Chemical and biological characteristics of selected wet soil in oil palm plantation attack with *Ganoderma* sp.

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**Abstract.** The expansion of oil palm plantation requires the use of suboptimal land such as peat soil. *Ganoderma* as soil born pathogen is the most important pathogen in palm oil cultivation. The objective of the study was to reveal the characteristics of chemical and biological characteristics of wet soil on land with mild and severe *Ganoderma* attack. The study was conducted in three oil palm estates with wet soil at two levels attack of *Ganoderma* sp. Palm oil is the first-generation plant and the previous habitat was a forest. The soil samples were taken from three principal plants and each staple, taken from four sample points, namely harvesting path, inter-row, around the stem, and the ground near the base of the stem. The soil samples were analyzed for the nutrient status of N, P, K, Mg, Cu and C by standard methods and soil biology characteristics such as total bacteria, total fungi, cellulolytic fungi, and *Azotobacter*. The results showed that there was a correlation between soil nutrient status of K and Mg with *Ganoderma* sp. attack on all of the plantation tested. While for Cu and C, there was a correlation between soil nutrient status and *Ganoderma* attack in 3 plantations only. The least correlation is between N and *Ganoderma* sp. While the correlation between total bacteria with *Ganoderma* sp. was most common although very low.

1. **Introduction**

Various soil management practice such as in balance of chemical fertilizer doses application and no addition of organic fertilizer supposed increase the incidence of basal stem rot disease caused by *Ganoderma* sp. The use of chemical fertilizers for many years and there is no practice of returning biomass to the soil, in turn, leads to disruption of the biotic soil communities. This imbalance, impacts on the decreasing of some soil properties and one of this suppressed soil microbial communities controlling soil borne pathogens such as *Ganoderma* sp., a fungus that causes major diseases in oil palm.

The soil can be said to be a major terrestrial ecosystem organizer. Soil minerals, organic components and soil microorganisms cannot be classified as separate parts of the constituent components of the soil but as a single unit that continuously maintains interaction and unity of one another in the terrestrial environment. The interaction of soil system components can affect the number of soil microbes, the global ionic cycle of soils, global climate change, biodiversity, biological
production and nutrients for humans derived from nature. In general, land/land degradation is defined as a decrease in the value of soil/function of the soil as a result of the decreasing of important elements of soil constituents or also as a decrease in potential/usefulness and decreased the ability to support the soil ecosystem [1]. This leads to a decrease in biomass production as well as the ability of water and air plant management [2]. Soil degradation is divided into 3 types of degradation processes namely physical degradation, chemical degradation, and biological degradation. Degradation of the soil will physically affect the structure of the soil, the ability of the soil to absorb water and air, and resistance to destruction by the flow of water and air. Soil chemical degradation affects soil acidity (pH), decreases availability and ease of use of nutrients for plants, the ability to destroy toxins for other organisms, and decreases the excessive increase of salt levels in plant root zones. Biological degradation affects the availability of soil organic carbon (SOC), the diversity of soil biota species and increases the population of soil pathogens [3].

The results showed that the main problem of wetland is bad aeration and anaerobe condition that does not support the development of plant roots. Restructuring of wetland can be done with application of empty fruit bunches oil palm which can be combined with soil trenching making so it is expected to improve the characteristics of the land include improvement of water conservation, plant roots so as to increase nutrient uptake, and wet soil aeration.

This paper aims to reveal the correlation between soil characteristics of both biological and chemical and the *Ganoderma* sp. attack. The results of this study, expected to know the relationship of soil character with *Ganoderma* as a fungus with soil as a growing habitat. In the future, it is hoped that improvement of soil character could be used as one technique in controlling BSR disease caused by *Ganoderma* sp.

2. Materials and Methods

The research was conducted by taking samples from four gardens i.e. Mamuang, Pasang Kayu, Letawa and LTT (Table 1).

| Estate     | Block | Year plant | Area (ha) | Yield | *Ganoderma* level attack (%) | Classification |
|------------|-------|------------|-----------|-------|------------------------------|----------------|
| Mamuang    | A13   | 1997       | 29.99     | 29.17 | 0.0060                       | Low            |
|            | K7    | 1996       | 38.95     | 25.72 | 0.0070                       | Low            |
|            | G14   | 1995       | 07.77     | 35.00 | 0.0400                       | Severe         |
|            | G15   | 1997       | 39.09     | 24.40 | 0.0300                       | Severe         |
| Pasang Kayu| C21   | 2002       | 20.93     | 17.04 | 0.0000                       | Low            |
|            | E16   | 2002       | 37.62     | 22.04 | 0.0700                       | Low            |
|            | E8    | 1996       | 39.73     | 26.86 | 1.2200                       | Severe         |
|            | E5    | 1998       | 41.17     | 24.39 | 1.4500                       | Severe         |
| Letawa     | F15   | 1999       | 44.00     | 23.84 | 0.0022                       | Low            |
|            | L5    | 2000       | 34.88     | 26.26 | 0.0094                       | Low            |
|            | L3    | 1998       | 31.46     | 23.62 | 0.0250                       | Severe         |
|            | L9    | 1995       | 31.22     | 21.23 | 0.0330                       | Severe         |
2.1. Analysis of soil and palm oil plant tissue

