The relationship of some characteristics of peat with oil palm basal stem rot (BSR) caused by *Ganoderma* in peatlands

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**Abstract.** Indonesia as the largest palm oil producer in the world, has the large percentage of oil palm on peatland, always associated with the issue of global warming that has triggered climate change. The serious problems of cultivating oil palm on peatland is the presence of BSR disease caused by *Ganoderma*. There are no effective methods to control this disease. Biological control is an environmentally friendly alternative method focus, but on peatland, the development of this method is constrained by lack of information about the effect of peat environmental factors. This study aims to determine the effect of the characteristics and biological environment of peat on the intensity of *Ganoderma* attacks on oil palm. The relationship between the intensity of *Ganoderma* attacks, characteristics of peat, and biological properties of peat was carried out by correlation test. The correlation analysis showed that the groundwater level and the pH has correlated with *Ganoderma* attacks. While the biological properties showed no significant correlation, except Summed Dominant Ratio of vegetation which tends to positively correlate to the number of *Ganoderma* antagonists. These results indicate that peatland water table management and vegetation management by maintaining the diversity of vegetation around oil palm can help reduce *Ganoderma* attacks.

**1. Introduction**

Oil palm (*Elaeis guineensis* Jacq.) is the most important and most productive vegetable oil producing crop in the world [1]. Indonesia has the largest percentage of on peatland oil palm plantations, i.e., 14.58% (equivalent to 2.04 million ha) of 14.03 million ha [2]. Poor management of oil palm plantations on peatlands is currently in the global spotlight because it is believed to be one of the causes of global warming that has triggered climate change. The disadvantages of on peatlands oil palm plantations is the high number of leaned palm trunk due to peat subsidence [3] and low carrying capacity [4], and severe micro nutrients deficiency, especially Cu, which is thought to be a predisposing factors to the emergence of basal stem rot disease (BSR) caused by *Ganoderma* fungus [5,6].

*Ganoderma* is the most devastating oil palm plantations pathogen [7] because it caused death and difficult to control [8]. BSR disease becomes a serious problem on peatlands because of higher intensity [9] and appears earlier (8 years) than those on mineral land [8]. Until now, there is no effective methods to control BSR disease on peatlands. The result of several methods that have been developed are still vary and only able to be slowing the rate of infection or prolonging the productive period of palms [9,10]. Biological control has developed become the focus of *Ganoderma* control methods [11], but in
peatlands, the development of this methods is constrained by peatland characteristics that are different from mineral soils.

So far, biological control of BSR research has not been carried out on peatland. One of the obstacles to the development of BSR biological control in peatlands is the limited information about the influence of environmental factors and their interactions, especially the physical and biological environment of peat on BSR biological control. Some of the factors that influence biological control are pH, soil humidity, soil atmospheric condition, and the deposition of organic matter in the soil [12]. The relationship of all these factors in influencing the development of BSR disease caused by *Ganoderma* on oil palm on peatlands has not been widely reported. This study aimed to determine the relationship and influence of some peat characteristics and peat biological environment on the intensity of *Ganoderma* attack on oil palm on peatlands.

2. Material and methods

2.1. Observation of peat pH and water table level

The study was conducted in the oil palm plantation of PT. Bumi Pratama Khatulistiwa (PT. BPK) in Kuburaya Regency, West Kalimantan Province, that all whose plantations area is on peatlands. Peat pH measured following the Notohadiprawiro [13] method. The pH value of peat is measured by mixing 2.5 ml of fresh field peat with 4 ml of 0.01 M CaCl$_2$ solution and allowed to stand for at least 1 hour, and the pH is measured. The water table level is measured in around the sampling site using the simple standpipe piezometer method.

