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Research Article
Incidence and Severity of *Ganoderma* Rot Disease in Tropical Land-use Systems and Their Virulence to Palm Oil

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Abstract

Background and Objective: *Ganoderma* spp., have been reported as invasive tree pathogen and mostly reported in oil palm, however, information about the degradation in different land-use are limited. The rot disease caused by *Ganoderma* in the rainforest and agro plantation was investigated. In addition, this study was aimed to analyze the pathogenicity of *Ganoderma* infected forest and rubber trees to oil palm tree. **Materials and Methods:** Rot disease incidence and severity were measured in the rainforest, oil palm plantation and rubber plantation in two landscapes in Indonesia. The basidiocarps on infected trees were collected and the growth rate of *Ganoderma* on potato dextrose agar was measured. Selected *Ganoderma* from the forest, oil palm plantation and rubber plantation were tested for their virulence on oil palm seedling. **Results:** *Ganoderma* was a generalist tree pathogen since trees in different land-uses were infected. Interestingly, forest trees are more severe than mono plantations. Each *Ganoderma* has significantly different growth ability. When the virulence of Ganoderma tested in the oil palm seedling, only Ganoderma collected from oil palm plantation infected the oil palm seedlings with almost 100% in 10 weeks. *Ganoderma* from rubber plantation infected the oil palm seedlings very slow while the forest's *Ganoderma* did not infect the oil palm. **Conclusion:** *Ganoderma* is a wide range pathogen that potentially degraded woody trees in different land-uses. Although the mycelial of *Ganoderma* showed vary differ rapid growth, which may have related to the virulence, *Ganoderma* from forest and rubber trees performed less virulence to oil palm seedlings.

Key words: *Ganoderma*, rot disease, rainforest, oil palm, rubber

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Forest conversion into managed plantations of oil palm and rubber has been reported to decrease the diversity of root-associated fungi and fungal community structures were changed with pronounced increases of plant pathogens[1,2]. *Ganoderma*, as a soil-borne pathogen[3], is one of the plant pathogen enriched in the forest compared to monospecific plantations[1]. For the last decade, there have been limited reports in Indonesia evaluating the root rot disease severity due to land-use change at the scale of the landscapes in Indonesia. Most presented about the management of the disease, for instance, the use of biological agents in controlling *Ganoderma*, bio fungicides and chemicals[4-8].

Ganoderma is the most distributed genus of pathogenic fungi in oil palm[9-11] and rubber plantations[12,13]. Distribution of *Ganoderma* is an essential feature to understand the epidemic spread of the pathogen better. Infections of *Ganoderma* to a plant initiated by the contact of healthy plant roots with infected roots. Subsequently, penetration and degradation of root tissue will continue because *Ganoderma* produces degradation enzymes for lignin and suberin[10,14]. Currently, there is still no effective control for *Ganoderma* infections in an existing stand[15,16]. There is also still a lack of information on the spatial as well as temporal pattern or distribution of the disease, especially under natural field epidemic condition. Distribution maps of plant diseases as an authoritative source for accurate data on the worldwide distribution of plant diseases of economic or quarantine importance are urgently needed.

Since the evolution of *Ganoderma* in Indonesia not studied much, it is crucial to know the extent of disease incidence and severity caused by this pathogen. This study was aimed to provide baseline data on the disease incidence and severity of rot disease in the forests and plantations of oil palm and rubber. Besides, the study was also conducted to show the virulence of *Ganoderma* from different land-uses to oil palm seedlings.

MATERIALS AND METHODS

The study was located in Jambi, Sumatra, Indonesia. Survey and sampling were started from March, 2018. The plots consisted of forest, oil palm plantation and rubber plantation in two landscapes of Bukit Duabelas and Harapan. The study sites have been described in the previous studies by Brinkmann *et al.*[1], Sahner *et al.*[2] and Schulz *et al.*[17]. There were 4 plots per land-use. Each plot was extended to 250 m^2 to have more tree vegetation out of existing plot. Trees assessed as dead or alive with rot disease symptoms and with or without a fruiting body of *Ganoderma*. Each *Ganoderma* found was collected and transported to the laboratory of Plant Pathology Tadulako University.

