

Evaluation of POME Sludge as Organic Soil Amendments on the Growth Performance and Yield of *Brassica rapa* subsp. *chinensis* L.

Zubaidah Yusop^{1*}, Siti Sahmsiah Sahmat¹, Suraiya Mahdian², Sharifah Mazenah Wan Yusuf¹, Syahira Jos¹

¹Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA, 94300 Kota Samarahan, Sarawak, Malaysia

²Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA, 96400 Mukah, Sarawak, Malaysia

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ABSTRACT

Palm oil mill effluent (POME) sludge is a nutrient-rich organic byproduct with potential application in sustainable agriculture. However, limited information about POME sludge deserves serious attention since its application in agriculture could enhance plant growth and productivity. This study assesses the effects of raw POME sludge and alginate-encapsulated POME sludge as soil amendments on the growth and productivity of *Brassica rapa* subsp. *chinensis* L. A field experiment was conducted using a Completely Randomized Design with three treatments: control (no amendment), POME sludge, and POME sludge encapsulated with sodium alginate. Key agronomic parameters including plant height (cm), chlorophyll content (SPAD), leaf width (cm), shoot and root biomass, total yield (g), and shoot-to-root ratio were measured at biweekly intervals. Statistical analysis was performed using ANOVA and post-hoc least significant difference (LSD) tests at $p < 0.05$. The results indicated no significant differences in plant height, SPAD, or leaf width among these treatments. In contrast, yield, shoot biomass, and shoot-to-root ratio were significantly improved, with the highest values observed in the alginate-encapsulated POME sludge treatment. Yield increased from 154.00 g in the control to 340.16 g in the encapsulated treatment. Correlation analysis further supported strong associations between shoot biomass, yield, and shoot-to-root ratio. The findings demonstrate that alginate-encapsulated POME sludge is an effective organic amendment for enhancing yield and biomass accumulation in *Brassica rapa* subsp. *chinensis* L. production.

* Corresponding author. E-mail address: sitis274@uitm.edu.my

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1 INTRODUCTION

Brassica rapa subsp. *chinensis* L or locally known as Pak choy or Bok choy (Chinese mustard), is a leafy vegetable that originated from both Southern and Northern of China¹. These leafy vegetables require a minimal amount of fertiliser and are commonly used in preliminary studies because they are easy to grow and a very quick-growing plant². However, to get a higher yield, farmers often apply chemical fertilisers which might contribute to the increase in soil acidity and the degradation of soil fertility for long-term use.

The intensification of agriculture has accelerated the demand for sustainable soil fertility management strategies. Among these, organic amendments derived from agro-industrial waste are gaining attention. Palm oil mill effluent (POME), a byproduct of palm oil processing, is often considered an environmental burden due to its high organic load and improper disposal. However, its composition is rich in organic carbon, nitrogen, phosphorus, and potassium, positioning it as a valuable organic input for soil fertility enhancement³. Previous research has reported that POME-based amendments improve soil physical properties, nutrient availability, and microbial activity, contributing to better crop productivity⁴. Table 1 shows the summary of previous studies that have been reported the positive effects of POME and its derivatives on soil and crops⁵⁻⁹. In addition, a study conducted by Loh et al.¹⁰ reported that treated POME can be used as a cheap organic fertiliser to substitute chemical fertiliser due to its substantial amount of NPK.

Additionally, integrating biopolymer encapsulation, such as sodium alginate, may optimise nutrient release dynamics and water retention capacity, further boosting agronomic outcomes¹¹. Biopolymers act as water barriers by controlling diffusion within the composite fertiliser and reducing the loss of gases and nutrients to the environment. These advancements align with circular economy principles by promoting waste valorisation and resource efficiency. Alginate is a biodegradable, environmentally friendly and non-toxic polymeric material¹². Encapsulated POME sludge in alginate matrices offers potential benefits for sustained nutrient release and enhanced water-holding capacity, especially under conditions of water or nutrient stress¹³. Despite growing interest, there remains limited empirical evidence comparing the effects of raw and encapsulated POME sludge on key physiological and agronomic traits in *Brassica rapa*. This study aims to evaluate the impact of POME Sludge and alginate-encapsulated POME Sludge on the growth, biomass accumulation, and yield of *Brassica rapa* subsp. *chinensis* L. Key parameters examined include shoot and root biomass, chlorophyll content, shoot-to-root ratio, and total yield.

