many as 20 to 40 wounds may occur on a stem resulting in a heavy exudation. This species also lays eggs on seeds and larvae bores through seeds. Mature larvae move from fruit to fruit feeding. Trees are attacked in their second or third year. Generally shoot borer attack weakens the tree and predisposes it to attack by other insects and fungi. With repeated infestations mortality can occur. Economic loss is usually due to reduced height growth and poorer forms of infested trees. Attempts to control *H. robusta* with systematic insecticides including brushing Bidrin on affected parts have been only partially successful. Silvicultural control methods are used to increase shade and isolate infested trees.

Catopyla dysorphanea lays eggs on fruit and larvae at first feed within individual seeds then move from fruit to fruit. *Xylosandrus compactus*, *Xyleborus perforans*, *X. semiopacus*, and *X. sharpi* attack temporarily stressed or injured trees but also attacks transplants that have yet to recover from transplant shock.

Gyroptera robertsi attacks mainly old trees. *Cledus obesus* has larvae which tunnel in the stem branch axils causing stem to swell at the point of infestation. *Udinia faraquarsoni* sucks sap from the abaxial portion of leaves and *Pseudophacopteron zimmerani* produces numerous galls (3 to 5 mm in diameter) on *K. ivorensis* (Wagner, Atuahene and Cobbinah, 1991).

Diseases in indigenous range

Fungus diseases include *Phellinus noxius*, which attacks the roots, and *Uredo tesoensis*, which attack the leaves.

Lovoa trichilioides

Order and Family: Sapindales: Meliaceae
Common names: African walnut

NATURAL DISTRIBUTION

L. trichioides is naturally distributed in the Guinea-Congolian region, from 10° N to 10° S (Hall and Swaine, 1976). It is one of the main timber species in the Congo and exploitation rates are high (Oldfield, Lusty and MacKinven, 1998).

PESTS

Very little is recorded regarding pests and diseases of *L. trichilioides*. It is considered less susceptible to tree borers and other insects than others in this genus, and *Catopyla dysorphnaea*, a minor stem borer of maize, has been recorded on the fruits and seeds of *L. trichilioides* (Wagner, Atuahene and Cobbinah, 1991).

Paulownia tomentosa

Order and Family: Scrophulariales: Scrophulariaceae
Common names: paulownia; princess tree

NATURAL DISTRIBUTION

Paulownia tomentosa is native to China, and is widely distributed in central and northern regions. It is one of the most important tree species in China and currently there are about 1.1 billion Paulownia trees planted throughout the country. It occurs in Japan and South Korea, but some Japanese taxonomists believe that these are naturalized populations resulting from past introduction and cultivation of this species in these countries. *P. tomentosa* naturally occurs in deciduous and mixed forest species, and to a lesser extent in secondary forest.

PESTS

Arthropods in indigenous range

The main pest found on *P. tomentosa* is *Eumeta variegata*, and Yang and Li (1982) discuss methods used to control this defoliator. *E. variegata* occurs throughout the distribution range of *P. tomentosa*; it develops one generation in northern China and two generations in southern China. Seedling stock is the major source of spread of this pest (Yang, Zhou and Gao, 1975).

Diseases in indigenous range

In plantations this species is susceptible to Paulownia witches' broom disease, which is caused by a phytoplasma (previously described as a mycoplasma-like organism). This disease may be identified by distinctive yellow broom-like shoots, which die back in the autumn. It is commonly found in seedling stocks and young trees (3 to 6 years old), and may greatly influence their growth. It may also occur in adult trees, but has little effect on their growth. In its natural environment the disease is spread by *Halymorpha picus*. Infected roots and seedling stock aid the spread of this disease, yet seeds obtained from infected trees may grow disease-free. The effects of Paulownia witches' broom disease vary depending on the *Paulownia* species. Selecting clones with good resistance and using suckers free of the disease will reduce spread of the disease.

