Ganoderma stem rot disease mapping and the chemical and biological characters of endemic lands

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Abstract. Basal stem rot disease caused by Ganoderma is threatening the palm oil industry. Information on the distribution of Ganoderma in the land is an important aspect to maintain oil palm production by a replanting activity. This study aimed to determine the distribution of the disease in the areas and characterized the chemical and biological properties of the soil. The research was conducted at Laras field, PTPN IV, Simalungun, North Sumatera, with a covered area of 200 Ha that consists of 13 blocks. The disease mapping was carried out by observing Ganoderma disease symptoms incidence of each area. The soil samples were analyzed for the content of C-organic, Cu, and pH. The total bacterial and fungal populations such as N-fixing and P-solubilizing bacteria were also analyzed from the soil samples. The results showed that areas with low disease incidence were blocks 94A, 94B, and 94C which covering of 55 Ha. In these blocks, consecutively the remaining healthy stands were 47, 48, and 53 trees from 130 trees per ha. The organic matter content in the soil of the blocks ranged from 0.7-1.3% (<2%), ranging from 1.2-4.4% for Cu, 10⁷cfu/g soil for the total bacterial population, and 10⁴colony/g soil for the fungi.

Keywords: field, distribution, soil-borne disease, pathogen, oil palm

1. Introduction

The biggest loss that causes a decrease in oil palm productivity today is the occurrence of basal stem rot disease (BSR) caused by the pathogenic fungus Ganoderma boninense (Basidiomycetes; Ganodermataceae). Losses due to Ganoderma infection can occur in nurseries, productive plants, and old plants. BSR caused reducing tree population by up to 40% [1], while mild infection can reduce the number and weight of oil palm fruit fresh bunches.

The fungus G. boninense belongs to the phylum Basidiomycota, Order Aphyllophorales, and the family Ganodermataceae formerly Polyporaceae, the genus Ganoderma was first reported by Karsten in 1881 as Polyporus lucidus [2]. Ganoderma boninense is a soil-borne pathogen, however, its spores can be spread by wind, water, and even insect carriers. Ganoderma disease is known to be systemic and monocyclic [3]. The morphology of G. boninense basidiocarp is highly variable; with stalks or not, grow horizontally or vertically, flat or swollen, and some are concentric circles. The basidiocarp of G. boninense was initially a small white hump which later developed into a thick fan-like disc (console bracket-like) [4]. The lower surface of the basidiocarp is pale white, has a pore layer which is the site of the formation of basidium and basidiospores [5].
The development of *Ganoderma* disease is closely related to the distribution of the disease, symptoms that occur in the plant, the chemical nutrient content, and the abundance of soil microorganisms. The purpose of this study is to determine the distribution of the disease and the chemical and biological properties of the soil characteristic.

2. Material and method

2.1. Plant health mapping

Plant mapping is a plant health census activity to determine the spread of *Ganoderma* attacks as a basis data to solve plant protection problems. Several parameters were observed visually, including plant condition (live or dead), plant health (healthy), disease attack rate (mild, severe, or acute), in dead condition (plant stump is still present, plant stump is no longer visible). The plant health categorization refers to the criteria plant damage level [1](Table 1).

| Color  | Status Code | Description                                                                 |
|--------|-------------|-----------------------------------------------------------------------------|
| Green  | H           | Plants are healthy or have no BSR symptoms and no *Ganoderma* activities occur. |
| Yellow | K           | The plant was attacked mild by *Ganoderma* but still produces Fresh Fruit Bunches (FFB) well. |
| Red    | M           | Plants were acutely diseased, shown by symptoms or signs of BSR disease which can be seen at the base of the trunk and on the canopy. |
| Black  | B           | Dead plants that the only bole leaving                                      |
| White  | P           | Dead plants that nothing part leaving                                       |
| Greenlight | L | Living insertion tree                                                      |
| Orange | D           | Dead insertion tree                                                        |

2.2. Leaf and soil nutrient analysis

Leaf samples were collected to found nutrient content such as Nitrogen (N), Phosphor (P), Kalium (K), and micronutrient Cu. The analysis methods were carried using the Kjeldahl method for N content, Bray method for P content, HCl extraction method for K content (25% HCl extraction), and DTPA, diethylene triamine penta acetic acid method for Cu content which was referred to [6].

