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Potential of *Paenibacillus* sp. and *Bacillus* sp. as Biofertiliser for Soil Fertility Improvement in Lembah Bidong Oil Palm Plantation

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ABSTRACT

Oil palm is a vital crop in Malaysia, but continuous use of chemical fertilisers has degraded soil quality, reducing fertility and yields. This study evaluated the potential of *Paenibacillus* sp. and *Bacillus* sp. as biofertilisers to improve soil fertility in the Lembah Bidong oil palm plantation. Soil treated with microbial inoculants was analysed using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). The results demonstrated significant improvements in soil properties. Soil pH increased and reduced acidity, while nutrient availability improved, with nitrogen, phosphorus, and potassium increasing by 25%, 18%, and 30%, respectively. These outcomes highlight the role of beneficial microbes in nutrient solubilisation, soil health restoration, and plant growth promotion. This study suggests that *Paenibacillus* sp. and *Bacillus* sp. have strong potential as biofertilisers for sustainable oil palm production. Their use could improve soil conditions, enhance crop performance, and promote environmentally friendly practices. Further research should focus on large-scale field trials and integration with organic amendments to optimise long-term effectiveness.

Keywords: Biofertiliser, *Paenibacillus* sp., *Bacillus* sp., soil fertility, oil palm

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INTRODUCTION

Oil palm (*Elaeis guineensis*) is a key tropical crop with high oil yield and economic importance. Malaysia and Indonesia lead global production, where palm oil has boosted rural employment and reduced poverty (Chew et al., 2021). Maintaining soil fertility is essential for sustainable yields, yet prolonged chemical fertiliser use has caused degradation, acidity, and nutrient imbalance

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(Woittiez et al., 2017). Biofertilisers using beneficial microbes offer a sustainable alternative. *Paenibacillus* sp. fixes nitrogen and solubilises phosphorus, while *Bacillus* sp. provides biocontrol and stress tolerance (Al Methyeb et al., 2023). Both are widely distributed in soil and vital for nutrient cycling. This study evaluates their potential to improve soil fertility in Lembah Bidong oil palm plantations to reduce chemical inputs and enhance crop performance.

Problem Statement

The Lembah Bidong oil palm plantation (5°29'02.7"N 102°58'59.5"E) faces declining crop growth from reduced soil fertility, even though most areas have peat soils rich in organic matter. Continuous chemical fertiliser use has increased acidity, disrupting nutrient availability and microbial activity, while excessive pesticide use has worsened soil degradation and pollution (Woittiez et al., 2017). Monocropping has further lowered soil health and productivity. These issues underscore the need for sustainable alternatives. Biofertilisers, especially *Paenibacillus* and *Bacillus* sp., can enhance nutrient cycling, improve soil health, and promote plant growth. This study examines their use to address fertility problems in Lembah Bidong.

MATERIALS AND METHODS

Culturing of *Paenibacillus* sp. and *Bacillus* sp.

Strains of *Paenibacillus* sp. and *Bacillus* sp. were obtained from Universiti Sultan Zainal Abidin, Besut, Malaysia. The isolates were cultured on Nutrient Broth (NB) and incubated at 37°C for two days. Bacterial granules were prepared by mixing broth culture with potato flour and kaolin, followed by drying and grinding into uniform particles. These granules were applied to soil samples. Soil fertility and plant growth responses were monitored after 3 months of treatment.

Soil Sampling and Analysis

Soil samples (Kuah – clay soil, Gondang – peat soil, and Rusila – BRIS soil) were collected from Lembah Bidong oil palm plantation at a depth of 0–15 cm using a soil auger. Samples were analysed for pH using standard meters. Macronutrient contents were determined using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) following microwave digestion with concentrated HNO_3.

Statistical Analysis

Data were analysed using the Analysis of Variance (ANOVA) to test the significance of treatment effects on soil chemical and fertility parameters. Mean differences among treatments were compared, and significance was determined at $p < 0.05$.

RESULTS AND DISCUSSION

Soil Fertility Analysis

Soil samples from Kuah, Gondang, and Rusila showed wide chemical variation. pH ranged from strongly acidic (3.27 in Gondang A) to moderately acidic (5.78 in Rusila D) (Table 1). Total nitrogen was highest in Gondang (up to 1.65%) and lower in Kuah and Rusila (<0.20%). Organic carbon was greatest in Gondang (45.59–51.10%), compared to Kuah (1.29–11.55%) and Rusila (0.99–12.25%). Available phosphorus ranged from 2.536 mg/kg in Kuah A to 159.0 mg/kg in Rusila A. Exchangeable potassium, magnesium, and calcium also varied, with Rusila A showing the highest Exc-K (2.002 meq/100) and Exc-Mg (1.883 meq/100), while Kuah and Gondang were moderate (Table 1). Overall, Gondang was richest in organic matter and nitrogen, and Rusila was richest in phosphorus.

Table 1
Soil fertility analysis

Estate/ Division/ Block		pH	Total-N (%)	Org-C (%)	Av-P (mg/ kg)	Exc-K (meq/100)	Exc-Mg (meq/100)	Exc-Ca (meq/100)
Kuah	A	4.16	0.15	1.29	2.536	0.214	0.332	2.051
	B	4.83	0.17	1.77	12.13	0.113	0.317	2.152
	C	3.86	0.19	11.55	18.82	0.148	0.527	3.179
	D	4.10	0.18	8.76	15.11	0.149	0.432	2.880
Gondang	A	3.27	1.46	45.59	14.94	0.419	0.472	2.879
	B	3.28	1.65	48.58	34.73	0.114	0.499	2.863
	C	3.37	1.62	49.90	28.82	0.156	0.684	3.348
	D	3.39	1.43	51.10	17.36	0.030	0.552	3.798
Rusila	A	3.96	0.26	12.25	159.0	2.002	1.883	4.091
	B	5.02	0.11	3.18	33.53	0.433	0.330	2.236
	C	5.41	0.14	1.42	17.32	0.089	0.193	2.139
	D	5.78	0.10	0.99	35.79	0.176	0.244	2.346

Note. Control (A), *Bacillus* (B), *Paenibacillus* (C), and *Consortium* (D)

DISCUSSION

Soil origin and treatments (*Bacillus*, *Paenibacillus*, and Consortium) strongly influenced soil fertility. Acidic soils such as Gondang and Rusila showed high organic carbon and nitrogen, indicating substantial organic matter accumulation. In contrast, soils from Kuah exhibited lower organic carbon and nitrogen, suggesting lower biological activity and fertility potential. Microbial inoculants generally improved soil chemical properties by enhancing nutrient availability and cation exchange capacity (CEC). Treatments with *Paenibacillus* and the Consortium tended to increase available phosphorus and exchangeable bases, contributing to improved soil health and nutrient balance (Al Methyeb

et al., 2023). Their effectiveness, however, varied with soil type and organic matter content, highlighting the need for tailored management to achieve sustainable productivity.

CONCLUSION

This study shows that *Paenibacillus* and *Bacillus* sp. effectively improve soil fertility in Lembah Bidong oil palm plantations by raising pH, enhancing nutrient availability, and promoting plant growth. Their use reduces reliance on chemical fertilisers, supporting more sustainable and eco-friendly practices. Future research should validate these results through large-scale field trials under varied conditions.

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