



## Evaluation of Oil Palm Leaf Nutrients Affected by Ganoderma Disease

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### ABSTRACT

Oil palm is a highly productive crop, yet its growth and yield are significantly influenced by nutrient availability, making leaf analysis essential to evaluate the nutritional status of oil palms. This study assesses the nutrient content of oil palm leaves in the Felde Chini, plantation in Pahang, where trees are affected by basal stem rot, a common disease caused by *Ganoderma boninense*. Leaf samples were collected randomly, with five replications, from trees at four severity levels of basal stem rot classified by FELDA based on observable symptoms. The study focused on five key elements—potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), and manganese (Mn)—analyzed through the wet digestion method and Atomic Absorption Spectroscopy (AAS). Results indicated a significant decrease ( $p < 0.05$ ) in nutrient concentrations as infection severity increased, with levels for healthy palms compared to severely infected palms as follows: K ( $1.03 \pm 0.06\%$  to  $0.65 \pm 0.04\%$ ), Ca ( $1.25 \pm 0.08\%$  to  $0.76 \pm 0.06\%$ ), Mg ( $0.60 \pm 0.09\%$  to  $0.40 \pm 0.04\%$ ), Zn ( $97.60 \pm 9.2$  mg/kg to  $85.02 \pm 10.6$  mg/kg), and Mn ( $320.36 \pm 18.5$  mg/kg to  $105.05 \pm 20.8$  mg/kg). The copper concentrations in oil palm leaves from Felde Chini were undetectable. This suggests either that copper levels in the leaves are extremely low or too minimal for detection by the Atomic Absorption Spectrometer (AAS). This research emphasizes the specific nutrient patterns associated with ganoderma infection, highlighting how this pathogen disrupts nutrient dynamics in oil palm. Future studies incorporating soil sampling could further elucidate the connection between soil nutrient availability and leaf nutrient concentration, advancing our understanding of nutrient management and its role in disease resistance. These findings are crucial for designing targeted soil management strategies to support healthy, sustainable growth in Malaysian oil palm plantations.

**Keywords:** Basal stem rot, Nutrient deficiency, Fungal infection, Plant nutrition analysis

### ABSTRAK

Kelapa sawit merupakan tanaman yang sangat produktif, namun pertumbuhannya dan hasilnya secara signifikan dipengaruhi oleh ketersediaan nutrisi pada tanah dan daun. Oleh karena itu, analisis nutrisi daun adalah penting untuk menilai status kesehatan kelapa sawit. Kajian ini menilai kandungan nutrisi dalam daun kelapa sawit di ladang Felde Chini, Pahang, di mana pokok-pokoknya terjejas oleh penyakit reput pangkal batang yang biasa disebabkan oleh *Ganoderma boninense*. Sampel daun diambil secara rawak dengan lima replikasi daripada pokok yang berlainan. Pokok di kawasan kajian telah dikenalpasti dengan empat tahap keterukan penyakit reput pangkal batang mengikut klasifikasi yang dibuat oleh FELDA berdasarkan simptom yang dapat dilihat. Kajian ini memfokuskan kepada lima elemen utama—kalium (K), kalsium (Ca), magnesium (Mg), kuprum (Cu), zink (Zn), dan mangan (Mn)—yang dianalisis melalui kaedah pencernaan basah (*wet digestion*) dan Spektroskopi Serapan Atom (AAS). Hasil kajian menunjukkan penurunan yang signifikan ( $p < 0.05$ ) dalam kepekatan nutrisi apabila keterukan jangkitan meningkat, dengan tahap nutrisi bagi pokok yang sihat berbanding pokok yang terjejas teruk seperti berikut: K ( $1.03 \pm 0.06\%$  kepada  $0.65 \pm 0.04\%$ ), Ca ( $1.25 \pm 0.08\%$  kepada  $0.76 \pm 0.06\%$ ), Mg ( $0.60 \pm 0.09\%$  kepada  $0.40 \pm 0.04\%$ ), Zn ( $97.60 \pm 9.2$  mg/kg kepada  $85.02 \pm 10.6$  mg/kg), dan Mn ( $320.36 \pm 18.5$  mg/kg kepada  $105.05 \pm 20.8$  mg/kg). Kepekatan kuprum dalam daun kelapa sawit di Felde Chini tidak dapat dikesan. Ini menunjukkan bahawa sama ada tahap kuprum dalam daun sangat rendah atau terlalu sedikit untuk dikesan oleh Spektrometer Serapan Atom (AAS). Selain itu, kajian ini juga menunjukkan corak nutrisi tertentu yang berkaitan dengan jangkitan *Ganoderma*, sekaligus membuktikan patogen ini mengganggu dinamik nutrisi dalam kelapa sawit. Kajian masa depan yang melibatkan pensampelan tanah dapat menjelaskan lagi hubungan antara ketersediaan nutrisi tanah dan kepekatan nutrisi daun, seterusnya meningkatkan pemahaman kita mengenai pengurusan nutrisi dan peranannya dalam ketahanan penyakit. Penemuan ini penting untuk merangka strategi pengurusan tanah yang disasarkan bagi menyokong pertumbuhan kelapa sawit yang sihat dan lestari di ladang Malaysia.

