Managing *Ganoderma* for Sustainable Plantation Forests in Indonesia

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Abstract
The reforestation effort in Indonesia is aimed at sustaining the supply of forest products while conserving the natural forests. This will maintain not only their economic importance, but also environmental and social roles. The Ministry of Forestry has set a development of plantation forests, both industrial and community-based plantation forests. In line with the policy, industrial plantation forests of fast-growing species, especially acacias and eucalypts, are being established on a large scale basis. A number of diseases have since been recorded. Root-rot is the most economically significant disease of *Acacia mangium* Willd. Elucidation of the identity of the causative organisms is very critical to develop its control strategies. Morphological and molecular characterizations have identified *Ganoderma philippii* Karst. as the fungal species most commonly found associated with the disease in *A. mangium* and eucalypt plantations. Components of integrated disease management including cost-effective and environmentally friendly biocontrol measures using *Trichoderma* and *Gliocladium* are also discussed in this paper.

Introduction
The Government of Indonesia has developed forest plantation programs as an anticipation to the ever increasing global wood demands. Since mid 1980s the area of both industrial and community-based forest plantations in Indonesia, particularly those of short-rotation species, has increased dramatically. Arisman and Hardiyanto (2006) stated that by 2006 industrial forest plantations already covered nearly 2.5 million ha, with various tree species being planted for wood and pulp production. This is aimed at providing the supply of forest products while at the same time maintaining the natural forest. Dependence upon exploitation of natural forest will eventually have to be terminated. Natural forests should be preserved and valued for their ecological functions and benefits. To fulfill this requirement, development of new plantation forests in responsible ways is very important. It is expected that through this
program, not only the economic importance of the forests, but their environmental and social roles will also be maintained.

As stated above, plantation forests of fast-growing species, especially acacias and eucalypts, are being established on a large scale basis. One challenge has been to maintain high survival and productivity of the trees. Disease is considered a limiting factor in plantation forest production. Root rot (especially red root rot) is considered a major disease of acacias (Gafur et al. 2007; Golani et al. 2007; Lee 2000; Old et al. 2000; Sankaran et al. 2005; Wingfield et al. 2010). *Acacia mangium* Willd. and *A. crassicarpa* Cunn. ex Benth. are important species planted primarily for fiber production in Indonesia and elsewhere in South East Asia. Ganoderma root rot disease is also found on different species of eucalypts although at present it occurs in lower magnitudes, (Coetzee et al. 2011; Francis et al. 2008; Gafur et al. 2010).

**Disease Symptoms and Signs**

Diseased acacia trees usually show a rapid decline, evidenced by off-color and sparse foliage wilting, and death (Figure 1 top). Recently infected roots are covered with a red-coloured rhizomorphs and white mycelium (Figure 1 bottom, left). Fruiting bodies are occasionally observed at the bases of dead trees (Figure 1 bottom, right). Foliage yellowing and senescence usually precede tree death. As infected woody materials (roots, stumps and other debris) remaining in or on the soil continue to build-up, root rot incidence increases in the following rotations. In the case of the *Eucalyptus*, roots have identical signs of infection including red rhizomorphs and the typical mottled pattern of mycelial growth below the bark. Fruiting bodies are sometimes also found on trees with roots having these symptoms. The current level of damage and incidence of this disease requires that effective management be developed to secure sustainable production of plantation forests in Indonesia. This is, however, not easy. Effective control strategies for root rot disease are not simple once the disease infects plants. Field management is complicated by the fact that its pathogen survives in the soil and on the woody debris between rotations. The discussion focus of this paper is the pathogen responsible for root rot disease in plantation forests with the emphasis on acacia and eucalypt plantations and options for its control in the field based on currently available information.
Figure 1. Symptoms and signs of Ganoderma root rot on *Acacia mangium*. Young trees showing yellowing and wilting of leaves (top, left), dead trees (top, right), roots covered with red-coloured rhizomorphs and white mycelium (bottom, left), and fruiting bodies of *Ganoderma philippii* (bottom, right).

**The Causal Agent**

In the past studies on fungal identification were based heavily, if not solely, on morphology of reproductive structures such as fruiting bodies or spores, whose presence in nature is unfortunately not always observed (Gafur et al. 2011a). Recent advancements in molecular biology, however, have enabled researchers to integrate morphological and molecular characteristics for identification purposes. While morphology has long been used extensively in taxonomy, the more recently developed molecular approaches provide excellent ways of identifying the vegetative stages of fungi (Coetzee et al. 2011; Gafur et al. 2011c).

