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Diseases and insect pests of *Gmelina arborea*: real threats and real opportunities

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Abstract. *Gmelina arborea* Roxb. (gmelina) is a rapidly growing tree, which due to its drought tolerance and excellent wood properties, is emerging as an important plantation species. Perhaps the greatest threat to plantations of this tree is damage due to pests and diseases. Numerous insect pests and pathogens have been recorded in stands of gmelina in areas where the trees are native. Some fungal pathogens have been introduced into areas where the trees have been established as exotics. Among these, leaf spot caused by *Pseudocercospora ranjita* is most widespread although it has not caused any substantial damage. A serious vascular wilt disease caused by *Ceratocystis fimbriata* in Brazil has caused the most significant failure of *G. arborea* in plantations. In plantations within the natural range of the tree, insects have caused substantial damage. Among these, the defoliator *Calopepla leayana* (Chrysomelidae) appears to be most important. No serious insect pest problems have been recorded where *G. arborea* is grown as an exotic. All indications are that pathogens and insect pests will become much more serious impediments to the propagation of gmelina in the future. However, excellent opportunities exist to resolve such problems through biological control of insects and integrated disease and pest management. In addition, gmelina can be vegetatively propagated and thus, breeding and selection for insect and pathogen tolerance will facilitate the propagation of healthy trees.

Palabras clave: Control biológico, Cuarentena, Especies exóticas, Implementación operacional de clones

Resumen. La *Gmelina arborea* Roxb. (gmelina) es un árbol de rápido crecimiento, el cual debido a su tolerancia a las sequías y a sus excelentes propiedades de la madera se está convirtiendo en una especie de importancia para las plantaciones forestales. Tal vez, la amenaza más grande para las plantaciones de estos árboles es el daño causado por las plagas y las enfermedades. En las áreas en donde la especie es nativa, se han reportado gran cantidad de plagas de insectos y de patógenos. Algunos hongos patógenos se han introducido dentro de las áreas en donde los árboles han sido establecidos como especies exóticas. Entre estos, las manchas de las hojas ocasionadas por el hongo *Pseudocercospora ranjita*, es el más extendido aunque no ha causado ningún daño sustancial. Una seria enfermedad de marchitamiento vascular causada por el *Ceratocystis fimbriata* en el Brasil, ha causado la pérdida más seria en las plantaciones de *G. arborea*. En las plantaciones dentro del rango natural del árbol, los insectos han causado un daño considerable. Entre estos insectos, el defoliador más importante parece ser el *Calopepla leayana* (Chrysomelidae). En las áreas en donde la gmelina crece como una especie exótica no se han reportado problemas con las plagas de insectos. Todo parece indicar que en un futuro, los agentes patógenos y las plagas de insectos se convertirán en un impedimento más serio para la progagación de la gmelina. Sin embargo, a través del control biológico de insectos y del manejo integrado de las enfermedades y plagas, existen excelentes oportunidades para resolver este tipo de problemas. Además, la gmelina puede ser propagada vegetativamente y por lo tanto su mejoramiento y selección facilitará la propagación de árboles saludables por su resistenciacia contra los insectos y los patógenos.

Introduction

Gmelina arborea (gmelina) is a tree native to India, Myanmar, Sri Lanka and other parts of South East Asia. The tree grows rapidly, producing light-coloured wood suitable for many purposes. It is relatively drought tolerant, tolerating annual precipitation in the range of 700–4500 mm (including a 6- to 7-month dry season) (NAS 1980). This has made gmelina an attractive species for the establishment of plantations both in countries were it is native and as an exotic throughout the tropics. In addition to its other positive attributes, gmelina can be propagated vegetatively and this has facilitated relatively rapid selection for growth form and yield (Leakey 1987; Chandra and Gandhi 1995). A considerable amount is known about gmelina's fruit, leaves and wood properties (Evans 1979; Akachuku 1984; Majgaonkar et al. 1987), but relatively little about its fundamental ecology in its native range, or where it is an exotic. It has been noted by experienced tropical plantation foresters, geneticists and disease and insect pest scientists that gmelina has performed very well in exotic locales, at least in part due to the relative absence of disease and pest attack (personal communication W. Dvorak, NC State University, USA). While in its native range in plantation culture, it is often devastated by these organisms (Greaves 1981). This situation argues strongly in favour of intensive disease and pest research and development efforts. These would better secure gmelina for use as an exotic, and to enable its expanded use as a native.