Anthracnose disease is a major disease in saplings that injures leaves, petolies and shoots, and causes early leaf drop. *P. tomentosa* also suffers damping-off disease caused by *Thanatephorus cucumeris* (Anamorphic Ceratobasidium) and *Fusarium* spp. (Anamorphic *Gibberella*) (Zhu *et al*., 1986). Other diseases include the nematode *Meloidogyne marioni*, which infects the roots of seedlings and results in mortality, and the fungus *Sphaceloma tsugii* (Anamorphic Elsinöe), which commonly damages seedling shoots and causes dieback. Both diseases have a common occurrence throughout the distribution range of *P. tomentosa*.

Picea sitchensis

Order and Family: Pinales: Pinaceae
Common names: sitka spruce

NATURAL DISTRIBUTION

Picea sitchensis is an ecologically important species of the north temperate coastal rain forest of western North America. The natural range of *P. sitchensis* spans a narrow strip on the north Pacific coast of North America, extending for 2 900 km from 61° N in south-central Alaska to 39° N in northern California. Throughout this tremendous north-south range, *P. sitchensis* is a coastal species. While its natural range is not extensive and the species' economic importance ranks far below that of other western conifers, it is a keystone species in some of the most productive ecosystems of North America, particularly in the Queen Charlotte Islands of British Columbia (Peterson *et al.*, 1997).

PESTS

Arthropods in indigenous range

By far the most serious insect pest of *P. sitchensis* in North America is the white pine weevil (*Pissodes strobi*), particularly in the southern part of the range and on warmer sites inland from the coast (Martineau, 1984; Warkentin *et al.*, 1992; Alfaro, 1994). Adults overwinter in the litter and emerge in the spring to mate and lay eggs in feeding punctures made on the tree's leader. The larvae hatch two weeks later and tunnel down the inner bark of the shoot, killing the leader and seriously affecting tree form and reducing merchantability (Alfaro, 1982, 1989). The risk and impact of damage is so great that annual *P. sitchensis* planting in British Columbia is limited to about 2 million seedlings, established only on cooler sites. Putative resistance of individual trees is a complex trait involving phenology, leader length and morphology, resin canal density and chemical components, and appears to be genetically inherited as is the level of damage sustained by trees following attack.

Arthropods in introduced range

Outside its natural range, *P. sitchensis* has played an important role in plantation forestry, particularly in northern Europe (Hermann, 1987).

Except in high-value seed orchards and nurseries, the economic impact of insect pests other than *P. strobi* in North America is low although the number of insect species with potential to do damage is rather high. In Great Britain, the diversity and impact of insect pests have been limited by the relatively short period since introduction and the area planted (Evans, 1987). In the United Kingdom, the green spruce aphid (*Elatobium abietinum*) is a sap-sucking insect feeding on many species of spruce, although *P. sitchensis* has the least resistance owing to low concentrations of volatile plant compounds (Nichols, 1987). Outbreaks occur periodically in both North America and Britain, particularly when mild weather results in favourable overwintering conditions (Powell and Parry, 1976; Straw, 1995), and defoliation can result in serious growth losses and up to 10 percent mortality (e.g. Seaby and Mowat, 1993).

Diseases in indigenous range

While many pathogens can attack *P. sitchensis* at various stages of its life cycle, only a small number of decay fungi cause serious commercial damage. In both North America and Europe, *P. sitchensis* is susceptible to *Heterobasidion annosum* causing butt rot (Morrison, Larock and Waters, 1986), and can result in significant loss of yield and quality in plantations (Pratt, 1979a, 1979b). *P. sitchensis* is also host to Armillaria root rot*, but usually only young trees are killed (Morrison, 1981). *Phellinus weirii* causes butt decay in older trees, but only young trees are likely to be killed (Nelson and Sturrock, 1993).

Pinus oocarpa

Order and Family: Pinales: Pinaceae
Common names: ocote pine; ocote chino; oocarpa pine

NATURAL DISTRIBUTION

Pinus oocarpa grows naturally in Mexico, Guatemala, Belize, Honduras, El Salvador and Nicaragua. Most of the trees are concentrated on the southwestern (Pacific) half of the axis running through these six states. In Mexico the tree grows in abundance on the lower slopes of the sierras of the western and southern parts of the country. It is plentiful in the mountains of southern Guatemala and central Honduras, northern El Salvador and northwestern Nicaragua.

