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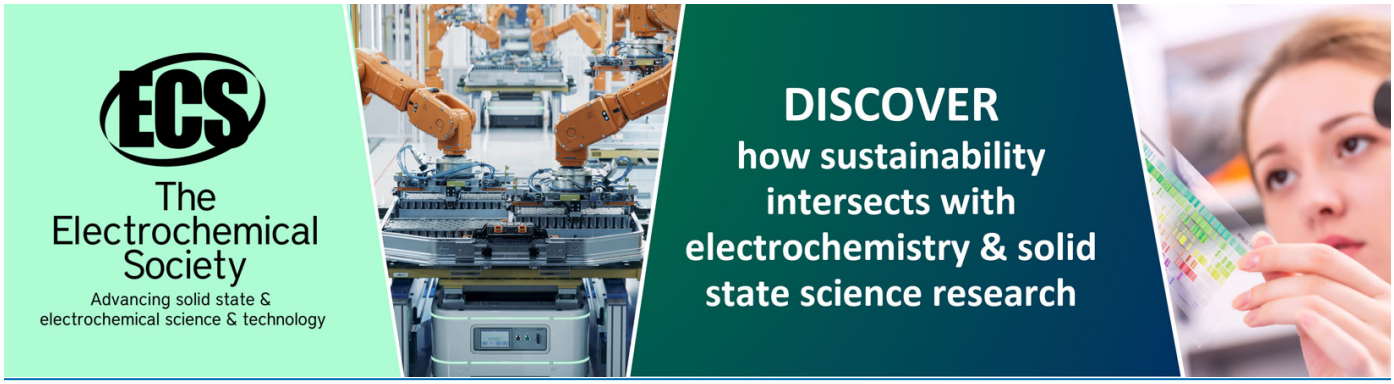

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Monitoring of *Ganoderma spp.* on the trees at Arboretum of Universitas Gadjah Mada, Yogyakarta, Indonesia: Implications for health care recommendation of old trees

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Abstract. The arboretum of Universitas Gadjah Mada (UGM), Yogyakarta, established in 1963, is host to various plants and trees originating from across Indonesia. Due to poor management and climate change, several cases of tree death and decline related to the *Ganoderma* sp. attack have been reported since 2015. The aims of this research were to evaluate the occurrence of root rot disease and to monitor the spatial and temporal distribution of *Ganoderma* spp. Completely survey on 638 trees with DBH more than 10 cm, monitored the number of basidiocarps attached on each infected species tree, and assessed the leaf and canopy condition were conducted on 2018 to 2021. The result showed that 0.78 % of trees with more than 10 cm diameter were infected by *Ganoderma* sp. since 2018 and become 1.57% in 2021. The species trees of *Pterygota alata* (1 tree), *Pterocarpus indicus* (1 tree), and *Adenanthera pavonina* (8 trees) were attacked by Ganoderma with a disease severity index of 25% to 100% in September 2021. The spatial pattern of trees associated with Ganoderma was random. However, since the density of trees at the arboretum is dense, the potential Ganoderma spreading through root contact will be high. Regular monitoring for early detection has to be conducted to prevent advanced infection and to set health care recommendations for infected trees with a high scientific value.

1. Introduction

The arboretum Pardiyan, located next to Faculty of Forestry Universitas Gadjah Mada (UGM), Yogyakarta, was established in 1963 as a part of the urban forest ecosystem in Yogyakarta city, has a good collection of various plants and trees originating from across Indonesia. According to [1], in about 1990, 64 tree species from 31 families were recorded in the arboretum of UGM. Due to the ecosystem's dynamic and much human activity inside the arboretum, old trees such as *Ochroma lagopus*, *Dalbergia latifolia*, *Pterocarpus javanicus* and *Delonix regia* were dead. They left several small gaps and open canopy, which eventually degraded the quality of the ecosystem within the arboretum. Therefore, based on forest inventory conducted by UGM Vegetation Team in 2018 (unpublished data), the number of species and families were decreased to 52 and 20, respectively.

