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Forest Pathology: The Threat of Disease to Plantation Forests in Indonesia

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Abstract: There has been a significant increase in the establishment of forestry plantation species in Indonesia over the last decade and it appears that this is likely to continue as the native forest resource rapidly dwindles. The future success of these monocultures will be dependent upon future breeding programs that not only select for yield and form, but more importantly a high level of resistance to a range of pests and diseases. A number of devastating diseases have been found in Indonesia and in other surrounding countries of South East Asia, with further discoveries highly similar. It is of utmost importance that the industry adopts a pro-active approach to combat these diseases by embracing breeding programs in the very near future. Forest pathologists will play a key role in the success of this breeding. It is therefore essential that both industry and government provide substantial support for forest pathology research in the future. This study discusses some of the potential diseases capable of causing significant losses to *Eucalyptus* plantations. The importance of selection of highly disease resistant genotypes and the essential role of taxonomists and forest pathologists to the future success of the industry are discussed.

Key words: Forest pathology, eucalypt, plantations, disease, south-east Asia

INTRODUCTION

Over the last decade, Indonesia's pulp and paper industries have been expanding at a rapid rate to become one of the countries major export earners. Until recently, the major source of fibre for this industry has come from the unsustainable practice of clear-cutting of native forests which has been of increasing concern to both the Indonesian government and international communities[1]. Indonesia has recently embarked on a large afforestation program recognising that forest plantations will be increasingly important sources of industrial wood in the future. By providing alternative sources of wood supply, forest plantations reduce logging pressure on natural forests, thereby playing a role in the conservation of natural forest resources[2]. These plantations will also help protect some of the previously deforested land against erosion, and will provide employment for local people[3]. However, these alternative sources of fibre require considerable resources for establishment and maintenance and therefore come at a financial cost, increasing the demand on companies to produce fast-growing and high yielding trees.

The selection of hybrids with subsequent vegetative propagation and the use of cuttings and tissue culture, has resulted in the rapid establishment of clonal plantations in many parts of the world including Brazil, South Africa and South East Asia. This method of establishment is becoming increasingly common as it is seen as a way of rapidly increasing yields by using superior genetic material. It is very important when adopting these methods to give consideration to species-site matching and the threat of pathogens. In the 1990's, quite a lot of effort was made to match genera and species with site in countries such as Philippines, Indonesia and China. Earlier, in the 1980's there was some very large selection trial work carried out in China leading to a wide range of genetics for crossing and establishment. Even so, these monocultures have become increasingly susceptible to a wide variety of diseases, many of which are poorly understood.

The most recently established plantations in Indonesia are exotic species, mainly *Acacia* and *Eucalyptus* spp. with the exception of *Eucalyptus urophylla* which naturally occurs in East Timer and eastern Indonesia. *Acacia mangium* is the principal species planted covering more than 80% of the plantations[4]. *Acacia mangium* plantations are affected by a range of diseases and are particularly susceptible to heart rot from an early age. Recent studies and surveys of this disease[5-7] have added to the knowledge base that already existed, however, there are still many knowledge gaps and opportunities for research[8].

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The area planted to eucalypts in Indonesia is quite limited compared to acacia plantations, which may be a reflection of the high impact of leaf and shoot pathogens on eucalypts in the humid environments commonly present in regions where plantations have been established[9]. However, there is no sector of world forestry that is expanding as rapidly as the industrial use of eucalypts, with more than 10 million ha planted in the tropics alone, mainly in South America and Asia[10]. These plantations have been grown as exotics where it has been generally recognized that their success has, at least in part, been due to the separation of the trees from their natural enemies[11]. Early signs of the breakdown in this artificial barrier were evident in the 1930s in South Africa where the planting of *E. globulus* in plantations had to be abandoned due to the impact of Mycosphaerella leaf blotch disease[12]. Some plantation companies have abandoned planting *Eucalyptus* in Vietnam in favour of *Acacia* due to disease problems.

