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Research Article

The Relationship Between Soil Fertility and Basal Stem Rot Disease in Oil Palm Plantations

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ABSTRACT

In oil palm, *Ganoderma boninense* causes stem rot disease, which is often difficult to control, and soil fertility status is related to the ecology of *G. boninense* as a soil-borne pathogen. Therefore, this study aims to evaluate the relationship between soil fertility and stem rot disease as well as appropriate management methods to control the disease. This was carried out at the Nusantara Plantation Company's 7, Unit Kiwah Rejosari-Pematang from June 2021 to January 2022. The determination of observation blocks was carried out selectively using three blocks of land attacked by *Ganoderma boninense* with the same criteria for the year of planting and the same soil type. Each block consists of five plots with a size of 50 x 50 m. Each plot consisted of five sub-plots measuring 10 x 10 m, consisting of 3 oil palms for disease severity assessment and soil sampling. The soil for each subplot was composed of 15 samples, which were analyzed for physical and chemical properties of the soil, including soil texture, pH, CEC, base saturation, C-organic, P_2O_5, and K_2O. Determination of fertility status is based on the soil research manual published by the Indonesian Bogor Soil Research Center with parameters from the analysis results. The limiting factor for fertility is the cation exchange capacity of the soil, which ranges from 10.07 meq/100 g to 17.68 meq/100 g, and the C-organic content, which ranges from 0.40 to 1.15%. According to chi-square analysis, this fertility-limiting factor is related to disease severity. Therefore, management needs to be done by adding organic matter to the soil, practicing organic or inorganic fertilization, and following the principles of cultivating healthy oil palm plants.

Keywords: Basal stem rot, soil physical chemistry, soil health

1. Introduction

Oil palm is the leading plantation commodity in Indonesia with an estimated area of 14,858.30 ha in 2020 (BPS 2021). Most of the plants are found in Sumatra and Kalimantan, while Papua and Sulawesi have the potential for oil palm development (Rianto 2010). Through this oil palm industry, the country becomes the world's largest vegetable oil producer supplying 61% of global production which accounts for 30% of its economic resources (Lam *et al.* 2019). According to Treu (1998), Semangun (1990), and Susanto *et al*. (2013a), the challenge in oil palm cultivation is *Ganoderma boninense* causing basal stem rot disease. Due to the attack by *G. boninense*, the standing trees per hectare in several oil palm plantations in Indonesia reach 50%-80% and a more severe fresh fruit bunch (FFB) loss is experienced (Subagio and Foster 2003; Susanto 2011), with economic losses of up to 67–73%

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(Kamu et al. 2021). Various controls, including biological agents, technical cultures, and resistant varieties (Susanto et al., 2005; Priwiratama et al., 2014a), have proven ineffective in controlling Ganoderma (Priwiratama et al., 2014b). *G. boninense* is difficult to be controlled because it has various resistant properties, such as being a good saprophyte (Susanto *et al*. 2005), and a soil-borne pathogen whose life cycle partly occurs in the soil (Nurhayati 2013).

Furthermore, *G. boninense* is transmitted to healthy plants through their root contact with an inoculum source in the soil. Therefore, an understanding of the soil ecology that affects pathogens ought to be the basis for controlling soil-borne pathogens (Bande *et al.* 2016). Plant nutrition influences disease resistance and susceptibility, as well as pathogens' ability to survive in hosts (Gupta et al. 2017). Because mineral elements play a role in plant protection, complete and balanced nutrition is the primary defense of plants (Tripathi et al. 2022). Nitrogen, potassium, and phosphorus are important macronutrients in plant resistance. Nitrogen is essential in many metabolic and physiological processes, including photosynthesis, amino acid synthesis, respiration, and the tricaroxylic acid cycle (Foyer et al., 2011). A high N supply can reduce the severity of infection in facultative parasitic pathogens such as Ganoderma (Dordas et al. 2008; Tripathi et al. 2022).

Meanwhile, plant resistance caused by potassium availability is related to the patterns and concentrations of the plant metabolites it affects (Marschener 2012). When there is an adequate supply of potassium, the concentration of phenol increases, while the concentration of low molecules such as organic acids, amino acids, and amides that play a role in disease development decreases (Prasad et al. 2010). Although no specific role of phosphorus (P) in plant disease resistance has been identified, high P content may increase plant susceptibility to pathogen. Similarly, micronutrients such as manganese, which can produce mitotoxins in pathogenic microorganisms, play a role in lignin biosynthesis and other metabolic functions (Tripathi et al. 2022). According to the description above, plant nutrients have an effect on increasing or decreasing plant diseases, so maintaining their availability in the soil is critical.