PESTS

Arthropods in indigenous range

Mexican pine bark beetles, *Dendroctonus mexicanus*, can destroy a substantial number of trees. Other Central American insects that can cause damage to trees are *Rhyacionia* spp. (pine tip moths), *Pissodes* spp. (shoot weevils), defoliators (Tortricidae), a pine bark beetle *Dendroctonus frontalis**, and cone weevils (Perry, 1991).

Diseases in indigenous range

Seedlings are prone to damping off while growing in the nursery.

Pinus radiata

Order and Family: Pinales: Pinaceae
Common names: radiata pine

NATURAL DISTRIBUTION

Pinus radiata occurs naturally in just five discrete populations off the coast of the Baja California Peninsula (Mexico). The location and habitats of the mainland populations have been described by Lindsay (1932), Roy (1966) and Forde (1964) and those for the islands by Libby, Bannister and Linhart (1968) (see also Moran, 1996) specifically for Guadalupe Island). The total extent of natural forest, prior to European impacts, was slightly under 10 000 ha, of which about 5 300 ha remain (Burdon, 2000). All natural habitats represent a special and highly localized variant of the dry to mesic Mediterranean climate (rainfall generally 700 mm or less), caused by a cold ocean current; summer temperatures are mild, and sea fogs during the essentially rainless summer months produce a crucial amount of occult precipitation in the form of fog drip. Nowhere do natural stands extend beyond 8 km inland. Altitude ranges from sea level to 420 m on the mainland, and from 300 to 1 200 m in the more southerly island populations. Geology and soils are highly variable, overall and within the Monterey population. Within its range, *P. radiata* is generally the sole high-forest species.

PESTS

The species has become naturalized in several countries, notably New Zealand, Chile, Australia and South Africa, often regenerating naturally within plantations and often invading surrounding land.

Damage agents, in the forms of fungal pathogens, insect pests and environmental factors, are inevitably important, given the attractions of growing the species to the limits of its site tolerances (Scott, 1960; Burdon, 2000).

Arthropods in indigenous range

Various insect pests are present in native stands (Ohmart, 1982), but have historically been in ecological balance with the *P. radiata*. Various scolytid beetles, and some other insects, have evidently become significant primarily for their role as vectors for the introduced pitch canker (*Gibberella circinata*).

Arthropods in introduced range

The woodwasp *Sirex noctilio** can kill trees very quickly by attacking the boles. Spectacular tree mortality in New Zealand in 1946–1949, but that did little real harm and sirex is now unimportant because of effective biological control. Sirex has since been introduced into many other countries where it is of major concern incuding Australia, Argentina, Brazil, Canada, Chile, South Africa, United States and Uruguay.

The bark beetle *Ips grandicollis* is a significant pest in Australia. The European pine shoot moth, *Rhyacionia buoliana* has long caused varying amounts of leader damage in plantings in Europe, and can limit the use of *P. radiata*. It has spread to Argentina and then to Chile, where it is a major pest. The processionary caterpillar, *Thaumetopoea pityocampa**, is a significant defoliator in warmer parts of Europe, where it limits the use of *P. radiata*. Another defoliator is the pine emperor moth, *Imbrasia cytherea*,

which can be troublesome in South Africa. The pine woolly aphid, *Pineus pini*, is a minor pest in many parts, but has recently caused concern in South Africa. Other insect pests of *P. radiata* have been covered by Rawlings (1955), Scott (1960) and Lavery (1986).

Diseases in indigenous range

Several fungal pathogens are known to limit the sites on which the species can be grown successfully (see Offord, 1964). Fungal pathogens are perhaps more important than insect pests because they tend to affect trees more on the moister sites that are potentially much more productive. These include *Mycosphaerella pini**, which causes needle cast although it can often be controlled by aerial spraying of copper fungicide, and western gall rust, *Endocronartium harknessii* (syn. *Peridermium harknessii*), which causes galls that often develop into serious stem cankers. These two pathogens have limited where *P. radiata* can be grown in wetter conditions north of the species' natural range on the California coast. Fortunately, western gall rust has not reached plantations outside North America, where its potential impacts are conjectural.

