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(Research Article)

The effects of using photosynthetic bacteria in bio-fertilizer products

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Abstract

This study aimed to examine the chemical composition of the bio-fertilizer formula by utilizing photosynthetic bacteria (PB) combined with other components, including agricultural residual raw materials, including rice husk (RH), Teak sawdust (TS), corn kernel (CK), coconut bark (CK) and cattle manure (CM). Eight treatments were arranged in a Complete Randomized Design (CRD) with three replicates. In the production of the bio-fertilizer formula, materials were fermented in black plastic bags for a total fermentation period of 45 days. Subsequently, the bio-fertilizer samples were analyzed to determine Chemical composition value, including pH, OM, N, P_2O_5, K_2O and EC. The results of each bio-fertilizer formula exhibited statistically significant differences at 95% ($p<0.05$). The bio-fertilizer formula with higher chemical composition values than all others was treatment T_8, which showed increases in the following parameters: OM (25.22%), N (4.47%), P_2O_5 (0.25%), K_2O (1.29%) and EC value (2.58 dS/m), followed by treatment T_7. Furthermore, when compared with bio-fertilizer formulas without PB composition (T_1-T_4), statistically significant differences were observed, with increases in chemical composition for 1-3 times. From this study, it can be concluded that photosynthetic bacteria (PB) solution can enhance the chemical composition values for plant nutrients in each bio-fertilizer formula, with statistically significant correlations.

Keywords: Bio-fertilizer; Photosynthetic Bacteria; Agricultural waste; Fermentation; Chemical Composition

1. Introduction

Currently, there is a large amount of agricultural waste in the fields, whether it is rice straw, teak sawdust, corn kernel, rice husk, coconut bark and also from animal husbandry (animal manure). Some farmers do not know how to use it or know their benefits. According to Soundara *et al*. (2024, it was reported that using agricultural wastes (coconut bark, corn kernel and rice husks) mixed with sand was used as a material for growing melons, which would help to capture water and nutrients. The study found that using these materials in growing lemons can be used as planting materials and can help reduce soil. However, using these wastes alone has little or no nutrients. Therefore, adding nutritional value to them is by mixing them with various types of animal manure, especially in the fields of farmers: Cattle manure, which is also rich in nitrogen, if used as a component in the production of compost, it would be considered, but when looking at its chemical composition, it is considered low (Prasert, 2000). Therefore, it is necessary to add microorganisms that help in the fermentation process, especially photosynthetic microorganisms, because this group of microorganisms has the ability to fix nitrogen on its own (Zheng *et al*., 2013). In addition, it has been found that this group of microorganisms can also help in the fermentation process and improve the nutritional value of compost (Solaiman *et al*., 2003; Bothe *et al*., 2010). The role of microorganisms is therefore important in the application of plant production (Sansinenea, 2021). Bio-fertilizer production and sustainable option to increase crop yields, improve and restore soil fertility, stimulate plant growth and reduce production costs, as well as reduce the environmental impact of chemical fertilizers and pesticides (Sarkar, 2021).

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Bio-fertilizer production and use of biofertilizers are another option that can increase crop yields and are considered an attractive and sustainable option to increase crop yields, improve and restore soil fertility, stimulate plant growth and reduce production costs, as well as reduce the environmental impact of chemical fertilizers and pesticides (Sarkar, 2021). In this regard, it is important to see the use of microorganisms, especially the use of biofertilizers using microorganisms, in agriculture, especially crop production. In this sense, it is important to know the importance of microorganisms that are used as bio-fertilizers to improve and restore the soil as a source of plant nutrition to improve crop yields, while also solving environmental problems (Singh, 2019). Furthermore, the use of bio-fertilizers to improve and restore the soil as a source of plant nutrition to improve crop yields also solves environmental problems. Common planting materials are mixtures of many different materials, often with different properties, including: coconut bark, cattle manure, teak sawdust, corn kernel, rice husks and soil. Soil may provide the nutrients plants need, but soil alone may cause water to flow through for a while, causing high compaction. However, adding materials that drain well will cause the material to drain and not compact. If only one of these materials is used, the benefits may not be complete (Ninsuwan and Matrud, 2019). In the case of planting materials, each type of plant has different environmental requirements for growth, including the suitability of each plant species and each strain, such as: stem support, water retention and air permeability. These are different for each plant species. In addition, the growth of the same plant species in different planting materials can vary, so the approach in this study is interested in using agricultural waste to be composted with cow dung, using a group of photosynthetic microorganisms as an accelerator of the fermentation process, to compare the chemical composition of compost using photosynthetic bacteria.

2. Materials and Methods

2.1. Study Area

Study Area: The experiment was conducted at the Demonstration Farm at ViengMai Village, Luan Prabang District and Luang Prabang Province, Lao PDR, from July **to** August 2025.

