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Review

Usage of Biofertilizers to Correct the Nutrient Deficiency of Oil Palm (*Elaeis guineensis*): An Observational Study and Review

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Abstract: Oil palm (*Elaeis guineensis*) is one of the most nutrient-intensive plantations in Malaysia. It requires many nutrients to reach its full potential and production stage. The main issue is that nutritional stress is a crop health issue caused by a lack of nutrient components to sustain crop growth requirements. We aimed to review the nutrient deficiency of oil palm based on an observation and literature study. The leaflet of the oil palm tree was analyzed for this study. The result showed that nutrient deficiency in oil palm is a common issue. Since oil palm is a heavy feeder plant that requires a well-balanced supply of nutrients, the continuous use of sustainable (eco-friendly) biofertilizers at a cost-effectively optimal level is necessary to achieve the maximum yield of oil palm. Though there are some inevitable causes of nutrient deficiencies, good management program should be carried out to lessen this problem and improve oil palm health and production.

***Keywords*:** nutrient deficiency, oil palm, biofertilizers, leaf analysis

1. Introduction

The oil palm trees (*Elaeis guineensis*) originate from the West African region [1]. Since then, Malaysia has established itself as the world's most significant producer of palm oil, although as of 2015, Indonesia has become the lead producer [2]. According to Yadegari et al. [3], Malaysia's export of oil palm by-products increased by 9% between 2008 and 2016. However, the sector's profitability is expected to decline due to a drop in global pricing, high-cost traditional agricultural practices, and decreased production due to nutrient deficiency (ND), pests, and disease.

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According to Rendana et al. [4], ND is one of the most critical factors influencing oil palm productivity and crop yield.

Oil palm is a nutrient-dependent plant that requires a well-balanced and appropriate food source for optimal growth and yield. For optimum fertilizer application, information on soil nutrient status and leaf nutrient content is needed. A lack of critical nutritional elements can cause plant stress in oil palms. According to Rendana et al. [4], oil palm nutrient stress contributes to yield decrease due to insufficient nitrogen. Biological and abiotic factors both contribute to the development of ND. Waterlogging and soil runoff are examples of environmental factors that inhibit the uptake of nutrients by oil palm tissue. Furthermore, biotic agents such as weeds and pests exploit the nutrition supply, interfering with the plant's intake of nutrients [5]. There are 14 necessary mineral nutrition components for plant growth and survival [6]. In addition to nitrogen (N) and phosphorus (P), suitable potassium (K), magnesium (Mg), and sulphur (S) levels are required for oil palm production. According to Behera et al. [7], dietary restrictions represent a fundamental productivity barrier in oil palm-growing nations such as India. NDs, such as N or K imbalances, K shortage, Mg insufficiency, and Boron (B) deficiency, are prevalent on oil palm plantations in India, hence lowering production. Nevertheless, because all mineral elements play critical and specific roles in plant metabolism, any deficiency would result in considerable plant growth and yield reductions. For example, B is an essential micronutrient, as oil palm-cultivated soils are weak in this element. Consequently, signs of B shortage are prevalent in oil palm crops.

"Deficiency demand" refers to the essential nutrients necessary to correct ND, which can be determined by monitoring nutrient uptake in the leaflet and rachis tissues [8]. Consequently, nutrient management in oil palm is conducted to ensure that each palm receives adequate nutrients in balanced proportions, guaranteeing efficient nutrient uptake, healthy vegetative growth, and optimal economic fruit bunch yields, as well as minimizing the adverse environmental effects associated with over-fertilization and land degradation.

This paper aimed to review the ND of oil palm in the literature and to interpret them based on an observational study.

2. Material and methods

An observational study was conducted in an oil palm plantation located at Tanjung Karang, Selangor (N 3° 29' 26" and E 101° 11' 57") on April 6, 2022. A total of 20 oil palm trees were inspected and chosen for this study to identify the nutrient deficiency in the oil palm leaflets. The leaflet of the oil palm tree was chosen for this study. Leaf analysis is the most common method used to assess the nutrient status of the oil palm, as suggested by Chapman and Grey [9]. They found that leaf analysis provided a more accurate indication of nutrient deficiency than soil analysis.

3. Results

Figure 1. Observational study of oil palm leaflets with nutrient deficiency symptoms.

Figure 2. Comparison between non-showing nutrient deficiency (left) and nutrient deficiency (right) symptoms on leaflets.

The oil palm leaflets with ND symptoms are shown in Figure 1. Figure 2 shows the comparison between ND and non-showing ND symptoms on leaflets. From the observation, most of the trees showed nutrient deficiency symptoms such as orange-yellow dots, chlorosis, and wrinkled leaflets. In contrast, fewer than three trees showed no nutrient deficiency symptoms on the leaflet. However, the trees cannot simply be deducted as healthy oil palm trees and need further analysis.

Table 1 shows the required percentages of nutrient concentration in oil palm leaflets for over six years, based on Yadegari et al. [3] and Uexkull and Fairhurst [10]. The nutrient levels of leaflets are compared from both tables, and nutrient deficiency can be identified.