Exotic plantation forestry has expanded rapidly during the course of the last Century (Dvorak and Hodge 1998). This has led to the establishment of highly efficient and profitable forestry companies producing both solid wood and pulp products. The success of exotic plantation forestry can partially be ascribed to the fact that trees have been separated from their natural enemies (Burgess and Wingfield 2002a, b). This has allowed for rapid growth in the absence of damage due to pests and diseases. However, in most cases where exotic species are grown in plantations, disease and pest problems gradually appear. The costs of forestry then tend to increase substantially. Financial analyses of plantation potential or even of tree genetic improvement programs (Hamilton et al. 1998; Pye et al. 1997) can be seriously flawed when biotic challenges are not accounted for (Gadgil and Bain 1999; Powers 1999). These problems include those caused by native insects and pathogens that inherently have, or develop the capacity to infect the newly planted exotics, and further, when pests and diseases are simultaneously or later (sometimes much later) introduced from the areas of origin of the trees.

In comparison to other trees commonly grown as exotics in the tropics and Southern Hemisphere, very little is known regarding the diseases and pests of gmelina. This is perhaps due to the fact that the tree is relatively less commonly planted than for example, species of *Eucalyptus*, *Pinus* and *Acacia*. For those diseases and pests that have been recorded on gmelina, relatively little information is available and some is of questionable validity. There are certainly also other damaging organisms that have not been studied, and damage for which the causal agents have not been identified. The aim of this review is to provide a summary of the diseases and pests that have been recorded on gmelina. We, furthermore, provide a view of the long-term health prospects for the tree, and how they might be maximised. The latter views rely on our experience with diseases and pests of other commonly grown plantation species as well on information gathered from inspections of gmelina plantations in various parts of the world.

Diseases

Leaf diseases

A relatively large number of fungi have been recorded causing leaf spots on *G. arborea* in plantations. These include the *Colletotrichum* state of *Glomerella cingulata*, reported from Kerala, India (Sharma et al. 1985), *Corynespora cassiicola* (Florence and Sharma 1987) in India, which is also recorded on various other plants including tomatoes, *Pseudocercospora ranjita* in India, Kenya, Uganda, Brazil, Philippines (Sharma et al. 1985), *Cercospora volkameriae* in various African countries including Sierra Leone and possibly Zambia and Malawi (Gibson 1975), *Guignardia gmelinae* in the Philippines (Kobayashi and Guzman 1988), *Phyllosticta gmelinae* (Kobayashi 1980) as well as species of *Ascochyta* and *Mycosphaerella* spp. in Malawi and Zambia (Gibson 1975).

Virtually nothing is known of the importance of these pathogens although most reports suggest that they cause minor damage. Many are caused by fungi that are known to have relatively wide host ranges and to be relatively opportunistic. In some cases it is difficult to have confidence in the species names provided and it is probable that modern taxonomic tools will show that some of these names are questionable.

The one leaf pathogen that occurs in the native range of *G. arborea* and is present in many other areas that gmelina is grown is *Pseudocercospora rangita*. The fungus belongs to a group of generally host specific pathogens and anamorphs of *Mycosphaerella*. It has been recorded from India as well as in plantations in various parts of Africa and Brazil (Gibson 1975; Sharma et al. 1985; Ferreira 1989). Surveys conducted in Mexico, Colombia and Venezuela have also shown that the fungus is present in those countries (Wingfield unpublished). Clones differ in their susceptibility to infection by this fungus and in the case of highly susceptible clones, leaf drop can be relatively severe.

Stem diseases

A number of stem diseases have been reported on *G. arborea*. For many of these, very little is known and they appear to be of negligible importance. Pathogens include *Griphosphaeria gmelinae*, which was recorded from Kerala, India and suggested to be a new species (Sharma et al. 1985); *Thyronectria pseudotricha* causing minor stem cankers (Sharma et al. 1985) and *Phomopsis gmelinae* that was reported by Sankaran et al. (1987) to girdle the stems of 3-year-old trees.

