Revelation and Science
Special Issue: Plant Science 2 (1446H/2024) 62-71

Evaluation of Selected Soil Nutrient Availability and pH in Oil Palm Plantations: Assessing The Impact Of *Ganoderma* Disease in Chini, Pahang, Malaysia

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ABSTRACT

Oil palm management involves the usage of fertilizer to satisfy the oil palm's needs as a heavy nutrient feeder. Over time, fertilization and irrigation practices could have attracted pathogenic microorganisms and affect the soil nutrient availability. The present study has been conducted to evaluate the current soil status in the area of oil palm plantation in Chini, Pahang by assessing the soil pH, total organic carbon (TOC), and selected soil nutrient availabilities; potassium (K), magnesium (Mg), calcium (Ca), zinc (Zn), copper (Cu), and aluminium (Al). Sampling were conducted based on the oil palm according to severity of the *Ganoderma* disease incidence evaluated by the plantation authorities. The distribution of nutrient in the soil samples were analyzed using atomic absorption spectroscopy (AAS). From the results, the soil pH were mostly found as acidic, ranging from 3.6 to 6.2. The mean concentrations of the K, Ca, Mg were observed the highest in soils from category A, the healthiest category with least incidents of *Ganoderma*, and the mean concentrations of micronutrients (Zn, Cu, Mn, Al) varied between all soil categories. This initial study is crucial as a foundational study that sets the stage for understanding soil nutrients availability and pH status with the occurrence of *Ganoderma* species.

Keywords: Basal stem sot disease, soil fertility, disease control

ABSTRAK

Pengurusan tanaman kelapa sawit melibatkan penggunaan baja kimia bagi pertumbuhan optimum kelapa sawit. Amalan pembajaan dan pengairan yang berterusan menyebabkan pembiakan patogen dan menjejaskan ketersediaan nutrien tanah. Jesteru itu, kajian ini dijalankan untuk menilai status tanah semasa di kawasan ladang kelapa sawit di sekitar Chini, Pahang. Jumlah organik karbon (TOC), pH tanah, dan ketersediaan nutrien tanah seperti kalium (K), magnesium (Mg), kalsium (Ca), zink (Zn), kuprum (Cu), dan aluminium (Al) ditentukan di makmal. Persampelan tanah dijalankan mengikut peringkat penyakit Ganoderma yang telah dinilai oleh pihak pengurusan ladang. Taburan nutrien dalam sampel tanah dianalisa menggunakan spektroskopi serapan atom (AAS). Keputusan menunjukkan pH tanah adalah berasid, antara 3.6 hingga 6.2. Purata kepekatan K, Ca, Mg adalah paling tinggi dalam tanah kategori A, dengan insiden Ganoderma tahap rendah. Walaubagaimanapun, purata kepekatan mikronutrien (Zn, Cu, Mn, Al) didapati berbeza-beza antara kategori tanah. Kajian ini dapat digunakan untuk menilai keadaan tanah semasa sebagai garis asas untuk rujukan masa hadapan dalam memahami penyebaran Ganoderma.

Keywords: Penyakit busuk pangkal batang, kesuburan tanah, kawalan penyakit

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Introduction

The cultivation of oil palm (*Elaeis guineensis* Jacq.) in Malaysia plays a pivotal role in supporting the nation's economic stability, driven by its extensive plantations that align with the growing global demand for palm oil. However, the industry faces a major challenge from the soil-borne pathogenic fungus Ganoderma, which causes basal stem rot (BSR) disease. This disease results in significant economic losses, estimated at up to USD 500 million annually (Zakaria, 2022), and can reduce yields by as much as 43% within just six months (Khoo & Chong, 2023; Jazuli et al., 2021; Zakaria, 2022; Bharudin et al., 2022; Tajudin et al., 2016).

Failure to detect their early presence and delayed control measures will leave the oil palm infected, risking fatalities within six to two years (Jazuli et al., 2021). According to Tajudin et al. (2016), BSR damages the basal stem of the palm and it restricts the water and nutrients transportation to the upper parts of the plant. Factors such as palm age, soil type, nutrient status, and previous crop plantation were discovered to be associated with the incidence of BSR.