**Kata kunci:** Reput pangkal batang, Kekurangan nutrisi, Jangkitan kulat ganoderma, Analisis nutrisi daun

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## Introduction

Oil palm (*Elaeis guineensis*) is a vital crop in the global agricultural landscape, especially in tropical regions such as Southeast Asia. It plays a significant role in the economies of countries like Malaysia and Indonesia, which are the world's largest producers of palm oil (Khor et al., 2023). The crop's high yield and efficiency make it a cornerstone of the agricultural industry, providing raw material for a wide range of products, from food to biofuels. However, the sustainability and productivity of oil palm plantations are constantly challenged by various biotic and abiotic factors, with nutrient management being a critical component of maintaining healthy and productive palms.

Among the biotic factors, *Ganoderma boninense*, a soil-borne fungus, poses a severe threat to oil palm cultivation. *Ganoderma boninense* is the causal agent of basal stem rot (BSR), which are among the most destructive diseases affecting oil palm. The impact of *Ganoderma* disease on oil palm plantations is profound, leading to significant economic losses due to reduced yields, premature palm death, and the need for early replanting (Khoo & Chong, 2023). Despite ongoing research and management efforts, ganoderma disease continues to spread, affecting both mature and young palms, and compromising the long-term sustainability of oil palm production.

The severity of ganoderma disease is exacerbated by its insidious nature, often going undetected until visible symptoms manifest, by which time the disease has typically advanced to a critical stage. Symptoms such as crown flattening, yellowing fronds, and the presence of fungal fruiting bodies on the stem are indicative of ganoderma infection. The disease not only disrupts the structural integrity of the palm but also affects its physiological processes, including nutrient uptake and assimilation (Jazuli et al., 2022). Nutrient management is a key aspect of oil palm cultivation, with leaf

nutrient analysis being an essential tool for assessing the nutritional status of oil palms (Kumar, Kumar, & Mohapatra, 2021). The evaluation of leaf nutrient content provides valuable insights into the overall health of the plant and helps diagnose nutrient deficiencies or toxicities that could impact yield. However, the presence of diseases like *Ganoderma* can complicate nutrient management strategies, as the pathogen can alter the nutrient dynamics within the palm. The fungus affects the root system, which in turn impairs the palm's ability to uptake and transport essential nutrients, leading to imbalances that can exacerbate the disease's impact.

In the context of ganoderma-infected palms, understanding the alterations in leaf nutrient content is crucial for developing effective management strategies. Nutrient imbalances caused by the disease can provide diagnostic clues and help in the formulation of targeted interventions aimed at mitigating the disease's effects. For instance, specific deficiencies or excesses in macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), or micronutrients like zinc (Zn), copper (Cu), and manganese (Mn) in infected palms, could inform the adjustment of fertilization practices to enhance the plant's resistance to the pathogen (Nuranis et al, 2016).