Furthermore, rapid urbanization and changing land use in the Sleman area and Yogyakarta resulted in the migration of bird species *Ardea cinerea* to this arboretum to seek a place to rest and build a nest the trees' canopy in 2005. Despite the positive effect on the biodiversity of arboretum, negative effects

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also arose from the birds' occupation of the arboretum's canopy, i.e., bad odors from the bird's feces and canopy damage, particularly during the dry season. When the feces, which contains a high concentration of minerals, lands directly on young leaves or fragile twigs tissues, it will cause a burned effect.. Consequently, during the dry season, the trees become leafless and aggravates the condition of arboretum Pardiyan. In 2015, we detected for the first time Ganoderma occurrence in *Delonix regia* within the arboretum. However, the fruiting body of the fungus was still little, and the trees were also still healthy, so no management effort was imposed. In 2017, when the tornado hits many places in Yogyakarta, including Bulaksumur UGM, many big and old trees were fallen, and later it was found that most of their roots were infected with Ganoderma.

Ganoderma is a genus from the Basidiomycotina group that acts as a wood-decomposing fungus in live and dead trees, including logs. Numerous researchers have reported that Ganoderma is a root disease-causing pathogen, killing and reducing the health of various types of woody plants. The genus Ganoderma has been recorded mostly in tropical and some in temperate countries either in the planted forest or natural forest as well as in the urban forest. Numerous studies have been reported that Ganoderma was associated with mortality and a general decline in various tree species [2,3]. In addition, [4] reported that the basidiospores as primary inoculum have the ability to initiate infections in the wounded roots at the lower boles of trees, which led to further wood decay and resulted in a decline of the tree health. According to [5], a group of white-rot fungi, including Ganoderma, are able to produce enzymes that break down cellulose, hemicellulose, and lignin, the major structural components of wood. While [6] mentioned that species of Ganoderma are capable of both simultaneous decays, the process where cellulose and lignin are gradually decayed over time, and selective delignification, where lignin is preferentially decayed over cellulose. Due to those processes, when we found a fruiting body of Ganoderma on the living trees, we do not need other advanced assessments of decay such as sounding, resistance drilling, or sonic tomography to declare the tree hazardous and need to be removed. However, when we were dealing with arboretum where trees, shrubs, and herbaceous plants are cultivated for scientific and educational purposes, removing the trees has to be avoided as much as possible.

Consequently, monitoring the occurrence of Ganoderma in the arboretum is needed to take care of and save the trees in the arboretum of UGM. The aims of this study were: 1. To evaluate the occurrence of root rot disease, 2. To monitor the spatial and temporal distribution of *Ganoderma* spp. on the trees at Arboretum Pardiyan, Universitas Gadjah Mada, Yogyakarta in 2018 to 2021.

2. Material and methods

2.1. Description of research location

The research location was at Arboretum Pardiyan, Universitas Gadjah Mada (UGM), which is located just north of the main building of UGM, and the west part of the Faculty of Forestry UGM (figure 1). It covers an area of 0.9 Hectares, with 726 trees (DBH $\geq$ 5 cm), and within them, 638 trees have DBH $\geq$ 10 cm. The arboretum was established in 1965 and hosted many old trees. Since 2005, Arboretum Pardiyan has also become the home of the *Ardea cinerea* bird, which also causes side effects in the form of bad odors from its feces. The bird's feces also cause canopy damage, particularly during the dry season. Based on the preliminary study, the old trees with DBH more than 10 cm were potentially attacked by Ganoderma. Accordingly, we monitored in detail the 638 trees at Arboretum as trees population in this study.

Figure 1. Location of Arboretum Pardiyan (inside yellow line), at the Faculty of Forestry, Universitas Gadjah Mada.