Harsh et al. (1992) reported top dying caused by *Natrassia mangiferae* following insect (*Tingis beesoni*) damage in India. The taxonomy of this fungus, which is particularly well known for the stem end rot disease that it causes on Mango, has been confused for many years (Jacobs 2002). Recent studies based on DNA sequence analyses have shown clearly that the fungus is a species of *Botryosphaeria* and that a new name in *Fusicoccum* should be provided for the asexual form (Jacobs 2002). *Botryosphaeria rhodina* (*Lasiodiplodia*) *theobromae* has also been isolated from dying tops of severely stressed trees in Venezuela (Wingfield, unpublished). This and other *Botryosphaeria* spp. are well known opportunistic pathogens of trees such as *Eucalyptus* spp. (Old et al. 1990; Smith et al. 2001). They exist in healthy trees as endophytes (Smith et al. 1996) and cause disease after physical damage or other stress. This is consistent with the report of '*Natrassia mangiferae*' infecting gmelina in association with insect damage.

Pink disease caused by *Erythricium* (*Corticium*) *salmonicolor* has been reported on gmelina in Kerala (Sharma et al. 1985). This was the first report of the pathogen on the tree and the authors suggest that it appeared to be relatively resistant to infection. Pink disease is, however, an important disease of many tree species both in the tropics and in temperate areas of the Southern Hemisphere. In countries such as Indonesia, Vietnam, Brazil and South Africa, the pathogen can cause severe damage to hardwoods such as *Acacia* spp. and *Eucalyptus* spp. (Ferreira and Alfenas 1977; Sharma et al. 1984). Its occurrence on gmelina suggests that it could be important on this host where conditions are conducive to infection.

Stem galls caused by *Agrobacterium tumefaciens* are well known on a wide variety of herbaceous and woody hosts. Maringoni and Furtado (1997) described this disease on gmelina in Paraná, Brazil although no indication was given as to its importance. In tree disease surveys in the South of Mexico, occasional trees with stem galls typical of those caused by *A. tumefaciens* have been observed (Wingfield, unpublished). However, no isolations were made from these symptoms and the bacterium is only presumed to be the cause of the galls, also reported by Arguedas (1992) on gmelina in Costa Rica.

Certainly the most important disease of *G. arborea* in plantations has been the stem and branch canker and vascular wilt disease in the Jari valley of northern Brazil (Dianese 1986; Muchovej et al. 1978). This disease is caused by the notorious tree pathogen *Ceratocystis fimbriata*. The fungus was first recorded at Jari and results of pathogenicity tests proving its ability to kill trees were described by Muchovej et al. (1978). *C. fimbriata* is one of the most important pathogens of trees and is well known for causing severe mortalities in crops such as coffee, citrus and cocoa in South and Central America (Kile 1993). The pathogen requires wounds to enter trees and these are common in highly cultivated sites such as coffee plantations in Colombia. Here, tree stems are damaged by farming implements such as machetes and the shoes of farmers who use the bases of trees to secure their footing on high steep slopes (Castro 1991).

Ceratocystis fimbriata and many other *Ceratocystis* spp. are spread by casual insects such as flies (Diptera) and picnic beetles (Coleoptera: Nitidulidae) that visit stem wounds (Kile 1993; Wingfield et al. 1993). Sap on the wounds is attractive to these insects that transmit the fungus, which produces a very strong fruity aroma. Wounds with *C. fimbriata* sporulating on their surface are subsequently attractive to the insects that pick up spore masses and transfer these to fresh wounds on trees. Muchovej et al. (1978) report the presence of tunnels of insects such as *Scolytus* sp. and *Platypus* sp. on cankers caused by *C. fimbriata* and suggests that these insects might be involved in the spread of the disease.

Ceratocystis fimbriata causes tree diseases in many parts of the world. There is growing evidence that the species represents a complex of different biological species that are virtually indistinguishable based on morphology but that can be separated based on DNA sequence data (Barnes et al. 2001). There is good evidence for host specialisation among isolates of the fungus (Webster and Butler 1967; Barnes et al. 2001) although some studies in Brazil (Riebiero et al. 1987) have suggested that isolates from one host are equally pathogenic on many other plants. Certainly, there is a clear group of isolates from South and Central America that also occurs in Africa (Roux 2000; Barnes et al. 2002) and in these areas care should be taken to avoid infection by *C. fimbriata*.