2.2. Observation of dominant vegetation

Dominant vegetation is determined by calculating the summed dominance ratio (SDR) following the Janiya and Moody [14] method with the following formula:

$$ SDR = \frac{\text{relative density} + \text{relative dry weight}}{2} $$

Where:

$$ \text{Relative density} = \frac{\text{density of a given species}}{\text{total density}} \times 100 $$

$$ \text{Relative dry weight} = \frac{\text{dry weight of a given species}}{\text{total dry weight}} \times 100 $$

2.3. Observation of the percentage of antagonistic fungi and bacteria

The percentage of antagonistic fungi is calculated by comparing the number of fungi that are antagonistic to *Ganoderma* with the amount of all fungi that have been successfully isolated from peatlands in the sample block. The same method is used to determine the percentage of antagonistic bacteria. Isolation is carried out by dilution methods. Each isolated fungi and bacteria were tested against *Ganoderma* in a dual culture. Fungi and bacteria are categorized as antagonists if the inhibition ability is at least 65% for fungi, and 60% for bacteria. The dominance index of fungi and bacteria was calculated following the formula [15].

$$ C = \sum_{i=1}^{n} p_i^2 = \sum_{i=1}^{n} \left( \frac{n_i}{N} \right)^2 $$

Where:

- $C$ = dominance index,
- $n_i$ = number of individual species 1,
- $N$ = total number of individuals

2.4. Observation of the type and intensity of *Ganoderma* attacks

Observation is carried out by census on sample plots of palm population on peatlands. Disease intensity are determined based on the number of palms that showed BSR disease symptoms compared to the total palm population in each sample block. The determination of the type of attack of *Ganoderma* follows
the criteria of Rakib et al. [16] with modification (Table 1). Attack were divided into two types, namely the basal stem rot (BSR) and the upper stem rot (USR). BSR when the stem rot or basidiocarp exist not more than 100 cm from the ground, otherwise was called USR. The distribution of Ganoderma attack patterns was determined using the nearest neighbour analysis [17,18] between infected palms. The calculation and presentation of the distribution pattern image is performed using the ArcMap ArcGIS 10.6 Program. The intensity of Ganoderma attack was determined by following Table 2.

### Table 1. Category of the BSR disease in oil palm [16].

| Symptoms |
|-----------|
| Having palm tree with no BSR disease symptoms: | Healthy palm |
| - three unopened emerging young leaves (spears) | Moderate |
| - yellowing leaves along with a wide range of necrosis, | |
| - older leaves fractured, | |
| - emerging fruiting bodies, | |
| - rotting in basal stem; | |
| Having more than one of the BSR disease symptoms, does not produce new fruits | Severe |
| - The oil palm tree dies, or all leaves wilt/turn yellow and accompanied by the appearance of the Ganoderma fruiting body | Dead palm |

### 3. Results and discussion

#### 3.1. Characteristics of peat and distribution of BSR disease on oil palm on peatlands

### Table 2. Characteristics of peatlands and intensity of the Ganoderma attacks in 10 observation blocks.

| Block/Ganoderma attack intensity category | Year of planting | Ganoderma attack intensity | Proportion of BSR/USR | Peat water table level | pH of peat |
|-----------------------------------------|-----------------|---------------------------|----------------------|-----------------------|------------|
|                                        |                 |                           |                      | 0-15 cm               | 50-60 cm   |
| Severe                                 |                 |                           |                      |                       |            |
| 12A                                     | 1996            | 69.81                     | 6.5/1                | 0.8                   | 2.4        | 2.2       |
| 13A                                     | 1997            | 50.17                     | 9.23/1               | 0.85                  | 2.9        | 2.3       |
| 13E                                     | 1997            | 49.75                     | 2.45/1               | 0.55                  | 2.9        | 2.4       |
| F1 Pls I                               | 2000            | 53.02                     | 3.9/1                | 0.9                   | 2.6        | 2.3       |
| Moderate                               |                 |                           |                      |                       |            |
| B3 Pls III                             | 2002            | 27.40                     | 5.25/1               | 0.7                   | 3.1        | 2.9       |
| C5 Pls III                             | 2003            | 29.54                     | 6.91/1               | 0.83                  | 3.4        | 2.8       |
| B4 Pls I                               | 2002            | 20.50                     | 4.25/1               | 0.6                   | 3.0        | 2.6       |
| A1 Pls I                               | 2002            | 24.74                     | 11.8/1               | 0.6                   | 3.0        | 2.3       |
| Mild                                   |                 |                           |                      |                       |            |
| E2 Pls III                             | 2004            | 4.62                      | 1.75/1               | 0.4                   | 2.9        | 2.8       |
| E4 Pls III                             | 2004            | 10.74                     | 5.19/1               | 0.45                  | 3.3        | 2.2       |