The causal agent of red root rot disease in acacia plantations had been linked to different fungal genera. Recent reports, however, indicated that in tropical areas the disease is caused
by *Ganoderma* spp. (Gafur et al. 2007; Glen et al. 2009; Golani et al. 2007; Lee 2000; Mohammed et al. 2006; Old et al. 2000). *Ganoderma* root rot is also known to affect *Eucalyptus* (Francis et al. 2008; Gafur et al. 2010) although the causal agent of the disease has not been exactly identified (Old et al. 2003). In this paper discussion on the pathogen responsible for root rot disease in acacia and eucalypt plantations is primarily based on the work done by Coetzee et al. (2011) who employed both morphological and molecular approaches. During the study they examined a total of 189 isolates obtained from the newly infected roots of *A. mangium* trees, 6 from *Eucalyptus* roots and 2 from fruiting bodies formed at the base of trees associated with infected roots. This represented one of the largest single collections of isolates from newly infected *A. mangium* roots in root rot centres in Indonesia to the authors’ knowledge.

Based on their investigation Coetzee et al. (2011) revealed that *Ganoderma philippii* Karst. is the fungal species most commonly found associated with root rot disease in *A. mangium* plantations in Riau. DNA-based identification of the collected isolates showed that 97 percent of them represented a single species, *G. philippii*. Some other basidiomycete species such as *G. mastoporum*, *Phellinus noxius*, and *Tinctoporellus epimilitinus* are also isolated from infected roots. The researchers also reported that DNA sequence comparisons and phylogenetic analyses showed that *G. philippii* is also the causal agent of the disease on eucalypts. This has been the first report of *G. philippii* causing root rot on *Eucalyptus* in Indonesia so far.

**Disease Management Options**

As mentioned earlier there has not been any single effective control of *Ganoderma* in the plantation forests. Controlling root rot disease is also difficult because the pathogen survives on the woody debris and/or in the soil. Thus, it is suggested that compatible components of integrated disease management be implemented to manage the disease in plantation forests. As chemical treatments are economically inefficient and environmentally not preferable (Gafur et al. 2011b; 2011d), silvicultural practices and limiting the growth and spread of the pathogen are potential options. Similarly, cost-effective and environmentally friendly bioccontrol measures employing consortium of different functional groups of synergistic microorganisms have been considered as an important component of root rot disease management in plantation forests (Gafur et al. 2011b; 2011d).
In one of their experiments Gafur et al. (2011b; 2011d) indicated that *Ganoderma* incidence in naturally regenerated *A. mangium* plots is lower than that in planted plots of the same rotation. Differences in root architectures are considered to be one of the determining factors in this case. Early space competition may have forced the roots of naturally grown stands to penetrate deeper. Also, naturally regenerated stands seem to have a more differentiated structure of tap roots compared to nursery-raised seedlings. Stands with more vertical and reduced lateral roots have a higher chance to escape the disease in the field.

Trials in two different locations in Riau (Baserah and Logas) reveal that de-stumping in general reduces incidence of *Ganoderma* root rot in plantation forests (Figure 2). This has been proven particularly in *A. auriculiformis*, *Eucalyptus pellita*, and hybrid eucalypt plots. In *A. mangium* sites, however, de-stumping fails to decrease disease incidence (Gafur et al. 2011b; 2011d). This might have been due to the fact that in the experiments only big sized roots were removed (partial de-stumping), whereas smaller wood debris remained in the field as food base for the pathogen. Another option for field control of *Ganoderma* disease is the implementation of the cost-effective and environmentally sound management of biological control measures using consortium of synergistic microorganisms. For example, in a trial site it was revealed that *Trichoderma* reduces *Ganoderma* incidence by 4.9%, whereas in another location *Gliocladium* decreases *Ganoderma* incidence by 6.7% (Gafur et al. 2011b; 2011d).

![Figure2](image_url)
Conclusions

Ganoderma root rot in plantation forests, especially *A. mangium* and eucalypts, is primarily caused by *G. philippii*. The disease represents the major disease in plantation forests. There are, however, options for field management of the disease employing silvicultural practices and consortium of different functional groups of synergistic microorganisms as biocontrol agents. These are considered as the key components of root rot disease management in plantation forests in Indonesia.

References