Fertilization and irrigation are fundamental practices in plantations, enhancing plant growth, development, and disease control by supplying essential nutrients. However, fertilizer application is a well-known contributor to soil acidification. This occurs due to the accumulation of hydrogen ions in the soil, which significantly lowers the pH after plants absorb nutrients from the fertilizer. Extreme soil acidity would impact the availability of plant nutrients as more acidic cations like zinc (Zn) and aluminium (Al) are made available in a low pH soil state instead of potassium (K), calcium (Ca), and magnesium (Mg). This would disrupt the species' physiological process as it depends on nutrients for its productivity and yield due to the toxic accumulation of acidic nutrients in the soil. Furthermore, in Malaysia the soil type that naturally occurs as oxisols and ultisols may have further degraded with the human activities in maintaining the oil palm plantation like harvesting, manuring, pruning, and weeding. The human management of oil palm is needed frequently to acquire an effectively managed oil palm field. This study was conducted to assess soil pH and total organic carbon (TOC) content in soils from healthy and Ganoderma-infected oil palm trees within a plantation in Chini, Pahang. Additionally, it aimed to evaluate the concentrations of selected macronutrients and micronutrients (Ca, Mg, K, Al, Cu, Mn, Zn) in these soils. The findings from this analysis are crucial for understanding the current soil quality in the plantation, particularly in the context of nutrient management practices aligned with the guidelines set by RSPO and MSPO certifications.

Methodology

Study Area and Soil Sampling

This study was carried out in selected oil palm plantations identified as being affected by BSR disease in Chini, Pahang (3° 22’ 40”N 102° 57’ 25”E) as in Figure 1. The study area were located approximately 70 km from Kuantan, the capital of Pahang. The area had been identified by the plantation management to have 30% oil palm that has been infected by *Ganoderma* disease.

Figure 1: The location of oil palm plantation in the area of Chini, Pahang. *(Source: Google Maps, 2024)*

A total of 24 samples were collected from the study plot. Samples were collected using a soil auger from the soil surface at depth of 1-20 cm at each identified oil palm and placed in labelled plastic bags. Soil samplings were done based on the severity level of the oil palm basal stem rot (BSR) diseases identified by the plantation authorities team as in Table 1.

Table 1: Classification of *Ganoderma* severity of oil palm in Chini plantation.

Category	Description
A	No infection: No fruiting body of *G. boninense*
B	Early infection/Mildly infected: Unhealthy canopy, unopened shoots, presence of frond skirting, no presence of white mycelium, no fruiting bodies, no rot on the stem or basal stem.
C	Moderately infected palm: Tree is still productive with bunch, presence of frond skirting and fruiting bodies.
D	Severely infected palm: Living trees, unopened shoots, unhealthy canopy, multiple frond skirting, not productive, fruiting bodies at the stem and rotting stem.
E	Very severely infected palm: Presence of fruiting bodies on stem and basal stem on living and dead fallen palms, presence of fruiting bodies.

Soil Sample Analysis

Soil pH, TOC and Exchangeable Nutrient

The collected samples were air dried at room temperature. Organic materials were removed and the samples were crushed and stored in a labelled universal bottle.

Measurement of soil pH were done using a 0.01 M calcium chloride ($CaCl_2$) solution with a 1:2.5 soil-to-solution ratio. Approximately 10 grams of air-dried soil and 25 mL of the $CaCl_2$ solution were mixed and stand for about 30 minutes to allow soil particles to interact with the solution fully. Then allowed the soil particles to settle. Clearer supernatant will provide more accurate pH measurements. The pH were then determined using a pH meter (Mettler Toledo, Switzerland) Measurement of TOC in soil sample were estimated using Wet-dichromate oxidation method, Walkley-Black procedure (Walkley and Black, 1934). The process involves wet oxidation of soil using a mixture of potassium dichromate ($K_2Cr_2O_7$) and sulfuric acid (H_2SO_4). For nutrients analysis, K, Ca, Mg, Al, Cu, Mn and Zn , these elements were extracted using Mehlich No III solution (Mehlich, 1984) and determined using atomic absorption spectroscopy (AAS). The extraction were performed by combining soil and Mehlich No. III solution at a 1:10 ratio, typically with 2 grams of soil to 20 mL of extractant. The mixture were then agitated to ensure complete contact between the extractant and soil particles, allowing the solution to react. Then, the mixture were filtered, and the filtrates were analysed using atomic absorption spectroscopy (AAS). This spectroscopic method detects each element by measuring the absorbance of light at specific wavelengths, providing precise quantification of nutrient concentration