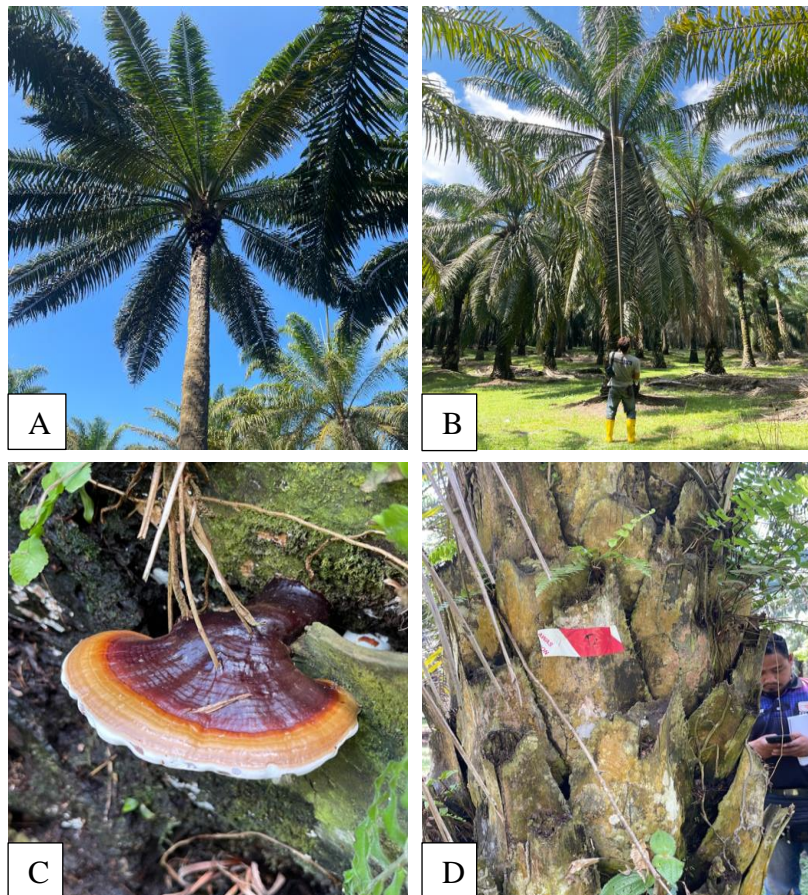
This study aims to evaluate the nutrient content in the leaves of oil palms affected by ganoderma disease, providing insights into how the pathogen influences nutrient dynamics. By comparing nutrient levels in healthy and diseased palms, this research seeks to identify specific nutrient patterns associated with ganoderma infection. The findings will contribute to the development of more effective nutrient management strategies for oil palm plantations, ultimately aiding in the control and mitigation of ganoderma disease and sustaining the productivity and health of this economically vital crop.

## Materials and Methods

### Sampling

Leaves were collected from Felda Chini, Pahang, Malaysia. For the leaf samples, frond 17 was collected from five different trees (Fairhurst & Mutert, 1999), each one of four different severities of *Ganoderma* infections and census was made by FELDA (Figure 1 & Table 1).

Frond 17 has been selected as the primary reference for analysis based on previous studies since the frond is at the midpoint position of the tree (Sabri et. al., 2019). Using a sickle and pole, the frond was cut, and leaflet samples were taken from the middle of fronds then tied and labelled



**Figure 1** A) Healthy oil palm tree, B) Frond skirting in C severity level, C) *Ganoderma* fruiting bodies occur in A and B severity level & D) Oil palm tree with severity tag.

**Table 1** Severity of Ganoderma in FELDA Tasik Chini 5

Severities type	Fruiting bodies	Characteristics
A	Present	- Unopened spears - Non-productive - Stem starting to rot - Fruiting body present at the base of the palm trunk
B	Present	- Canopy shows signs of poor health - Still productive with fruiting and new flower bunches - Frond skirting
C	Absent	- Fruiting body present at the base of the palm trunk - Signs of an unhealthy tree, including unopened and yellow spears - Some frond skirting, but not severe - No mycelium, fruiting body, or rot on the trunk and trunk base
D	Absent	- Healthy tree

### Nutrient Analysis for Leaf Samples

20 samples were oven-dried and prepared using a wet digestion method (Twyman, 2005). The leaf samples were digested using sulphuric acid (H<sub>2</sub>SO<sub>4</sub>) and hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>). First, 0.25 g of plant tissue was weighed and placed in a digestion tube. Then, 5 ml of concentrated H<sub>2</sub>SO<sub>4</sub> was added to wash any tissue down to the bottom of the tube. The tubes were placed on a digestion block and heated at 330°C for 2 hours. After cooling for 15 minutes, 4-5 drops of H<sub>2</sub>O<sub>2</sub> were added, and the tubes were returned to the digester for 5 minutes. This step was repeated until the solution became clear. The

tubes were then digested for an additional hour. Once the samples turned transparent, they were cooled, and distilled water was added to bring the solution to 100 ml. Each digested sample was then diluted 30 times and analyzed for K, Ca, Mg, Cu, Zn, and Mn using AAS. The AAS results are compared with the standard sufficiency ranges for oil palm leaf nutrients, as outline by Bahera et al. (2015) in Table 2. Then the results are interpreted through ANOVA statistical analysis and graphical representation.