Samples were collected from the thirteenth blocks in Afdeling 1 Laras field PTPN 4. Each sample was taken from 5 sampling points of oil palm trees (Figure 1) that represented the block. For the soil sample, 65 samples were collected from 13 blocks, meanwhile, for the leaf sample, one sample was collected from each block taken from the center of blocks. So that 13 leaves samples were obtained from the study. Method for soil and leaf sampling [7].

![Figure 1](https://example.com/figure1.png)

*Figure 1.* The five soil samples position represented block and the leaf sample that is taken from the tree in the center of the block at Afdeling 1 Laras field.
All the 65 soil samples were then composited. The 5 soil samples of each palm were composited into 3 soil samples. Soil samples at points 1 (northeast) and 2 (southeast) were composited (coded number 1), soil samples at point 3 (central) were not composited (coded number 2), while the soil samples from sampling points 4 (northwest) and 5 (southwest) were composited (coded with number 3) so that the total soil samples were 39. Soil nutrient analysis was carried out to know N, P, K, and Cu content [6].

Calculating the microorganism population method of 13 blocks of soil samples was carried out using the plate count method of serial dilution soil suspension. Furthermore, bacterial suspension was planted on NA medium, PDA medium for total fungi, Nitrogen free broth medium was used for nitrogen-fixing bacteria selection, and P solubilizing bacteria were grown on Pikovskaya medium [8,9].

3. Result and discussion

3.1. Plant health mapping

The results of the census from the 13 observed blocks showed that blocks with the largest number of healthy plants to the smallest were block T (1997), block O (1997), block A (1997), block P (1997), block K (1997), block C (1994), block U (1997), block Y (1997), block J (1997), block F (1997), block B (1994), Block A (1994), and block E (1997) respectively. The number of healthy plants in block T was 1371 trees, while block E has 667 trees of healthy plants (Table 2).

The blocks with the number of diseased trees that are still producing from the largest to smallest are block B (1994), block C (1994), block A (1994), block F (1997), block T (1997), block U (1997), block E (1997), block P (1997), block Y (1997), block K (1997), block J (1997), block O (1997), and block A (1997) respectively. The number of diseased trees in block B (1994) was 267 trees, while in block A 72 diseased trees can still produce FFB.

Blocks with an acutely diseased tree from the largest to smallest are block C (1994), block A (1994), block B (1994), block J (1997), block U (1997), block F (1997), block K (1997), block P (1997), block Y (1997), block O (1997), block T (1997), block A (1997) and block E (1997) respectively. The number of acutely diseased trees in block C (1994) was 114 trees, while the number of the acutely diseased in block E (1997) was 5 trees.

Blocks with living insertions sequentially from largest to smallest are block E (1997), block Y (1997), block K (1997), block F (1997), block P (1997), block A (1997), block T (1997), block J (1997), block B (1994), block C (1994), block A (1994), block U (1997), block O (1997). Block E had the most 511 living insertion trees, it was the highest. Block O was the smallest which had 16 living insertion trees.

Blocks with the number of dead plants, that nothing part leaving from highest to lowest respectively were block C (1994), block B (1994), block A (1994), block A (1997), block Y (1997), block T (1997), and block K (1997). Blocks with the number of dead plants, that only bole leaving (code B) sequentially from the most to the least are Block J (1997), Block O (1997), Block U (1997), Block F (1997), block B (1994), block K (1997), block C (1994), block P (1997), block T (1997), block A (1994), block Y (1997), block A (1994), and block E (1997). The dead plant's numbers of block J were 599, while block E was 126.

Based on the tree census, the number of plants acutely diseased, dead plants that nothing part leaving and dead plants that the only bole leaving in block A (1994), block B (1994), and block C (1994) is higher than the number of healthy plants (Table 3). In addition, the number of plants attacks acutely diseased, dead plants that nothing part leaving and dead plants that the only bole leaving (Code G) in block C (1994), block B (1994), and block A (1994) were 1273; 1183; 936 trees respectively. The data also show that the ratio of healthy plants to diseased and dead plants (Code G) sequentially from the largest to the smallest is block C (1994), block A (1994), and block B (1994) with a value of 0.9, 0.8, 0.7. Accumulation of acutely diseased plants, dead plants that nothing part leaving and dead plants that the only bole leaving in block represented the real
losses for the afdeling.