Leaf and soil nutrient and microbial diversity analysis were conducted to find out the general description of plant nutrient status with *Ganoderma* attack. The soil sampling for nutrient and microbial analysis is taken from 3 points in 1 block consisting of the 1st point (main point), the 2nd point is the 6th lane from the main point (towards the West), and the point 3 is the 12th line from the main point (towards the South). The sample is taken from a healthy tree and not located on the edge of the area. At each point, 4 soil samples were taken from harvesting path, inter-row, around the stem, and the ground near the base of the stem. Then all four samples were composite to be one sample. Soil sampling is taken by using bamboo. The depth of soil taken is 20 cm from the soil surface and the weight of samples taken is 500 g. Microbial analyses included total fungi, cellulolytic fungi, bacteria, N-fixing bacteria (*Azotobacter* sp.), while the nutrients analyzed included C, N, P, K, Mg, and Cu. Leaf samples were taken from the same location as the soil in the form of 5 pieces of the leaves the right and left after the sweet spines. The leaf nutrients analyzed was N, P, K, and Cu.

3. Results and Discussion

3.1. Analysis of soil and palm oil plant tissue

3.1.1. Chemical characteristics of soil

The correlation of chemical properties of soil in Mamuang gardens with *Ganoderma* sp. attack are presented in Table 2. The results of chemical analysis or chemical characteristics are not distinguished between sampling sites i.e. base, circle, and “harvesting path”. The carbon content in Mamuang soil is highly correlated with *Ganoderma* sp. The higher the carbon content the lower the attack rate of *Ganoderma* sp. This result can be understood because by increasing the carbon content of the population of heterotrophs and especially the antagonist’s microbe to *Ganoderma* sp. and suppress the activity and development of *Ganoderma* sp. However, it is suspected that the form of carbon compound is more correlated with the attack rate of *Ganoderma* sp. compared with the total carbon compounds. Qudsai *et al* [4] showed that there is positively and significantly correlated between pathogen with soil organic matter and nitrogen content. Kanwal *et al* [5] showed that in the rice-wheat cropping system, number of saprophytic fungi colonies and the total number of fungal colonies were significantly and negatively correlated with organic matter and N, but positively correlated with EC and K, respectively. Correlation between a number of colonies of pathogenic fungi and other soil characteristics was insignificant.

A high correlation was also found between K$_2$O content and *Ganoderma* sp. To some extent, K content will decrease *Ganoderma* attack but in certain content will increase *Ganoderma* sp. attack. The low content of K will increase pathogenic infection both obligate and facultative. Potassium is a macronutrient that plants need for membrane permeability. A high correlation was also found between MgO content and *Ganoderma* sp. The equation describing the relationship between the two is the quadratic which means the higher the MgO the higher the attack *Ganoderma* sp. Marschner [6] suggests that Mg is a macronutrient needed by plants as a chlorophyll component.

A high correlation was also found between Cu content and *Ganoderma* sp. from the equation, the relationship between the Cu content and the attack rate of *Ganoderma* sp. shown that the higher soil Cu content will be followed by increasing attacks of *Ganoderma* sp. Cu is a cofactor for laccase enzyme [7] secrete by *Ganoderma* sp. that belong to the white-rot Basidiozymes. This possibility is related to laccase activity of *Ganoderma* sp. Nevertheless, the linkage of the Cu content of soil with an attack rate of *Ganoderma* sp. needs to be tested further.

The correlation analysis of some soil chemical properties in the Pasang Kayu shows that there is a high correlation between Carbon, K$_2$O, MgO and Cu with the attack rate of *Ganoderma* sp. (Table 3). The high correlation of K$_2$O, MgO and Cu with the attack rate of *Ganoderma* sp. seems to be the same as those found in Mamuang and Letawa.
Table 2. Correlation of soil chemical characteristics and *Ganoderma* sp. attack of Mamuang estate.

| Variable parameter | Functional equation            | Coefficient determination R² |
|--------------------|--------------------------------|------------------------------|
| N total            | Y=-1.543x²+2.5x+1.364          | 0.474                        |
| C total            | Y=-0.036x+2.674                | 0.972                        |
| K₂O total          | Y=-556x²+88.14x-1.329          | 0.911                        |
| P₂O₅ total         | Y=-6.59x²-0.034x+1.854         | 0.156                        |
| MgO total          | Y=-0.538x²+1.951x-0.260        | 0.982                        |
| Cu                 | Y=0.059x+0.116                 | 0.820                        |