2.2. Monitoring methods

Monitoring was conducted on August 2018, August 2019, June 2020, March 2021, and September 2021. Inspection of Ganoderma was done using the complete survey method, tree by tree of 638 trees with DBH ≥ 10 cm. The tree with Ganoderma attached to its basal trunk was documented, and its positioning was recorded using GPS (Global Positioning System) Garmin Type 64S. The number of Basidiocarp of Ganoderma on each tree was counted, while the condition of the leaves within the canopy was described and scaled, using a modification of [7] for further disease severity assessment (table 1).

Table 1. Class of disease scale assessment based on modification [7].

Scale of severity	Description
0	Healthy tree
1	The appearance of basidiocarp of Ganoderma in any part of a tree, without chlorotic leaves at a canopy
2	The appearance of basidiocarp of Ganoderma in any part of the tree, with yellowing leaves at the canopy
3	The appearance of basidiocarp of Ganoderma in any part of the tree, with wilting or dried leaves at the canopy
4	The appearance of basidiocarp of Ganoderma in any part of the tree, dead branches, and tree

Disease incidence (percentage) was calculated by counting the diseased and healthy trees (equation 1), while disease severity index (percentage) was examined using the formula in equation 2.

$$\text{Disease Incidence (\%)} = \frac{\text{Number of trees associated with Ganoderma fruiting body}}{\text{Total number of trees with DBH> 10 cm at the arboretum}} \times 100\% \quad (1)$$

$$\text{Disease Severity Index (\%) each tree} = \frac{\text{The scale of severity tree}}{\text{The biggest scale (4)}} \times 100\% \quad (2)$$

Spatial and temporal analysis from the field data were performed using ArcGIS software was to determine the nearest distance between the trees. Nonparametric analysis was also performed using Microsoft Excel software. Moreover, a qualitative descriptive analysis was also performed.

3. Result and discussion

3.1. The occurrence of root rot disease caused by Ganoderma spp. *at Arboretum Pardiyan*

Based on monitoring data from 2018 to 2021, the tree species at Pardiyan arboretum, which were associated with *Ganoderma* spp., were *Adhenanthera pavonina, Pterocarpus indicus*, and *Pterygota alata* (figure 2), with *A. pavonina* posed the most preference species (80%). However, more information on *Ganoderma* spp. attack on *A. pavonina*, as well as *Pterigota alata*, remains needed. While according to [8], *P. indicus* has been proving more susceptible to Ganoderma than *P. longifolia*, based on artificial inoculation. In arboretum Pardiyan, when the number of *P.indicus* was not many, this species was become wilting and dried the canopy after more than two years of infection.

The number of fruiting bodies of Ganoderma on every season on each species varied and didn't have a certain pattern for indicating the severity. Some individual trees which have more basidiocarp of Ganoderma in their basal stem were shown healthy with a green canopy. While other similar species with less basidiocarp of Ganoderma were showed dried leaf and canopy. Consequently, the number of fruiting bodies attached to the host tree cannot be used as an indication of the disease severity. Although according to [9] presence of basidiocarp of Ganoderma on the tree was the only method of diagnosing disease in the early days. Based on qualitative and quantitative observation, the canopy symptom likely was more suitable for indicating the degree of severity of each tree infected by *Ganoderma* spp. (table 2).

Figure 2. Fruiting bodies of *Ganoderma spp*. on: a. *Pterygota alata*, b. *Pterocarpus indicus*, and c. *Adenanthera pavonina* at Arboretum Pardiyan, Universitas Gadjah Mada, Yogyakarta, Indonesia.

The disease severity based on canopy conditions on each infected tree was varied. *Adenantera pavonina* has the greatest number of infected trees and shows different severity rates at each tree. Two of them died three years since the beginning of infection. However, one of them was died rapidly just 6-month after the infection (figure 3). Based on correlation analysis between the diameter of trees with the disease severity, there is no correlation or just a very small relationship (0,7% to 6.8%). The *Pterigota alata* trees showed better tolerance to Ganoderma. Although Ganoderma has infected them for at least three years, their leaves remained green, and no abnormality on the canopy was found. According to [10] and [11]. Ganoderma infections are often associated with such abiotic stress factors, e.g., flooding or soil compactions which destroy the root system and aggravate the damages. In addition, the yellow foliage from the diseased trees was commonly associated with the destruction of the root system, which subsequently disrupts water and nutrients supply to the foliage [12].