Table 1. Summary of previous findings on POME-based amendments on soil quality and crop performance

Authors (Year)	POME Type / Form	Application / Context	Crop / Soil Tested	Main Findings
Sanches et al. (2024)	POME apply to soil	Soil fertilization	Agricultural soil	Altered soil bacterial diversity in short term
Ugwu et al. (2024)	Fermented vs fresh POME	Soil amendment	Tomato and low- fertility soils	Fermented POME improved soil pH, organic matter, N, available P at optimal $\leq 25\%$
Lau et al. (2024)	Compost from POME, EFB and decanter cake	Nursery growing media	Oil palm seedlings	Compost enhanced oil palm seedling height (+20–50%), leaf length, chlorophyll, and foliar nutrient assimilation (5–15%).
Alam et al. (2022)	Raw POME mixed with cocopeat and sand	Growth medium in polybags	Brazilian spinach	At 70% of POME application, the Brazilian spinach shows the highest plant height, branch and leaf number, fresh and dry weight
Osman et al. (2020)	Final discharge POME	Phytoremediation / growth medium	<i>Pennisetum purpureum</i> grass	The application of POME shows 61.7% height increase, higher cellulose; nutrients and heavy metals within safe limits

2 MATERIALS AND METHODS

2.1 Preparation of alginate-encapsulated POME sludge

POME sludge was obtained from the Felcra Jaya Mill, Kota Samarahan. The sludge was partially dried and moulded into bean-shaped pieces size, and subsequently oven-dried at 110 °C. The dried POME beans were then encapsulated with commercially manufactured sodium alginate at a 1:1 ratio into 50 mL of distilled water for 1 hour and slowly stirred using a magnetic stirrer until homogeneous. Then, the encapsulated bean-shaped POME was taken out from the solution and subsequently soaked into a solution of 1% CaCl₂. After 30 minutes the bean shape POME was then rinsed with distilled water and oven-dried at 40 °C for 24 hours^{12,14}.

2.2 Experimental design

A field experiment was conducted at Farm Unit, Universiti Teknologi MARA (UiTM) Cawangan Sarawak, Kampus Samarahan, using a Completely Randomized Design (CRD) with three treatments: (1) control (no amendment), (2) POME sludge, and (3) alginate-encapsulated POME sludge. Each treatment was replicated three times and applied to plots cultivated with *Brassica rapa* subsp. *chinensis* L. under standard agronomic practices.

2.3 Data collection

Plant performance of *Brassica rapa* subsp. *chinensis* L. was assessed biweekly. Parameters measured included plant height (cm), leaf chlorophyll content (SPAD values), leaf width (cm), shoot and root biomass, total yield (g), and shoot-to-root ratio. The height of each plant was measured from the base of the stem to the tip of the tallest leaf using a ruler. SPAD values were recorded using a SPAD 502-Plus (Konica-Minolta, Japan). The leaf width was measured with a ruler at the widest point perpendicular to the longitudinal axis of the leaf. The total yield was measured using an electronic balance 35 days after transplanting. The shoot and root biomass were weighed separately, and the shoot-to-root ratio was determined by dividing the shoot biomass by the root biomass.

2.4 Data analysis

Data was analysed using R Studio (version 2024.12.1). Analysis of variance (ANOVA) determined treatment effects, followed by post-hoc comparisons using the Least Significant Difference (LSD) test at $p < 0.05$.