Some valuable lessons have been learned in relation to destructive epidemics of eucalypt plantations caused by pathogens that have co-evolved and been introduced along with their host and also by local fungi ('new-encounter' pathogens) moving on to the introduced host. These lessons can be applied to other exotic forestry species also. Two of the most serious 'new-encounter' pathogens on eucalypts are *Puccinia psidii* causing the disease known as Eucalypt Rust or Guava Rust and *Cryphonectria cubensis* causing Cryphonectria canker. The potential damage caused by such pathogens is often underestimated due to a limited understanding of the taxonomy and ecology. The present study discusses some of the more serious pathogens of eucalypt plantations in the sub-tropics, the selection of resistant varieties to help combat these diseases and the importance of classical taxonomic techniques and collaborations with researchers in the Australia-South East Asia region to ensure the future success of forestry plantations in Indonesia.

Cryphonectria canker: Cryphonectria canker caused by *Cryphonectria cubensis* is the most important stem canker disease of plantation eucalypts grown in the tropics and subtropics[13]. In South Africa, cankers are most commonly found at the base of young trees which can be killed within their first 2 years of growth[11]. These symptoms are distinctly different from those found in South America and South East Asia where cankers can be found at the bases of trees, but they are also common higher up on stems (Fig. 1a), often associated with branch stubs[11]. In addition to its presence on *Eucalyptus,* this pathogen has been recorded on clove (*Syzygium aromaticum*), like *Eucalyptus* a member of the *Myrtaceae* and *Tibouchina* spp. which is a member of the Melastomataceae, closely related to the Myrtaceae in the Myrtales[14]. Originally, Hodges *et al.* [15]suggested that *C. cubensis* may have been spread widely on clove (native to the Molucca Islands of Indonesia), throughout areas where it is now a pathogen of eucalypts. However, more recent studies[16,17] have provided support for the hypothesis that *C. cubensis* in South Africa originated on native Myrtaceae in that country and subsequently became established on exotic *Eucalyptus* and *Tibouchina* spp. Studies have shown that there is considerable intraspecific and interspecific variation of *Eucalyptus* in susceptibility to Cryphonectria canker[18]. Further research on resistance to this disease is essential, especially in South-East Asia.

Eucalypt Rust: Eucalypt Rust caused by *Puccinia psidii* is regarded by forest pathologists and conservationists in Australia as a major exotic threat to Australia's biodiversity[9]. This rust is now an important shoot and leaf pathogen of eucalypts in Central and South America and the Caribbean[19] producing prolific, yellow uredinia on leaves, petioles and young stems which can be followed by blighting and destruction of shoots. The very wide host range of this fungus in the Myrtaceae means it has the ability to affect many plantation genera with dire consequences if it were to find its way into either Indonesia or Australia.

This fungus has been shown to affect a number of eucalypt species with susceptibility varying between and within species[20]. *Eucalyptus grandis* is quite susceptible, with extensive losses occurring in various provinces of Brazil[21,22]. *Eucalyptus globulus* and *E. viminalis* have shown promise for eucalypt cultivation in Brazil, however, the recent discovery of these species being infected by *P. psidii* in commercial *Eucalyptus* plantations in Brazil for the first time[23] has raised concerns. This study showed disease severity to be highly variable among plants of both species, with hybrids of *E. viminalis* proving to be more susceptible. It may therefore be possible to select highly resistant varieties for future plantings to limit the damage caused by *P. psidii* should it ever be introduced to the South East Asian region.

Phaeophleospora destructans: This species was newly described as *Kirramyces destructans* associated with leaf blight disease on one-year old to three-year old *E. grandis* in Northern Sumatra, Indonesia[24]. It is an aggressive pathogen that can cause extensive blights (Fig. 1b), distortion of young leaves and premature leaf

