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Comparative Relationships of Leaflet Essential Elements of Immature Oil Palm (*Elaeis guineensis*) between A Novel Biochemical Fertilizer and Standard Practice Application

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Abstract The standard practice application (SPA) of fertilizer is now thought of as Malaysia's most cost-effective fertilization technique when comparing total expenses per hectare of palm oil plants and fertilizer costs. There is also a strategy to reduce the cost of labour and fertilizer per acre to make it more cost-effective. Under a field plot experimental study conducted in Telang oil palm plantation, Kuala Lipis (Pahang), the present study aimed to compare five essential elements (chloride (CI), copper (Cu), sulfur (S), zinc (Zn), and Iron (Fe)) in the oil palm (*Elaeis guineensis*)'s leaflets between Universiti Putra Malaysia biochemical fertilizer (UPMBF) and SPA. Based on the established guideline proposed by Fairhurst and Mutert (1999), overall, three elements in both UPMBF and SPA showed the 'Optimum' category for CI, Cu, and Zn. However, only S levels are categorized as 'Deficiency', while the Fe guideline has not been established yet. All the five essential elements in UPMBF are not significantly different ($P > 0.05$) from those in SPA based on the three statistical analyses namely cluster analysis, correlation analysis and multiple linear stepwise regression analysis. Therefore, they are comparable to each other. With lower costs using UPMBF, the UPMBF could be employed as a cost-effective and novel fertilization application for immature oil palm in Malaysia.

Keywords Novel Biofertilizer, Oil Palm, Essential Elements

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1. Introduction

The oil palm (*Elaeis guineensis* Jacq.) has historically contributed significantly to GDP growth, particularly in Malaysia and Indonesia. Due to their enormous size, the oil palm trees would require a significant quantity of fertilizers and other critical components to support and sustain their development and output. The oil palm, which is the commercial component of the palm, specifically needs a considerably larger amount of essential elements for optimum production of fresh fruit bunch [1]. The oil palms have different dietary needs from dicot trees or shrubs since they are monocots [2]. Various complex elements regulate plant development and output, including climate, soil type, moisture, diseases, pests, mineral nutrition, and genetic control [3].

However, poor fertility levels are typically associated with cultivating terrestrial land for the oil palm species [4]. Applying the right fertilizers to planting locations will help address the low nutrient levels. To apply fertililzer properly, it is therefore logically necessary to know the state of the soil's nutrients and the concentrations of nutrients in the leaves [5-8].

Regarding the total costs per hectare of palm oil trees and the fertilizer costs, the standard practice application (SPA) of fertilizer is now regarded as Malaysia's most cost-effective fertilization method [8]. To make it more cost-effective, there is a further plan to lower the expenses of manpower and fertilizers per acre. In a prior study, Tony Peng et al. [8] investigated the potential of an innovative biochemical fertilizer (known as Universiti Putra Malaysia biochemical fertilizer (UPMBF)) in the immature oil palm, focused on six nutrients' requirement (nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), and boron (B)).

As a continuation of the research by Tony Peng et al. [8], the current paper sought to ascertain a) the variations of sulphur (S), chloride (Cl), copper (Cu), zinc (Zn), and iron (Fe) levels in oil palm leaflets between SPA and UPMBF; and b) the relationships of the five essential elemental concentrations with vegetative growths in oil palm, under a field plot experimental study.

2. Materials and Methods

2.1. Field Trial Plot Experiment

Previously, Tony Peng et al. [8] have provided detailed information on the trial site and study setting, similar to the present study. Overall, the present sampling and sample preparation methodology followed that described by Woittiez et al. [9]. Laboratory tests for S, CI, Cu, Zn, and Fe were performed on dried leaflet samples. The elemental analysis was conducted in accordance with the procedures outlined in the Malaysian SIRIM [10] Standards namely: (i) Cu, Zn, and Fe through atomic absorption spectrophotometer after ashing; (ii) CI through sulphuric acid digestion and semi-micro Kjeldahl distillation; and (iii) S through ashing followed by spectrophotometric analysis (vanadomolybdate method). The vegetative parameters examined were frond growth, frond number of leaves, frond length, frond thickness, frond width, leaf length, chlorophyll, leaf width, and canopy, all in accordance with Woittiez et al. [9]. Tony Peng et al. [8] have previously reported the abovementioned vegetative parameters from this study.

2.2. Statistical analyses

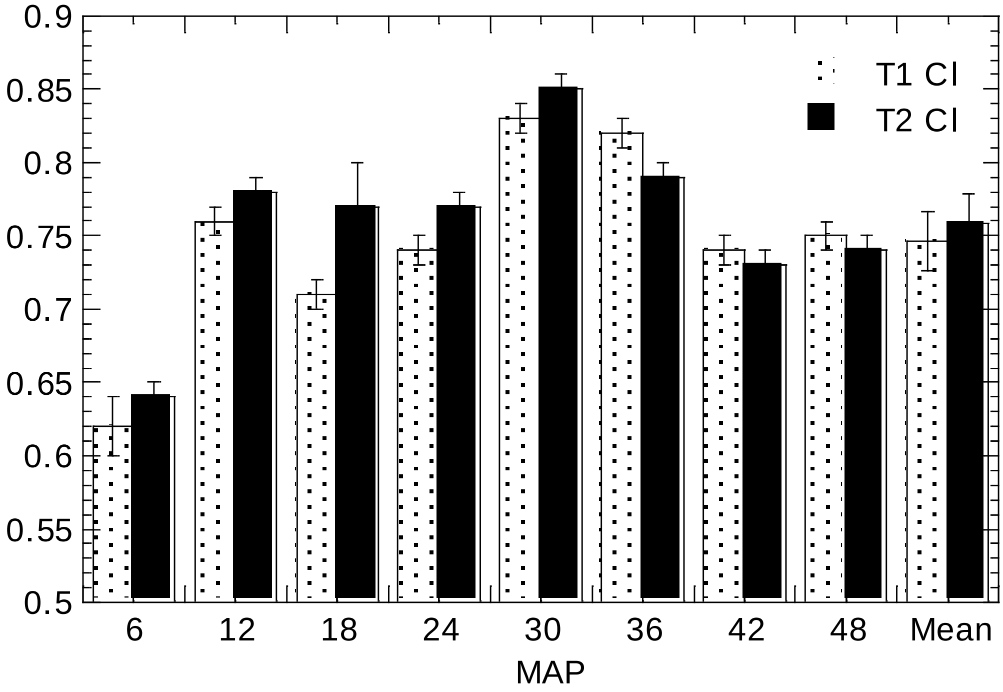
Utilizing Statsoft STATISTICA version 10 for Windows, statistical analyses were carried out. The data for N, K, P, Ca, B, and Mg are cited for statistical purposes from Tony Peng et al. [8]. The coefficients of variation (CV) were also produced using the same statistical programme. Before doing any statistical analysis, all the data underwent an additive logarithmic transformation [log10 (mean + 1)] to eliminate the impact of orders of magnitude differences between variables and prevent the use of negative values [11-12].