Table 1: Class of disease scale assessed

Scale of severity	Description
0	Healthy tree
1	White fungal mass in tree part without chlorotic leaves
2	Appearance of basidiocarp of *Ganoderma* in any part of plants with chlorotic leaves, skirt-like appearance of the leaves resulting in collapse of the lower leaves
3	Formation of well-developed basidiocarp and bole creation
4	The plant death

Rot disease incidence and severity in different land-uses: The diagnosis of the disease incidence and severity classes[4] in Table 1 and calculated with the equations[18].

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected trees}}{\text{Total number of trees assessed}} \times 100$$

$$\text{Disease severity index (\%)} = \frac{\text{Number of the plant with the scale (1 – 4)}}{\text{Total number of plants assessed highest score scale}} \times 100$$

Mycelial growth of *Ganoderma* and the disease incidence in oil palm seedling: *Ganoderma* collected were grown on potato dextrose agar (PDA) at 25°C and repeated 3 times. The fastest growth of *Ganoderma* from each land-use was selected and inoculated in rubber-wood block (12×6×6 cm: Length×width×height). Once the rubber-wood covered by the mycelia, it is then added into the pot filled with soil and incubated for a week[19]. The pot planted with three months of oil palm seedling and repeated 15 times for each *Ganoderma* tested. The disease incidence caused by *Ganoderma* in oil palm seedling was calculated.

Statistic analyses: The data of *Ganoderma* growth were compared and calculated with ANOVA one way. Significant results then continued with the Tukey's honestly significant difference test. Since the data of the disease incidence in oil palm seedling did not meet the normal distribution for ANOVA, the statistics were performed with the Kruskal-Wallis test ($p = 0.05$). All the data analysis[20] were done in R 3.5.1.

RESULTS

***Ganoderma* rot disease symptom, incidence and severity in different land-use systems:** The observation of the rot disease showed that forest, oil palm and rubber trees potentially infected by *Ganoderma*. Forest trees infected by *Ganoderma* showed more severe than oil palm and rubber trees (Table 2). Bukit Duabelas and Harapan rainforests had 86.95 and 83% disease incidence, respectively. However, Harapan rainforest had the highest disease severity (64.26%) than Bukit Duabelas (46.07%). During the survey, it was noted that the tree decay was not only a basal stem rot but also upper stem rot, which is the most diagnostic sign of rot disease caused by *Ganoderma* in the forest, rubber and oil palm trees as presented in Fig. 1-3. Not only basal stem rot, upper stem rot was also found, for instance in the forest (Fig. 1a) where the basidiocarp of *Ganoderma* was found as a specific sign at the basal stem (Fig. 1b). Infected oil palm trees showed symptoms with spear ±3 leaves that were not open. The old leaves were necrosis and hang on the tree (Fig. 2a), with some basidiocarps at the bottom of the stem (Fig 2b). Also, upper stem rot was recorded in oil palm tree (Fig. 2c). The rubber tree showed necrosis leaves and die with the basidiocarp of *Ganoderma* at the basal stem (Fig. 3a, b).

Growth of *Ganoderma*: A total of 10 *Ganoderma* collected from the forest, 8 from oil palm and ten from rubber plantations were inoculated on PDA. *Ganoderma* BF1, HF1, HF5 and HF7 were significantly growing faster compared to other *Ganoderma* collected from Bukit Duabelas and harapan rainforests (Fig. 4a). The mycelial growth of *Ganoderma* BO1, BO2, HO2 from oil palm was the fastest colonizer compared to other *Ganoderma* collected from oil palm plantations (Fig. 4b). *Ganoderma* BR1 and BR4 grew significantly faster compared to other *Ganoderma* from rubber plantations (Fig. 4c). In the seventh day after inoculation on PDA, the fast growing *Ganoderma* covered 7-9 cm diameter of the media.