**Table 2** Sufficiency ranges of oil palm leaf nutrients (Bahera et al., 2015)

Variable	Deficient	Low	Optimum	High	Excessive
N (%)	<1.87	1.87–2.24	2.24–2.97	2.97–3.34	>3.34
P (%)	<0.05	0.05–0.08	0.08–0.14	0.14–0.17	>0.17
K (%)	<0.72	0.72–0.78	0.78–0.91	0.91–0.97	>0.97
Ca (%)	<0.35	0.35–0.74	0.74–1.53	1.53–1.93	>1.93
Mg (%)	<0.05	0.05–0.25	0.25–0.98	0.98–1.34	>1.34
S (%)	<0.54	0.54–0.72	0.72–1.09	1.09–1.28	>1.28
B (mg kg <sup>-1</sup> )	<2.12	2.12–5.71	5.71–31.0	31.0–43.6	>43.6
Cu (mg kg <sup>-1</sup> )	<4.68	4.68–7.42	7.42–12.9	12.9–15.6	>15.6
Zn (mg kg <sup>-1</sup> )	<21.1	21.1–33.6	33.6–58.6	58.6–71.1	>71.1
Mn (mg kg <sup>-1</sup> )	<46.4	46.4–82.5	82.5–681	681–1063	>1063
Fe (mg kg <sup>-1</sup> )	<55.1	55.1–82.8	82.8–936	936–1363	>1363

## Results and Discussions

### Nutrient Analysis for Plant Samples

#### Potassium (K)

Figure 2 shows the concentration of potassium in oil palm leaflets in Felda Chini. The leaflets in the D level, which were

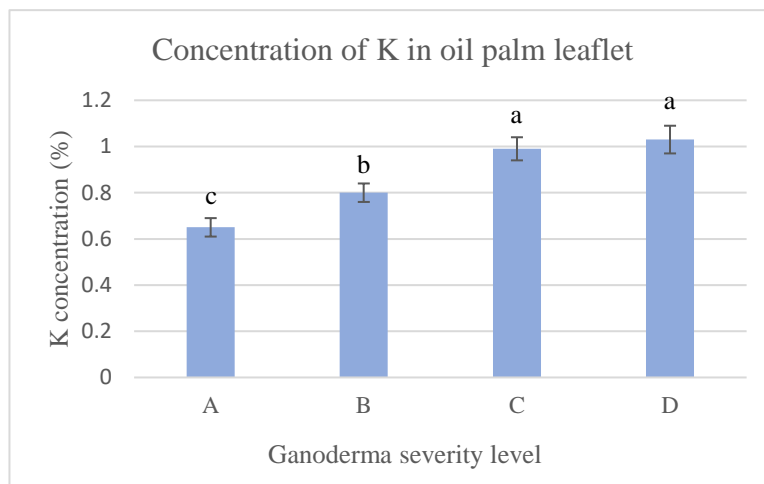
healthy, exhibit the highest mean potassium concentration at 1.03 ± 0.06 %, while the A level, which experienced severe infestation,

has the lowest mean at  $0.65 \pm 0.04$  %. According to Bahera et al. (2015), the optimum concentration of potassium in oil palm leaflets falls within the range of 0.78 to 0.91%. Result shown the mean potassium concentrations of B level ( $0.80 \pm 0.04$ ) are within in the optimum range, whereas samples in the C level ( $0.99 \pm 0.05$ ) exhibit the slightly exceed the optimum concentration. Samples A level was obviously fall under deficiency category. A study conducted by Kamireddy, Behera, and Kancherla (2023) in Krishna District of Andhra Pradesh on the East Coast of India reported an average potassium concentration of 0.72% in fronds 17, which is among the lowest obtained.