Four statistical tests were conducted to understand the relationships of the essential elements between SPA and UPMBF. First, a statistical study utilizing the T-Test method was performed on the six fundamental components of oil palm leaflets and their vegetative characteristics. The other three statistical studies employed multivariate techniques, including multiple linear stepwise regression analysis (MLSRA), cluster analysis, and Pearson's correlation analysis, to study the relations between vegetative characteristics and essential elemental (plus nutrition) levels. Numerous investigations on the interactions between independent factors and a dependent variable have well indicated this type of relationship [13-17]. The tissue essential elemental concentrations (N, P, K, Ca, Mg, B, CI, S, Cu, Fe, and Zn) and the MAP are correlated for CA using the vegetative growth parameters (canopy, chlorophyll, frond growth, frond length, frond number of leaflets, frond thickness, and frond width). Vegetative growth parameters are dependent variables for the MLSRA. The independent variables included were the tissue essential elemental concentrations (K, B, N, Ca, P, Mg, CI, S, Cu, Zn, and Fe) and the MAP (palm age). Only significant independent influencing factors ($P< 0.05$) were utilized to construct the equation.

3. Results and Discussion

3.1. Chloride

Based on Figure 1a, Cl levels range from 0.56-0.86% and 0.62-0.85% for SPA and UPMBF, respectively. There is a similar pattern of increment of CI levels between SPA and UPMBF during the period of field plot experiment. This shows that the Cl levels between SPA (mean: 0.75 ± 0.02, %) and UPMBF (mean: 0.76 ± 0.02, %) are not significantly ($P> 0.05$) different. Therefore, these findings demonstrate that Cl uptake in the oil palm's leaflets using UPMBF is comparable and almost similar to those in SPA.



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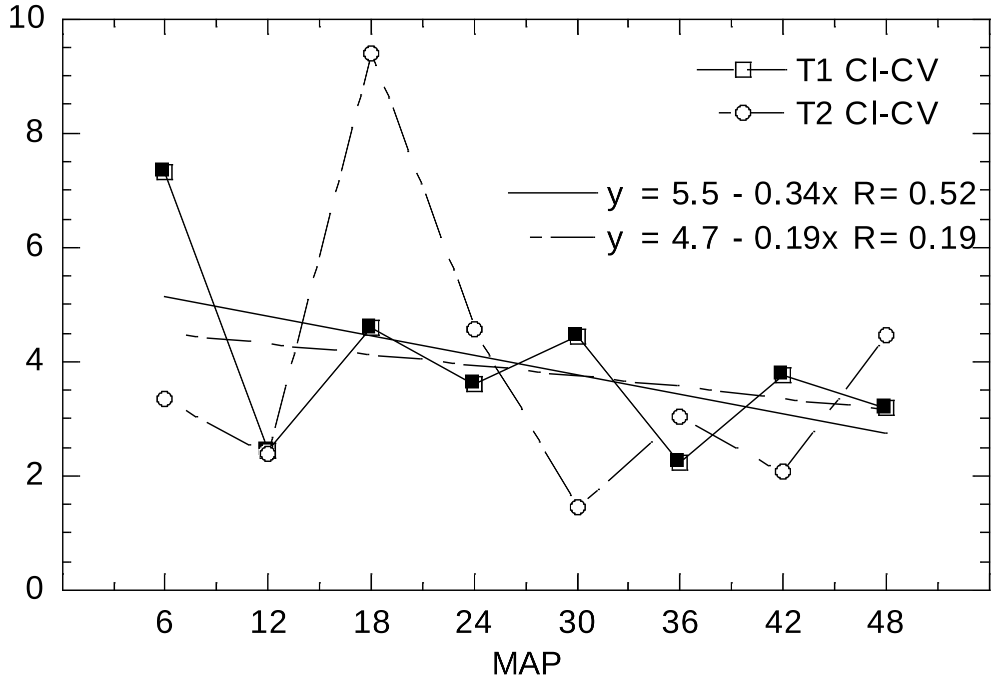


(b)

Figure 1. Variations of (a) Chloride (Cl) concentrations (mean ± SE, %) and (b) its coefficients of variation (CV) during the field plot experimental period in the oil palms' leaflets between Universiti Putra Malaysia biochemical fertilizer (PMBF; T2), and standard practice application (SPA; T1), from the present study.

Based on the CV of the Cl during the study period of the oil palm (Figure 1b), the CV values for both SPA and UPMBF show one consistent pattern. SPA and UPMBF show oxygen production during photosynthesis, raising cell osmotic pressure and owning the negative equations (SPA with R= 0.52; UPMBF with R= 0.19). This indicates the lower variation of Cl levels in the oil palm's leaflets in UPMBF, with increasing MAP. These findings also show that both SPA and UPMBF are becoming constant in their CI uptake with increasing MAP. Since all the Cl levels range from 0.62 and 0.85%, this shows that all SPA and UPMBF of all periods of MAPs are close to the 'Optimum' category based on Fairhurst and Mutert [18]'s CI guideline.

The chloride anion (CI^-) contributes to tissue hydration, increasing cell osmotic pressure, and oxygen synthesis during photosynthesis. Some employees believe it is only necessary for palm and kiwi fruit. Younger leaves develop chlorosis due to Cl deficiency, and general withering results from the potential impact on transpiration.

Both the pygmy date palm (*Phoenix roebelenii*) and the clustered fishtail palm (*Caryota mitis*) exhibited new chlorotic leaves, according to research by Broschat [19]. The leaflets of the latter species continued to be partly joined along their borders, giving them a ladder-like look. Fruit yields for coconut and African oil palm have dramatically increased by Cl fertilization in the Philippines, despite the absence of obvious signs of this shortage in palm production [20].

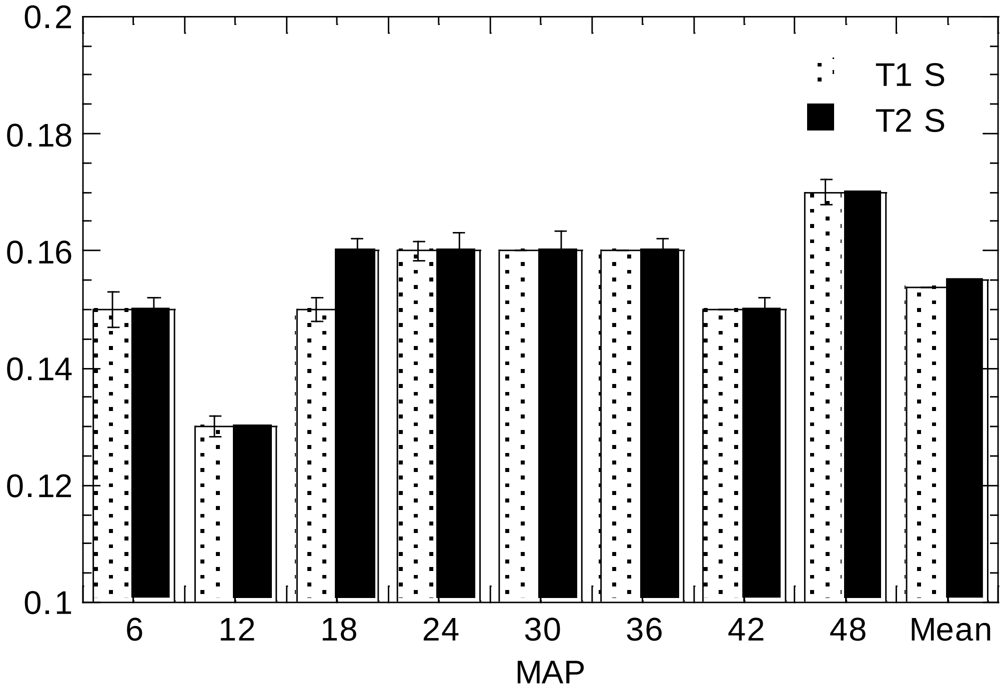
3.2. Sulfur

Based on Figure 2a, S levels range from 0.13-0.18% and 0.13-0.17% for SPA and UPMBF, respectively. There is a similar pattern of increment of S levels between SPA and UPMBF during the period of the field plot experiment. This is well-shown that the S levels between SPA (0.154 ± 0.001, %) and UPMBF (0.155 ± 0.001, %), are not significantly ($P > 0.05$) different. Therefore, these findings demonstrate that S uptake in the leaflets of oil palm using UPMBF is comparable and almost similar to those in SPA.