On the other hand, Ganoderma species in each infected tree at Arboretum Pardiyan were not identified yet. There is a probability that the species of Ganoderma at the Arboretum Pardiyan were varied, resulting in different pathogenicity to each tree. Consequently, further identification of Ganoderma species with molecular assessment would be needed.

Table 2. The number of Ganoderma fruiting bodies and leaf canopy condition of each tree species attacked by *Ganoderma* spp. at Arboretum Pardiyan, Universitas Gadjah Mada, Yogyakarta, Indonesia.

No	Species	Dbh (cm)	The number of fruiting bodies, leaf color, and canopy condition (inside the bracket): August 2018	August 2019	June 2020	March 2021	September 2021
1	*Adhenanthera pavonina*	37	1 (green leaves, normal canopy)	1 (green leaves, normal canopy)	1 (green leaves, normal canopy)	1 (green leaves, normal canopy)	1 (dead branches and tree)
2	*Adhenanthera pavonina*	36	1 (green leaves, normal canopy)	1 (green leaves, normal canopy)	5 (yellow leaves and canopy)	11 (yellow leaves and canopy)	11 (wilting leaves, dried canopy)
3	*Adhenanthera pavonina*	43	-	3 (green leaves f, normal canopy)	4 (yellow leaves and canopy)	5 (yellow leaves and canopy)	7 (yellow leave and canopy)
4	*Pterocarpus indicus*	91	6 (green leaves, normal canopy)	11 (green leaves, normal canopy)	13 (green leaves, normal canopy)	14 (green leaves, normal canopy)	16 (wilting leaves, dried canopy)
5	*Adhenanthera pavonina*	11	-	-	-	1 (green leaves, normal canopy)	1 (green leaf, normal canopy)
6	*Adhenanthera pavonina*	15	3(green leaves, normal canopy)	7 (green leaves, normal canopy)	10 (green leaf, normal canopy)	11 (wilting leaves, dried canopy)	11 (dead branches and tree)
7	*Adhenanthera pavonina*	16	1 (green leaves, normal canopy)	1 (green leaves, normal canopy)	1(green leaf, normal canopy)	1(green leaf, normal canopy)	1 (dead branches and tree)
8	*Pterygota alata*	89	-	2 (green leaves, normal canopy)	2 (green leaf, normal canopy)	2 (green leaf, normal canopy)	2 (green leaf, normal canopy)
9	*Adhenanthera pavonina*	24	-	-	-	2 (wilting leaves, dried canopy)	wilting leaves, dried canopy)
10	*Adhenanthera pavonina*	35	-	-	-	-	1 (green leaf, normal canopy)

3.2. Spatial and temporal distribution of Ganoderma spp. on the trees at Arboretum Pardiyan, Universitas Gadjah Mada, Yogyakarta in 2018 to 2021

Arboretum Pardiyan area was 0.9 Ha, which means the density of the trees is about 709 trees/ha. The ecosystem of a dense tree created a specific microclimate in the arboretum. Based on monitoring the Ganoderma incidence, the number of infected trees was low (figure 4). However, low light intensity (less than 20%), high relative humidity (70% to 90%), less temperature (22 ^{0}C to 26^{0}c), and dense trees are suitable for macrofungal development, including Ganoderma fungus. According to [13], in the case of *G. boninense* on oil palm plantation, the shading from full canopy formed by matured trees was the favorable condition for active inoculum, since those conditions were able to reduce the temperature of the soil and had higher humidity. Hence, [14] reported that the development of Ganoderma was closely affected by environmental factors. Tree death could be either slow or rapid, depending on water availability and temperature. Thus, despite the occurrence of Ganoderma

incidence at Arboretum Pardiyan being still low, special attention for investigating, monitoring, and preventing the existence of Ganoderma is needed in order to control the diseases.