Sphaeropsis sapinea (syn. *Diplodia pinea*) is often the immediate cause of failure in summer-rainfall areas characterized by damp heat. It usually causes shoot dieback and can attack both wounds and uninjured shoots. It also affects drought-stressed trees, causing the condition that is called 'autumn brown top' in Australia.

Pitch canker, caused by *Gibberella circinata* is a disease that has recently reached the native populations of mainland California (Storer *et al*., 1997). It causes shoot dieback resembling that caused by *S. sapinea*, but can readily affect much larger limbs, including the bole. Its final impact is unclear, but it is seen as a very serious threat to the native stands, *P. radiata* being one of the most susceptible pines (see also Dick, 1998; Hodge and Dvorak, 2000).

The potential impact of pitch canker in exotic stands, where it is not yet present, is unknown; most of its Californian vectors are not present elsewhere, but its ready transmission by seed is a concern.

Diseases in introduced range

Root-rot fungi of the genus *Armillaria*, notably *A. mellea**, are locally important. In New Zealand they can cause severe losses where *P. radiata* has replaced freshly-cut native forest and may become progressively more troublesome after the first rotation planted on unforested land. The impact can be much increased by the presence of significant *Mycosphaerella* infection.

The root pathogen *Phytophthora cinnamomi* is locally important where there is seasonal waterlogging, especially in Western Australia. The needle-cast fungus, *Naemacyclus minor* (syn. *Cyclaneusma minus*), is notable for its almost ubiquitous occurrence, rather than acute impacts. Various other pathogens have been reported; some being locally serious (see Rawlings, 1955; Poynton, 1960; Lavery, 1986; Burdon, 2000).

INVASIVENESS

Its invasiveness can sometimes lead to bonus crops of timber, but often leads to the production of unusable trees. It can invade plant communities of considerable conservation value, and in the course of that can reduce catchment water yields. On the other hand, *P. radiata* can often act as an effective nurse crop for re-establishment of natural vegetation. There can be considerable impacts on fauna, some adverse, but some surprisingly favourable (Burdon, 2000).

Populus nigra

Order and Family: Salicales: Salicaceae
Common names: black poplar

NATURAL DISTRIBUTION

The natural distribution of *Populus nigra* covers a large range from central and southern Europe (including the United Kingdom) to Western and Central Asia reaching the Jenisse River in Siberia.

PESTS

Arthropods in indigenous range

Poplars are hosts to a large number of insect species, but only a few of these are of any importance. The most important are: the goat moth (*Cossus cossus*); the large longhorn beetle (*Saperda carcharias*) and the weevil (*Cryptorhynchus lapathi*). *Paranthrene tabaniformis* attacks young trees. Larval damage of wood by boring is caused by all these pests. *C. cossus* and *S. carcharias* attack old trees, whereas *C. lapathi* only damages young trees. The woolly poplar aphid (*Phloeomyzus passerinii*) can also damage trees; only genotypes of *P. nigra* collected in xeric and warm habitats are resistant (Allegro and Cagelli, 1996).

Defoliating beetle pests of *P.* x *canadensis* include the large poplar-leaf beetle (*Chrysomela populi*) and larvae of the white satin moth (*Leucoma salicis*). Larvae of the poplar shoot borer (*Gypsonoma aceriana*) may cause failure of the leading shoots by boring them. Occasionally other insect pests such as *Operophtera brumata*, *Leucoptera sinuella*, *Lymantria dispar** and *Clostera* spp. can cause damage. The minor pest, woolly poplar aphid, *Phloeomyzus passerinii*, can be controlled by selection of resistant clones (Giorcelli and Allegro, 1998).