Results And Discussion

Soil PH

Figure 2 shows the result of soil pH in the sample collected from Chini oil palm plantation. The pH value in this soil of the study area ranged between 3.59 and 6.20, indicating acidic category of soil. Soil samples from Category A recorded the highest pH with an average value of 5.1±0.76, and soils from Category E recorded the lowest pH value with an average of 4.2±0.71. In Malaysia, the average soil pH in the oil palm soil were around 4.3 and usually acidic (Mahmud and Chong, 2022). The acidic soil in oil palm plantations may result from the long-term application of fertilizers combined with the characteristics of tropical soils, which are highly weathered and subject to year-round rainfall (Behera et al., 2015; Manorama et al., 2021). Continuous application of chemical fertilizers, such as ammonium-based fertilizers, is known to decrease the soil pH in the long term through the nitrification process that releases hydrogen ions as an exchange for plant uptake of nitrate. This process is prone to cause the occurrence of nitrate leaching (Beeckman et al., 2018) which also increases the risk of soil acidification. (Bolan et al., 1991).

The lower soil pH collected from oil palms category E could be an indicator of high *Ganoderma* incidences. Studies have shown that disease can be flourish in soils that have lower pH (<6), leading to more of its incidence and severity (Goh et al., 2020), compared to the category A soil samples. Generally, fungi thrive the best in acidic medium, and pH 5.0-6.0 is an ideal pH for fungal growth. However, research conducted by Rousk et al. (2009) showed that the maximum fungi growth was observed even at pH 4.5. According to Khoo and Chong (2023), *G. boninense* can grow at pH 3 – 8.5 under ideal temperature of 30°C. They further discussed that pH 6 would be the ideal soil pH that could suppress the productivity *Ganoderma*. This could be related to the lower category of *Ganoderma* incidence in oil palm category A which have higher average of pH than the category E.

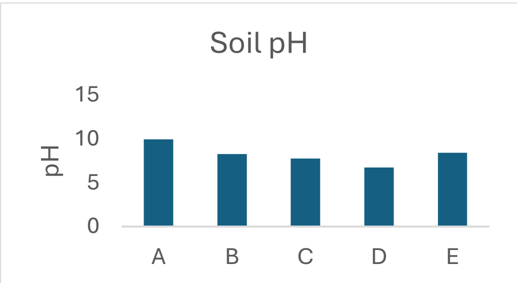

Figure 2: Distribution of soil pH in Chini oil palm plantation based on disease categories A, B, C, D and E

***Soil Total Organic Carbon* (TOC)**

Total organic carbon (TOC) in samples collected from Chini oil palm plantation were ranged from 0 to 2.94% (Figure 3). On average, soil samples from category D displayed the highest average of TOC with value of 1.7±1.02% , whereas the lowest average TOC was in observed in soil of category C 0.72±0.77%.

In soil, the organic carbon content is crucial for plant growth as it serves energy source besides regulating nutrient availability via mineralization. Soil TOC is beneficial as an indicator of the state of organic matter content in the soil since the organic carbon lies in the soil organic matter. A high soil TOC reflect higher soil organic matter, which is responsible for the presence of soil microorganisms such as fungi. This was also highlighted by Du et al. (2022), who observed an increased abundance of fungal phytopathogens, including *Monographella*, *Phoma* and *Volutella*, in conjunction with rising levels of soil organic carbon.

According to Liu et al. (2019), the regulation of soil microbial biomass depends on several driving factors, including soil TOC, total nitrogen, and water content. In our findings, the highest average soil TOC were recorded in category D.