Table 2. The number of the health status of oil palm trees in each code

| Planting Year | Blocks   | Code |
|---------------|----------|------|
|               |          | H    | K   | M   | B   | P   | L   | D   |
| 1997          | Block A  | 1233 | 72  | 11  | 127 | 66  | 212 | 0   |
| 1997          | Block E  | 677  | 191 | 5   | 126 | 0   | 511 | 23  |
| 1997          | Block F  | 1029 | 210 | 30  | 351 | 0   | 330 | 0   |
| 1997          | Block J  | 1106 | 166 | 44  | 599 | 0   | 143 | 0   |
| 1997          | Block K  | 1157 | 168 | 25  | 283 | 2   | 339 | 0   |
| 1997          | Block O  | 1302 | 129 | 21  | 590 | 0   | 16  | 0   |
| 1997          | Block P  | 1191 | 185 | 22  | 273 | 0   | 302 | 1   |
| 1997          | Block T  | 1371 | 207 | 19  | 266 | 3   | 185 | 2   |
| 1997          | Block U  | 1123 | 203 | 37  | 541 | 0   | 40  | 0   |
| 1997          | Block Y  | 1110 | 177 | 22  | 232 | 32  | 394 | 4   |
| 1994          | Block A  | 755  | 228 | 95  | 246 | 595 | 68  | 0   |
| 1994          | Block B  | 873  | 267 | 92  | 306 | 785 | 118 | 0   |
| 1994          | Block C  | 1124 | 248 | 114 | 274 | 885 | 71  | 0   |

Notes: H: plants are healthy or no BSR symptoms and no Ganoderma activities occur; K: plant attacked mild by Ganoderma but still produce Fresh Fruit Bunches (FFB) well; M: plants were acutely diseased, shown by symptoms or signs of BSR disease which can be seen at the base of the trunk and on the canopy; B: dead plants that the only bole leaving; P: dead plants that nothing part leaving; L: living insertion tree; D: dead insertion tree.

On endemic land, we can conclude that the distribution of the plant disease was spread evenly (Figure 2). Almost in all Blocks, the distribution of the BSR disease especially Blocks A (1994), B (1994), C (1994) were spread evenly. It was in contrast to the land which wasn’t categorized as endemic land that was usually in a sporadic model (the figure wasn’t shown). The mapping technique was more emphasis on assessing the health status of plants based on the individual number of plant categories [1]. It is helpful particularly for the farmer to determine the decision of replanting and doing good agricultural practices activity.
Figure 2. Mapping result on Block J which were described healthy code status of plant such status B in black color for dead plants that the only bole leaving, M in red color for plants were acutely diseased, L in green light color for living insertion tree, K in yellow color for Sick plant but still can produce EFB, and H in green color for healthy plants. Health criteria of palm-based on [1].
Table 3. The number of each status of palm in Block of Laras Field.

| Plant Year | Block | Healthy Plants (H) | Plant acutely diseased, dead plants that the only bole leaving and dead plants that nothing part leaving (G)* | Ratio H: G |
|------------|-------|--------------------|-------------------------------------------------------------------------------------------------|-----------|
| 1997       | Block P | 1191               | 296                                                                                             | 4.023649  |
| 1997       | Block Y | 1110               | 290                                                                                             | 3.827586  |
| 1997       | Block U | 1123               | 578                                                                                             | 1.942907  |
| 1997       | Block T | 1371               | 290                                                                                             | 4.727586  |
| 1997       | Block O | 1302               | 611                                                                                             | 2.130933  |
| 1997       | Block J | 1106               | 643                                                                                             | 1.720062  |
| 1997       | Block K | 1157               | 310                                                                                             | 3.732258  |
| 1997       | Block F | 1029               | 381                                                                                             | 2.700787  |
| 1997       | Block E | 677                | 154                                                                                             | 4.396104  |
| 1997       | Block A | 1233               | 204                                                                                             | 6.044118  |
| 1994       | Block A | 755                | 936                                                                                             | 0.806624  |
| 1994       | Block B | 873                | 1183                                                                                           | 0.737954  |
| 1994       | Block C | 1124               | 1273                                                                                           | 0.882954  |

*G was code for the accumulative number of plants acutely diseased, dead plants that the only bole leaving and dead plants that nothing part leaving (M+B+D) by Ganoderma