Root diseases

Two well-known root pathogens have been recorded on *G. arborea*. The associated diseases both occur in Africa and include one caused by *Pseudophaeolus baudonii* in Nigeria (van der Westhuizen 1973; Gibson 1975) and Ivory Coast (Brunk 1965) and another caused by *Armillaria mellea sensu lato* in Nigeria (Gibson 1975). *Pseudophaeolus baudonii* occurs on many woody plants such as *Eucalyptus* and tea (van der Westhuizen 1973) and is restricted to Africa. *Armillaria mellea* recorded on gmelina in Nigeria, could represent one of a number of species of *Armillaria* that occur in Africa and that are well-known pathogens of woody plants (Coetzee et al. 2000). Nothing is known regarding the impact that they have had on the tree but they generally only cause damage on sites cleared of natural forest. In these situations, it is usually possible to reduce the impact of the disease by removing stumps and roots prior to planting.

Decay and heart rot

Heart rot and basal stem decay has been described in gmelina where it can be caused by a number of decay fungi. *Trametes stramina* has been reported to cause a white stringy rot in northern India and *Fomes roseus* has been associated with brown cubical rot on trees in Pakistan (Gibson 1975). *Lentinus squarrosulus* is recorded to cause occasional basal decay in India. No work has been done on this category of disease that is generally not considered important in short-rotation plantations. In surveys in Mexico and Venezuela, stems of large numbers of trees from plantations have been inspected and no signs of severe heart rot problems have been observed (Wingfield, unpublished).

Pests

This report includes all available references to herbivores on *G. arborea*. Information pertaining to insects involved in litterfall decomposition, domestic livestock feeding on the tree and insect pests of gmelina timber has not been included.

Browne (1968) provides a general review of the insect pests of *G. arborea* and other plantation species. An extensive survey of tree plantations in Zambia in 1983 revealed that the tree suffered from no major insect pests (Selander and Bubala et al. 1983), and a review of publications from Zambia on this topic yielded similar findings (Bubala et al. 1989). In India, surveys of insects and pathogens in various tree plantations, including gmelina, have been reported (Ali et al. 1996; Asham et al. 1996). Other surveys of insect pests on gmelina have been completed in Bangladesh (Baksha 1990), Indonesia (Nair 2000; Suratmo et al. 1996), and Central America (Pinzon-Florian and Moreno-Beltran 1999).

Leaf insects

Reports by Mathew (1986) and Nair and Mathew (1988) indicated 34 insect species, mostly defoliators, on gmelina in Kerala plantations. These included three lepidopterans, six hemipterans and 25 coleopterans. Most foliar damage in these surveys was attributed to the hemipteran *Tingis beesoni* (Tingitidae), and lessor damage recorded for the lepidopteran *Epiblema fulvilinea* (Epiplemidae), and the coleopteran *Calopepla leayana* (Chrysomelidae). *C. leayana* was reported for the first time on gmelina in Meghalya, India in 1995 (Kumar et al. 1995), indicating an apparent expansion of its range to the northeast of India. Earlier reports from Burma (Myanmar) of planted gmelina also include records of severe defoliation by *C. leayana*, but subsequent inspections revealed only negligible levels of infestation (Anonymous 1949). Aung-Zeya (1981, 1983) reported on leaf pests on gmelina in Burma, including *T. beesoni*, and Chey (1987) reported on defoliators of the tree in Malaysia.

Calopepla leayana is perhaps the most widely reported and studied defoliator of *G. arborea* in Asia. The general biology and ecology of *C. leayana* (= *Craspedonta leayana*), including studies of phenology, digestion, natural enemies, abiotic impacts and control tactics have been described (Garthwaite 1939; Ahmed and Sen-Sarma 1983, 1990; Ahmed et al. 1983; Sen-Sarma et al. 1983; Sen-Sarma and Ahmed 1984; Baksha 1997). Mathur (1979) studied the biology of *T. beesoni*.

Other important defoliators of *G. arborea* reported from India are *Eupterote undata* (Lepidoptera: Eupterotidae) (Sheikh and Kalita 1995) and *Indarbela quadrinotata* (Lepidoptera: Indarbelidae) (Kumar 1994). Minor defoliators reported from India include *Parasa lepida* (Lepidoptera: Limacodidae) and *Trypanophora semihyalina* (Lepidoptera: Zygaenidae) (Meshram and Garg 2000). Meshram et al. (2001) reported on 12 insect pests and their relative incidence and impact, including the defoliators mentioned above, in various plantations in India. In the Philippines, *Ozola minor* (Lepidoptera: Geometridae) has been reported as a defoliator of *G. arborea* (Lapis and Genil 1979). In Nigeria, *Spilosoma (Diacrisia) maculosa* (Lepidoptera: Arctiidae) (Okiwelu et al. 1992), and *Lixus camerunus* (Coleoptera: Curclionididae) (Eluwa 1979) are reported as damaging the tree.