Disease incidence in oil palm seedling: Of all the *Ganoderma* tested, the disease development was only clearly appeared in oil palm seedling infected by *Ganoderma* collected from oil palm plantations. Figure 5 shows the disease incidence caused by *Ganoderma* BO1 developed from time to time. Until the 10th week, the oil palm seedlings mostly infected with all necrosis leaves. *Ganoderma* collected from rubber tree (BR1) infected the oil palm slower, about 20% incidences until 10 weeks. In contrast, *Ganoderma* from the forest (BF1) did not infect and produce any symptom in oil palm seedlings. The basidiocarp of *Ganoderma* on the basal stem of the oil palm seedling was appeared as infected by *Ganoderma* BO1 with all necrotic leaves at the 10th week (Fig. 6). Kruskal-Wallis test indicated that *Ganoderma* from oil palm trees differs in producing disease incidence compared to *Ganoderma* from the forest and rubber trees (p = 0.05).

Fig. 1(a-b): Basal stem rot disease of (a) Forest tree and (b) With *Ganoderma*'s basidiocarp

Table 2: Rot disease incidence and severity of forest, oil palm and rubber trees in Bukit Duabelas and Harapan rainforest

Transformation systems	Disease incidence (%)	Disease severity (%)
Bukit Duabelas		
Forest	86.95	46.07
Oil palm plantation	64.27	26.41
Rubber plantation	68.40	34.78
Harapan rainforest		
Forest	83.00	64.26
Oil palm plantation	52.66	22.89
Rubber plantation	60.84	32.08

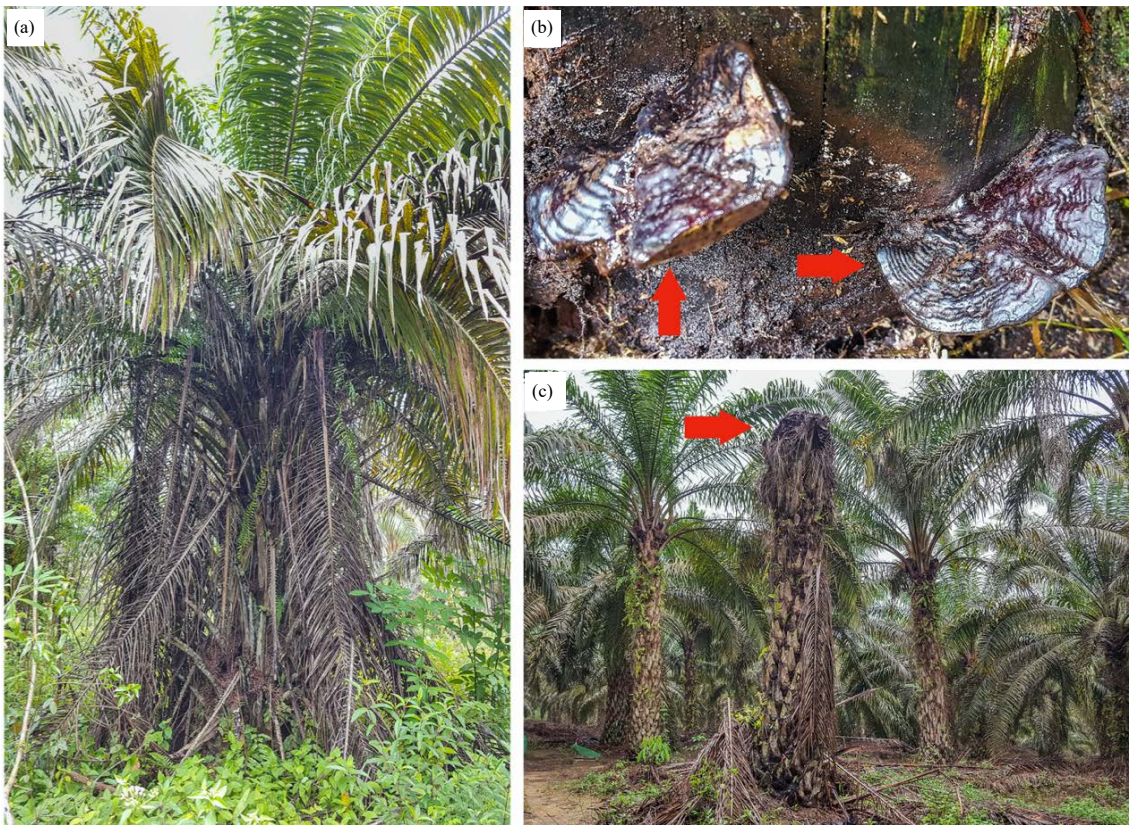

Fig. 2(a-c): Symptoms of basal stem rot disease in oil palm, (a) Old leaves were necrosis and hang on the tree, (b) Basidiocarp of *Ganoderma* at the basal stem and (c) Upper stem rot symptom