The average potassium concentration of samples from the D level is slightly higher than the optimum range, while samples from the A level are slightly lower. Schmidt and Hughes-Games (2010) noted that prolonged application of manure or fertilizer at rates

exceeding crop requirements can elevate soil potassium levels. Elevated soil potassium concentrations may lead to foliar potassium uptake that surpasses the crop's normal growth needs. Conversely, potassium deficiency may result from insufficient potassium in the soil, low soil pH, or high N or Ca ratios.

Moreover, increased potassium has been shown to reduce the incidence and severity of basal stem rot (BSR) in oil palm by enhancing plant resistance, as it strengthens cell walls and stimulates defense enzymes like polyphenol oxidase and peroxidase (Ramdan et al., 2024). Additionally, the increase of potassium to 14mg/mL inhibited cellulase and xylanase activities, key enzymes involved in lignocellulose degradation by ganoderma (Anothai et al., 2023), offering insights into nutrient balance that can aid in controlling disease.



**Figure 2** Concentration of potassium in oil palm leaflet.

Note: Bars with different letters indicate significant differences at  $p \leq 0.05$ .

### **Calcium (Ca)**

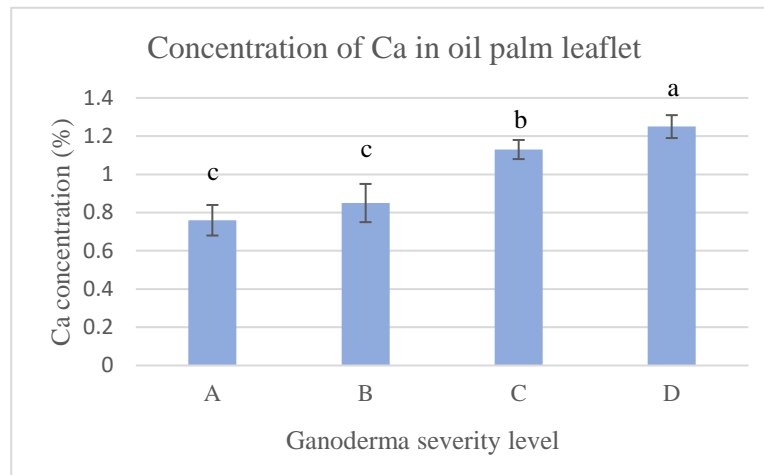
Figure 3 illustrates the concentration of calcium in oil palm fronds in Felda Chini. The leaflets in the D level exhibit the highest mean calcium concentration at  $1.25 \pm 0.08$ %, while the A level has the lowest mean at  $0.76 \pm 0.06$ %. According to Bahera et al. (2015), the optimum concentration of calcium in oil palm fronds falls within the range of 0.74% and 1.53%. This indicates that all the oil palm leaf samples maintain an adequate amount of

calcium. However, pattern of calcium concentration decreases progressively from healthy palms (D level) to those experiencing severe infestation (A level).

This result is supported by the study by Kamireddy, Behera, and Kancherla (2023), in which the average calcium concentration in oil palm leaves in Krishna District, India, is 1.19%, which is within the

optimum range. Calcium plays a crucial role as a signaling intermediate in plants. The cytosolic free  $\text{Ca}^{2+}$  concentration in plant cells fluctuates rapidly and dynamically in response to various endogenous or environmental cues. Elevated calcium concentrations in plant cells serve as an

important early event in plant defense responses, helping plants cope with biotic and abiotic stresses (Bhar et al., 2023). According to a study by Bivi et al. (2016), calcium was shown to strengthen cell walls, enhancing resistance to diseases like basal stem rot in oil palm plantations.



**Figure 3** Concentration of calcium in oil palm leaflet.

Note: Bars with different letters indicate significant differences at  $p \leq 0.05$ .