Based on CV of the S during the experimental field plot study of the oil palm (Figure 2b), the CV values for both SPA and UPMBF are showing an inconsistent pattern from 6 to 48 MAPs. There are no obvious patterns of relationships that can be observed. Since all the S levels range from 0.13 and 0.18%, this indicates that all SPA and UPMBF of all periods of MAPs are in the 'Deficiency' category based on Fairhurst and Mutert [18]'s S guideline.

Crops need S in quantities equivalent to P. The typical total S concentration in vegetative tissue is between 0.12 and 0.35%, and the total N/total S ratio is around 15. It is a component of the vitamins thiamine (B1) and biotin, and it's necessary for the production of mustard oils and the sulphydryl linkages that give onions, oils, and other foods their pungent flavour. Because the S in structural compounds cannot be translocated, mobility is poor under low S circumstances. Young leaves are lacking in S and display indications of shortage as the supply of S grows increasingly scarce. S deficit is quite similar to N deficiency. It begins with the emergence of light-green or pale-yellow leaves. In contrast to N deficiency, S-deficiency symptoms typically start to show up on younger leaves first and persist even after N treatment [21]. S-deficient plants have tiny, spindly leaves and thin, short stems. Both their development and cereal maturity are slowed down. Legumes have weak nodulation and decreased N fixation. Fruits frequently don't reach complete maturity and are still a light green shade. Low yields and lower oil content are the results of S-deficient oilseed crops. Under extremely low circumstances, S toxicity can happen, potentially due to sulphide (H_2S) damage.

High quantities of atmospheric SO_2 can harm the majority of plants. When SO_2 concentrations rise over 0.6 mg SO_2/m^3, poisoning symptoms become visible. Normal SO_2 values are between 0.10 and 0.20 mg SO_2/m^3. S-toxicity signs include necrotic patches on leaves that cover the entire leaf. The youngest leaves become chlorotic due to sulphur deficiency, and the severity of the condition is correlated with an increase in leaf size and necrosis at the leaflet tips [21-22].



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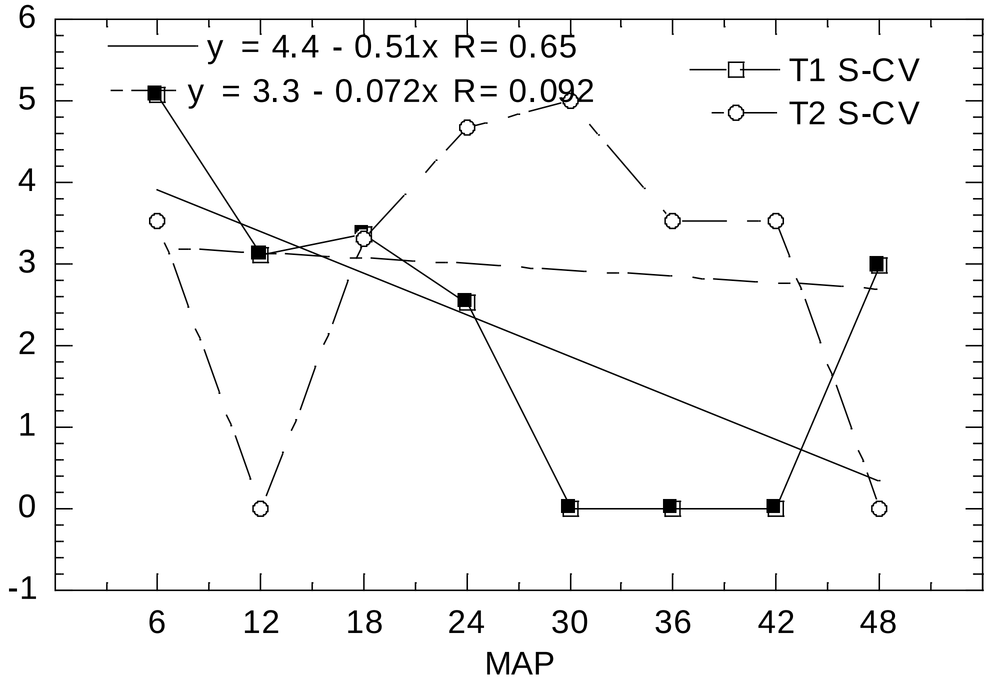
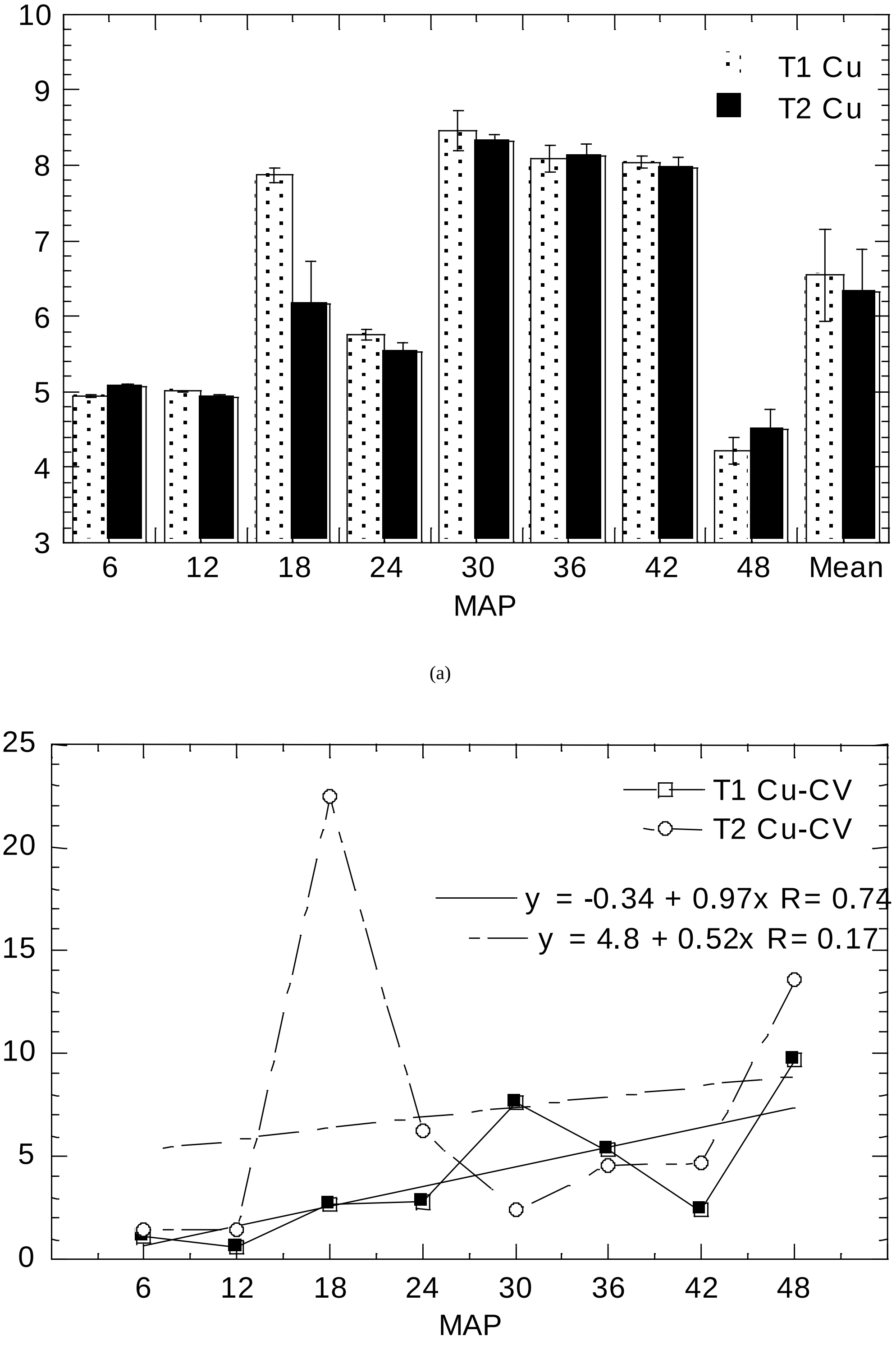