Table 3. Correlation of soil chemical characteristics and *Ganoderma* sp. attack of Pasang Kayu.

| Soil character | Equation                                     | R²   |
|---------------|----------------------------------------------|------|
| N total       | Y=1.519x²-2.134x+1.925                       | 0.129|
| C total       | Y=-0.001x²+0.098x+0.324                      | 0.999|
| K₂O total     | Y=267.1x²-44.53x+2.813                       | 0.870|
| P₂O₅ total    | Y=11.18x²-12.61x+3.225                       | 0.505|
| MgO total     | Y=0.847x²-2.144x+2.274                       | 0.975|
| Cu            | Y=0.001x²-0.117x+3.295                       | 0.944|

Analysis of soil carbon content, N, K, Mg and Cu of Letawa showed a fairly high correlation with *Ganoderma* sp. (Table 4). The equation which illustrates the fourth correlation of the soil with *Ganoderma* sp attack is quadratic. These results indicate that at certain nutrient levels the four nutrients will reduce the attack *Ganoderma* sp.

Table 4. Correlation of soil chemical characteristics and *Ganoderma* sp. attack of Letawa.

| Soil characteristics | Equation                                     | R²   |
|----------------------|----------------------------------------------|------|
| N total              | Y=-5.135x²+6.297x+0.418                     | 0.827|
| C total              | Y=-0.011x²+0.355x+0.619                     | 0.846|
| K₂O total            | Y=-152.4x²+39.99x-0.24                      | 0.879|
| P₂O₅ total           | Y=136.1x²-7.207x+1.107                      | 0.460|
| MgO total            | Y=-2.3x²-3.301x+0.846                       | 0.984|
| Cu                   | Y=-0.0x²+0.055x+7.34                       | 0.985|

The results of the chemical analysis showed that the correlation between MgO, K₂O, N and P₂O₅ in LTT soil correlated with the attack rate of *Ganoderma* sp. (Table 5). The equation which illustrates the fourth correlation of the soil with *Ganoderma* sp. attack is quadratic. The high correlation of K₂O, N, P, and MgO with the attack rate of *Ganoderma* sp. seems to be the same as those found in PSK, Mamuang and Letawa.
Table 5. Correlation of soil chemical characteristics and *Ganoderma* sp. attack of LTT.

| Soil character | Equation                     | \(R^2\) |
|---------------|------------------------------|---------|
| N             | \(Y=-14.34x^2+10.9x+0.208\) | 0.887   |
| C             | \(Y=-0.003x^2-0.127x+2.225\) | 0.434   |
| K<sub>2</sub>O | \(Y=-36.41x^2+15.4x+0.404\)  | 0.909   |
| P<sub>2</sub>O<sub>5</sub> | \(Y=69.87x^2-32.03x+4.514\) | 0.790   |
| MgO total    | \(Y=0.41x^2+0.387x-0.88\)   | 0.985   |
| Cu           | \(Y=-0.033x^2+1.682x-19.36\) | 0.105   |

3.1.2. The characteristic of leaf nutrient content of palm

The analyses of leaf nutrient are presented in Table 6. It is shown that leaf nutrient content in all blocks did not show any association between intensity of *Ganoderma* sp. attack and leaf nutrient content. However, this is thought to be due to a very limited number of examples.

Leaf N content ranges between 2.43% (Pasang Kayu, heavy) - 3.13% (LTT, weight) and based on literature studies, the levels of N in this range are sufficient. Leaf P analysis showed a range between 0.19 (Mamuang, height) - 0.24% (Mamuang, low). The range of normal P content is between 0.3 - 0.5%. The result of P analysis shows that the leaf P content is below the normal or low range. Marschner (1986) suggested that P deficiency would cause hormonal imbalances, plant growth inhibition, chlorophyll content increase despite low photosynthetic efficiency. The leaf K content of the analysis also showed deficiency because the normal K content was in the range of 2 - 5%. In the analyzed samples the lowest content (0.78%) i.e. the leaves in Pasang Kayu with severe *Ganoderma* attack, while the highest content (1.91%) was leaves in LTT with severe *Ganoderma* attack too. The deficiency of K elements causes the plant to be easily infected with both obligate and facultative parasite fungi. This is because, at low K, the synthesis of high molecular weight organic compounds decreases and accumulates low molecular weight organic compounds.