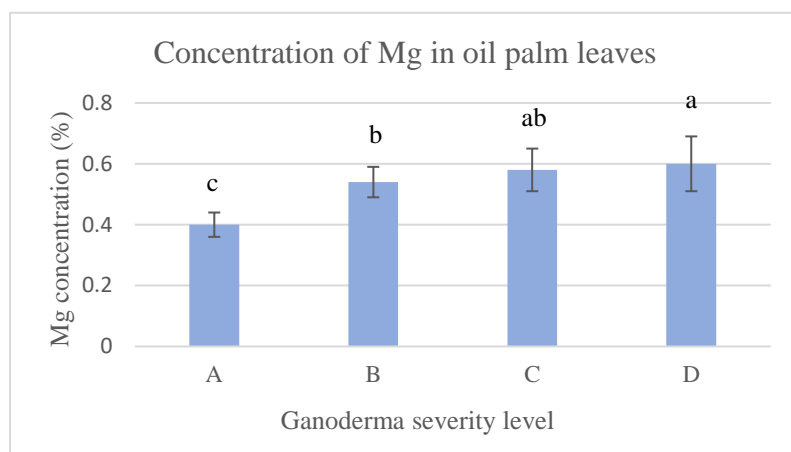
### **Magnesium (Mg)**

Figure 4 represents the concentration of magnesium in oil palm leaflets in Felda Chini. The leaflets in the D level, which represent the healthiest palms, exhibit the highest mean magnesium concentration at  $0.60 \pm 0.09\%$  while the A level, corresponding to very severe infestation, has the lowest mean at  $0.40 \pm 0.04\%$ . The magnesium concentrations for the B and C levels are  $0.54 \pm 0.05\%$  and  $0.58 \pm 0.07\%$ , respectively. According to Bahera et al. (2015), the optimal concentration of magnesium in oil palm fronds ranges from 0.25 to 0.98%, suggesting that all the samples maintain an adequate amount of magnesium.

The trend of magnesium concentration decreasing from the D level (healthy palms) to the A level (severely affected palms) highlights the role of magnesium in maintaining palm health. This aligns with findings in a study by Kamireddy, Behera, and Kancherla (2023) in Krishna District, India, the magnesium concentration in oil palm leaf samples averaged 0.61%,

consistent with the D level in Felda Chini. There are possibility that High K concentrations in the soil solution inhibit Mg uptake and may induce Mg deficiency in plants (Tränkner et al., 2018)

Magnesium is a vital nutrient involved in photosynthesis and enzyme activation in plants. Studies have shown that magnesium deficiency can impair these processes, leading to reduced plant health and increased susceptibility to diseases. According to Senbayram et al., (2015), maintaining optimal magnesium levels is crucial for nutrient uptake and overall palm health. Moreover, research indicates that palms with higher magnesium concentrations are more resilient to stress and disease. For instance, magnesium's role in chlorophyll synthesis supports efficient photosynthesis, enhancing plant vitality and resistance to biotic stresses like *Ganoderma boninense*, which causes basal stem rot (Zhang et al., 2022).



**Figure 4** Concentration of magnesium in oil palm leaflet.  
Note: Bars with different letters indicate significant differences at  $p \leq 0.05$ .

### **Copper (Cu)**

The concentrations of copper in the oil palm leaves from Felda Chini were not detected. Two assumptions can be made regarding the copper content in the collected leaf samples: the copper concentration in oil palm leaves in Felda Chini is extremely low, or the contents were too minimal for the Atomic Absorption Spectrometer (AAS) machine to detect. AAS has relatively high detection limits, making it less effective for trace analysis. In contrast, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) has higher sensitivity across a broader range of elements and significantly lower detection limits. The AAS machine typically reads concentrations in parts per million (ppm), while ICP-MS can analyze samples in parts per billion (ppb).

According to Bahera et al. (2015), the optimum copper concentration in oil palm leaves ranges from 7.42 to 12.9 mg/kg. In a study conducted by Mohd Rakib et al. (2017) in Sarawak, the average copper concentration in oil palms infected with ganoderma disease in Betong and Miri was 6.03 mg/kg and 3.54 mg/kg, respectively, which is lower than the optimum range. Similarly, in the same study, the average copper concentration in oil palms not infected with ganoderma in Betong and

Miri was 5.67 mg/kg and 6.21 mg/kg, also falling below the optimum range.