According to Harahap *et al.* (2020), soil fertility constraints in the Labuan Batu Oil Palm plantation are the organic matter content and base saturation, divided into low and very low categories, respectively. There is a correlation between soil fertility and plant diseases in bananas, for example, the severity of yellow sigatoka leaf spot disease is higher on land with low soil fertility (Freitas et al. 2015). Meanwhile, the fertility status of land infected with Ganoderma is not yet reported. Soil chemical properties have been stated to not affect the pathogen presence (Puspika and Pinem 2018), but physical properties such as sand percentage and soil moisture affect the spread and rate of infection (Susanto *et al.* 2013b; Utami *et al*. 2016; Puspika and Pinem 2018). Therefore, this research aims to to evaluate the relationship between soil fertility and basal stem rot disease as well as appropriate management methods to control the disease.

2. Material and Methods

This research was conducted at Perkebunan Nusantara 7 Company, Rejosari Unit-Pematang Kiwah, Lampung, and the Laboratory in the Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University from June 2021 to January 2022. The observation blocks were determined selectively on land affected by *G. boninense* with the same criteria for planting year and soil type. Plants in each block were censused visually by considering the symptoms of those infected. Disease incidence (DI) was then calculated by the formula: DI = (n / N) × 100%, where n = the number of affected plants and N = the total sample plants observed. Soil sampling and disease incidence assessment were carried out in the same block.

Each block was divided into five plots of a 50 × 50 m size comprising four at the corners and one in the middle, making a total of 15 observation plots as presented in Table 1. Furthermore, each plot was re-divided into five subplots measuring 10 × 10 m with the position of four subplots at the edge and one in the middle. Each subplot was made up of three oil palms. Each plant was evaluated for disease severity using the MPOB (2014) method, as shown in Table 2. Therefore, soil samples in a topsoil form with a depth of 10 – 20 cm were collected at three points from the disk of each of the three palm trees found in each subplot. After obtaining the samples from each plot, they were composited into a total of 15 and analyzed at the Laboratory of the Soil Science and Land Resources Department, Faculty of Agriculture, IPB University.

The samples were analyzed for physical and chemical properties including soil texture, namely sand, clay, and loam, using the pipette method. Moreover, the pH and total P_2O_5 (mg/100g) were determined using a pH meter with a soil-solvent ratio of 1:1 and 25% HCL extraction, respectively. Total K_2O and organic C were determined with 25% HCl extraction and using wet digestion and bichromatic acid according to the Walkley and

Black method. The CEC value was ascertained through saturation using 1 N ammonium acetate at pH 7.0, and base saturation (BS) was calculated by dividing the number of bases by the CEC multiplied by 100. The test data were then classified according to the soil value criteria provided by the Center for Soil Research (1995), as presented in Tables 3 and 4. Descriptive analysis was carried out based on the results of soil fertility status to determine the limiting factors and give recommendations for soil fertility management.

Table 1. Coordinate points of sampling in each observation block

No	Coordinat points	
	x	y
1	5°17'59.0"S	105°09'38.0"E
2	5°17'55.0"S	105°09'35.0"E
3	5°17'50.0"S	105°09'28.0"E
4	5°18'02.0"S	105°09'29.0"E
5	5°17'47.9"S	105°09'37.7"E
6	5°17'49.0"S	105°09'41.0"E
7	5°18'00.0"S	105°09'43.0"E
8	5°17'55.0"S	105°09'48.0"E
9	5°18'00.0"S	105°09'52.0"E
10	5°17'48.0"S	105°09'53.0"E
11	5°17'46.0"S	105°09'54.0"E
12	5°17'48.0"S	105°09'41.0"E
13	5°17'43.0"S	105°09'47.0"E
14	5°17'38.0"S	105°09'41.0"E
15	5°17'36.4"S	105°09'51.9"E

The severity of the disease was classified into three categories: mild (scores 1-2), moderate (score 3), and severe (scores 4-5). On the limiting factors of soil fertility, chi-square analysis was used to examine the relationship between the two qualitative variables (disease severity class and limiting factors of soil fertility). Limiting factors for soil fertility values are first classified into classes. The information is then organized into a contingency table, with disease incidence classes as columns and factors as rows. A significant correlation coefficient value indicates the presence of a correlation. Factors with a significant relationship according to the chi-square test ($P < 0.05$).