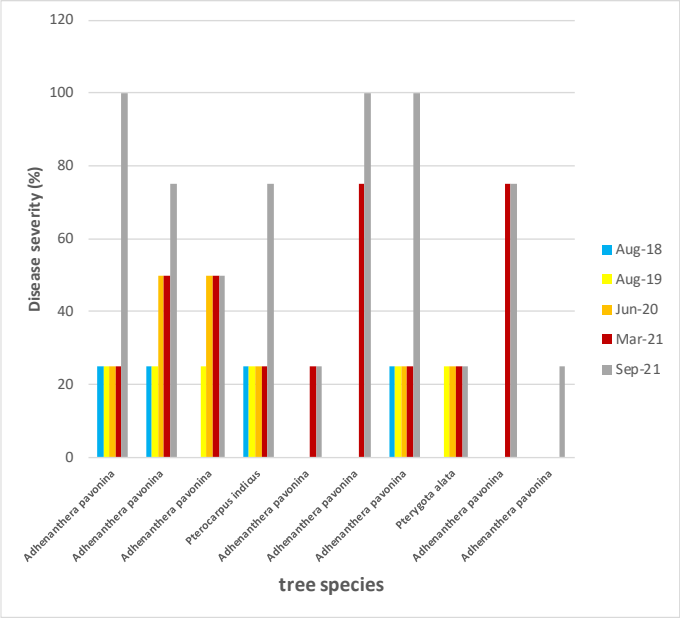

Figure 3. Disease severity indicated on the leaf color and canopy condition of each species attacked by *Ganoderma* spp. at Pardiyan Arboretum, Universitas Gadjah Mada, Yogyakarta, Indonesia.

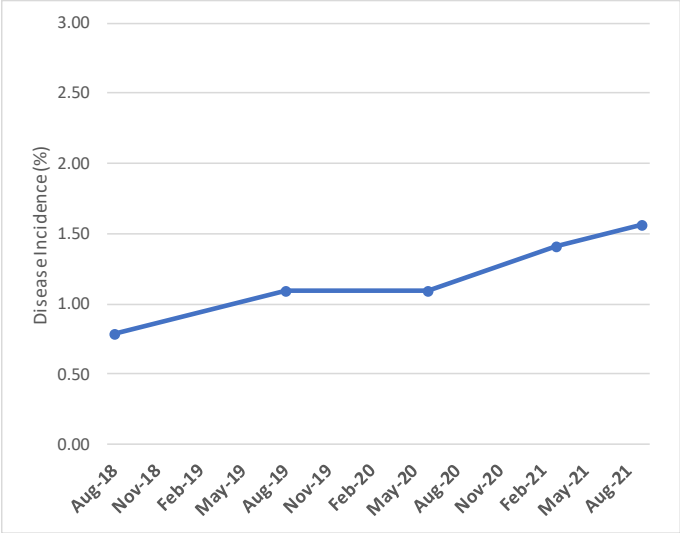

Figure 4. Disease incidence of root rot diseases caused by *Ganoderma* spp. at Pardiyan arboretum, Universitas Gadjah Mada, Yogyakarta, Indonesia.