To combat ganoderma infestation, it is suggested to increase copper levels in the fertilizers applied to oil palms, especially in areas with severe infestation. The dosage of copper should increase with the age of the palms, as older palms are more susceptible to ganoderma disease. Studies, such as Viégas et al. (2024), indicate that copper accumulation in oil palm organs increases with age, suggesting that older palms require higher levels of copper. Furthermore, copper's role as a cofactor in enzyme systems vital for plant defense can help mitigate disease, including ganoderma (Bloodnick, 2022). The tendency for ganoderma infestations to occur more frequently in older palms may be linked to insufficient copper levels as the trees age, underscoring the need for adjusted copper management strategies. As demonstrated by Daljit et al. (2020), copper application at a dosage of 8 mg Cu/palm enhanced root development without causing toxicity, indicating that controlled increases in copper can be beneficial for long-term health and productivity.

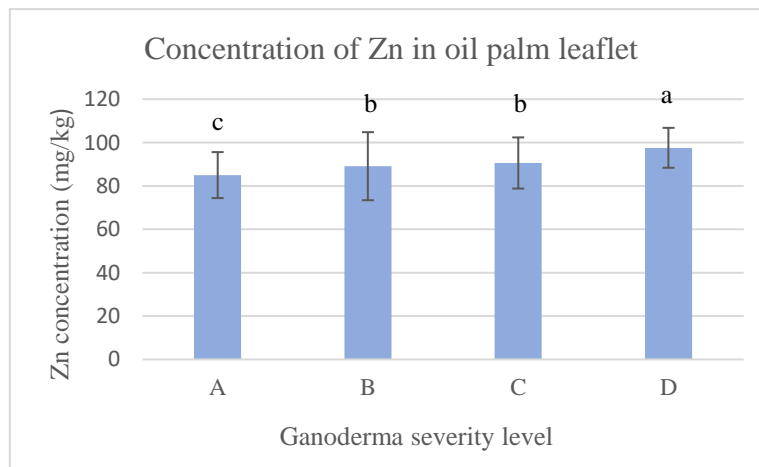
### Zinc (Zn)

Figure 5 illustrates the concentration of zinc in oil palm leaflets in Felda Chini. The leaflets in the D level exhibit the highest mean zinc concentration at  $97.60 \pm 9.2$  mg/kg, while the A level has the lowest mean at  $85.02 \pm 10.6$  mg/kg. According to Bahera et al. (2015), the optimal zinc concentration in oil palm fronds ranges from 33.6 to 58.6 mg/kg, indicating that all the leaf samples from Felda Chini contain zinc levels above the recommended range.

The excess zinc in the oil palm leaves could be due to low soil pH or over-application of zinc-based fertilizers. Additionally, Felda implemented treatments containing zinc, recognizing its importance in managing ganoderma disease. Zinc plays a critical role in plant defense mechanisms, as high concentrations of micronutrients like manganese, copper, ferum, and zinc are

known to protect plants from pests and diseases (Cabot et al., 2019). Zinc fertilization has been shown to reduce disease symptoms in plants (Machado et al., 2018). However, there is a risk that a protective concentration of zinc against one pathogen might increase susceptibility to another pathogen (Helfenstein et al., 2015).

Despite its beneficial role, zinc toxicity can occur when leaf concentrations exceed 300 mg/kg (Broadley et al., 2007). Excessive zinc can interfere with the absorption of other essential elements, stimulate the production of reactive oxygen species (ROS), and result in heavy metal toxicity, which can damage plant tissues (Kaur et al., 2021). The elevated zinc levels observed in Felda Chini's oil palm leaflets, though below the phytotoxic range, raise concerns about potential long-term impacts on nutrient balance and overall plant health



**Figure 5** Concentration of zinc in oil palm leaflet.

Note: Bars with different letters indicate significant differences at  $p \leq 0.05$ .