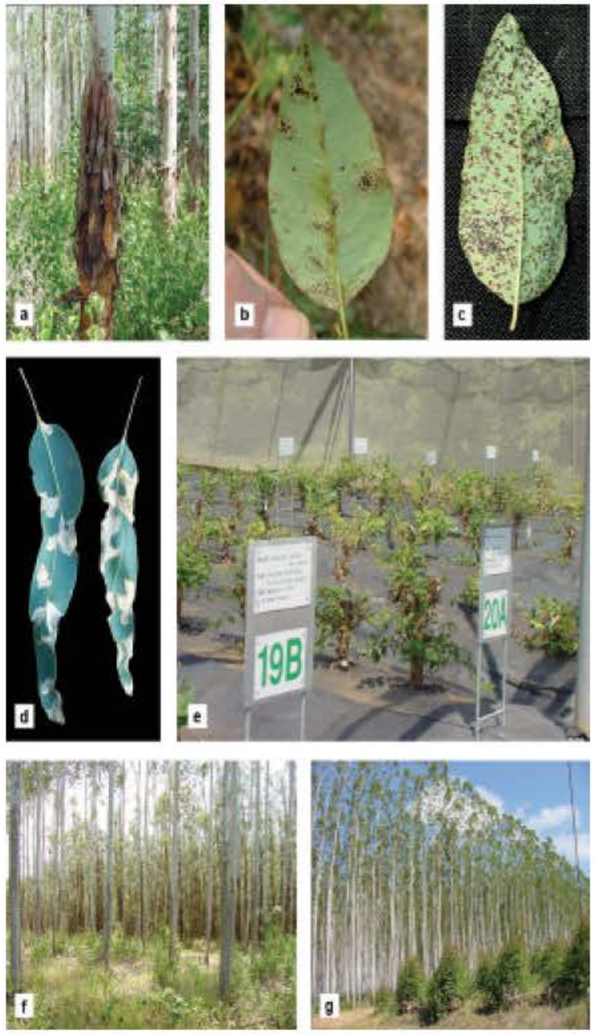

Fig. 1a-g: Symptoms of diseases on eucalypts grown in plantations and examples of clonal forestry. (a) Canker of *Eucalyptus grandis* stem caused by *Cryphonectria cubensis*. Photograph: G.E.St.J. Hardy. (b) Blights and exuded spores of *Phaeophleospora destructans* on under-surface of *E. grandis* leaf in Indonesia © Small necrotic lesions and exuded spores of *P. epicoccoides* on under-surface of *E. grandis* leaf in Indonesia (d) Severe blight caused by *Mycosphaerella cryptica* on *E. globulus* in southern Australia. (e) Shade-house resistance trial in South Africa. Photograph: G.E.St.J. Hardy. (f) Clonal plantation infected by Coniothyrium canker (resistant clones in foreground, susceptible clones in background) in South Africa. Photograph: G.E.St.J. Hardy. (g) Mature and immature clonal plantations in South Africa showing a high degree of uniformity. Photograph: G.E.St.J. Hardy.

abscission as a result of necrosis of the leaf and petiole. This pathogen was found in 2000 invading clonal plantations of *E. camaldulensis* in eastern Thailand[9] and in 2002 was found for the first time in several locations, encompassing south, central and northern Vietnam, on *E. camaldulensis, E. urophylla* and hybrid clones[25]. The rapid spread suggests movement on infected planting stock or even seed, posing a serious threat to eucalypts in South-East Asia and, possibly, native vegetation and plantations in Australia's tropical north[25]. In order to help manage the disease, tolerant clones have been selected and deployed in Sumatra[26]. A recent study carried out in New Zealand[27] has shown significant variation between species, within species and within subspecies of eucalypts to disease caused by a closely related species, *P. eucalypti*. Further research is required to ensure the successful selection and establishment of eucalypts highly resistant to *P. destructans* in Indonesia where it continues to be one of the major causes of disease.

***Phaeophleospora epicoccoides*:** This fungus is one of the most widely reported and well-studied foliar pathogens of eucalypts in the world, occurring on a range of species in many countries including those of the sub-tropics. It has been regarded as an important nursery pathogen in Australia[28] and India[29], has caused death of young plants in Malawi[30] and South Africa[31], extensive defoliation of plantations in Australia (G. Hardy pers. comm.) and significant damage in nurseries and plantations in Indonesia. Symptoms are variable but often they have a biotrophic state prior to the development of angular, vein-limited necrotic zones containing sub-stomatal pycnidia which commonly ooze spores onto the surface giving a sooty mould-like appearance (Fig. 1c). Spores are splash-dispersed and readily infect seedlings and clonal gardens in nurseries with poor hygiene practices. The teleomorph, *Mycosphaerella suttoniae*, is most-likely wind-dispersed and has a limited occurrence when compared to the anamorph, being found only in Brazil[32], Indonesia[33] and the north-east of Australia[34]. Research has been carried out on the susceptibility of *Eucalyptus* spp. to *P. epicoccoides*[35] and the effect of site preparation and fertilization on this susceptibility[36]. These studies included a number of plantation species grown throughout Indonesia.

