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ROOT ROT DISEASES OF FOREST PLANTATION SPECIES

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INTRODUCTION

Root rot disease is a notorious disease causing serious economic losses in forest plantations throughout the world. The disease causes significant tree mortality in forest plantations and is the most common reason of failure in the early phase of plantation development (Wingfield 1999). Trees infected by the disease are very difficult to detect especially at early stage of infection. The appearance of symptoms such as yellowing and wilting of leaves and defoliation indicate that tree roots are seriously affected by the disease. At this stage, the trees are often beyond the point of treatment and recovery.

Root rot is caused by fungi of the genus *Rigidoporus, Phellinus* and *Ganoderma* from the Basidiomycetes class. In general, root rot fungi can survive for years as saprophyte on root remnants, tree stumps and other woody debris buried in the soil even after land is cleared for plantation establishment. These plant debris play important roles in initiating root disease infection. They have often been reported as the main source of inoculum for root disease infection in monoculture plantations. The disease is often spread through root contact between healthy tree and roots of infected host or residual inocula in wood debris, or infected stumps of forest trees or from the previous crop. Other than root contact, the disease can also spread through wind-borne spores. At present, control of the disease in the field is difficult because there are no effective fungicides available in the market. This article aim to provide a guideline on diagnosing and identifying infected trees based on signs and symptoms. The management and approaches for root rot disease control is provided in Table 1.

Table 1 Management approaches for root rot diseases control

Approach	Technique	Note
Cultural practice	Remove and destroy stumps and woody debris of the previous trees during land clearing.	Labour intensive and expensive, in particular for large-scale forest plantations.
Cultural practice	Construct isolation trenches around identified diseased trees.	Costly and labour intensive, especially when large areas or many patches of diseased trees occur in the plantations. More suitable/ practical for small-scale forest plantations, especially for smallholders who converted their *H. brasiliensis* plantations to forest tree plantation.
Chemical application	Apply fungicides such as hexaconazole, tridemorph, propiconazole, tridemefon, cyproconazole and penconazole by means of soil drenching.	Recommended only on newly infected trees or trees with mild infection levels. More practical and cost effective to apply in small-scale plantations as monitoring of the disease is easier and can be conducted more frequently compared to large scale plantations.
Tree improvement	Plant resistant species or alternative species developed from breeding programme.	Planting of species/ cultivar/ variety resistant to root disease fungi may have to be considered because no effective methods are available in controlling the disease at present.
Regular monitoring program	Conduct regular inspections for pest and disease management in plantation.	An important program to be established for early detection of pest and disease in plantation and to avoid the disease outbreak. Cutting edge technologies such as remote sensing, GIS and drone are also recommended.
Capacity building	Equip planters with knowledge on diagnosis, detection and identification of root disease.	Provide continuous training to planters on detection, identification and management of root disease.

Type of root rot diseases

Three types of root rot disease are known to occur in forest plantation species in Malaysia namely, white root disease, brown root disease and red root disease. In forest plantations, tree species that are often infected by white root disease are *Azadirachta excelsa*, *Aquilaria malaccensis* and *Hevea brasiliensis* (timber clone). For brown root disease, incidences have been reported to occur in monoculture plantations of *Tectona grandis, A. excelsa, Acacia mangium* and *Khaya ivorensis*. In contrast, red root disease is common in monoculture plantations of *A. mangium*.

Signs and symptoms

Above ground

In plantations, crown symptoms of trees infected by root rot disease are generally similar regardless of host species or pathogens. The most common symptoms of root rot disease observed are pale green or yellowing of foliage (Figure 1), wilting and drying of leaves, defoliation and death tree (Figure 2). Other symptoms such as smaller in leaf size compared to leaf of healthy tree, short internodes of twig and presence of buds or flowers can also be seen. Sometimes, fungal basidiocarps can be seen on root collar of seriously infected trees by the disease. In some observations, the infected trees are also susceptible to windthrow due to the rot of anchoring and lateral roots (Figure 3). The spread of this disease in plantations also can be observed as gradually enlarging patches of dead trees (Figure 4). Trees with advanced infection are located at the centre, while trees with less-advanced infections are around the periphery.