(b)

Figure 2. Variations of (a) Sulfur (S) concentrations (mean ± SE, %), and (b) its coefficients of variation (CV) during the field plot experimental period in the oil palms' leaflets between Universiti Putra Malaysia biochemical fertilizer (UPMBF; T2), and standard practice application (SPA; T1), from the present study.



(a)

(b)

Figure 3. Variations of (a) copper (Cu) concentrations (mean ± SE, mg/kg dry weight), and (b) its coefficients of variation (CV) during the field plot experimental period in the oil palms' leaflets between Universiti Putra Malaysia biochemical fertilizer (UPMBF; T2), and standard practice application (SPA; T1), from the present study.

3.3. Copper

Based on Figure 3a, Cu concentrations range from 3.69-9.73 mg/kg and 3.93-8.69 mg/kg for SPA and UPMBF, respectively. There is a similar pattern of increment of Cu levels between SPA and UPMBF during the period of field plot experiment. This is well-shown that the Cu levels between SPA (6.55 ± 0.61, mg/kg) and UPMBF (6.33 ± 0.56, mg/kg), are not significantly (P> 0.05) different. Therefore, these findings demonstrate that Cu uptake in the oil palm's leaflets using UPMBF is comparable and almost similar to those in SPA.

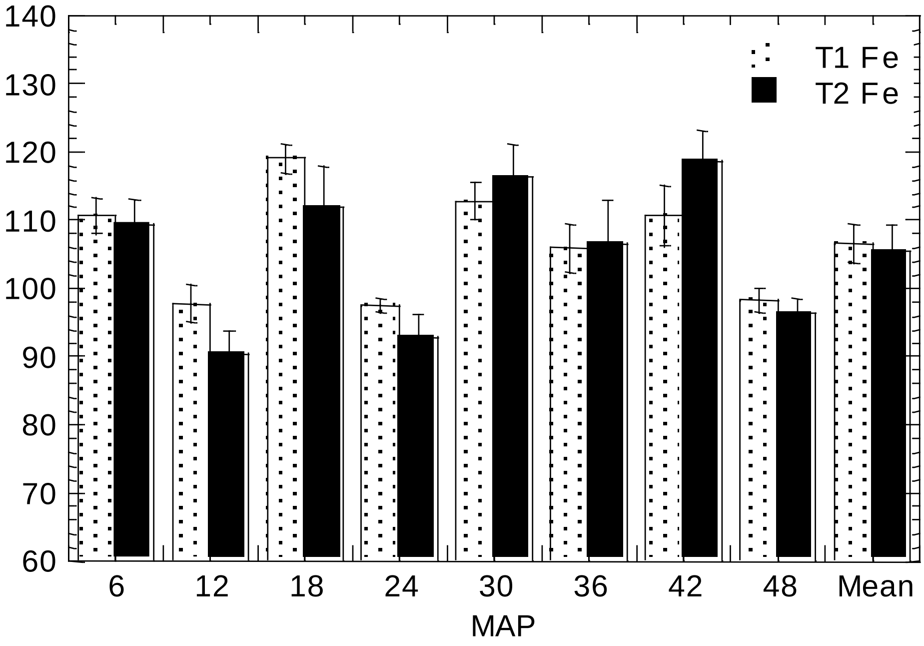
Except for 18 MAP for UPMBF (Figure 3b), the CV values for both SPA and UPMBF show one consistent pattern. Both SPA and UPMBF show positive equations, with the obviousness of positive in SPA (R= 0.70) than UPMBF (R= 0.17). This indicates a higher variation of Cu levels in the leaflets of oil palm in both SPA and UPMBF, with increasing MAP. These findings also show that both SPA and UPMBF are getting more variable or unstabilizing with increasing MAP, in terms of Cu uptake in the frond of oil palm. Since all the Cu levels range from 4.20 to 8.40 mg/kg, this shows that all SPA and UPMBF of all periods of MAPs are in the 'Optimum' category based on the by Fairhurst and Mutert [18]'s Cu guideline.

Cu is absorbed as Cu^{2+}. Its absorption seems to be a metabolically controlled process. Cu absorption, however, principally depends on the quantities of accessible Cu in the soil and is essentially independent of competing effects. Cu plays a role in chlorophyll synthesis and is a component of various enzymes, including cytochrome oxidase. Chlorophyll, which is mostly associated with chloroplasts, may contain up to 70% of the Cu in plants. It involves in the metabolism of proteins, carbohydrates, and lignin and may be necessary for symbiotic N fixation [18]. Plastocyanin, a component containing Cu completes a link in the electron transport chain involved in photosynthesis [23].

3.4. Iron

Based on Figure 4a, Fe concentrations range from 85.7-126 mg/kg and 79.8-136 mg/kg for SPA and UPMBF, respectively. There is a similar pattern of increment of Fe levels between SPA and UPMBF during the period of field plot experiment. This is well-shown that the Fe levels between SPA (107 ±2.86, mg/kg) and UPMBF (105 ±3.83, mg/kg), are not significantly (*P*> 0.05) different. Therefore, these findings demonstrate that Fe uptake in the leaflets of oil palm using UPMBF is comparable and almost similar to those in SPA.