A variety of defoliator regulation and control studies on gmelina have been described. In India, Mahesh-Kumar et al. (1996) reported good laboratory results using the heteropteran (Pentatomidae) *Eocanthecona furcellata* as a predator against *C. leayana*, Mohandas (1986) reported a pupal parasitoid, *Brachymeria excarinata* (Hymenoptera: Chalcididae), of this species, and Pandey et al. (1997) studied defoliator deterency using camphor oil. Collectively, these reports suggest that increasingly sophisticated studies are underway to manage this primary pest. Additionally, Gupta et al. (1989) tested 22 conventional insecticides against adult *C. leayana* and ranked their relative effectiveness. Sharma et al. (2001) reported success against the larvae of this insect with the biological insecticide *Bacillus thuringiensis* sub sp. *kurstaki*. Sankaran et al. (1989) reported on the potential of the fungal pathogen *Beauveria bassiana* as a control for *C. leayana*, and Garthwaite (1939) reported on some early control methods.

A number of experimental studies have been conducted on defoliation of *G. arborea*. These include a trial in the Philippines where artificial defoliation was employed on coppiced seedlings. Here, the overall % defoliation: % growth reduction ratio was ca. 1.15:1 (Lapis and Bautista 1977). Agbooda and Kadiri (1999) conducted a defoliation study on nursery gmelina in Nigeria.

Stem insects

Xyleborus [*Euwallacea*] *fornicatus* (Coleoptera: Scolytidae) has been reported in India as an important pest on *G. arborea* (Mathew 1986; Nair and Mathew 1988). The wood boring larvae of the generalist (wide-host range) moth, *Sahyadrassus malabaricus* (Lepidoptera: Hepialidae), has been described and damage assessed in Kerala, India on gmelina (Nair 1982), and the bee-hole borer, *Xyleutus ceramica* (=*X. ceramicus*) (Lepidoptera: Cossidae) has been reported on gmelina in Malaysia (Abe 1983). Other unidentified sapwood-boring insects have been observed on the tree (DJR, personal observation in Burma), but have escaped formal reporting. No specific reports on shoot boring or deforming insects were found.

Termites are known to attack *G. arborea* in some situations. In southern Nigeria, several termite species have been specifically identified as damaging to live trees (Bayode 1979). Patel and Sahu (1995) in India report on tactics to control termites in plantations, and Mukherjee et al. (1996) reported on the use of irrigation and insecticides in gmelina nurseries as tools to reduce termite impacts on survival. Chey (1996) reported that the primary pest termite in a study in Sabah, Malaysia was *Coptotermes curvignathus* (Isoptera) and tested five insecticides against them, with success. In Cuba the termite *Nasutitermes costalis* (Isoptera: Termitidae) has damaged young gmelina in association with mechanical damage from forest operations (Menendez and Rodriguez 1990).

Freshly cut *G. arborea* logs have been surveyed for insect attack in Zambia, where low levels of attack were reported (Loyttyniemi 1980). In contrast, a large variety of beetles, especially ambrosia beetles (Coleoptera: Scolytidae and Platypodidae) were found to attack freshly cut logs in Malaysia (Motohiro 1991).

Fruit/seed and nursery pests

In Sabah, Malysia an unidentified lepidopteran (Pyroridae) has been reported as a defoliator of *G. arborea* flowers (Abe 1983). A survey of insects in fallen fruit was presented by Chey (1986). Other studies of insect pests in gmelina in nurseries are reported above.

Root insects

No reports on root insects have been found.