3 RESULTS AND DISCUSSION

Table 2 presents the ANOVA (mean square) outcomes for the growth parameters of the *Brassica rapa* subsp. *Chinensis* L. in response to the POME sludge treatments. For yield (g), shoot biomass, and shoot-to-root ratio exhibited significant treatment effects ($p < 0.001$) indicating that the application of POME sludge contributes positively to crop productivity, while plant height (cm), SPAD, and leaf width (cm) did not differ significantly among treatments ($p > 0.05$). This shows that, POME sludge treatment promotes physiological and biomass related parameters rather than vegetative growth characteristics.

Table 2. ANOVA table (mean square) for the parameter measured of *Brassica rapa* subsp. *chinensis* L. in response to POME sludge treatment

SOV	DF	Height (cm)	SPAD	Leaves Width (cm)	Yield (g)	Shoot (g)	Root (g)	Shoot-Root Ratio
Treatment	2	16.333	2.72	10.36	26063***	25028.6***	11.86**	63.448**
Residual	33	12.975	15.89	9.02	36.8	31.4	3.14	5.558
CV		19.63	10.88	33.91	2.43	2.34	13.34	13.38

Note: SOV = source of variance; CV= coefficient of variation; DF = degrees of freedom; significance codes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table 3 summarises the mean comparison of treatments. Both POME treatments increased yield and biomass parameters significantly as compared to the control. Encapsulated POME sludge yielded the highest biomass and productivity gains. Although Table 2 indicates that there is not significantly different in plant height and SPAD readings and leaves width among the treatments, the post-hoc analysis presented in Table 3 revealed that the POME treatments consistently recorded the highest in mean values for these parameters as compared to the control treatment (without POME). This shows the effectiveness of POME sludge as a biofertiliser.

Table 3. The mean comparison of parameters measured in *Brassica rapa* subsp. *chinensis* L.in response to POME sludge treatment

Treatment	Height (cm)	SPAD	Leaves Width (cm)	Yield (g)	Shoot (g)	Root (g)	Shoot-Root Ratio
Control	17.02 ^a	36.12 ^a	7.80 ^a	154.00 ^c	143.00 ^c	11.00 ^b	13.29 ^b
POME Sludge	19.18 ^a	37.06 ^a	9.21 ^a	255.47 ^b	241.31 ^b	14.17 ^{ab}	17.12 ^b
POME Sludge Alginate	18.85 ^a	36.71 ^a	9.55 ^a	340.16 ^a	325.50 ^a	14.67 ^a	22.45 ^a

Note: Mean values in the same column with different alphabets (a>b) are significantly different at p -value < 0.05

3.1 Plant height, SPAD and leaf width

POME treatments resulted in marginally taller plants and wider leaves, but the changes were statistically insignificant. This is consistent with previous findings suggesting these traits are less responsive to short-term organic inputs unless nutrient limitations are pronounced¹⁵. This may be attributed to the genetic stability of these traits or environmental variables such as light intensity and temperature, which often exert a stronger influence than nutrient amendments over short cultivation periods. Moreover, the SPAD values did not differ significantly among treatments, indicating that chlorophyll synthesis and leaf morphology are sometimes buffered against changes in soil fertility due to homeostatic mechanisms within the plant¹⁶. However, SPAD values in POME treatments were slightly higher (36.71 and 37.06) as compared to the control treatments (36.12) (Table 3), indicating an improvement in chlorophyll content, which is critical for photosynthesis and biomass accumulation. These findings are in line with a previous study conducted on the oil palm at the nursery stage, where the combination of soil and POME was reported to increase the chlorophyll content of the plants¹⁷.

3.2 Yield and biomass production

The yield increased from 154.00 g in the control to 255.47 g with POME sludge and 340.16 g with POME sludge combined with alginate (Table 3). Similarly, the shoot biomass reflected this trend. These findings affirm the enhanced efficacy of alginate-encapsulated POME, likely due to its ability to control nutrient release and improve soil moisture status¹⁸. The alginate matrix likely provided a slow and consistent supply of nutrients, minimising leaching and allowing for improved nutrient uptake efficiency. Additionally, the enhanced soil structure and microbial activity associated with organic matter inputs may have improved root function and nutrient absorption, directly contributing to biomass accumulation.