Arthropods in introduced range

P. nigra is naturalized in North America (USDA, 1999) and in South America (Jobling, 1990) where the cv. Chile, remarkable for its almost evergreen habit, is found (Van Kraayenoord, 1959). Larvae of a sesiid (*Paranthrene dollii*) in the United States and a hepialid (*Phassus excrescens*) in Japan are reported to bore in trunks and branches. *Hyphantria cunea* can be a significant defoliator in North America (Allegro and Picco, 1992) but can be controlled by *Bacillus thuringiensis*. In South America ants of the leaf-cutting genera *Atta* and *Acromyrmex* are harmful to poplars, cutting and consuming leaves.

Diseases in indigenous range

The fungal pathogen *Drepanopeziza populorum* and several species of *Melampsora* (for example, *Melampsora laricis-populina*) can cause premature defoliation of trees. *Venturia populina* attacks leaves and young shoots causing complete defoliation and deformation of the shoot/branch early in spring (Vietto and Giorcelli, 1996).

Serious attacks of *Cryptodiaporthe populea* cause cankering and dieback especially in nurseries or on the young sapling after transplantation (Gojkovic and Avramovic, 1985; Anselmi, 1986). *Davidiella populorum* causes leaf spot and cankers.

Fungal disease can be controlled spraying fungicides, or by selecting varieties or clones which are tolerant or resistant (Giorcelli and Vietto, 1995, 1998).

Pseudotsuga menziesii

Order and Family: Pinales: Pinaceae
Common names: Douglas fir

NATURAL DISTRIBUTION

The latitudinal range of *Pseudotsuga menziesii* is the greatest of any commercial conifer of western North America – from 19 to 55 °N latitude. The range of var. *menziesii* extends from central British Columbia south along the Pacific Coast Ranges for about 2 200 km into California (near 35 °N latitude); the range of var. *glauca* stretches from central British Columbia along the Rocky Mountains into the mountains of central Mexico over a distance of nearly 4 500 km (Hermann and Lavender, 1990).

PESTS

Arthropods in indigenous range

The Douglas-fir tussock moth (*Orgyia pseudotsugata*) and the spruce budworm (*Choristoneura fumiferana*) are the most important destructive insects of *P. menziesii* in its native range. Both insects attack trees of all ages at periodic intervals throughout the range of interior population, often resulting in severe defoliation of stands. The Douglas-fir beetle (*Dendroctonus pseudotsugae*) is a destructive insect pest in old-growth stands (Hermann and Lavender, 1990). The Douglas-fir woolly aphid (*Gilletteella cooleyi*) can severely check the growth of some provenances on some sites (Savill, 1991).

The cones and seeds are host to a number of destructive pests (Furniss and Carolin, 1977; Hedlin *et al*., 1980). The Douglas-fir seed chalcid (*Megastigmus spermotrophus*) matures in the developing seed and gives no external sign of its presence. Larvae of the Douglas-fir cone moth (*Barbara colfaxiana*) and the fir cone worm (*Dioryctria abietivorella*) bore through the developing cones. The Douglas-fir cone gall midge (*Contarinia oregonensis*) and the cone scale midge (*C. washingtonensis*) destroy some seed but prevent harvest of many more by causing galls that prevent normal opening of cones.

The European strawberry root weevil (*Otiorhynchus ovatus*) and cranberry girdler (*Chrysoteuchia topiaria*) may cause significant damage to seedlings in nurseries (Hermann and Lavender, 1990).

Diseases in indigenous range

P. menziesii is host to hundreds of fungi, but relatively few of these cause serious problems. Various species of *Pythium*, *Rhizoctonia*, *Phytophthora*, *Fusarium*, and *Botrytis* may cause signficant losses of seedlings in nurseries (Peterson and Smith, 1975; Sutherland and van Eerden, 1980), whereas *Rhizina undulata*, shoestring root rot (*Armillaria mellea**), and laminated root rot (*Phellinus weirii*) have caused significant damage in plantations. The latter two fungi represent a serious threat to management of young stands of *P. menziesii*, especially west of the Cascade Mountains. Trees die or are so weakened that they are blown over. Effective control measures are not available.