There are three types of nutrient concentration levels in the leaflets of matured oil palm documented in the literature (Table 2). The first type is the status of insufficiency. For example, Rendana et al. [4] found K and P deficiencies with mean values of 0.61 and 0.10 respectively. Siang et al. [8] reported mean values of 1.81 and 0.12 for N and P deficits respectively. According to Tajudin et al. [11], K concentration is deficient (mean: 0.50). Woittiez et al. [12] stated that K concentrations are in deficiency (mean: 0.59 and 0.60) at the sampling locations of Jambi and Kalimantan respectively. Sung [13] reported that the mean concentrations of P and Mg are 0.11 and 0.16 respectively. Sidhu et al. [14] concluded that magnesium content is inadequate (mean: 0.06).

Type 2 is a situation of marginal deficiency. Previous studies have shown that borderline nutrient levels necessitate the addition of soil nutrients such as fertilizers. For example, Tajudin et al. [11] showed that the mean concentrations of N and P are 2.98 and 0.20 respectively. Also described in the literature are the marginal values of nutrients. Woittiez et al. [12] and Lee et al. [15] found that Mg content is negligible, with the mean concentrations of 0.20 and 0.21 respectively. According to Jacquemard et al. [16], N concentration is negligible (mean: 2.98). Woittiez et al. [12] determined that the mean concentrations of N and P are 2.33 and 0.15 respectively. Sung [13] reported that the mean concentrations of N and K are 2.33 and 1.33 respectively. Sidhu et al. [14] demonstrated that the concentrations of N, P and K are marginal, with mean values of 2.36, 0.15 and 1.50 respectively.

Table 1. Percentages (%) of nutrient concentration in oil palm leaves over six years.

Nutrient	Deficiency	Marginally deficient	Optimum	Marginally excess	Excess
N	< 2.30	2.30 to 2.40	2.40 to 2.80	2.80 to 3.00	> 3.00
P	< 0.14	0.14 to 0.15	0.15 to 0.18	0.18 to 0.25	> 0.25
K	< 0.75	0.75 to 0.90	0.90 to 1.20	1.20 to 1.60	> 1.60
Mg	< 0.20	0.20 to 0.25	0.25 to 0.40	0.40 to 0.70	> 0.70
Ca	< 0.25	0.25 to 0.50	0.50 to 0.75	0.75 to 1.00	> 1.00
S	< 0.20	0.20 to 0.25	0.25 to 0.35	0.35 to 0.60	> 0.60
Cl	< 0.25	0.25 to 0.50	0.50 to 0.70	0.70 to 1.00	> 1.00
B	< 8.00	8.00 to 15.00	15.00 to 25.00	25.00 to 40.00	> 40.00
Cu	< 3.00	3.00 to 5.00	5.00 to 8.00	8.00 to 15.00	> 15.00
Zn	< 10.00	10.00 to 12.00	12.00 to 18.00	18.00 to 80.00	> 80.00

Source: Yadegari et al. [3] and Uexkull and Fairhurst [10].

Table 2. Nutrient concentration of the leaflets of matured oil palm reported in the literatures.

Sampling location	Mean of nutrient concentrations of the leaflets of matured oil palm						Source
	N (%)	P (%)	K (%)	Mg (%)	Ca (%)	B (mg/kg)	
Layang-Layang, Johor, Malaysia	1.81	0.12	1.00	0.20	0.54	12.50	Siang et al. [8]
FELDA, Pahang, Malaysia	3.03	0.17	1.05	0.30	-	-	Yadegari et al. [3]
UKM palm oil plantation, Bangi, Selangor, Malaysia	2.75	-	0.61	0.10	0.37	-	Rendana et al. [4]
Seberang Perak, Malaysia	2.98	0.20	0.50	-	-	-	Tajudin et al. [11]
Tun Razak Centre, Jerantut, Pahang, Malaysia	2.71	0.17	1.03	0.21	0.87	15.80	Lee et al. [15]
MPOB Station, Kluang, Johor, Malaysia	2.79	0.15	-	0.32	0.55	-	Ibrahim et al. [17]
Aek Loba Estate (PT Socfindo), North Sumatra, Indonesia	2.98	0.18	1.02	0.26	0.78	-	Jacquemard et al. [16]
Ramin Village, Jambi, Indonesia	2.33	0.15	0.59	0.39	-	-	Woittiez et al. [12]
Sintang, West Kalimantan, Indonesia	2.66	0.17	0.60	0.28	-	-	Woittiez et al. [12]
Indonesia	2.33	0.11	1.34	0.16	1.09	-	Sung [13]
Asian Agri Sumatra, Indonesia	2.36	0.15	1.51	0.06	0.39	-	Sidhu et al. [14]