Based on the CV of the Fe during the experimental field plot study of the oil palm (Figure 4b), the CV values for both SPA and UPMBF are very variable and fluctuate from 6 to 48 MAPs. However, one obvious pattern can be observed in which all the CV values in UPMBF are higher than those in SPA, in all periods of MAPs (except for 42 MAP). This is indicated by the negative equation in UPMBF (R= 0.14), showing the lower variation of Fe levels in the leaflets of oil palm in SPA, with increasing MAP. However, a positive relationship is found for SPA (R= 0.22), showing more variations of Fe uptake with increasing MAP. Unfortunately, there is no Fe guideline established. Hence, a comparison with any Fe guidelines is not possible.



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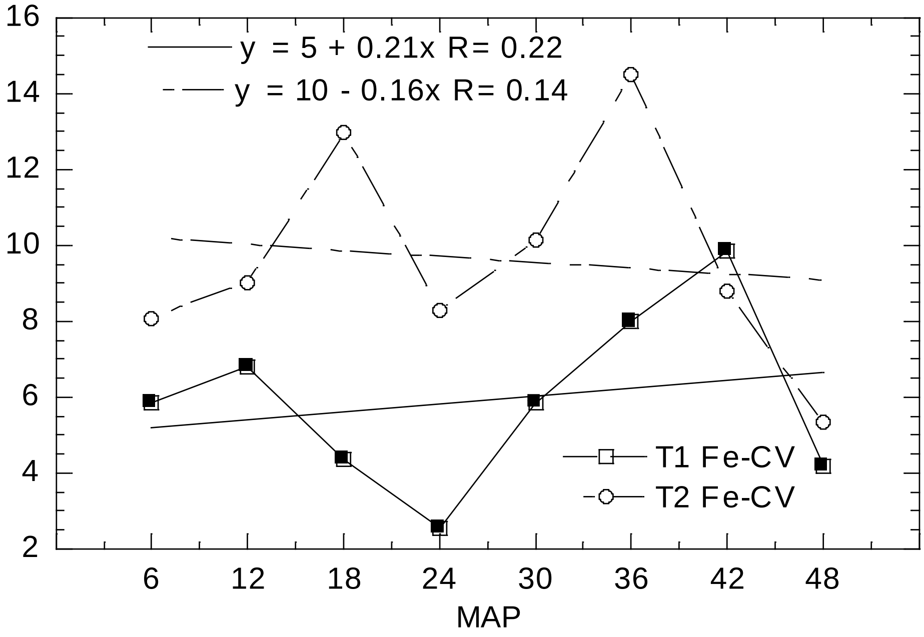


(b)

Figure 4. Variations of (a) iron (Fe) concentrations (mean ± SE, mg/kg dry weight) and (b) its coefficients of variation (CV) during the field plot experimental period in the oil palms' leaflets between Universiti Putra Malaysia biochemical fertilizer (UPMBF; T2), and standard practice application (SPA; T1), from the present study.

Plant roots can absorb Fe as Fe^{2+} and, to a lesser extent, as Fe chelates. After reducing Fe^{3+} to Fe^{2+}, the separation between Fe and the organic ligand is required at the root surface for effective utilization of chelated Fe. Chlorophyll synthesis, carbohydrate synthesis, cell respiration, chemical nitrate and sulphate reduction, and N absorption are all impacted by it. In extreme circumstances, new leaves may develop with widespread necrosis of the leaf tips and an almost white colour. Fe tends to build up in older leaves [19], therefore, symptomatic leaves may turn green as they ripen. Fungicides cannot prevent leaf spot illnesses like *Exserohilum* leaf spot (produced by *Exserohilum rostratum*) on the foxtail palm (*Wodyetia bifurcata*) without first treating the Fe deficit, according to Broschat and Elliott [24]. In calcareous soils, palms may show signs of Fe shortage, but not to the extent that dicot trees or shrubs are harmed. In palms planted in containers where the substrate has broken down and reduced root zone aeration, the Fe shortage is widespread [25].

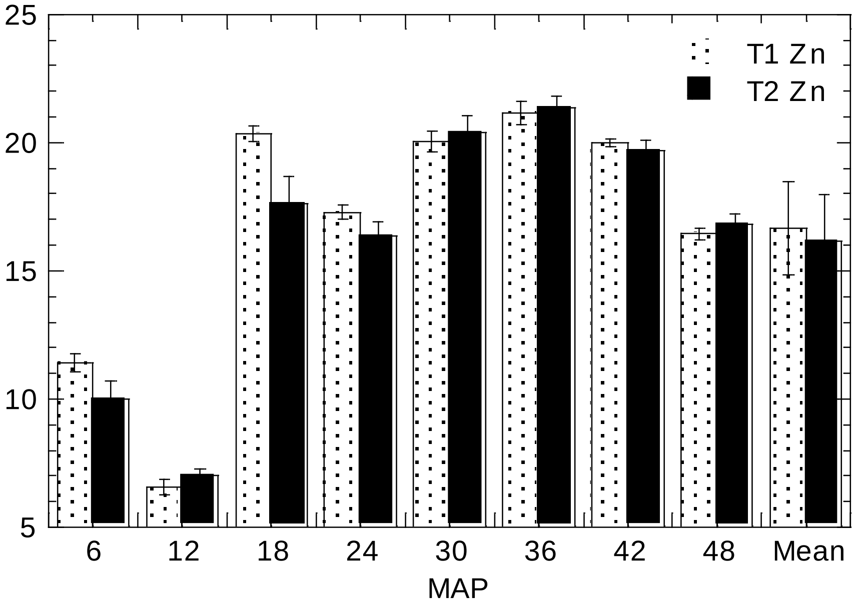
3.5. Zinc

Based on Figure 5a, Zn concentrations range from 5.41-22.9 mg/kg and 6.17-22.9 mg/kg for SPA and UPMBF, respectively. There is a similar pattern of increment of Zn levels between SPA and UPMBF during the period of field plot experiment. This is well-shown that the Zn levels between SPA (16.7 ± 1.83, mg/kg) and UPMBF (16.2 ± 1.80, mg/kg), are not significantly ($P > 0.05$) different. Therefore, these findings demonstrate that Zn uptake in the leaflets of oil palm using UPMBF is comparable and almost similar to those in SPA.

Based on the CV of the Zn during the experimental field plot study of the oil palm (Figure 5b), the CV values for both SPA and UPMBF show one consistent pattern. Both SPA and UPMBF show negative relationships between Zn levels and MAP (SPA with R= 0.71; UPMBF with R= 0.81). This indicates the lower variation of Zn levels in oil palms' leaflets in both SPA and UPMBF, with increasing MAP. These findings also show that both SPA and UPMBF are becoming constant in their Zn uptake with increasing MAP. It is clearly indicated that after 18 MAP, the Zn levels in both SPA and UPMBF are categorized between 'Optimum' to 'Excessive' according to the Zn guideline by Fairhurst and Mutert [18].

The divalent cation Zn^{2+} is used to absorb zinc. Zn uptake was first thought to be passive, but more recent research suggests that it is active (energy-dependent). Numerous enzyme systems, auxins, protein synthesis, seed formation, and maturity rates all depend directly or indirectly on zinc. Zn is thought to encourage the synthesis of RNA, which is necessary for the formation of protein. Zn has little mobility. In Zn-deficient plants, the rate of Zn mobility to younger tissue is significantly suppressed [23].