Of the many heart rot fungi (over 300), the most damaging and widespread is red ring rot (*Porodaedalea pini*). Knots and scars resulting from fire, lightning, and falling trees are the main routes of infection. Losses from this heart rot far exceed those from any other decay. Other heart rot fungi in the Pacific Northwest are *Fomitopsis*

officinalis (=*Laricifomes officinalis*), *F. cajanderi* and *Phaeolus schweinitzii* (Hepting, 1971). In the southwest United States, *Echinodontium tinctorium*, *Fomitopsis cajanderi*, and *F. pinicola* are important.

Among several needle diseases, the most conspicuous is a needlecast caused by *Rhabdocline pseudotsugae*. It is mainly a disease of younger trees, reaching damaging proportions only after prolonged periods of rain while the new needles are appearing (Hermann and Lavender, 1990). The Swiss needle-cast fungus (*Phaeocryptopus gaeumannii*) also occurs on *P. menziesii* throughout its natural range, usually causing little damage.

Diseases in indigenous range

Where Douglas fir has been planted elsewhere (eastern United States, Europe and New Zealand), significant reductions in growth have been associated with *Phaeocryptopus gaeumannii*. Studies in New Zealand have indicated that the losses are linked to a variety of influences, including insect defoliators, and are not solely attributable to the needle-cast fungus (Miller and Knowles, 1994).

Parasitic plants

A mistletoe species, *Arceuthobium douglasii*, is a significant parasite throughout most of the natural range of *P. menziesii* (Hawksworth and Wiens, 1972).

Shorea macrophylla

Order and Family: Malvales: Dipterocarpaceae

NATURAL DISTRIBUTION

Shorea macrophylla is indigenous to Borneo, and is especially widespread in west and central Sarawak, Kapuas valley, Tidung and Burau. It is commonly found in lowland tropical rain forest, and seldom occurs above 600 m in altitude (Ashton, 1964). In Brunei, this species is confined to damp clay soils near rivers and streams and has less favourable growth in hillsides, ridge tops or upper slopes (Rasip and Lokmal, 1994). *Shorea macrophylla* is rarely gregarious and is often scattered at a low density. This climax species is commonly found in riparian forests and also establishes well in canopy gaps.

PESTS

Diseases in indigenous range

Seedlings of *S. macrophylla* are affected by damping-off in the nursery resulting in decay and death. This is caused by fungi which occur naturally in the soil such as *Fusarium* spp. and *Pythium* spp. (Chin, 1995). This species also suffers from wilt, the control of which is discussed by Chin (1995). Heart rot is another form of decay whereby the heartwood loses its strength and may crumble.

A deformed stem is likely to develop in the species if the apical shoot is destroyed either by insects, climbers, or heat stress, as is found in other dipterocarps such as *S. platyclados* (Ang and Maruyama, 1995).

Swietenia macrophylla

Order and Family: Sapindales: Meliaceae
Common names: big-leaved mahogany; broad-leaved mahogany

NATURAL DISTRIBUTION

The genus *Swietenia* has a natural distribution from 20 °N to 18 °S in tropical America. *Swietenia macrophylla* is the most widely distributed species occurring from the Atlantic regions of southeast Mexico, through Central America, northern South America and in an arc across the southern Amazon Basin, in Bolivia and Brazil (Lamb, 1966; Styles, 1981).

PESTS

Arthropods in indigenous range

Shoot borers, *Hypsipyla* spp., principally *H. grandella**, are the major limitation to artificial establishment of mahogany in Central and South America (Martorell, 1943; Ramirez-Sanchez, 1964; Bauer, 1987). In Colombia, various silvicultural and agroforestry trials show no consistent successful methods of shoot borer control (Vega Gonzalez, 1987). However, trials established in many parts of Central America proved that shoot borer damage can be partially controlled by cultural methods (Newton, Leakey and Mesen, 1992). A combination of silvicultural, biological and chemical control was proposed by Newton, Leakey and Mesen (1992); and production of resistant plants through selection has been suggested as the most effective method (Grijpma, 1976; Newton, Leakey and Mesen, 1992). The use of slow release/systemic insecticides has also shown promising results (Chaplin 1993). See Newton *et al.* (1993) and Floyd and Hauxwell (2001) for reviews.