3.3 Shoot-to-root ratio

A significantly higher shoot-to-root ratio was recorded in the encapsulated treatment (22.45) (Table 3). This indicates a preferential biomass allocation towards shoot growth, which aligns with the aim of maximising above-ground yield in leafy vegetables, as noted by Sun et al.¹⁹. A higher shoot-to-root ratio also implies a more efficient translocation of assimilates toward harvestable plant parts. The encapsulation likely optimised nutrient availability in the rhizosphere, reducing stress signals that would typically promote root elongation. As a result, biomass allocation favoured shoot development. This effect is particularly important in leafy vegetable crops, where economic yield is directly linked to shoot growth.

3.4 Correlation analysis

Pearson correlation analysis (Fig. 1) revealed strong positive correlations between shoot biomass and yield ($r = 0.87$), and between shoot-to-root ratio and both yield ($r = 0.63$) and shoot biomass ($r = 0.72$). These associations underscore the central role of shoot development in driving yield under organic amendment regimes. Increased shoot biomass typically indicates improved photosynthetic efficiency and nutrient assimilation, both crucial for achieving higher yield outcomes²⁰. The strong correlation suggests that amendments like POME and its alginate-encapsulated form enhance above-ground productivity by promoting optimal nutrient dynamics in the rhizosphere.

In contrast, the weak correlations observed between SPAD and leaf width with yield and biomass may indicate that these traits do not respond significantly to external nutrient inputs in otherwise non-limiting environmental conditions. This observation is consistent with earlier findings, which suggest that morphological and physiological parameters are influenced more by genetic and ambient factors than by short-term soil amendment²¹.

						1 ***	Leaves Width
					1 ***	0.77 ***	Height
				1 ***	0.64	0.36	Shoot
			1 ***	1.00 ***	0.64	0.35	Yield
		1 ***	0.87 **	0.88 **	0.63	0.47	Shoot:Root
	1 ***	0.29	0.72 *	0.70 *	0.37	0.05	Root
1 ***	0.36	0.18	0.28	0.27	0.30	0.28	SPAD
SPAD	Root	Shoot:Root	Yield	Shoot	Height	Leaves Width	

Note: Significance codes: *** denotes 0, ** represents 0.001, * represent 0.05

Fig. 1. The correlation between parameters measured.

4 CONCLUSION

The study demonstrates that both POME sludge and alginate-encapsulated POME sludge significantly improve yield, shoot biomass, and shoot-to-root allocation in leafy vegetables. The use of alginate encapsulation provides additional agronomic advantages, likely due to better nutrient management and soil water dynamics. However, morphological traits such as plant height, chlorophyll content, and leaf width were not significantly affected during the study period. Future research should investigate the longer-term effects and evaluate the scalability of encapsulated organic amendments across various cropping systems.

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CONFLICT OF INTEREST

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

AUTHORS' CONTRIBUTIONS

Conceptualization: Z. Yusop & S. S. Sahmat
 Data curation: Z. Yusop, S. S. Sahmat & S. Mahdian
 Methodology: Z. Yusop & S. Mahdian
 Formal analysis: Z. Yusop & S. S. Sahmat
 Visualisation: S. M. W. Yusuf & S. Jos
 Software: Z. Yusop & S. S. Sahmat
 Writing (original draft): Z. Yusop & S. M. W. Yusuf
 Writing (review and editing): S. S. Sahmat, S. Mahdian & S. Jos
 Validation: Z. Yusop, S. S. Sahmat, & S. Mahdian,
 Supervision: Z. Yusop, S. S. Sahmat, S. Mahdian, S. M. W. Yusuf, & S. Jos

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