Another typical sign is the little-leaf disease. The internodes are short. It is possible to postpone flowering, fruiting, and maturity. Shoots might disappear, and leaves could turn early. Not all plants exhibit the same deficiencies signs. Chlorosis can accompany a decline in root development and leaf expansion caused by Zn poisoning [26].



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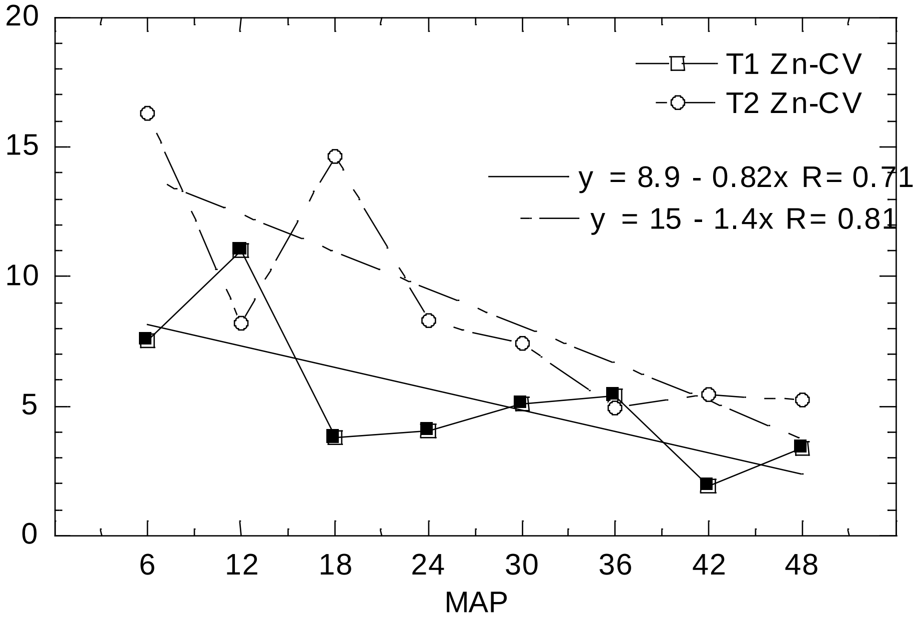

(b)

Figure 5. Variations of (a) zinc (Zn) concentrations (mean ± SE, mg/kg dry weight), and (b) its coefficients of variation (CV) during the field plot experimental period in the oil palms' leaflets between Universiti Putra Malaysia biochemical fertilizer (UPMBF; T2), and standard practice application (SPA; T1), from the present study.

3.6. Comparative Levels of Essential Elements between UPMBF and SPA

The use of UPMBF is comparable and similar to SPA that is supported by statistical analysis. First, there are no significant differences between UPMBF and SPA based on the T-test analysis. Table 1 displays the overall findings of the T-Test comparison of the oil palm plants' nutrient concentrations during the experimental field plot study between SPA and UPMBF. The results of the T-Test analysis show that there is insignificant difference (*P*> 0.05) between SPA and UPMBF for all the five elements (CI, S, Cu, Fe, and Zn).

Second, similar clustering patterns between SPA and UPMBF based on cluster analysis are found, as indicated in Figure 6. In both SPA (Figure 1a) and UPMBF (Figure 1b), the eleven elements in the leaflets of oil palm are clustered into two major entities. The first is only the Fe, while the second major cluster consists of the other ten elements, with a subcluster grouping B and Fe. The almost similar clustering patterns between SPA and UPMBF indicated the UPMBF is comparable to SPA.

Table 1. Analysis of T-Test results for essential elemental concentrations of the leaflets oil palms during the experimental period from the present study

	T1	T1	T2	T2			
	Mean	SD	Mean	SD	T-value	P	F-ratio
Cl	0.75	0.07	0.76	0.06	-0.92	0.36	1.14
S	0.15	0.01	0.15	0.01	0.41	0.68	1.10
Cu	6.55	1.67	6.33	1.59	0.67	0.51	1.11
Fe	107	9.90	105	14.3	0.49	0.62	2.08
Zn	16.7	4.94	16.2	5.00	0.49	0.63	1.03

Note: Universiti Putra Malaysia Biochemical Fertilizer (UPMBF; T2); Standard practice application (SPA; T1); N= 48.

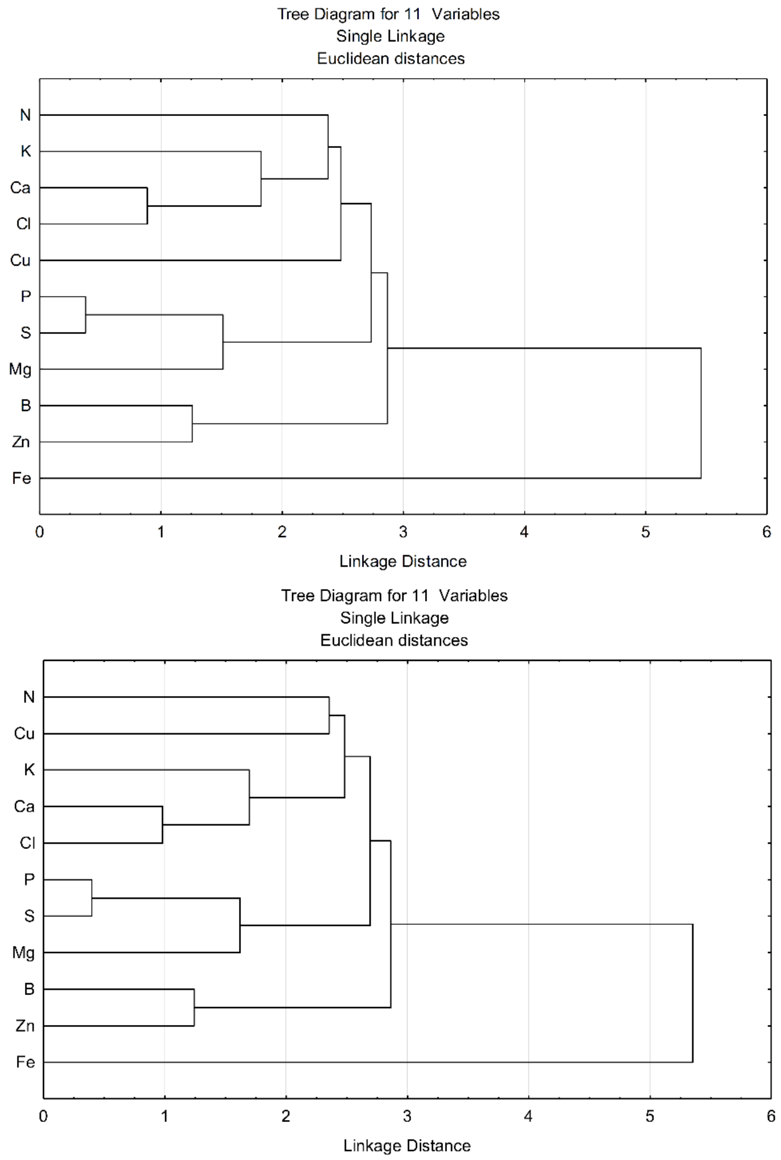

Figure 6. Comparisons between standard practice application (SPA;Top) and Universiti Putra Malaysia biochemical fertilizer (UPMBF; Bottom) based on cluster analysis based on Single Linkage Euclidean distances, on the nutrient concentrations (log10 [mean + 1]) in the fronds of oil palm trees (N = 48 for T1 and N= 48 for T2). Note: The data for N, P, K, Ca, Mg and B are cited from Tony Peng et al. [8].