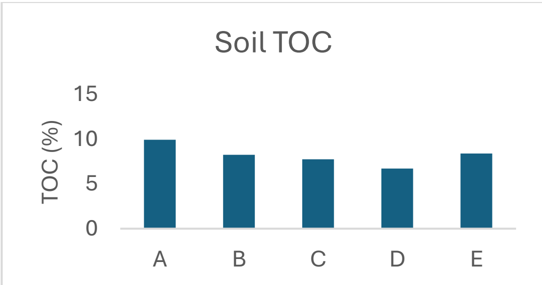

Figure 3: Percentage of soil TOC from Chini oil palm plantation based on disease categories A, B, C, D and E

Nutrient Analysis

Potassium (K)

Figure 4 illustrates the potassium (K) concentration in soil samples collected from Chini oil palm plantation. The highest average potassium content was recorded in category C with average concentration of 0.70 ±0.12 $cmol_{(c)}/kg$, while the lowest soil potassium content was recorded in category B with average of 0.3 ± 0.10 $cmol_{(c)}/kg$.

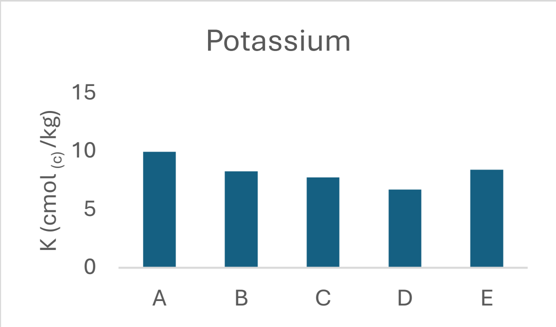

Figure 4: Concentration of potassium in soil samples from Chini oil palm plantation based on disease categories A, B, C, D and E

According to Joo et al. (1994), 0.25 $cmol_{(c)}/kg$ depicts a moderate potassium content. However, in this study, only soil samples from category B exhibited the potassium content nearest to moderate at 0.3 ± 0.10 $cmol_{(c)}/kg$. Other categories of soils showed a potassium content above 0.30 $cmol_{(c)}/kg$, surpassing the very high potassium level, which could indicate the chances of overfertilization in the plantation. Overfertilization is a prominent problem as farmers assume providing more fertilizer to plants would secure maximum crop production and quality (Stigter, 2010). Overfertilization can promote the growth of fungi as the soil carries more nutrients for their feed, supplied by the fertilizer (Yeoh et al., 2015). This suggests that in future, oil palms in category A could face the risk of BSR incidence such in categories B, C, D, and E.

Calcium (Ca)

Figure 5 depicts the content of calcium in the Chini oil palm plantation soil. The soils collected from category A showed the highest average of calcium concentration with 5.36 ±3.00 $cmol_{(c)}/kg$, while category E computed the least average of calcium content soil with 1.84 ± 2.33 $cmol_{(c)}/kg$ of calcium. The calcium content in the present study is within range of study conducted in soil of Parit Botak and Jawa series done by Goh et al. (2017) with value of 4.46 and 4.32 $cmol_{(c)}/kg$, respectively.

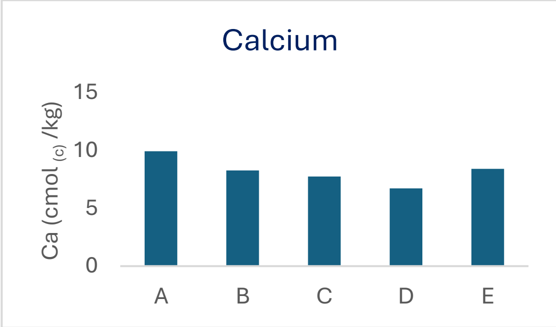

Figure 5: Concentration of calcium in soil samples from Chini oil palm plantation based on disease categories A, B, C, D and E

Calcium in soil were found higher than the potassium. The comparison between calcium and potassium content can be explained by the affinity of exchangeable potassium and potassium that follows the order: calcium > potassium. Calcium and potassium are reported to be antagonistic among each other (Nguyen et al., 2017; Rhodes et al., 2018). High availability of calcium in soils are capable of suppressing the uptake of potassium.