Arthropods in introduced range

*Hypsipyla robusta** causes serious damage in nurseries and plantations in the Solomon Islands (Chaplin, 1993) and other areas. In Fiji, ambrosia beetles (*Crossotarsus externedentatus*, *Platypus gerstaeckeri*) may attack living trees and cause variable, sometimes major, levels of pinhole damage. The small holes and associated staining may considerably reduce the value of the timber for decorative uses (Oliver, 1992). An ambrosia beetle (*Xylosandrus compactus*) has also been observed to cause damage in young stands in Puerto Rico (Bauer, 1987). Termites are also potentially a major damage agent in mahogany plantings in Fiji.

Tectona grandis

Order and Family: Lamiales: Verbenaceae
Common names: teak

NATURAL DISTRIBUTION

Tectona grandis is the principal timber tree of peninsular India, Myanmar, Indonesia and Thailand and one of the most valuable timbers in the world. The reputation of teak timber is due to its matchless combination of qualities such as: termite, fungus and weathering resistance; lightness with strength; attractiveness; workability; and seasoning capacity without splitting, cracking, warping or materially altering shape (Kadambi, 1972). *Tectona grandis* is indigenous to south and Southeast Asia. It grows naturally between latitudes of 9° N to 25°30' N in most of peninsular India, large areas of Myanmar, and parts of the Lao People's Democratic Republic and Thailand (White, 1991).

T. grandis has been widely planted both within and beyond its natural range. In Africa, it is a major exotic species planted for sawlogs. It is widespread in Central and South America and in the Pacific. Long established plantations now extend from 28 °N to 18 °S (Rao, 1997). Locations in which *T. grandis* occurs include Southeast Asia, the Pacific, East Africa, West Africa, South Africa, the Carribbean Islands, South America, and Central America (Tewari, 1992).

PESTS

Arthropods in indigenous range

Over 180 species of insects are reported to be associated with teak (Mathur, 1960; Mathur and Singh, 1960). Most of them are minor pests. Those which cause serious damage include white grubs in nurseries, sapling borers in young plantations, trunk borers in older plantations and two species of defoliators (Beeson, 1941; Sen Sarma and Thapa, 1981; Day, Rudgard and Nair, 1994).

In nurseries, white grubs (*Holotrichia* spp.) eat the seedling roots causing wilting and subsequent death. White grubs can be controlled by treating the nursery beds with systemic soil insecticides (Oka and Vaishampayan, 1981; Varma, 1991).

The sapling borer (*Sahyadrassus malabaricus*) is a problem in young plantations, with dense weed growth. It can be managed through regular pest surveillance and spot application of selected insecticides (Nair, 1987).

The defoliator (*Hyblaea puera*) and the skeletonizer (*Paliga machoeralis*, *P. damastesalis*) are recognized as serious pests (Beeson, 1941; Nair, 1988). In young plantations in Kerala, India the teak defoliator causes repeated severe defoliation in the early part of the growth season of a loss of up to 44 percent of the potential volume increment. The skeletonizer on the other hand causes defoliation later in the season and has no significant impact (Nair *et al*., 1996). Although biological control methods using native parasites and silvicultural practices were recommended in the past (Beeson, 1941; Mathur, 1960), this is not currently practiced. Current emphasis is on the use of a naturally-occurring nuclear polyhedrosis virus (NPV) for control of the teak defoliator (Sudheendrakumar, Ali and Varma, 1988; Nair *et al*., 1997).

The beehole borer (*Xyleutes ceramicus*) is a serious pest in Myanmar and Thailand (Beeson, 1941), which also attacks *Gmelina arborea*. It riddles the tree trunk with borer holes severely degrading the quality of wood (Beeson, 1921, 1941; Chalerempongse,

Boonthavikoon and Chairuangsirikul, 1990; Hutacharern, 1990). *Cossus cadambae* causes similar problems in the southern states of India, but the incidence is limited to pockets where the trees are subject to repeated lopping (Beeson, 1941; Mathew and Rugmini, 1996).

Arthropods in introduced range

Hyblaea puera occurs widely in the tropics, but curiously there are no significant reports of damage outside its indigenous range.