| Estate        | Leaf nutrient content |
|---------------|-----------------------|
|               | Ganoderma attack (%)  | N (%) | P (%) | K (%) | Cu (ppm) |
| Mamuang       | Severe                | 2.66  | 0.21  | 0.96  | 3.60     |
| Mamuang       | Low                   | 2.68  | 0.24  | 1.49  | 4.10     |
| Mamuang       | Low                   | 2.66  | 0.22  | 0.96  | 2.60     |
| Mamuang       | Severe                | 2.50  | 0.19  | 1.02  | 4.50     |
| Pasang Kayu   | Low                   | 2.58  | 0.21  | 1.43  | 4.10     |
| Pasang Kayu   | Severe                | 2.43  | 0.20  | 0.78  | 4.90     |
| LTT           | Low                   | 2.72  | 0.21  | 1.25  | 8.80     |
| LTT           | Severe                | 3.13  | 0.24  | 1.91  | 8.70     |
| Letawa        | Low                   | 2.63  | 0.20  | 1.30  | 8.30     |
| Letawa        | Severe                | 2.87  | 0.22  | 1.45  | 9.40     |

The leaf content of Cu leaves is in the normal range, whereas for leaf samples from Mamuang, one deficient example (less than 3%) detected low *Ganoderma* attack. Nevertheless, leaf samples from LTT and Letawa have a higher Cu content above normal. Cu nutrient which is a micronutrient
function in the process of lignification of the cell wall of plants so that plants that have Cu deficiency cell wall damage, containing cellulose high while low lignin. However, this element is also a cofactor of the laccase enzyme, which is one of the enzymes possessed by *Ganoderma* that plays a role in the delignification of cell walls. However, the plant will interact with *Ganoderma* sp. and nutrient status will affect the anatomy and physiology of the host plant and the activity of *Ganoderma* sp. Management of plant nutrient status that supports plant growth but suppresses pathogenic activity is very important.

3.1.3. Characteristics of soil biology in experimental land

The result of correlation analysis between several microbial function and attack rate of *Ganoderma* sp. in Mamuang showed that the total fungi, total bacteria and population of *Azotobacter* had low correlation with *Ganoderma* sp. However, for the population of cellulolytic fungi showed a rather high correlation number that is 0.460. While Nuria *et al* [8] showed that manipulating the soil microorganism community leading to suppress the disease.

Similar results were also found in the soil of Letawa which is only total bacteria that have the highest correlation with *Ganoderma* attack that is 0.493. This result is the same as the soil sample in LTT but the correction is 0.370. In contrast to Mamuang, Letawa and LTT, the correlation between total bacteria and soil fungi Pasang Kayu with *Ganoderma* sp. attacks i.e. 0.700 and 0.540 respectively. De Graaff *et al* [9] reported that there is a correlation between soil biodiversity and the soil C cycling process. It also highlights the importance of diversity across groups of organisms (e.g., primary consumers and secondary decomposers) for maintaining full functionality of C cycle processes. Moreover, the statistical analysis of the DGGE fingerprints showed that both plant age and genotypes influenced the bacterial community structure in the tuber rhizosphere [10].

3.1.4. The principal census of *Ganoderma* attacks on the ground.

Based on the criteria of the principal census of *Ganoderma* attacked the land, it was found that in Mamuang there were 8 palms with yellow status, 5 red, and 105 items with a green status. Data on Pasang Kayu, there was 15 palm trees with yellow status, 54 palm trees with red status and 88 green colours, whereas in Letawa there are 11 trees with yellow status, 51 trees with red status and 236 palm trees with a green status. The oil palm tree with white status in all land not found. With these data then the existence of *Ganoderma* sp. should be various. The observations with the highest number of attacks were found in the Pasang Kayu then Letawa and Mamuang. Based on previous field research results it is known that if in one hectare with planting density 130 trees there are 20 dead plants, then usually on the land 10 plants have been heavily infected, and 10 plants have been infected lightly. The productivity of 10 plants with a heavy infestation is up to 50%. The loss of one-hectare land production can be calculated by the formula \(\frac{[20 + (50\% \times 10)]}{130} \times 100\%\) equals 19.23% [9]. Thus, it is appropriate that the field of research is treated with preventive measures *Ganoderma* sp. by increasing the consortium of superior microbes such as *Trichoderma* sp., N fixing bacteria, bacterial solubilized phosphate, mycorrhiza and combination of them.

4. Conclusions

Research sites are mostly wet soils. Some soil nutrients correlate with *Ganoderma* attacks. The correlation between microbial populations with *Ganoderma* attacks is very low. The results of leaf nutrient analysis showed that P and K nutrient deficiency was present in all instances of oil palm leaf. While in the Letawa and LTT, the analyses showed that there is the excessive content of Cu leaf.

However, the data were only drawn from a limited number of samples taken from a very limited area and only from individual plants with two levels of *Ganoderma* sp. attack. i.e. light and heavy. Further analysis needs to be done to determine the nutrient status of individual plant samples associated with disease progression in individual plants of the same sample over time. In addition, it is necessary to examine the relationship of nutrient status in the garden with mild attack rate (less than 1%), moderate (about 5%), and weight (about 30%) in the wider area.
5. References

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