According to Tajudin et al. (2016), calcium deficiency could increase the risk of *Ganoderma* incidence through the fungi invasion of the xylem that occurred due to membrane leakage of low molecular weight compounds. Research by Ahmad Azmi et al. (2012) discussed that high calcium levels could decrease basal stem rot (BSR) infections. This statement aligns with the research findings for category A soils, which have high calcium content and could be the reason for the lower *Ganoderma* incidence category. Thus, it can be said that oil palms in category A soils were healthier with sufficient calcium content.

Magnesium (Mg)

The magnesium in soil of Chini oil palm plantation (Figure 6) were observed the highest in soils collected from category A of oil palm with an average of 1.14 ± 0.72 $cmol_{(c)}/kg$. Whilst, the soils collected from category E recorded the lowest average content with value of 0.42 ± 0.51 $cmol_{(c)}/kg$. The same trend as the calcium also can be observe, which soil from A category of oil palm had the highest average of magnesium content and category E demonstrated the lowest average of magnesium content. The presence of *Ganoderma* can alter the soil pH over time, potentially leading to more acidic conditions. This was observe in this study where soil of category E had the lowest pH value if 4.2. Basic cations including the magnesium availability tends to decrease in acidic soils, as it becomes less available. The presence of magnesium in plants is crucial as the element that can impact the pathogen invasion way into a plant by colonizing the plant phloem tissues, and its deficiency could reduce the energy production needed for defence functions that inactivate pathogen metabolites (Tripathi et al., 2022). Pathogens often exploit weak points in plants, and magnesium deficiency can create such vulnerabilities. When magnesium is lacking, the structural integrity of the phloem and other tissues may be compromised, making it easier for pathogens to infiltrate and colonize these areas. Thus, maintaining adequate magnesium levels in soil is essential not only for plant growth but also for effective disease resistance.

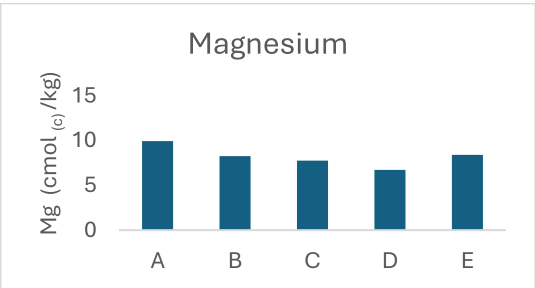

Figure 6: Concentration of magnesium in soil samples from Chini oil palm plantation based on the disease categories A, B, C, D and E

Zinc (Zn)

Figure 7 soils collected from oil palm category D had the highest zinc content, with an average of 19.61 ± 0.89 mg/kg, while category C soils had the least zinc content, with an average concentration of 13.98 ± 3.44 mg/kg.

The results were comparable to the zinc content in Parit Botak and Jawa, reported by Goh et al. (2017), ranging from 15.95 to 23.26 mg/kg. Both studies denoted their zinc content as high. The high zinc content in this study could be due to the mineralogical composition of parent material and their weathering factors, which are heterogeneous depending on geographical locations, climate, and other factors (Noulas et al., 2018). The zinc concentration in soil from the study site is still within the range of agricultural soils reported by Noulas et al. (2018) between 10 and 300 mg/kg.

According to Nandal and Solanki (2021), zinc is one of the essential micronutrients attributed to a lot of physiological functions, enzyme systems, antioxidant properties, cell membrane integrity and more. However, the beneficial effects of zinc are not the same for all plants since it may also create susceptibility in some plants. In plant, zinc can reduce the infection such as *Fusarium graminearum*, *Alternaria solani*, *Penicillium citrinum*, *Aspergillus flavus*,and *Phytophtora nicotianae* (Bastakoti, 2023). Zinc may be crucial in combatting *Ganoderma* as zinc is contain in molecular structure of antifungal compounds such as flavonoids and phenolic compounds that can harm pathogens when they exist (Karunarathna et al., 2024).