Diseases in indigenous range

Although diseases are not recognized as major problem in teak, some pathogens are of importance. In nurseries, bacterial wilt caused by *Pseudomonas* spp., leaf spots caused by *Phomopsis* (Anamorphic *Diaporthe*) and leaf rust caused by *Olivea* often cause serious problems (Sharma, Mohanan and Florence, 1985; Balasundaran *et al*., 1995). *Ralstonia solanacearum* causes typical vascular wilt in India, Indonesia, Malaysia and Myanmar while *P. tectonae* is prominent in the Philippines (Gibson, 1975; Sharma, Mohanan and Florence, 1985). Lack of soil drainage and root injury are predisposing factors of bacterial wilt. The leaf spots caused by *Phomopsis tectonae* (Anamorphic *Diaporthe*) in combination with *Colletotrichum gloeosporioides* (Anamorphic *Glomerella*) result in defoliation and death of the seedlings. Rust caused by *Olivea tectonae* results in premature defoliation in nurseries and plantations in India, Pakistan, Sri Lanka, Myanmar, Indonesia and Thailand (Gibson, 1975). In nurseries, rust can be controlled by foliar spray of sulfur-based fungicides. In 1- to 3-year-old plants *Corticium salmonicolor* (pink disease) causes death of terminal shoots in India (Sharma, Mohanan and Florence, 1985) and Indonesia (Gibson, 1975).

In Kerala, India, *T. grandis* is attacked by the trunk borer, *Cossus cadambae*. This results in the infection of the tunnels by the fungus *Pleurostomophora richardsiae* (Anamorphic Ascomycetes) and causes dieback of trees (Sharma, Mohanan and Florence, 1985).

Diseases in introduced range

Several fungi have been reported to cause root rot and decay of standing trees in India, the United Republic of Tanzania, Dahomey, Nigeria and Papua New Guinea, but they are of local and minor importance (Bakshi, 1976; Gibson, 1975; Sharma, Mohanan and Florence, 1985).

Parasitic plants

The mistletoe, *Dendrophthoe falcata*, is a major problem in plantations in almost all the teak-growing countries especially, India, Bangladesh, Indonesia and Trinidad (Murray, 1961; Gibson, 1975; Ghosh, Balasundaran and Ali, 1984). It was found to cause up to 40 percent reduction in annual increment and mortality reaching 9 percent in teak plantations in Kerala, India (Ghosh, Balasundaran and Ali, 1984). Lopping the infested branches before the flowering season is the usual method of management.

Terminalia amazonia

Order and Family: Myrtales: Combretaceae
Common names: nargusta

NATURAL DISTRIBUTION

Terminalia amazonia is found over a very wide area from southern Mexico through Central America and into Brazil and Peru, as well as in Trinidad and Guyana. It is a component of moist to wet tropical forests throughout this region, on a large variety of soil types, including sands and gravels, upland volcanic soils, low fertility clays, and limestone soils. It is generally absent on drier sites within its range. Apparently, plantations to date have been little used and there are no records of the species spreading from its natural range.

PESTS

Arthropods in indigenous range

In general, *T. amazonia* appears to be capable of growing in pure stands with few insect or disease problems, although cautious optimism is warranted in regard to its potential in pure plantations. Ford (1986) reported borer attacks of 4 to 45 percent on various *Terminalia* species in Costa Rica. Larvae of the genus *Cossula* bore underneath the bark and into the xylem and then bore upwards for 25 to 40 cm, making galleries 12 to 14 mm in diameter. Moulaert and Arguedas (1993) reported moderate defoliation damage to plantation trees from *Exophthalmus* spp., a weevil. More seriously, Montagnini *et al.* (1995) observed low survival (66 percent) of planted seedlings due to attacks by leaf-cutting ants.

Diseases in indigenous range

In Costa Rica, Nichols *et al.* found unidentified fungi on 4-year-old plantation trees, causing red spots and yellowing of leaves. Care should be taken when pruning to avoid wet weather, so that fungal entry into stems is minimized.