Other pests and associated fauna

Significant damage by browsing mammals (wild and domestic) to young *G. arborea* has been widely reported in Asia, especially by deer and cattle around the margins of plantations (Baconguis et al. 1978; Duff et al. 1984; Lauridsen and Kjaer 2002). In general, plantations of gmelina in Asia (specifically studied in Malysia) are known to support diverse and substantial populations of many non-pest and potential pest mammals (Duff et al. 1984; Stuebing and Gasis 1989) and insects (Chey et al. 1997). Small mammal use of gmelina plantations has also been studied in Ghana (Decher and Bahian 1999). The tree has been included in studies of forest production of food for lemurs in Madagascar (Ganzhorn 1995), in plantations implicated as a land use change diminishing the habitat for Central American squirrel monkeys in Costa Rica (Boinski et al. 1998), and debarking by elephants in India (Vanaraj 2001). Raju and Reddi (2000) reported on gmelina pollination by foraging carpenter bees, *Xylocopa* spp. (Hymenoptera: Xylocopidae).

Studies in southeastern Nigeria of native forests replaced by *G. arborea* and *Tectona grandis* (teak) plantations have shown a concomitant decline in populations of yellow fever vectoring mosquitoes (Diptera: Culicidae) (Bown et al. 1980). Chey et al. (1998) and Intachat et al. (1999) have studied Arthropod richness and abundance in Malaysian natural forests and plantations, including gmelina.

Mistletoes (*Loranthus* sp.) have been recorded as damaging *G. arborea* in Bangladesh (Alam 1984). Seeds of these mistletoes on gmelina in India are reported to be consumed and spread by the purple sunbird, *Nectarinia asiatica* (Rahman et al. 1993).

Basis for enhanced pest and disease management and resistance development

Most of the pathogens and insect pests or purported pathogens and insect pests of *G. arborea* have been recorded from countries in South and Southeast Asia where the tree is native. There are also a relatively large number of reports from West Africa and relatively few from Central and South America. In general, most reported diseases appear to be of relatively minor importance, whereas several of the insect pests, particularly *C. leayana*, are chronic challenges in Asia. There are no substantial reports of insect pests outside of the natural range of gmelina. The only pathogens that appear to have caused marked damage to plantations outside the native range of the tree are the canker and vascular wilt pathogen *C. fimbriata* in northern Brazil and the leaf pathogen *Pseudocercospora rangita*, virtually wherever the tree is grown.

It is difficult to predict the future health of *G. arborea* in plantations. There are certainly a good number of fungi that could cause severe damage if conditions were favourable to infection, when planted as a native or exotic species. And with regard to insect pests, there are a host of current pests in the native range, and tremendous potential for some of them to become pests in the exotic planting areas, should they be introduced. As with some other plantation tree species, clonal stands are most likely to have a magnifying effect. Where disease or insect-susceptible clones are planted, problems are likely to be very obvious (Ahuja and Libby 1993; Bishir and Roberds 1999; Robison 2002). However, advanced breeding strategies and vegetative propagation will make it possible to easily select disease and insect pest tolerant planting stock, which would form an important component of avoidance. This approach has been most successful with *Eucalyptus* (Wingfield et al. 1991), *Pinus* spp. (Redmond and Anderson 1986; Carson and Carson 1989), *Populus* and *Salix* (McCraken and Dawson 1998; Newcombe 1998; Robison and Raffa 1998; Zsuffa 1975), and others. There is every reason to believe that the same will be true for gmelina (Dvorak et al. 2003).

There is an excellent opportunity to address the disease and pest threats, current and potential, to *G. arborea*, given the information already known about the tree (Greaves 1981, 1982; Moldenke 1984; Tewari 1995). This is despite the relative lack of information known about its biotic threats. There is ample and emerging knowledge of gmelina genetics and improvement (Akachuku 1984; Afzal and Muhammad 1987; Gua and Sandiford 1990; Sandiford 1990), seedling and vegetative propagation (Chandra and Gandhi 1995), plantation culture and ecology (Boulet-Gercourt 1977; Halenda 1988), and foliar and wood properties (Evans 1979; Majgaonkar et al. 1987; Ramirez and DiStefano 1994). What is lacking is the merger of this information with classic biological and chemical control tactics, and importantly the integration of this and disease and pest biology/ecology with genetic improvement programs (Lauridsen and Kjaer 2002; Nichols et al. 2002).