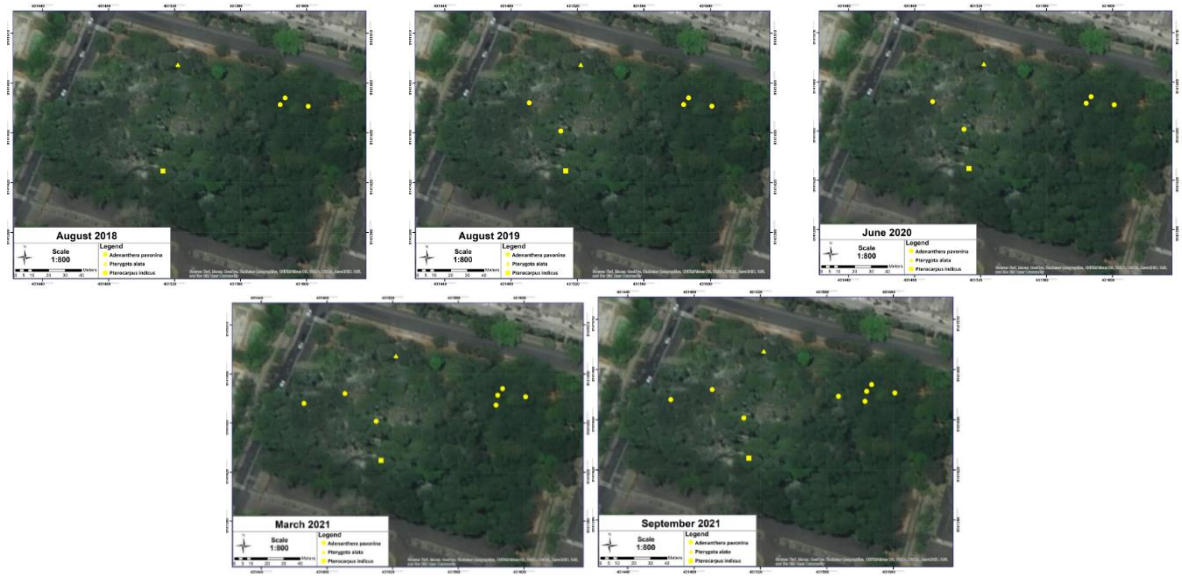

Figure 5. The distribution of trees attacked by *Ganoderma* spp. in August 2018, August 2019, Jene 2020, March 2021 and September 2021 at Arboretum Pardiyan, Universitas Gadjah Mada, Yogyakarta, Indonesia.

Based on Nearest Neighbors Analyses, the general spatial pattern of trees associated with Ganoderma infection in the arboretum was random from 2018 to 2021 (figure 5). However, based on our ground check observations, there was a spot within trees infected tends to form a clustered pattern, particularly from March 2021 to September 2021. According to [15], *Ganoderma* spp., as a soil-borne pathogen, could spread in three ways, i.e., plant roots contact with *Ganoderma* spp. inoculum sources, through the air with basidiospore, and through secondary inoculums in the form of oil palm stumps, litterfall, and other debris as alternative hosts. The arboretum is grown with dense vegetation and shrubs in between. The humidity that is maintained throughout the year, particularly in the rainy season, is suitable for Ganoderma to have a long-term host. The fact that the plant is able to get infected by Ganoderma through roots in the soil by vegetative spread [16] and cell penetrations by spores [17] cemented the arboretum as a suitable place for the Ganoderma to grow and spread.

Nevertheless, since Ganoderma could spread through the root contacts, we can predict the next potentially infected trees based on spatial and temporal monitoring. According to [18], Ganoderma can survive in roots for decades after the infected tree has died. Accordingly, the dead tree and the stump and root removal from the arboretum were needed to reduce the inoculum of Ganoderma fungus. However, the trees with a severity index of less than 30%, with a small number of basidiocarp, still have a survival chance with the addition of physical or chemical treatment. In general, regular monitoring of the Ganoderma existing at Arboretum Pardiyan is needed in order to early detect the infected trees and for further early health care recommendations.

4. Conclusions

Based on the monitoring of Ganoderma fungus in Arboretum Pardiyan Universitas Gadjah Mada, from August 2018 to September 2021, it was found that Ganoderma spp. were attacks *Pterygota alata* (1 tree), *Pterocarpus indicus* (1 tree), and *Adenanthera pavonina* (8 trees), with a disease severity index ranged from 25% to 100% in September 2021. The incidence of Ganoderma infection and the number of infected trees from 2018 (5 trees, 0.78%) to 2021 (10 trees, 1.57%) were low, and the spatial pattern of trees associated with Ganoderma was random. However, the high tree density within the arboretum makes the potential Ganoderma spreading through root contacts also higher. Regular monitoring for early detection was strongly needed in order to prevent further infection, which could take more damages and casualties to the arboretum. Moreover, health care management and recommendations with high scientific value also need to be established.

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