Mycosphaerella leaf disease: More than thirty *Mycosphaerella* species are described from leaves of *Eucalyptus* in many parts of the world with many of these being widely distributed on a variety of eucalypt host species. There are at least six species recorded from eucalypts in Indonesia, *M. gracilis, M. heimii, M. marksii, M. parkii, M. suberosa* and *M. suttoniae*[33,34,37]. Some *Mycosphaerella* species are known to be important pathogens and are among the most common causes of foliar diseases of eucalypts, some capable of destroying entire plantations. Typical symptoms include spotting of leaves, with the more aggressive species capable of causing extensive leaf and shoot blights and severe necrosis (Fig. 1d) resulting in premature defoliation of affected trees.

A significant body of research has reported variation in susceptibility to disease caused by *Mycosphaerella* spp. between *Eucalyptus* species[38], provenances[38-41] and families[40,42]. However, the majority of this research has been conducted in southern Australia, outside the tropics. These pathogens may pose a significant threat to any large-scale establishment of eucalypt plantations in Indonesia, considering they are already known to exist in the region. Preceding any large-scale plantation establishment, it would be advisable to build upon the existing knowledge base and establish field trials of a wide range of genetic material in order to select highly resistant varieties for harvest of seed or cuttings for future plantings.

Genetic variation in susceptibility to disease: Due to increasing economic costs, commitment to investors and competition within the industry, growers are being attracted to the higher yields often obtainable from clonal plantations or establishment of a few 'high yielding varieties'. Considerable research has been carried out on selection for superior wood characters, growth rate and form. Plantation managers assume that when they select for these traits they are also selecting for a degree of pest and disease resistance. It is unwise to assume this, as there are many abiotic and biotic factors that can have an important impact on yield in field situations. Eucalypt plantations established on sites differing in some important features, edaphic and/or climatic, from those of their natural distribution may be growing under stress and are likely to be more susceptible to disease caused by non-specialised pathogens[43]. It is therefore critical to establish species and provenance trials to match genotypes to sites during plantation development, incorporating selection of disease resistant genotypes based on their performance in such trials in order to manage potential disease problems. It is of utmost importance to adopt a pro-active approach and establish these trials before large-scale planting as the effect of such diseases may not become fully evident until plantations have been established on a wide scale for several years[44]. When exotic tree species are established in new environments, there is often a 'honeymoon period' when pest and disease problems are relatively few, followed by a period when such problems may build up to damaging proportions as indigenous parasites adapt to the introduced tree species or co-evolved parasites eventually also find their way to the new location.

The diseases briefly described above all have characteristic symptoms that can be quite easily detected in the field by suitably trained forest pathologists without the need for expensive equipment. Once the identity of the pathogen causing the disease has been confirmed, the development of a scoring technique is required to determine levels (incidence and severity) of damage, which can be based on a range of previously published methods[39,45,46]. Different scoring techniques may be developed for individual diseases according to their symptoms. The person carrying out the scoring should train their eye in order to detect slight variations in the level of damage. This can be done by producing a range of photographs or diagrams showing various levels of disease severity (e.g. percentage leaf area affected) as carefully measured in the laboratory. These diagrams can then be used to train an observer to accurately measure disease severity in the field. It is reasonable to expect that such assessments, providing of course that a significant number of individuals from each genotype are assessed, should distinguish between the most highly resistant and highly susceptible genotypes.

It is important to note that studies of natural infection as described above do pose problems for predicting resistance at the individual level as levels of natural infection in a field trial may not be uniform and susceptible individuals may escape infection[43]. The expression of genetic variation in disease resistance and hence heritability estimates, may also depend on the overall level of infection[40].