Fig. 3(a-b): Rubber tree attacked by, (a) Basal stem rot disease and (b) With fungal basidiocarp at the basal stem

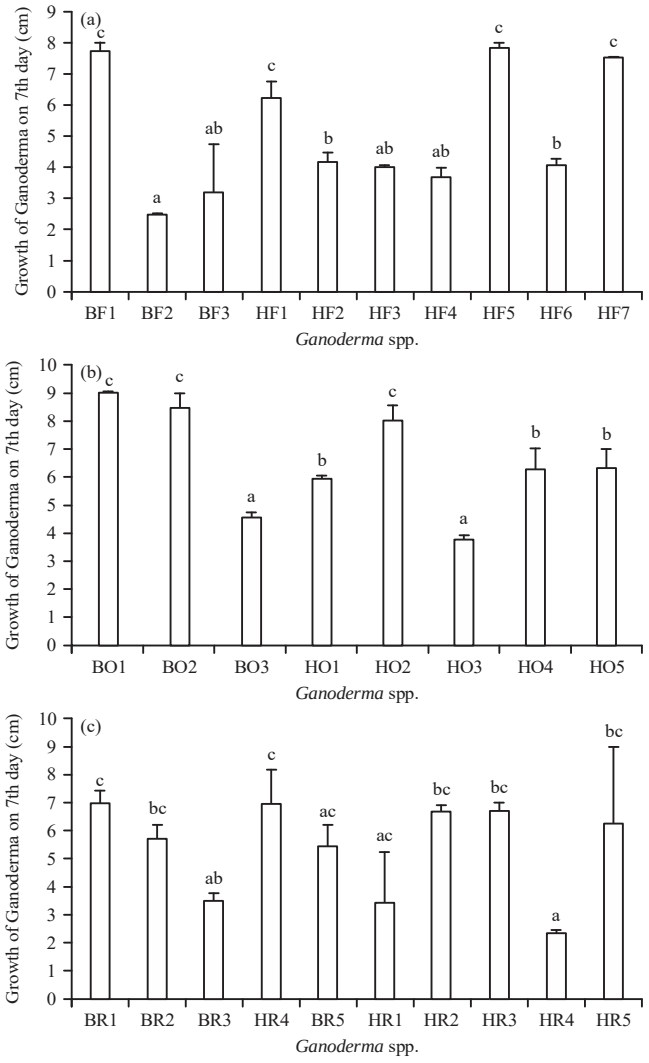

Fig. 4(a-c): Mycelial growth of *Ganoderma* spp., on the 7th day after inoculated on PDA. The *Ganoderma* collected from, (a) Forest trees in Bukit Duabelas (BF) and Harapan (HF), (b) Oil palm trees in Bukit Duabelas (BO) and Harapan (HO) and (c) Rubber trees in Bukit Duabelas (BR) and Harapan (HR)

Data show Mean±SD (n = 3), alphabets represented that they are statistically significant then each other

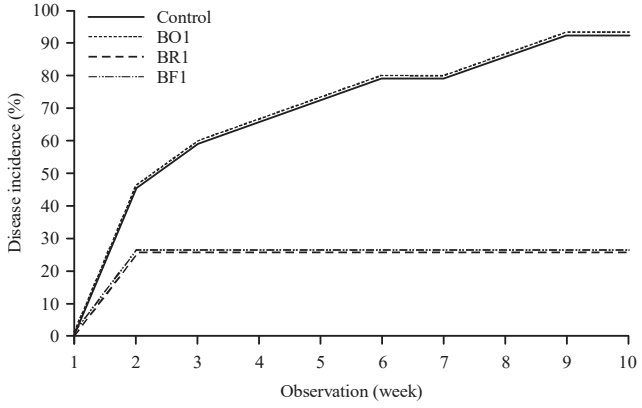

Fig. 5: Rot disease incidence caused by *Ganoderma* in oil palm seedlings

Three *Ganoderma* used to virulence tests were representing the origin plot (*Ganoderma* BF1 from the forest, BO1 from oil palm and BR1 from the rubber trees), mean (n = 15)