Table 2. Comparisons of the correlation coefficients between standard practice application (T1) and Universiti Putra Malaysia Biochemical Fertilizer (T2) of their 5 essential element concentrations in the leaflets, and 13 vegetative parameters of oil palm trees.

	MAP-T1	MAP-T2	Cl-T1	Cl-T2	S-T1	S-T2	Cu-T1	Cu-T2	Fe-T1	Fe-T2	Zn-T1	Zn-T2
Frond growth	0.38	0.62	0.79	0.72	0.02	0.43	0.16	0.33	-0.29	-0.10	-0.02	0.50
Frond length	0.98	0.97	0.61	0.36	0.60	0.52	0.25	0.33	-0.13	0.09	0.61	0.70
Frond no leaflet	0.91	0.92	0.71	0.46	0.60	0.55	0.34	0.40	-0.13	0.09	0.65	0.74
Frond thickness	0.78	0.79	0.63	0.33	0.32	0.21	0.01	0.26	-0.47	-0.13	0.19	0.37
Frond width	0.88	0.84	0.63	0.30	0.43	0.26	0.05	0.23	-0.40	-0.06	0.30	0.45
Leaf right length	0.88	0.90	0.70	0.39	0.47	0.37	0.31	0.35	-0.18	0.01	0.51	0.64
Leaf right width	0.73	0.77	0.60	0.34	0.44	0.36	0.22	0.24	-0.13	-0.08	0.43	0.48
Leaf left length	0.88	0.89	0.70	0.45	0.46	0.36	0.27	0.31	-0.21	-0.01	0.49	0.60
Leaf left width	0.76	0.34	0.66	0.31	0.47	0.15	0.31	0.06	-0.13	0.02	0.49	0.29
Chlorophyll left	0.66	0.65	0.73	0.45	0.39	0.60	0.47	0.39	-0.06	0.15	0.52	0.75
Chlorophyll right	0.61	0.60	0.73	0.50	0.30	0.49	0.45	0.48	-0.09	0.25	0.45	0.74
Canopy north	0.96	0.96	0.66	0.42	0.59	0.50	0.31	0.40	-0.13	0.09	0.62	0.73
Canopy south	0.97	0.96	0.65	0.40	0.60	0.51	0.30	0.40	-0.12	0.09	0.62	0.72

Note: Based on $\log_{10}$ (mean + 1)-transformed data (N = 48 for both T1 and T2) The month after planting (MAP) is also included in the present correlation analysis. Red-marked correlation coefficients are significant at $p < 0.05$.

Third, comparable correlation coefficients between SPA and UPMBF are found (Table 2). Table 2 compares the correlation coefficients between SPA and UPMBF of the concentrations of the five necessary elements in the leaflets and the thirteen vegetative parameters. The 13 vegetative parameters and their correlation coefficients varied from 0.38 to 0.98 (mean: 0.80) for SPA and from 0.34 to 0.97 (mean: 0.79) for UPMBF. The 13 vegetative parameters and the correlation coefficients varied from 0.60-0.79 (mean: 0.68) for SPA and 0.30-0.72 (mean: 0.42) for UPMBF. The 13 vegetative parameters were correlated with S using correlation values ranging from 0.02-0.60 (mean: 0.44) for SPA to 0.15-0.60 (mean: 0.41) for UPMBF. The 13 vegetative parameters had correlation values ranging from 0.01-0.47 (mean: 0.27) for SPA and 0.06-0.48 (mean: 0.32) for UPMBF. The 13 vegetative parameters had correlation values ranging from -0.47 to -0.06 (mean: -0.19) for SPA and -0.13 to -0.25 (mean: 0.03) for UPMBF. Zn and the 13 vegetative parameters had correlation values that varied from -0.02 to 0.65 (mean: 0.45) for SPA and 0.29 to 0.75 (mean: 0.59) for UPMBF. Again, the 13 vegetative parameters used to calculate the correlation coefficients for UPMBF are essentially identical to those used for SPA.

Fourth, there are similarities in the selection of influential parameters to influence the vegetative parameters between SPA and UPMBF (Table 3). Between SPA and UPMBF, certain parallels and changes in the fundamental element characteristics are chosen to significantly affect the vegetative parameters (Table 3). All 13 vegetative parameters have at least one comparable component chosen as a determining factor. For instance, the canopy north of T1 and T2 exhibits similarities, with a comparable total number of eight important components chosen, and 4 similar elements (CI, B, Ca, and K). However, the distinctions between four different variables that have an influence on the canopy north may be assessed. The differences may also be shown by comparing the influential factors, such as the Frond growth for SAP (10 elements) and UPMBF (7 elements). MLSRA is an ecologically preferred multivariate statistical approach since the oil palm plantation agroecosystem comprises several components with abiotic and biotic interactions [13]

The ranges of essential element levels from the present study are compared to those reported by Behera et al. [5] and Tao et al. [6]. Behera et al. [5], based on oil palm leaves in 42 oil palm plantations collected from the southern plateau of India (Karnataka) during 2012–2013, the mean leaf nutrient ranges varied from 0.72-1.09 %, 7.42-12.9 mg/kg, 33.6- 58.6 mg/kg, and 82.8-936 mg/kg for S, Cu, Zn and Fe, respectively. These mean values are higher than those found in SPA and UPMBF (0.15% for S; 6.33-6.55mg/kg for Cu; 105-107 mg/kg for Fe; 16.2-16.7mg/kg for Zn) from the present study. The present CI range (0.75-0.75%) is higher than the average level of CI reported for sandy soils in Central Kalimantan [6]. The S range (0.15%) is comparatively close to that (0.17%) reported by Tao et al. [6].

Table 3. Statistical outputs of the multiple linear stepwise regression analysis between standard practice application (SPA; T1) and Universiti Putra Malaysia biochemical fertilizer (UPMBF; T2) in their vegetative parameters (as dependent variables) that to be influenced by of essential elements in the leaflets (as independent variables) of the oil palm from the present study.