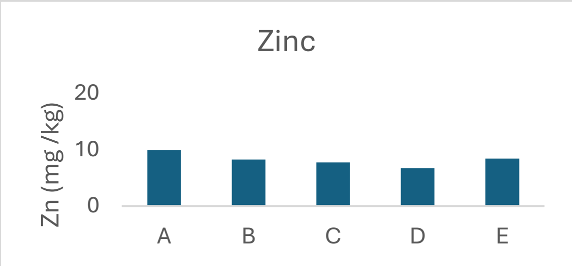

Figure 7: Concentration of zinc in soil samples from Chini oil palm plantation based on disease categories A, B, C, D and E

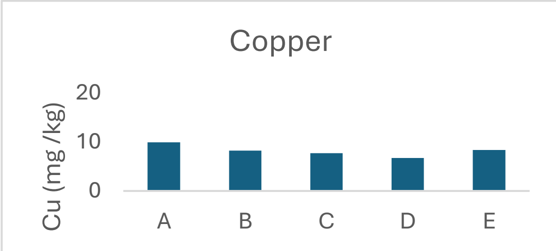

Figure 8: Concentration of copper in soil samples from Chini oil palm plantation based on disease categories A, B, C, D and E

Copper (Cu)

The highest copper content was recorded in category A of oil palm with copper average of 5.56 ± 0.67 mg/kg on average, and soils from category C had the lowest average of copper content with value of 1.84 ± 1.09 mg/kg. The copper content in soil from the Chini oil palm plantation were found lower than the study conducted by Goh et al. (2017) which ranged between 6.53 and 10.89 mg/kg, and Thompson-Morrison et al. (2022), which reported a copper concentration in an average of 20 mg/kg. Based on these comparisons, the soils of Chini oil palm plantation were observed to have lower value of soil copper content.

In plant defence mechanism, copper plays a role as a cofactor for peroxidase and laccase enzymes for lignin synthesis that will act as a barrier against the penetration of pathogen into plants (Rakib et al., 2017). Like zinc, copper is also related to the antifungal property through its ability to increase the content of phenolic compounds and flavonoids. Soils collected from oil palm categories B, C, D, and E had lower copper content compared to category A, which represents the healthiest oil palms. This suggests that reduced copper content may be linked to disease occurrences. Further studies are needed to confirm this relationship.

Aluminium (Al)

Figure 10 illustrated the aluminium distribution from oil palm soils in Chini. It is observed that the highest average of aluminium were of category A with value of 9.94 ± 2.47 cmol/kg, while category D recorded the lowest average of aluminium with a concentration of 6.72 ± 0.60. The obtained results were similar to the aluminium content in Parit Botak done by Goh et al. (2017), with an aluminium concentration of 8.34 cmol/kg. Goh et al. (2017) discussed that their aluminium content is considered high due to the jarosite oxidation in the soil. The study area was identified as having oxisols order-type soil. Oxisols in tropical regions often contain high levels of both exchangeable and non-exchangeable aluminum. Additionally, the acidic conditions contribute to the dissolution of aluminum-bearing minerals, such as feldspars and micas, which release aluminum ions into the soil solution. High aluminum concentration found in soil can be detrimental to oil palm trees, as aluminum toxicity can impair root development, reduce nutrient uptake, and ultimately decrease tree growth and productivity.

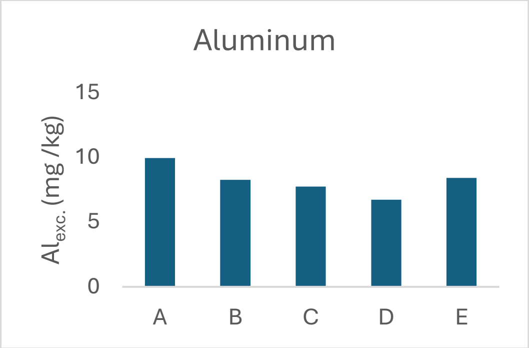

Figure 10: Concentration of aluminum in soil samples from Chini oil palm plantation based on disease categories A, B, C, D and E

Conclusion

The distribution of macronutrients and micronutrients in the soil of the Chini oil palm plantation was assessed by measuring the pH, total organic carbon (TOC), and selected macro and micro-nutrients concentration from the soil samples.The average nutrient levels were observed align with findings from other studies on oil palm plantation soils. Overall, soils collected from category A oil palm, which represent the healthy oil palm had the highest average content of K, Ca and Mg and has soil that is less acidic compared to categories B, C, D, and E. Soil pH, as a key factor, significantly influences soil health and nutrient availability. Notably, the

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Received: 18 September 2024
Accepted: 27 November 2024