2.2. Materials

- KCl, standard buffer solution, NaOH and HCl
- Photosynthetic Bacteria
- Soil
- Teak sawdust
- Cattle manure
- Coconut bark
- Rice husk
- Corn kernel
- Black plastic bags

2.3. Methods

Study Area: The experiment was conducted at the Demonstration Farm at ViengMai Village, Luan Prabang District and Luang Prabang Province, Lao PDR, from July - August 2025.

Experimental Design: Eight treatments were arranged in a Complete Randomized Design with three replicates:

Table 1 Treatment and proportion of treatment

No	Treatment	Proportion (%)						
		RH	TS	CK	CB	CM	S	PB
1	T_1	25	-	-	-	25	50	-
2	T_2	-	25	-	-	25	50	-
3	T_3	-	-	25	-	25	50	-
4	T_4	-	-	-	25	25	50	-
5	T_5	25	-	-	-	25	50	5mL

6	T_6	-	25	-	-	25	50	5mL
7	T_7	-	-	25	-	25	50	5mL
8	T_8	-	-	-	25	25	50	5mL

Note: RH: Rice husk; TS: Teak sawdust; CK: Corn kernel; CB: Coconut bark; CM: Cattle manure; PB: Photosynthetic Bacteria; S: soil

2.4. Procedure and Data Collection

All raw materials were crushed and mixed together according to the proportion shown in Table 1 and moistened to approximately 50% moisture content. The mixture was packed in 20 kg black plastic bags, sealed tightly to ensure aerobic fermentation, and left in the shade for 1.5 months before analysis.

Figure 1 Mixed all raw materials

Figure 2 Mixed all raw materials

Figure 3 Mixed all raw material

Figure 4 Left in the shade

Chemical Analysis: Chemical analyses (pH, N_2, P_2O_5, K_2O, OM and EC) were conducted following AOAC (1990) methods. pH was determined using a digital pH meter, mixing 5g of ground sample with 25ml of distilled water and measuring after overnight incubation.

Statistical Analysis: Data were analyzed using analysis of variance (ANOVA), and treatment means were compared using Duncan's Multiple Range Test (DMRT; $P<0.05$) using Sirichai Statistics Version 6.00.

3. Results.

The utilization of agricultural waste, such as teak sawdust, rice husk, corn kernels, and coconut bark, fermented with Photosynthetic Bacteria (PB) to produce bio-fertilizers, yielded the following results: Enhancement of Chemical Composition: The addition of PB significantly increased the chemical constituents of the bio-fertilizers compared to those without PB. In particular, Formula T8 exhibited the highest chemical composition and was determined to be the optimal formula in this experiment.

3.1. pH value

pH value of each formula was slightly to moderately alkaline, with an average range from 7.85-8.57. When comparing the experimental groups, it was observed that the pH value with the addition of Photosynthetic Bacteria "PB" and without the addition of PB was statistically different at 95% ($p<0.05$). However, the pH value in each formula was within the standard value of 6.5-8.5. This means that the formula of the fertilizer in this experiment is suitable for use in the production of all types of crops (Table 2) Consistency with Prior Research: These findings align with Chantip et al. (2025), who found that mixing agricultural waste with cassava husk and microbial fermentation increased essential plant nutrients in compost, including pH 7.08.

Table 2 pH value

No	Treatment	pH of Compost	
		pH (H_2O)	pH value
1	T_1	8.57^a	6.5-8.5
2	T_2	8.28^b	
3	T_3	7.85^d	
4	T_4	8.28^b	
5	T_5	8.56^a	
6	T_6	8.48^a	
7	T_7	8.48^a	
8	T_8	7.98^c	
F-prob		0.000	
CV (%)		0.30	

Note: The results of the above analysis show that different letters in the table indicate a statistical difference at 95% ($p<0.05$) using Duncan's Multiple Range Test (DMRT) analysis.

3.2. Organic matter (OM)

Organic matter (OM) values of each formulation were in the middle range compared with standard value at ≥30%. The highest OM values were found in the organic fertilizer formulation of T_8 (25.22%) and T_5 (24.55%), respectively. Furthermore, when comparing the samples, there was a statistical difference at 95% ($p<0.05$), especially when compared to the sample without the addition of photosynthetic bacteria (PB), which was significantly different at 95% ($p<0.05$). Furthermore, these values were still lower than the standard value. From this study, it was found that the organic fertilizer formulation with the addition of PB, resulted in a statistically significant difference in OM values and increased by 1-fold compared to the formulation without PB. (Table 3) The results of this experiment are also consistent with other findings, observing that the Organic Matter (OM) value in each fertilizer formula increased by 1-fold. This stands in contrast to the study by Đạt (2000), which utilized microbial fertilizer to produce organic fertilizer but achieved an increase in organic matter of only 0.21%. However, this experiment made the OM value compared to the standard value and was still in the middle level.