Canopy north	T1	Intercept	MAP	Cl	B	S	Ca	N	Cu	K			R	R^2	F
	B	0.11	0.01	0.96	0.26	0.42	-0.26	1.01	0.20	-0.26			0.99	0.99	382.7
	T2	Intercept	MAP	Cl	B	P	Ca	Zn	Fe	K			R	R^2	F
	B	0.69	0.02	0.98	0.42	2.11	-0.12	0.20	-0.30	0.49			0.986	0.972	167
Canopy south	T1	Intercept	MAP	Cl	B	S	Ca	K	N	Cu	Zn		R	R^2	F
	B	0.82	0.01	0.82	0.35	0.80	-0.25	-0.41	0.69	0.22	-0.12		0.99	0.99	315.1
	T2	Intercept	MAP	Cl	P	K	B	Fe	Zn	Ca			R	R^2	F
	B	0.60	0.02	0.97	2.53	0.58	0.37	-0.29	0.18	-0.11			0.986	0.971	165
Chlorophyll left	T1	Intercept	Cl	Zn	N	MAP	Ca	B	K	Cu	S		R	R^2	F
	B	0.89	0.47	-0.05	0.76	0.00	-0.19	0.22	-0.23	0.16	0.51		0.92	0.85	23.9
	T2	Intercept	Zn	Cl	MAP	P	S	B	Ca	Cu			R	R^2	F
	B	1.79	0.10	0.25	0.00	0.77	0.30	0.23	-0.11	-0.05			0.903	0.815	21.5
Chlorophyll right	T1	Intercept	Cl	MAP	B	N	Ca	Zn					R	R^2	F
	b	0.47	0.68	0.00	0.24	0.75	-0.14	0.09					0.9	0.82	30.3
	T2	Intercept	Zn	Cl	B	MAP	Ca	N	P	Mg			R	R^2	F
	b	1.07	0.12	0.43	0.23	0.00	-0.11	0.39	0.56	-0.08			0.892	0.796	19.1
Frond growth	T1	Intercept	Cl	N	Ca	P	Mg	MAP	Fe	Cu	S	Zn	R	R^2	F
	b	-4.27	2.67	1.90	-0.44	-1.60	0.67	0.00	0.68	-0.02	1.13	-0.25	0.9	0.81	16
	T2	Intercept	Cl	MAP	P	Ca	B	S	Fe				R	R^2	F
	b	-0.67	1.80	0.01	2.75	-0.33	0.60	0.80	-0.27				0.924	0.854	33.5
Frond length	T1	Intercept	MAP	Cl	B	Ca	S	P					R	R^2	F
	B	2.05	0.01	0.44	0.40	-0.17	0.48	-1.18					0.99	0.98	337.5
	T2	Intercept	MAP	Cl	P	K	B	Mg	Fe	Zn			R	R^2	F
	B	1.31	0.01	0.74	1.54	0.50	0.34	-0.20	-0.22	0.07			0.982	0.965	135
Frond no leaflet	T1	Intercept	MAP	Cl	B	S	Fe	N	Ca	K	P	Zn	R	R^2	F
	B	-0.09	0.01	1.12	0.51	0.78	-0.11	1.16	-0.27	-0.46	-1.41	0.12	0.99	0.97	127.8
	T2	Intercept	MAP	Cl	P	B	S	Ca	Fe	Zn			R	R^2	F
	B	-0.34	0.01	0.96	1.76	0.40	0.34	-0.23	-0.27	0.07			0.98	0.96	88.2

Table 3 Continued

Frond thickness	T1	Intercept	MAP	Fe	Cl	Ca	P	Zn	Cu	Mg	R	R²	F
	B	2.81	0.01	-1.05	0.99	-0.14	4.39	-0.48	0.47	-0.44	0.94	0.88	36.1
	T2	Intercept	MAP	N	Zn	P	Mg	Fe	Cu	B	R	R²	F
	B	6.13	0.01	-2.64	-0.29	4.99	0.78	-0.88	0.08	-0.50	0.93	0.864	23.6
Frond width	T1	Intercept	MAP	Ca	Cl	Zn	P	N	Fe		R	R²	F
	B	2.81	0.01	-0.19	0.83	-0.21	3.30	-0.78	-0.43		0.97	0.93	78.1
	T2	Intercept	MAP	S	Fe	N	P	Zn			R	R²	F
	B	4.03	0.01	-0.40	-0.33	-1.19	1.65	-0.13			0.892	0.796	26.6
Leaf left length	T1	Intercept	MAP	Cl	B	Ca	N	S	P		R	R²	F
	b	0.74	0.01	0.64	0.46	-0.28	0.49	0.36	-1.36		0.96	0.92	65.3
	T2	Intercept	MAP	Cl	K	B	Ca	Mg	Fe	S	R	R²	F
	B	1.41	0.01	0.49	0.33	0.48	-0.13	-0.22	-0.21	-0.30	0.962	0.926	53.1
Leaf left width	T1	Intercept	MAP	B	K	Cl	S	N	Ca		R	R²	F
	B	-0.15	0.00	0.23	0.30	0.42	0.39	0.27	-0.05		0.93	0.86	35.7
	T2	Intercept	MAP	Cl							R	R²	F
	B	1.23	0.00	0.36							0.404	0.163	4.39
Leaf right length	T1	Intercept	MAP	Cl	B	Ca					R	R²	F
	B	1.36	0.01	0.64	0.35	-0.17					0.95	0.89	90.6
	T2	Intercept	MAP	B	Fe	K	Zn	S	Cl	N	R	R²	F
	B	0.93	0.01	0.17	-0.34	0.53	0.20	-0.65	0.45	0.61	0.957	0.915	45.6
Leaf right width	T1	Intercept	MAP	Cl	N	K	Zn				R	R²	F
	b	-0.36	0.00	0.49	0.54	0.42	0.09				0.88	0.77	27.5
	T2	Intercept	MAP	Mg	K	Fe	P	Zn	B		R	R²	F
	b	1.23	0.00	0.12	0.35	-0.21	0.55	0.05	0.10		0.875	0.765	18.6

Note: Independent variables included in the present study are N, P, K, Ca, Mg, Cl, S, B, Cu, Fe, Zn, age of plant (month after planting). The data for N, P, K, Ca, Mg and B are cited from Tony Peng et al. [8] (2022); N = 48 for both T1 and T2; All P= 0.000.

The soil characteristics, rainfall, fertilizer application, and vegetative factors like as leaf number, canopy, chlorophyll, and MAP (palm age) can all affect the leaf essential elemental content of the oil palm [27]. Therefore, employing the right quantity of important ingredients [18]. The usage of UPMBF in contrast to SPA may therefore be demonstrated to be more effective over a four-year period in this investigation with immature oil palm. The use of UPMBF as an innovative, affordable, alternative biofertilizer treatment for improved control of important foliar essential elements and vegetative parameters has been proven from the present Kuala Lipis trial site.

The combination of the outcomes of leaflet analysis with practical experience and common sense typically leads to successful fertilizer recommendations [18]. Large levels of critical CI, S, Cu, Fe, and Zn are required for the oil palm [28-30]. The most used diagnostic method for assessing the nutritional status of oil palm and estimating the appropriate fertilizer amounts is still leaflet analysis [31-34]. The three statistical analyses presented here have, therefore, clearly shown that UPMBF may be advised as being as excellent as SPA for the innovative biofertilizer application from the current field plot trial research. With the significantly lower costs using SPA [8], the UPMBF could be employed as a cost-effective and novel fertilization application for immature oil palm in Malaysia. Therefore, the present findings well supported the report by Tony et al. [8], who focused on the nutritional status of N, K, P, Mg, B, and Ca.

4. Conclusions

This study investigated the levels of five essential elements and vegetative parameters in *E. guineensis* by comparing the UPMBF to SPA under field plot experimental conditions. The statistical analyses provided evidence that UPMBF is comparable and close (insignificantly ($P> 0.05$) different) to T1. Therefore, this study suggested a novel use of UPMBF as a more cost-effective approach since it can minimize the overall fertilization cost for better managing essential elements of the immature oil palm in Malaysia.

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