Table 2. Criteria for disease severity MPOB (2014)

Score	Description
0	There are no fruit bodies and signs of leaf and stem rot at the base
1	White mycelium or fruiting bodies are present (e.g., the form of small white buttons). There are no foliar symptoms, and there is little or no stem rot (10%) at the base.
2	White mycelium or fruiting bodies are present (e.g., a small white button shape or bracket shape). At the base, the oil palm displayed symptoms of leaf (50%) and slight stem rot (30%).
3	White mycelium or fruiting bodies are present (e.g., a small white button shape or bracket shape). At the base of oil palms, there is evidence of leaf rot (>50%) and stem rot (>30%).
4	White mycelium or fruiting bodies are present (e.g., a small white button shape or bracket shape). Symptoms include dead or collapsed palms.

Table 3. Criteria for assessing soil chemical properties based on Soil Research Center (1995)

Soil properties	Very low	Low	Moderate	High	Very High	Desc.
CEC (me/100 g)	<5	5-16	17-24	25-40	>40	
Base Saturation (%)	<20	20-35	36-50	51-70	>70	
Organic C (%)	<1,00	1,00-2,00	2,01-3,00	3,01-5,00	>5,00	
P_2O_5 (mg/100 g)	<10	10-20	21-40	41-60	>60	
K_2O (mg/ 100 g	<10	10-20	21-40	41-60	>60	
pH H_2O	Very acidic	Acidic	Rather acidic	Neutral	Rather alkaline	Alkaline
	<4,5	4,5-5,5	5,6-6,5	6,6-7,5	7,6-8,5	>8,5

Table 4. Criteria for determining soil fertility status based on Soil Research Center (1995)

No	CEC	Base Saturation	Organic C, P_2O_5, K_2O	Fertility Status
1	H	H	≥ 2 H without L	High
2	H	H	≥ 2 H with L	Moderate
3	H	H	≥ 2 M without L	High
4	H	H	≥ 2 M with L	Moderate
5	H	H	H > M > L	Moderate
6	H	H	≥ 2 L with H	Moderate
7	H	H	≥ 2 L with M	Low
8	H	M	≥ 2 H without L	High
9	H	M	≥ 2 H with L	Moderate
10	H	M	≥ 2 M	Moderate
11	H	M	Another combination	Low
12	H	R	≥ 2 H without L	Moderate
13	H	R	≥ 2 H with L	Low
14	H	R	Another combination	Low
15	M	L	≥ 2 H without L	Moderate
16	M	L	≥ 2 M without L	Moderate
17	M	L	Another combination	Low
18	M	M	≥ 2 H without L	Moderate
19	M	M	≥ 2 M without L	Moderate
20	M	M	Another combination	Low
21	M	L	3 H	Moderate
22	M	L	Another combination	Low
23	L	H	≥ 2 H without L	Moderate
24	L	H	≥ 2 H with L	Low
25	L	H	≥ 2 M without L	Moderate
26	L	H	Another combination	Low
27	L	M	≥ 2 H without L	Moderate
28	L	M	Another combination	Low
29	L	L	All combination	Low
30	VL	H/L/M	All combination	Very low

3. Result

3.1. Incidence of Basal Stem Rot (BSR) Disease

According to Table 5, the disease incidence in field observations showed different percentages in three locations, namely 10%, 41%, and 54%, respectively. The BSR symptoms discovered in the field ranged from mild attacks to dead trees. In the initial symptoms or mild attacks, the affected oil palm plants experienced symptoms in the form of an association of spear or young leaves not opening, as well as leaves that were pale yellowish, dull, and not shiny. Severe symptoms were characterized by basidiocarp appearance at the stem base which became porous and perforated, thereby causing the palm trees to fall as demonstrated in Figure 1.

Table 5. Incidence rate of BSR in oil palm at the study site

No Block	Disease Incidence (%)	Attack category
1	10	Mild (< 10%))
2	41	Moderate (11 – 50%)
3	54	Severe (>50%)

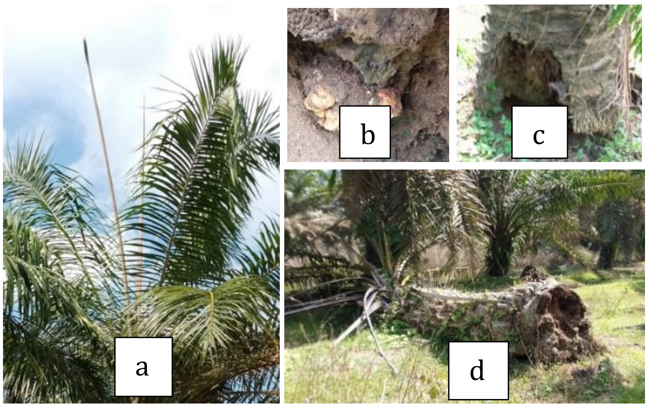

Figure 1. Variations in symptoms of basal stem rot disease, a) appearance of two or more spear, b) presence of fruiting body, c) stem rotting at the base, and d) palm dead/collapsed.