Thirdly, are the optimal or excessive quantities of nutrients. According to Woittiez et al. [12], K concentration is optimal (mean: 1.00). Rendana et al. [4] demonstrated optimal N concentration (mean: 2.75). Yadegari et al. [3] determined the optimal P, K and Mg levels to be 0.17, 1.05 and 0.30 respectively. According to Lee et al. [15], N, P and K concentrations are optimal, with respective values of 2.71, 0.17 and 1.03. Ibrahim et al. [17] determined that N, P and Mg concentrations were optimal with values of 2.79, 0.15 and 0.32 respectively. According to Jacquemard et al. [16], the optimal P, K and Mg concentrations are 0.18, 1.02 and 0.26 respectively. According to Woittiez et al. [12], Mg concentration is optimal (mean: 0.39). They [12] also found that at various sampling locations, the concentrations of N, P and Mg are optimal with respective values of 2.66, 0.17 and 0.28. Only Yadegari et al. [3] discovered an excessive N concentration (mean: 3.03).

4. Discussion

Effective biofertilizer usage is necessary to maintain the health of oil palm trees and ensure that they receive sufficient nutrients for growth and productivity. ND is caused by numerous circumstances including environment-related factors such as precipitation, leaching and soil runoff. Pests and diseases are also accountable [12].

Maene et al. [18] reported that nutrient loss owing to runoff and erosion can be substantial and is typically greater than leaching losses. The soil texture, oil palm maturity, terrain, soil permeability, land reclamation, insufficient soil conservation measures, and lag time between fertilizer application and rainfall contribute to nutrient loss by runoff and sedimentation. Such soluble minerals as N, K and Mg are particularly susceptible to runoff losses [5]. Significant nitrogen losses can occur via surface runoff when significant rainfall occurs immediately after fertilizer application.

The amount of precipitation is a significant factor in soil and nutrient depletion. The rate of soil erosion caused by runoff rose dramatically as rainfall intensified. This present study was conducted during the rainy season. Therefore, there is a strong link between precipitation and ND due to soil erosion. In addition, a significant association exists between water build-up, runoff and soil degradation. When soil protection is insufficient, rains separate and transport soil particles, resulting in soil erosion. Minor and significant runoff events frequently result in deterioration in soil health due to the loss of topsoil and nutrients, the loss of organic materials, and the subsequent reduction in the soil's capacity to retain water and minerals [19]. Therefore, soil conservation measures are essential to prevent soil erosion, reduce soil deterioration and maintain soil fertility to utilize soil sustainably.

Waterlogging is one of the causes that contribute to nutrient loss in oil palms, by hindering oxygen delivery to roots, hence limiting root respiration. This results in a considerable decrease in the energy status of root cells, affecting important plant metabolic processes [20]. The topography of the soil is the primary cause of waterlogging. Although oil palm is resistant to transitory floods due to the propensity for pneumatodes to sprout in its roots, its submerged roots are unable to breathe consistently, resulting in reduced nutrient absorption, more extended frond emergence, and diminished glucose availability via translocation [21]. The movement of water and fertilizers from summits to side slopes via valleys results in heterogeneous soil fertility [22]. Under wet conditions, oil palm photosynthetic activity and transpiration rates are three to four times lower than on well-drained soils [23].

Additionally, biotic variables may influence the ND of the oil palm. Weeds prevent soil erosion by interacting with the water and nutrient cycles. In contrast, weeds also provide a habitat for natural pest predators. According to Wood [24], woody and creeping weeds and speargrass (*Imperata cylindrica*) compete vigorously with oil palms for nutrients and water. Clean weeding techniques that leave no plant cover on the soil's surface may compact the soil and diminish its permeability [25]. Moreover, pests, namely caterpillars, and a reduction in soil moisture can be generated by clean weeding [26].

Oil palm is among the most nutrient-intensive plantations in Malaysia. It is required for the crop to reach its maximum potential and production stage. A deficiency in nutrient components necessary for crop growth creates nutritional stress, a crop health issue. Excellent management of biofertilizer requirements is crucial to ensuring that the oil palm tree receives adequate nutrients. Through the practice of sound and balanced nutrition has demonstrated the increase of plantation yields to more than 5 tonnes oil per hectar [27]. With the continuing growth of palm oil production over the next decades, the need for biofertilizers is guaranteed. Zainuddin et al. [28] concluded that the usage of biofertilizers was capable of increasing vegetative measurements and nutrient uptake, also in reducing the sole use of 100% chemical fertilizers, which is non-environmental-friendly and expensive. Even though there are several unavoidable causes of nutrient deficiencies, such as rainfall, soil run-off, leaching, and waterlogging, good management practices should be conducted to mitigate this problem and boost oil palm health and output.

5. Conclusions

Based on the current observation and review study, it is possible to conclude that nutrient shortage in oil palm is a widespread problem. Because oil palm is a heavy feeder that requires a well-balanced nutrient supply, it is essential to regularly apply sustainable (eco-friendly) biofertilizers to improve production, to mitigate negative impacts on environment and to increase profits.

Conflict of interest

The authors declare no conflicts of interest.

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