Pre-existing information on *G. arborea* foliar and bark/wood properties from livestock forage and wood utilisation studies (see references above), for example, and data on general site adaptability and seed source zones (Haman et al. 2000;

Lauridsen and Kjaer 2002) may make selection for genetic resistance to disease and pests organisms more efficient. While many reports on gmelina genetic improvement programs mention disease and pest problems, few have made specific recommendations on including these factors in the genetic selection and breeding efforts (Thakur 1983; Jamaluddin et al. 1992; Lauridsen and Kjaer 2002). This is an important and critical opportunity. There is ample evidence that a well-designed disease and pest resistance effort, as an integral part of a genetic improvement program, and seedling (McKeand et al. 1999; Alfaro et al. 2002) or clonal (Zobel 1982; Leakey 1987; Wingfield et al. 1991) deployment scheme, can be very successful.

Special effort needs to be made to avoid the movement of pathogens and insects between countries (Niemela and Mattson 1996; Kliejunas et al. 2001). The most likely means of movement of various stem and leaf diseases would be on seed. *G. arborea* has large seeds and these are likely to carry a wide range of fungi, including pathogens. Seed predator insects can also be transported this way, and ultimately cause major difficulties in nursery production if ignored (Murillo 1992). Thus, the existence of *P. rangita* on the tree in its native range, and its wide spread occurrence on the tree as an exotic, suggests that it has been moved on seed or seed parts. This mode of spread deserves special consideration and study, as the movement of clean seed will slow the appearance and reduce the impact of diseases that are seed borne, and insect seed predators within them. Movement of plants or trade of wet wood products is less likely to occur and this avenue of spread for pathogens such as *C. fimbriata*, and insects would appear to be of modest importance. However, there are very many examples of insects and diseases from a variety of guilds being moved widely with devastating consequences.

Classic disease and pest management, including cultural and genetic controls, will be increasingly required in Asia as the area planted to *G. arborea* expands and with it, the host resource for these organisms. The same approach will be required where the tree is planted as an exotic. An aggressive prevention program will also be needed to avoid the introduction of damaging organisms. Likewise, prophylactic genetic selection and improvement will be essential to reduce the threat of damage should known/likely disease and pests organisms arrive from its native range (Robison 2002; Wagner et al. 2002).

Vigilant surveys of exotic *G. arborea* plantings should be undertaken to identify emergent problems from locally adapting disease and pest organisms, and to enable rapid response. Without these approaches, planting of this tree in Asia will be restricted, despite its promise as a local and preferred species. Where gmelina is planted as an exotic, the tree may be hard hit by emergent or arriving pests and diseases. There are numerous examples of similar regrettable situations, for example, pitch canker (Gordon et al. 2001; Wingfield et al. 2002) and wood wasps (Morgan 1968; Slippers et al. 2003) on pines worldwide (in exotic and native locales), exotic *Phytophthora* root rots (Burgess and Wingfield 2002a; Erwin and Ribeiro 1997) and homopteran Adelgid pests (Aman and Speers 1965) on native firs (*Abies* spp.) in North America, cankers on *Eucalyptus* worldwide (Zobel 1982), etc.

All trees are affected by diseases and insect pests and plantations are particularly threatened by them. These organisms can result in substantial damage and in severe situations, can also lead to the abandonment of planting programmes. It has, for example, been suggested that *Ceratocystis* canker led to the cessation of gmelina planting in the Jari of Brazil, *Septoria musiva* canker nearly led to the abandonment of hybrid *Populus* planting in North America (Zsuffa 1975), *Matsucoccus josephi* (Homoptera: Margarodidae) has led to provenance and species change in pine plantings in Israel (Mendel 1984), and Sirex wood wasps (Morgan 1968; Slippers et al. 2003), pine wood nematode (Wingfield 1987) and pitch canker (Godon et al. 2001; Wingfield et al. 2002) have led to major research and development efforts to preserve *Pinus radiata* as a plantation species in a variety of exotic locales.

While threats due to diseases and pests should be taken seriously, intensive plantation development with species such as *G. arborea* give us much cause for optimism. Sophisticated tree breeding methods have already shown that disease risks can be significantly reduced by careful breeding, selection, improvement and deployment. In addition, modern molecular biology tools are increasingly giving rise to new opportunities for tree improvement (Kannan and Jasrai 1996; James et al. 1998). In this regard, gmelina is an outstanding tree that contains tremendous opportunity for improvement. While diseases and pests might hamper gains sporadically, there is every reason to believe that these can be resolved, and managed through persistent and integrated efforts.

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