In order to overcome some of these problems, intensive shade house (Fig. 1e) trials using artificial inoculation techniques have been established in countries such as South Africa in order to select clonal material that is highly resistant to a range of diseases. Differences between these highly susceptible and highly resistant clones have been particularly evident also after their establishment in the field (Fig. 1f), resulting in some very successful examples of clonal forestry (Fig. 1g). It is important to note, however, when considering selection for resistance to a particular disease that a diversity of genotypes should be planted in case of breakdown of resistance due to adaptation of the pathogen or of an increase in the effect of other pests and diseases[44]. Cryphonectria canker of eucalypts is controlled in Brazil by selecting and planting resistant trees[26] and in South Africa by the replacement of susceptible species with hybrid clones selected for resistance to the disease[47, 48].

Disease management: The successful management of disease in the forestry industry begins in the nursery. This is particularly important in high-rainfall countries such as Indonesia where close planting of clonal material can encourage the rapid spread of pathogens capable of causing disease epidemics and the loss of valuable genetic material. All of the diseases discussed in this study are capable of causing significant problems in the nursery. Some of the most serious nursery diseases in South East Asia are caused by *Phaeophleospora destructans* and *P. epicoccoides* and their increasingly widespread occurrence in the region suggests that they may be spreading with the movement of nursery stock. It is therefore essential that pathogens be detected early, nursery hygiene be improved and quarantine restrictions be placed on plant movement.

Diagnosis of pathogens: There is a wide range of techniques that have been adopted to identify pathogens that cause disease on plantation species, ranging from classical taxonomic methods through to the more recently developed molecular methods that identify pathogens *in planta*. Students readily embrace the molecular tools as they become more accessible, in many cases failing to learn how to use a microscope correctly. Although these molecular tools are certainly useful in being able to distinguish between morphologically identical or similar taxa, it is important to remember that they also have their limitations. In comparison to classical taxonomic methods, molecular diagnostic tools are expensive, often time-consuming and may rely on the ability of the pathogen to grow in culture, which is not always possible. In addition, to correctly identify a species, DNA sequence data of that species must have been lodged on an accessible database (e.g. GenBank) for comparative alignment. This is not the case for many pathogens, in particular those that were described before the development of molecular methods (e.g. older herbarium types).

The study of diseases of plantation species such as *Eucalyptus* and *Acacia* is still in its infancy and, accordingly, is still largely concerned with establishing the identity and basic biology of the causal fungi[19]. Surveys for pathogens of these plantation species in the 1990s revealed a large number of taxa, some of these new to science and many associated with severe disease[24,33,34,37]. It is highly likely that more intensive surveys will reveal a wider array of pathogens that have the ability to cause serious damage in plantations. There is an ongoing need to monitor plantations on an annual basis for health issues, especially in Indonesia, as there is much native Myrtaceae in the region and the opportunity for new disease outbreaks is high. It is therefore critical that substantial support is provided for forest pathology research in Indonesia, including the training of taxonomists and pathologists. This type of training could help develop valuable resources for foresters, including atlases of diseases, their management and detection, written in local languages. Such resources would help provide the essential support for breeding programs and also enable rapid and accurate identification of threatening pathogens and new incursions.

The future success of Indonesia's plantation industry will depend on the impact of diseases that already exist within Indonesia and those that exist in nearby countries of South East Asia and in other tropical regions. These diseases could have devastating effects if they were to be introduced to Indonesia. Some examples of diseases affecting eucalypts that fall into those two categories and have been discussed in this study are Cryphonectria canker, Eucalypt rust, Mycosphaerella leaf disease and the diseases caused by *Phaeophleospora destructans* and *P. epicoccoides*. It is essential that breeding programs are embraced and disease resistance is seen as a high priority. Examples from Brazil and South Africa have shown that it is possible to breed for highly resistant genotypes. Forest pathologists will be required to contribute to such tree-improvement programs and taxonomists will provide valuable support in being able to quickly and accurately identify potential pathogens. It is therefore essential, given the close proximity of Australia and Indonesia and the similarities between the plantation species and some native tree species, that collaborative initiatives are encouraged to provide the necessary resources for the training and development of scientists

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