3.2. Soil Physical and Chemical Properties

The test results show that the oil palm area infected with Ganoderma is dominated by sandy loam texture, as presented in Table 6. Soil acidity consists of two criteria: slightly acidic and neutral with a pH range of 6.1–7.1, while the organic C content is at a low to very low level. with a range of 0.4%–1.2%. Low to moderate CEC values with a capacity of 10.1–17.7 me/100g, while low to very high base saturation is 36.3–96.3%. Total P2O5 has very low to very high phosphorus content, ranging from 18.5–171 mg/100g, and moderate to very high potassium content, ranging from 2.55–95.55 mg/100g.

3.3. Assessment of Soil Fertility Status

Table 6 shows that the infected oil palm areas had low fertility status based on the soil value criteria at all collection points. Low CEC (ranging from 10.07 meq/100 g to 17.68 meq/100 g) and low organic content (ranging from 0.40 to 1.15%) were the limiting factors for soil fertility.

Table 6. Physical and chemical properties of soil and soil fertility status in oil palm land

No	Texture	pH	CEC	BS	Total P_2O_5	Total K2O	C-organik	Fertility Status
1	Sandy clay loam	7.06 (N)	14.02 (L)	87.62 (VH)	9.3 (VL)	0.99 (VL)	0.65 (VL)	L
2	Sandy clay loam	6.32 (RA)	15.94 (L)	36.33 (L)	8.1 (VL)	0.97 (VL)	0.66 (VL)	L
3	Sandy clay loam	6.89 (N)	14.72 (L)	50.50 (M)	8.3 (VL)	1.21 (VL)	0.82 (VL)	L
4	Sandy clay loam	6.63 (N)	14.73 (L)	53.36 (M)	71.3 (VL)	1.20 (VL)	0.67 (VL)	L
5	Sandy clay loam	7.12 (N)	13.71 (L)	66.29 (H)	10.9 (VL)	1.41 (VL)	1.12 (L)	L
6	Sandy loam	7.05 (N)	10.07 (L)	96.15 (VH)	17.6 (L)	1.74 (VL)	0.65 (VL)	L
7	Clay laom	6.31 (RA)	17.25 (M)	45.20 (M)	12.8 (VL)	1.70 (VL)	0.57 (VL)	L
8	Clay laom	6.45 (RA)	14.70 (L)	58.60 (M)	91.7 (VH)	2.04 (VL)	0.74 (VL)	L
9	Sandy loam	6.86 (N)	11.83 (L)	78.13 (H)	73.3 (VH)	0.93 (VL)	0.57 (VL)	L
10	Sandy clay loam	6.62 (N)	12.75 (L)	79.76 (H)	54.1 (H)	1.41 (VL)	1.15 (L)	L
11	Sandy clay loam	6.74 (N)	10.70 (L)	75.68 (H)	74.8 (VH)	1.75 (VL)	0.40 (VL))	L
12	Sandy clay loam	6.56 (RA)	13.53 (L)	44.64 (M)	21.5 (M)	0.54 (VL)	0.74 (VL)	L
13	Sandy clay loam	6.48 (RA)	14.34 (L)	54.23 (M)	40.7 (H)	0.70 (VL)	0.90 (VL)	L
14	Sandy clay loam	6.56 (RA)	17.68 (M)	46.91 (M)	32.5 (M)	1.85 (VL)	0.74 (VL)	L
15	Sandy loam	6.48 (RA)	13.14 (L)	66.19 (H)	69.8 (VH)	1.95 (VL)	0.90 (VL)	L

4. Discussion

Due to the incidence of various diseases at the observation sites, soil fertility status needs to be determined. Priwiratama *et al.* (2014a) discovered that BSR incidence tends to increase continuously all through the year. Even in the treatment performed with hole-in-hole planting and the standard planting system 10 years after cultivating an oil palm land, a similar incidence occurred.