Figure 1 Yellowing of foliage (red arrow) is a common symptom associated with root disease infection

Figure 2 Symptoms of root rot disease on *K. ivorensis* (a) wilting of leaves and (b) drying of leaves and defoliation

Figure 3 Tree fall due to the rotting of anchor roots and windthrow indicating a serious infection of root rot disease

Figure 4 A patch of trees in a plantation died due to root rot disease via root contact

Below ground

Signs and symptoms of root rot disease varied depending on fungal pathogens. The presence of white and rough rhizomorphs on surface of tree root is characteristic of *R. microporus* white root disease (Figure 5a). On trees freshly killed by the fungus, the infected root wood remains tough and hard. In more advanced stage of infection, the root wood becomes white or cream in colour, soft and friable (Figure 5b). The presence of white rhizormorphs on the root surface often indicates that the entire root system has been infected.

For *Phellinus noxius* brown root rot, a rough sheet of brown mycelial crust intermingled with soil particles and sand present on the root surface are common symptoms (Figure 6a). In the wood, the presence of brown zigzag lines forming a honeycomb-like pattern is common (Figure 6b). At this stage, the wood texture is friable, light and dry when crushed manually.

Figure 5 Presence of white rhizomoprhs on root surface (a) and bleach rotted root system (b) are indications of infection by white root disease

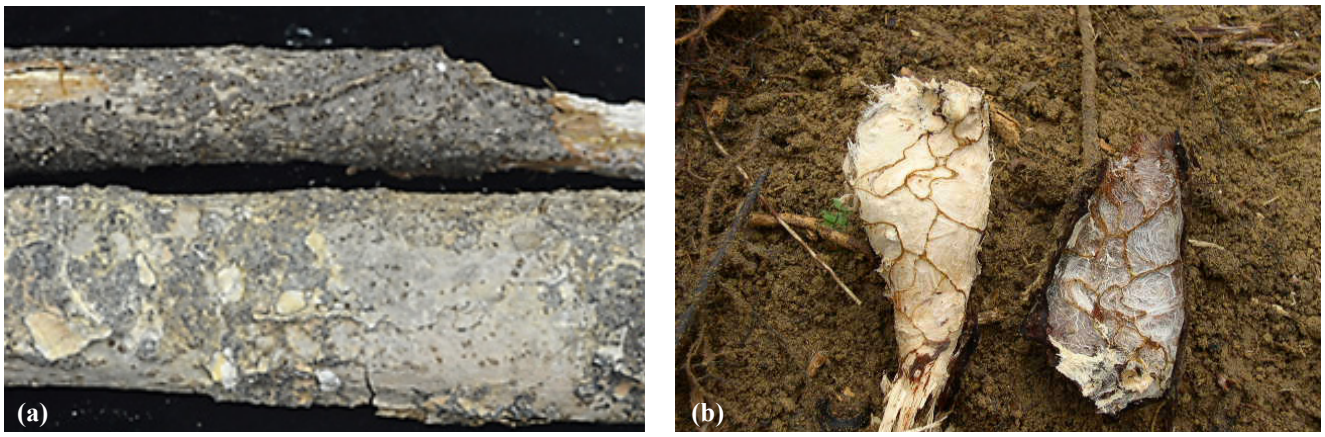

Figure 6 (a) Dark brown mycelia crust intermingled with sand on bark surface and (b) the presence of golden brown pockets of fungal hyphae in wood are characteristics of *P. noxius* brown root disease

In contrast, trees infected by red root disease are often recognised by the presence of a wrinkled reddish-brown rhizomorphic skin on the root surface (Figure 7a). When the root bark is peeled off, a white mottling pattern of mycelia is often present on the underside of the infected bark (Figure 7b). It also produces a very characteristic mushroom-like odour. In more advance stages, the woody part of the infected root is often pale yellow coloured and spongy.