### Manganese (Mn)

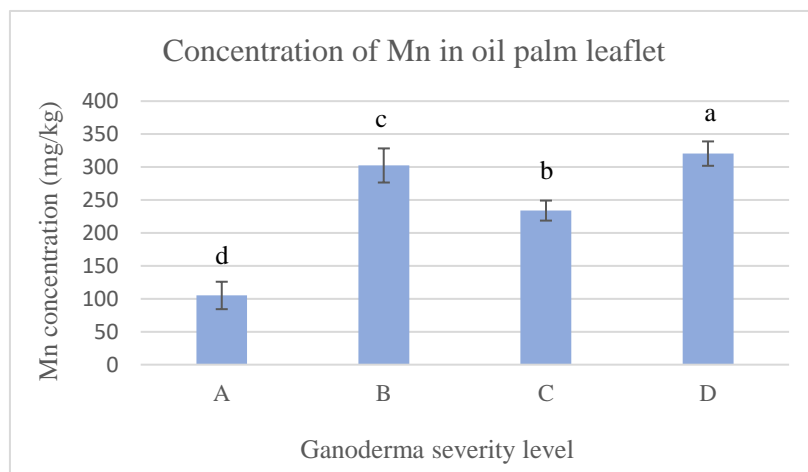
Figure 6 depicts the concentration of manganese (Mn) in oil palm leaflets in Felda Chini. The leaflets from the D level exhibit the highest mean manganese concentration at  $320.36 \pm 18.5$  mg/kg, while the A level, representing the most severe symptoms, has the lowest mean at  $105.05 \pm 20.8$  mg/kg. According to Bahera et al. (2015), the

optimal manganese concentration for oil palm fronds ranges from 82.5 to 681 mg/kg, indicating that all the leaf samples from Felda Chini have adequate levels of manganese.

In a study by Bahera et al. (2015) conducted in the southern plateau of India, the average manganese concentration in oil

palm leaflets was 299 mg/kg, which also falls within the optimal range. The study noted that manganese use efficiency tends to increase with the age of oil palms across all organs. This reflects how the nutritional demands of oil palm plants evolve as they mature, influencing the dynamics of Mn immobilization, recycling, and exportation (Viégas et al., 2023). Manganese is essential for photosynthesis, as it is involved in chloroplast function and electron transport (Alenjendro et al., 2020, Oliveira et al., 2022). Additionally, Mn activates enzymes in the shikimic acid pathway, which leads to the biosynthesis of essential aromatic amino acids like tyrosine, tryptophan, and phenylalanine, as well as lignin and flavonoids (Tzin & Galili, 2010).

Manganese is also highly concentrated in the growth areas of the plant, especially around meristematic tissues, where its role in cell division and plant growth is crucial (Alenjendro et al., 2020). These high Mn concentrations likely contribute to the overall health and development of the palm. The importance of manganese corroborates with Rebitanim et al. (2020), who highlighted the development of new fertilizer technologies that include Mn as one of the key elements, recognizing its importance in supporting plant health and growth. These technologies aim to optimize nutrient management in oil palm plantations, ensuring that vital micronutrients like manganese are supplied in the right amounts to improve productivity and disease resistance.



**Figure 6** Concentration of manganese in oil palm leaflet.

Note: Bars with different letters indicate significant differences at  $p \leq 0.05$ .

The interaction of manganese with other micronutrients plays a key role in disease management. Studies have shown that combinations of micronutrients, such as boron+copper, boron+manganese, and copper+manganese, can suppress basal stem rot (BSR) disease in oil palm. However, single supplementation of manganese was found to increase BSR infection, possibly due to ganoderma manganese-oxidizing enzymes that interfere with the protective effects of Mn (Tengoua et al., 2014). In other crops, Mn fertilization has been shown to reduce infection rates for diseases like cotton

wilt, potato scab, rice blast, and sugar beet leaf spot. In cereals, Mn sufficiency decreases the infection of take-all disease caused by *Gaeumannomyces graminis* by enhancing lignin deposition, a key defense mechanism (Zhou et al., 2023).

These findings highlight the importance of Mn in disease prevention, particularly through its role in lignin and suberin biosynthesis, which are crucial for forming barriers against fungal pathogens. The adequate Mn levels in Felda Chini's oil palms may be playing a role in disease

resistance, though care must be taken in its management to prevent imbalances that could increase susceptibility to *Ganoderma*.

### Conclusion

This research found its aim in assessing the nutrient content in the leaves of oil palms infected with ganoderma disease by comparing healthy and diseased palms. The results showed that macronutrients such as potassium, calcium, and magnesium and micronutrients namely manganese and zinc were far higher in healthy palms at D level than those severely infested at A level. These findings underline the specific nutrient patterns associated with ganoderma infection and therefore provide important information on how this pathogen disrupts nutrient dynamics in oil palm. Nutrient dynamics in oil palm plantations could be further understood through soil sampling, recommended for future studies. This would create the link between soil nutrient availability and leaf nutrient concentration, providing a better understanding of how nutrient management and plant health interact in their relationship with disease resistance.

### Acknowledgement

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