Based on the nearest neighbour analysis, the spread of Ganoderma attack patterns through BSR and USR tends to be clustered. Similar results have been reported by Kamu et al. [18] in which the epidemic did not occur randomly but occurred in a cluster which indicates a contagious disease from palm to palm through the roots. This is different from the findings by Rakib et al. [9] and Azahar et al. [19] where the distribution patterns of Ganoderma attacks both BSR and USR occur randomly which describe the spread of Ganoderma occurring primarily through basidiospores. This further reinforces the notion that the spread of Ganoderma in peatlands occurs through two distribution types and has an equally
important role, through basidiospores and through root contact. In this case, since BSR emergence is higher, the main spread is through root contact. The distribution of the *Ganoderma* attack pattern is shown in Figure 1.

![Figure 1. Distribution patterns of Ganoderma attack on peatlands.](image)

3.2. Relationship between peat characteristics and *Ganoderma* attack intensity

There are two characteristics of peat that affect *Ganoderma* attacks on peatlands, that is peat water table and peat pH at a depth of 0-15 cm (Table 4). The average peat water table level is positively correlated with the level of *Ganoderma* attack. These results are like the study by Susanto et al. [20] in North Sumatra peatlands, which concluded that field that was often flooded would tend to have a lower BSR *Ganoderma* attack. Huan and Wahidin [5] also got the result that the highest *Ganoderma* infection was found in field that had excessive drainage so that the water table level exceeded 75 cm. This is likely related to the influence of water table level on the aerobic activity of *Ganoderma* in the soil. The deeper surface of the water table will cause more space with good aeration, giving better support for the growth of *Ganoderma*.

**Table 3.** Results of correlation analysis of peat characteristics with the level of *Ganoderma* attack.

| Environmental characteristics | Pearson correlation; p value |
|------------------------------|------------------------------|
| Palm age                     | 0.916**; 0.00                |
| Peat water table             | 0.728*; 0.017                |
| 0-15 cm peat depth pH        | -0.701*; 0.024               |
| 50-60 cm peat depth pH       | -0.488; 0.152                |
| SDR of vegetation            | -0.268; 0.455                |
| Dominance Index of antagonistic bacteria at depth 50-60 cm | -0.286; 0.424 |
| Dominance Index of antagonistic bacteria at depth 0-15 cm | 0.134; 0.713 |
| % of antagonistic bacteria    | 0.013; 0.973                 |
| Dominance Index of antagonistic fungi at depth 50-60 cm | -0.327; 0.356 |
| Dominance Index of antagonistic fungi at depth 0-15 cm | -0.026; 0.942 |
| % of antagonistic fungi       | -0.034; 0.927                |

**. Correlation is significant at the 0.05 level.
**. Correlation is significant at the 0.01 level.
The degree of peat pH at a depth of 0-15 cm has a negative correlation with the level of *Ganoderma* attack, but the pH at a depth of 50-60 cm does not affect *Ganoderma* attack intensity and *Ganoderma* attack pattern. *Ganoderma boninense* has an optimal growth range at pH 3.7 to pH 5 [21]. Peat pH values at depths of 0-15 cm in the study area ranged from 2.4 to 3.4, thus this is not an ideal pH for *Ganoderma*. However, the high incidence of *Ganoderma* attacks at the study site is likely caused by three situations. First, *Ganoderma* in peatlands has adapted to the environment so that despite various limitations, it is still able to survive and attack palms. Secondly, *Ganoderma* attack on oil palm is also related to palm conditions, especially those related to the adequacy of micronutrients such as Cu and Zn. Research also revealed that *Ganoderma* attack on oil palm is also related to the nutrient deficiency conditions of Cu and Zn which are common in peatlands [6]. Very low peat pH conditions will limit the uptake of limited amounts of micronutrients in the peatlands so that plants suffer from Cu and Zn deficiency, making plants more susceptible to *Ganoderma*. Third, *Ganoderma* is a facultative parasitic fungus that can survive as a saprophyte but can turn into parasites and attack plants when it finds a suitable host [22]. In an environmental situation with a pH of 2.4 to 3.4, all organic matter as a food substrate is in conditions that are less suitable for *Ganoderma*, then the presence of oil palm which is one of the preferred host plants without the presence of other plants, is the most possible alternative to be used by *Ganoderma*.