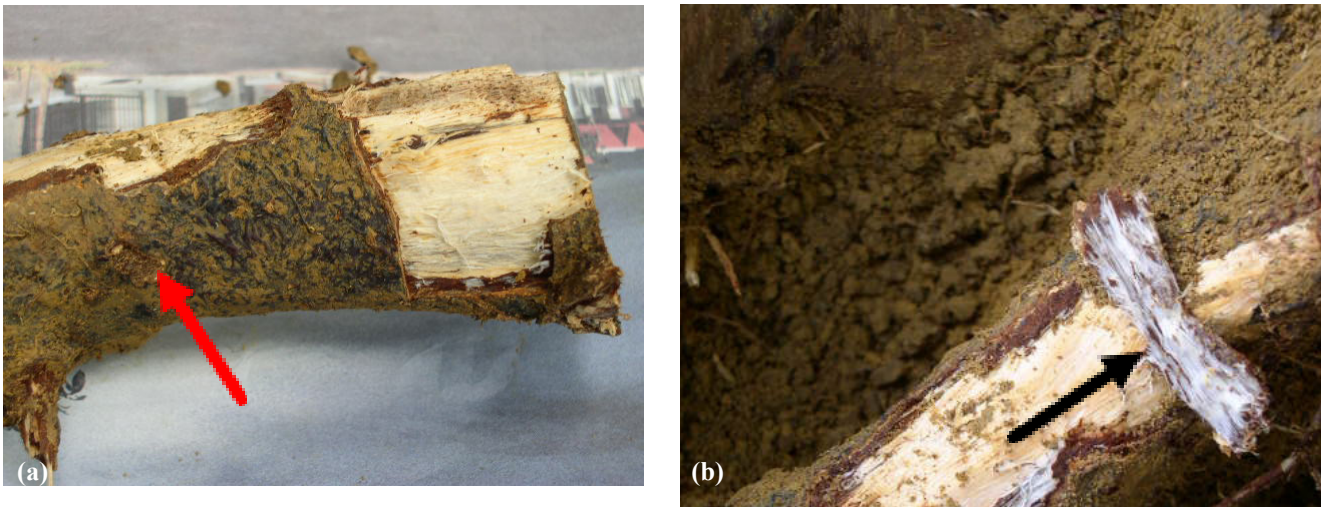

Figure 7 (a) Root infected by red root disease showing thin and wrinkled red skin-like mycelial crust on the surface (red arrow) and (b) the presence of white mottling pattern of mycelia on the underside of the bark (black arrow)

The fungal fruiting bodies

The fruiting bodies of *Rigidoporus microporus* are dimidiate, sessile and broadly attached to the substrate or at the base of trees heavily attacked by the fungus. They are leathery and hard when dry. The margin of the fruiting bodies is generally thin. It has orange-yellow upper surface with concentric zonation and a bright yellow margin (Figure 8). The pore surface is bright orange to reddish brown, which turns pale brown with time. The presence of fruiting bodies is common during rainy season.

Figure 8 Dimidiate fruiting body of *R. microporus* with leathery and concentric zonate-sulcate orange-yellow upper surface on root collar of an infected tree

The presence of *P. noxius* fruiting bodies in the field is uncommon. If present, it occurs in the form of resupinate (sock-like) or bracket form. The resupinate form of the fungus is characterised by flat, undulating and finely velvety surface with hard, crusted and resinous structure when sectioned (Figure 9). It is pale reddish-brown to umber (dark yellowish-brown) in the inner region, and brown towards the margin. The bracket form fruiting body is hard, woody and broadly attached to the substrate (Figure 10). It is brown to dark brown on the upper surface and dark grey on the lower surface. Tissues of the fruiting bodies are golden-brown. Pores are usually invisible to the naked eye.

Figure 9 Resupinate fruiting body of *P. noxius* induced artificially is characterized by hard, crusted and brown undulating surface

Figure 10 Bracket-shaped of *P. noxius* basidiocarp formed on an exposed *K. ivorensis* root

The fruiting body of *Ganoderma philippii* is broadly attached, woody shelf with concentric furrows and warty. It has a smooth upper surface and is semi glossy with a dark reddish or purplish brown colour. The margin of the fruiting body is usually narrow and white (Figure 11). The lower surface is white or brownish with medium to fine pores.

Figure 11 Fruiting bodies of *G. philippii* on the root collar of an infected *A. mangium*

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WINGFIELD MJ. (1999). Pathogens in exotic plantation forestry. *International Forestry Review* 1:163–168.

Root rot is one of the most important tree disease in forest plantation. The disease is destructive and easily spread to healthy neighboring trees to initiate new infection through root contact. A serious root rot disease infection can kill infected trees irrespective of health status. Early detection is very important to avoid spread of the disease and loss of tree stands in future. This article provides practical guideline in diagnosing and identifying infected trees by root rot fungi. Appropriate control measures are also discussed for the disease management.

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