3.2. Leaf and Soil Nutrient Analysis

Soil analysis shows that the soil in Laras has a pH value of 4-5. The soil with these acidity values is still categorized as good criteria, with moderate land suitability criteria (S2). The criteria for land suitability (LS) are S2, capable of supporting the productivity of oil palm plantations of up to 19-24 tons of FFB/ha/year. Data has shown Block E (1997) has the highest soil acidity value of 4.26 while block A (1994) was the lowest soil acidity value with an acidity value of 4.7. The condition of the high incidence of Ganoderma disease in the Laras field was thought to be due to the low pH value of the soil (Figure 3). Soil acidity (soil pH) decreases with the continuous application of chemical fertilizers over a long time [10]. The decrease in the acidity value (pH) of the soil will be beneficial for the development of pathogens, especially fungi. Low soil pH can support the germination of pathogenic fungi [11]. Conditions of low soil acidity (soil pH) pathogens were more infective than those with high soil pH [12]. However, the results of the correlation analysis showed that the distribution of soil pH which tended to be low in the 1997 planting blocks in the Laras field was negatively correlated with the incidence of disease. These results indicate that low soil pH does not always correlate with high disease incidence [11]. It might be pH may not only be one factor that determines the incidence of Basal stem rot disease caused by the soil-borne pathogen Ganoderma sp.
The level of the organic matter content of Laras is low (C-organic < 2%). The data shows that the C-organic content in the Laras soil samples ranged from 0.76% (block Y, 1997) to 1.386% (block F, 1997) (Figure 5). This value is below the standard value of organic matter content in agricultural soil, which is 4-5%. If left unchecked, the land will harm the soil, resulting in a decrease in soil support, a decrease in the efficiency of nutrient absorption, and a decrease in the number and activity of beneficial microbes in the soil. The addition of organic matter in the Laras fields will improve the physical, chemical, and biological properties of the soil which in turn can increase soil resistance to the growth of soil-borne pathogenic fungi.

Moreover, the addition of organic matter with high N content has the potential to suppress soil-borne pathogens through the release of decomposition products (allelochemicals) [13]. Organic matter also stimulates the development of beneficial microorganisms. The role of organic matter in suppressing the development of pathogens is not only by increasing the activity of beneficial soil microorganisms but also by improving root health which makes plants more resistant to disease [14]. One of the reasons for the high incidence of disease in the Laras field is thought to be due to the low organic matter contained in the land.

Figure 3. Soil pH level compared to BSR disease incidence in Afdeling 1 Laras field.

Figure 4. Soil organic content compared to BSR disease incidence in Afdeling 1 Laras field.
The content of copper (Cu) ranged from 3.386 ppm (block E, 1997) to 12.26 ppm (block Y, 1997), soil Cu content in the normal range was 2.0 - 10.0 ppm, while excess Cu content was > 11 ppm [15]. Excess soil Cu nutrient content was obtained from the analysis of soil nutrient blocks T (1997) (11.528 ppm) and block Y (1997) (12.26 ppm). The abundance of Cu nutrients is thought to be closely related to the incidence of BSR disease. Nutrient Cu is a cofactor for the enzyme laccase produced by the fungus *Ganoderma* sp.[16] This result is in line with what was reported by [17] that supplementation in the form of Cu (Cu2+) was able to increase the activity of the ligninolytic enzyme laccase produced by white-rot fungi. *Ganoderma* sp. belongs to white-rot fungi. This result seems to be in line with what happened in Laras, mainly there is a positive correlation between soil Cu nutrient content and disease incidence (Figure 4).

The average results of the nutrient analysis of oil palm leaves showed a tendency for nitrogen deficiency in block K (1997) with a value of 2.286% while the normal standard was more than 2.3 - 2.8% [15]. Meanwhile, the results of the analysis of the P nutrient content in the oil palm leaves of the Laras field showed the optimum conditions. The value of phosphorus (P) nutrient content of oil palm leaves in the Laras field ranged from 0.152% (block U and Y, 1997) to 0.196% (block P, 1997). The optimum condition of phosphorus nutrient content in oil palm leaves with the planting year 1997 was 0.15-0.18%. The nutrient content of Potassium (K) in oil palm leaves of Laras field ranged from 0.998% (block T, 1997) to 1.656% (block E, 1997). Based on the results of the analysis, the potassium nutrient content in the leaves of oil palm plants is at optimum conditions. The optimum concentration of potassium in oil palm leaves is 0.90%-1.20% [15].

3.3. Microbial Diversity Analysis

Soil is the main organizer of terrestrial ecosystems. Soil minerals, organic components, and soil microorganisms cannot be classified as separate parts of the soil constituent components but as a unified system that continuously maintains interaction and unity with one another in the terrestrial environment. Soil fertility and health will affect the fertility and health of plants.