Palm age was positively correlated with *Ganoderma* attack intensity. This fact is easily understood because it is related to the development of the *Ganoderma* colonization process on the field that are accumulative, especially on peatlands which contain abundant organic material. In addition, the development of *Ganoderma* infection is also going on slowly [23] so that the disease symptoms will be seen when it is severe and requires a long time. This causes most the disease symptoms can be seen when the age of the oil palm was old. The phenomenon of the higher incidence of *Ganoderma* attack on the next generation of oil palm [24] is basically due to the accumulation of *Ganoderma* inoculum in the field.

### 3.3. Relationship of peat biological characteristics with the level of *Ganoderma* attack

The results of fungi and bacteria isolation from 10 blocks of oil palm samples on peatlands in this study showed that the total fungal population at a depth of 0-15 cm ranged from $1.1 \times 10^4$ to $9.1 \times 10^4$ and the bacterial population ranged from $3.1 \times 10^4$ to $9.7 \times 10^4$. These results indicate that the population of microorganisms in the field is slightly lower compared to the population of microorganisms in undisturbed soil which generally ranges from $10^5$ to $10^6$ for fungi [25] and $10^5$ to $10^6$ for bacteria [26]. This is normal because commonly microbiological population of field under constant disturbance will be lower than that of undisturbed soil. Field with extreme environmental conditions such as low pH will also have a different microbiological composition compared to mineral soil which has a more suitable environment [26]. Similar results have also been reported in Malaysia [27] where microorganism population on oil palm field on peat land is also lower than those on mineral soil.

Based on the Pearson correlation analysis, there are no correlation between the biological characteristics of peat with the intensity of the *Ganoderma* attack on oil palm. The absence of such correlation is eventuality occur mainly due to extreme peat environmental factors, which is mainly due to the very low pH. This is consistent with the results of the total population of microorganisms that have been isolated from peat soil which is lower than common soil environment. The low pH will cause biological control cannot work [28], and various other biological activities in the soil do not proceed as it should [12,29]. Studies on the activities of microorganisms in acidic environments, especially under the peatland environment relating to biological control, are currently still limited and require further study.

Further analysis examining the relationship between the biological characteristics of peat and fungal and bacterial populations also did not correlate. Interesting results were found in the negative correlation between SDR of vegetation ($r$ = -0.641) with the number of *Ganoderma* antagonist fungi at a depth of 0-15 cm (Table 3). The SDR value of vegetation shows the level of vegetation diversity at a location. The higher SDR value of vegetation indicates the more uniformity of vegetation [14]. Vegetation affects
microorganisms in the soil probably through the control of solar radiation, temperature, and humidity in the field [30]. These results indicate that the level of diversity of vegetation populations on peatlands also influences the number of Ganoderma antagonistic species on oil palm field. These results illustrate that maintaining the diversity of vegetation populations around oil palm can increase antagonistic fungal diversity for Ganoderma.

4. Conclusion
The intensity of Ganoderma attack on peatlands in the study area is influenced by the water table level, peat pH at a depth of 0-15 cm and oil palm age. However, the intensity of Ganoderma attack was not influenced by the biological characteristics of peat. Only SDR of vegetation has influenced the number of Ganoderma antagonist species. The results of this study indicate that management of peat water table levels, management of peat pH and vegetation management in order to remain the diversity, can provide more favourable conditions in managing of oil palm stem rot disease caused by Ganoderma in Peatlands. Further research is needed to answer the question why the peat biological factors did not correlate with the intensity of Ganoderma attacks and peat biological factors did not correlate with the peat water table level and peat pH.

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