The soil texture in the cultivated land was dominated by sandy clay loam and sandy loam. The sand fraction content at the research site was higher than other soil fractions. Soils with a higher sand fraction permit easier water escape (Holilullah *et al.* 2015; Haridjaja *et al.* 2013). Susanto *et al.* (2013b) reported that the infection rate is high in sandy soils due to their physical properties of high porosity or loose soil nature, hence plant roots move more quickly to the source of Ganoderma inoculum. Furthermore, gardens adjacent to sandy soil conditions experience a high disease incidence (Salsabila *et al.* 2022).

Soil pH in oil palm fields varies from 6.13 to 7.12, which affects disease development and plant ability to resist pathogen attack (Sewards 2014). The influence of this parameter on *Ganoderma boninense* was reported by Chong *et al.* (2017). Soil pH has a significant positive effect on BSR, and pH 6 is the most effective in suppressing the development of this disease in nurseries (Rahman & Othman 2020). It can inhibit the Ganoderma transmission process in soil with a pH of 6. Furthermore, the root biomass will grow. This rise is due to an increase in soil microbial activity, which breaks down organic matter and allows plant nutrients to be absorbed (Alexander *et al.* 2019). Plant resistance to pathogens is eventually formed.

Soil texture with a high proportion of sand correlates with low organic C, according to Xia *et al.* (2021). The macropores dominate the high sand fraction, resulting in a low capacity to bind water and nutrients (Zulkoni et al. 2020). The C-organic content of oil palm infected with Ganoderma was found to be very low (0.4%-1.2%) in this study. Low cation exchange capacity can be caused by both low and high sand content. According to the CEC, this study showed a low level ranging from 10.7 me/100 g to 17.7 me/100 g, as shown in Table 6. Organic C and CEC are soil fertility limiting factors in oil palm plantations. Unlike other materials with moderate to high content. In the Chi square factor analysis presented in Table 7, the limiting factors for fertility in the form of organic C and CEC were shown to have a relationship with BPB disease severity. Low nutrient availability can make it difficult for soil microorganisms to survive (Smith et al. 2013). Furthermore, nutrient-deficient soil causes plants to lose resistance to pathogenic infections (Susanto et al. 2013b).

According to Husni et al. (2016), fertile soil has a base saturation of more than 80%, but similar values were only found in two plots of study locations, while saturation was 80% in the other plots. The BS of soil and pH have a positive relationship because the value increases proportionally (Suarjana et al. 2016). Because the availability of phosphorus in soil is affected by pH, soil organic matter, and soil texture (Hadi et al. 2014), the phosphorus content in this test ranged from low to very high levels in the range of 18.5-210 mg/100g. In contrast, total potassium levels in the test range from 25.5-91.4 mg/100g, indicating moderately to very highly elevated levels.

Improvement efforts are required due to the low fertility status, such as increasing the carbon content of the soil and improving its texture through the addition of organic matter. Applying 40 tons/ha of oil palm empty fruit bunches at least once a year can contribute to increasing the C-organic content in sandy soils (Darlita *et al.* 2017). The carbon cycle, nutrients, and soil pH also need the presence of organic matter (Wang *et al*. 2013). Besides organic matter addition, soil liming is used to overcome an acidic pH. According to Parulian *et al*. (2013), the addition of microorganisms increases soil fertility.

The BSR disease incidence caused by *Ganoderma* attack is greater in soil containing relatively poor nutrients. Therefore, the principles of healthy plant cultivation need to be applied to oil palm. These include 1) increasing soil fertility by adding organic fertilizer and dolomite lime to neutralize the soil from acidic pH and toxic compounds (Molle *et al*. 2021). 2) Returning plant residues such as empty bunches to facilitate organic matter addition (Darlita *et al*. 2017). 3) BSR control with preventive measures such as hole-in-hole planting systems, surgery, and backfilling accompanied by *Trichoderma* application (Priwiratama *et al*. 2014a).

5. Conclusion

The disease incidence in oil palm infected with Ganoderma ranges from 10% to 54%, and soil fertility in the fields is low. Low soil fertility in oil palm affects the development of stem rot disease. This is supported by the existence of a significant relationship between organic C and CEC and BPB disease severity. Recommendations for improvement are lime and organic fertilizer addition, return of crop residues, and preventive measures to control the pathogen.

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7. Declaration of Conflicting Interests

The authors have declared no potential conflicts of interest concerning the study, authorship, and/or publication of this article.

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