Soil that has been degraded is not able to provide optimal support for plant development compared to soil that is not degraded. The results of the analysis of the diversity of soil microbes showed that the content of soil microorganisms in Laras, both classified as bacteria or as fungi,
was not different from the soil in general name in the range of $10^7$ for bacteria and $10^4$ for fungi.

The interesting thing is that although the cultured fungus population is normal, it has low diversity. In Block A (1994), microscopic analysis shows that there are 2 types of fungi, namely *Penicillium* sp. and *Rhizopus* sp. (Table 5). The highest amount of diversity was found in block 97Y as many as 4 types of fungi from different genera, namely *Trichoderma* sp., *Penicillium* sp., *Absidia* sp., and *unidentified hyphae*.

The results of the analysis of the activity of bacteria that play a role in the nutrient cycle show low activity of N fixing and P solubilizion for free leaving N fixing bacteria and P solubilizing bacteria. These results showed that in the endemic soil of *Ganoderma*, the populations of both fungi and bacteria were normal but the diversity was low as well as the activity.

### Table 4. Microbial Diversity Analysis

| Blocks | Total Bacteria | N fixing microbes | P Solubilizing bacteria | Total Fungi | Type of fungi            |
|--------|----------------|-------------------|-------------------------|-------------|--------------------------|
| 94A    | $14 \times 10^7$ | +                 | -                       | $16 \times 10^4$ | *Penicillium* sp.; *Rhizopus* sp. |
| 94B    | $18 \times 10^7$ | -                 | -                       | $8 \times 10^4$  | *Trichoderma* sp.; *Penicillium* sp. |
| 94C    | $15 \times 10^7$ | -                 | -                       | $16 \times 10^4$ | *Penicillium* sp.; *Acremonium butyri*; *Trichoderma* sp. |
| 1997A  | $17 \times 10^7$ | -                 | +                       | $15 \times 10^4$ | *Trichoderma* sp.; *Penicillium* sp.; *Rhizopus* sp.; aggregation hyphae |
| 1997E  | $21 \times 10^7$ | +                 | +                       | $12 \times 10^4$ | *Penicillium* sp.; *Rhizopus* sp aggregation hyphae |
| 1997F  | $9 \times 10^7$  | +                 | -                       | $15 \times 10^4$ | *Trichoderma* sp.; *Penicillium* sp.; *Mucor* sp. |
| 1997J  | $11 \times 10^7$ | -                 | +                       | $15 \times 10^4$ | *Penicillium* sp.; *Rhizopus* sp. |
| 1997K  | $21 \times 10^7$ | +                 | +                       | $12 \times 10^4$ | *Penicillium* sp.; *kumpulan hifa (bti)* |
| 1997O  | $13 \times 10^7$ | +                 | -                       | $11 \times 10^4$ | *Rhizophus* sp.; *Trichoderma harzianum* |
| 1997P  | $17 \times 10^7$ | -                 | -                       | $12 \times 10^4$ | *Unknown hyphae*, *Aspergillus* sp. |
| 1997T  | $19 \times 10^7$ | +                 | +                       | $14 \times 10^4$ | *Penicillium* sp.; *Rhizopus* sp., *unknown hyphae* |
| 1997U  | $9 \times 10^7$  | -                 | +                       | $13 \times 10^4$ | *Aspergillus* sp.; *Rhizopus* sp., *Penicillium* sp. |
| 1997Y  | $18 \times 10^7$ | +                 | -                       | $24 \times 10^4$ | *Trichoderma* sp.; *Penicillium* sp.; *Absidia* sp.; *unknown hyphae* |

### 4. Conclusion

The results of the census of 13 blocks showed that in Block 1994 A, Block 1994 B, and Block 1994 C, the number of plants acutely diseased, dead plants that the only bole leaving and dead plants that nothing part leaving was much greater than the number of healthy plants. The mapping technique would adopt by the farmer. Analysis of soil chemical properties showed that Laras soil reacted acid with low C content, but sufficient N, P, K, and Cu content. The low pH and C content are thought to be one of the triggers for *Ganoderma* attacks. Analysis of the biological properties of the soil, especially the microbial population, showed that the population was not different from the microbial population in the soil in general, however, the microbial diversity in the *Ganoderma* sp infested soil was lower than in the non-*Ganoderma* infested soil.

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