Fig. 6: Rot disease in oil palm infected by *Ganoderma*
The basidiocarp of *Ganoderma* appeared on the soil after the oil palm seedling dead

DISCUSSION

Ganoderma, a fungal genus belonging to the Ganodermataceae family and Polyporales order, is a plant-pathogenic species in this genus that can cause severe diseases (stem, butt and root rots). As plant pathogens, *Ganoderma* spp., have been studied since it kills trees and other woody species valued for their products (wood, seeds, gum, fragrances, bioactive compounds) and their ecological importance[21,22]. The plant infected by *Ganoderma* through roots in the soil by vegetative spread[15] and enters the plant cells by spores[23].

A mass high throughput sequencing has been done[1] and *Ganoderma* was detected enriched in rain forest compared to a monospecific plantation of oil palm and rubber. At the same study sites, it was found higher disease rot incidence and severity caused by *Ganoderma* in the forest. *Ganoderma* has a broad host range as a generalist woody plant pathogen[24]. The spread of the rot disease explained traditionally by a root contact between infected tree root to surround oil palm[25]. This fact tends to be a possible way of the spread of the disease in the current study. Tropical rain forests are grown with dense vegetation and shrubs in between. The humidity that is maintained throughout the year is suitable for *Ganoderma* to have a long-term host. The airborne dispersal by spores might also be the case since wind, rain and insect are potential vectors[26,27]. Unlike forests, oil palm and rubber plantations very common fertilized and fungicide by the farmers in Sumatra. It could be the reason the low incidence of rot disease on those sites compared to forests.

The mycelial growth of *Ganoderma* on PDA showed not similar rate. The previous study reported that the growth rate *Ganoderma* on various substrates. The growth of *Ganoderma* on media has been tested different culture conditions and found optimum temperature, carbon and nitrogen sources for the growth of *Ganoderma*[28]. Different carbon-nitrogen sources for the substrate of *Ganoderma* also has been observed[29]. Dextrin, galactose and fructose were favorable carbon. Ammonium acetate, glycine, arginine and calcium nitrate were the most preferred nitrogen for *Ganoderma* growth. This study, however, did not assess substrate content since PDA in the same condition was used. Therefore, the different growth of *Ganoderma* hypothetically affected by different fungal ability in utilizing the same substrate.

Interestingly, *Ganoderma* collected from forest did not infect the oil palm seedlings until ten weeks after inoculation, while *Ganoderma* from rubber plantation infected the seedling very slow. *Ganoderma boninense* has been reported as the most invasive *Ganoderma* against oil palm in East Asian countries[30]. Other *Ganoderma* spp., were harmful to many woody plants. *Ganoderma* is a degrading wood fungus with its ability to lignify[31]. Plantation areas or other tree ecosystems are susceptible to this fungus. This study shows a fundamental data about woody plant damage in different land-uses caused by *Ganoderma*. This result can be essential information to stakeholders to develop recommendations for controlling the rot disease.

CONCLUSION

Overall, this study showed that *Ganoderma* is a wide range pathogen that potentially degraded woody trees in different land-uses. Although the mycelial of *Ganoderma* showed differ rapid growth, which may have related to the virulence, *Ganoderma* from forest and rubber trees performs less virulence to oil palm trees.

SIGNIFICANCE STATEMENT

From the results of this study it was discovered that rot disease by *Ganoderma* spread in different land-uses of forest, oil palm plantation and rubber plantation. The growth rate of *Ganoderma* collected was determined. Interestingly, *Ganoderma* from forest and rubber trees were not harmful as *Ganoderma* from oil palm when tested in oil palm seedlings. The results of this study contributes to design disease control strategies. On that basis, this study has provided accurate

baseline data on the distribution of rot disease by the land use change. Currently, these data are not available by the relevant authorities in Jambi where the study conducted. These data will also be a national reference to estimate yield losses of palm oil and rubber production caused by *Ganoderma*. In addition, it also improving the register of *Ganoderma* in National databases related varying virulence, which is important for practical management advice in the long term.

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