Table 3 Organic matter (OM) value

No	Treatment	OM of compost	
		OM value (%)	Standard value of OM
1	T_1	24.20[c]	≥30
2	T_2	23.71[d]	
3	T_3	23.27[e]	
4	T_4	24.28[c]	
5	T_5	24.55[b]	
6	T_6	23.27[e]	
7	T_7	24.42[b]	
8	T_8	25.22[a]	
F-prob		0.000	
CV (%)		0.61	

Note: The results of the above analysis show that different letters in the table indicate a statistical difference at 95% ($p<0.05$) using Duncan's Multiple Range Test (DMRT) analysis.

3.3. Nitrogen (N)

Nitrogen value with the addition of PB resulted in a gradual increase in nitrogen (N) according to each formula and there was a statistical difference of $p<0.05$. Moreover, the N value in the addition of PB, namely: T_5-T_8, was higher than the standard value of N specified in organic fertilizers, which was 1.5%, which was high. In this case, N was highest in T_8 (4.47%) and followed by T_3 and T_7 (3.35%), respectively. When comparing the N values in the experimental groups, there was a difference at 95% ($p<0.05$). It can be said that the organic fertilizer formula with the addition of PB resulted in a statistically significant difference in N values and increased by 2 times compared to the formula without PB, namely T_1-T_4 (Table 4). The results of this experiment indicate that the nitrogen (N) content increased and reached a high level when compared to the organic fertilizer standards. This finding is consistent with the study by Tan and Chanh (2014), which demonstrated that the nitrogen value shifted in a positive direction with a clear tendency to increase relative to the standard values.

Table 4 Nitrogen value of compost fermented with photosynthetic bacteria

No	Treatment	N of compost	
		N value (%)	Standard value of N
1	T_1	2.10[e]	≤ 0.10 (Very low) 0.11-0.15 (Low) 0.16-1.0 (Medium) ≥1.5)High(
2	T_2	1.95[f]	
3	T_3	2.10[e]	
4	T_4	2.36[d]	
5	T_5	3.35[b]	
6	T_6	2.77[c]	
7	T_7	3.35[b]	
8	T_8	4.47[a]	
F-prob		0.000	
CV (%)		0.48	

Note: The results of the above analysis show that different letters in the table indicate a statistical difference at 95% ($p<0.05$) using Duncan's Multiple Range Test (DMRT) analysis.

3.4. P_2O_5 value

The P_2O_5 value was increased and statistically significantly at 95% ($p<0.05$). It increased from 0.11%-0.25% (almost 2 times) and was at a high level compared to the standard value ≥ 0.2% (Table 5). Furthermore, the P_2O_5 value in each formula with the addition of photosynthetic microorganisms (PB), the P_2O_5 value was higher than without the PB, but with the addition of PB, the P_2O_5 value was high in T_8 (0.25%) and followed by T_6 (0.23%), respectively. When comparing the P_2O_5 values of each group, there was a difference at 95% ($p<0.05$). In particular, the bio-fertilizer formulas without PB, namely T_1-T_4, the P_2O_5 value was only 0.11-0.18%. This biofertilizer, with the addition of PB, resulted in a statistically significant difference and was increased by 2 times compared to without PB. In this experiment, it was found that the phosphorus P_2O_5 content was quite high and exceeded the standard values. This result is consistent with the study by Ghosh *et al*. (2010), which reported an increase in available P_2O_5 because organic fertilizers decomposed by microorganisms release organic ligands, thereby enhancing the availability of phosphorus for plant uptake.

Table 5 P_2O_5 value of compost fermented with photosynthetic bacteria

No	Treatment	P_2O_5 of compost	
		P_2O_5 value (%)	Standard value of P_2O_5
1	T_1	0.17^d	≤ 0.05 (Very low) 0.05-0.2 (Medium) ≥0.2)High(
2	T_2	0.12^e	
3	T_3	0.11^e	
4	T_4	0.18^c	
5	T_5	0.19^c	
6	T_6	0.23^b	
7	T_7	0.18^c	
8	T_8	0.25^a	
F-prob		0.000	
CV (%)		4.19	

Note: The results of the above analysis show that different letters in the table indicate a statistical difference at 95% ($p<0.05$) using Duncan's Multiple Range Test (DMRT) analysis.

3.5. K_2O

K_2O values of both the composted manure with and without photosynthetic microorganisms (PB) were all at a high level compared to the standard value set for organic manure of 0.5%, and when compared to other values such as the values of OM, N, and P, it was found that the K2O values were in the same trend. In particular, the highest K2O values were in the formula with the addition of PB, namely T8 = 1.29, followed by T7 = 1.23% and T6 = 1.22%, respectively. Furthermore, when comparing the four experiments with each other, there was a statistical difference of $p < 0.05$, especially when comparing the experiments without the addition of PB (T1-T4), as shown in Table 6, the difference was at a confidence level of 95%. The results of this study showed that the biofertilizer formula containing 5 mL of PB resulted in a statistically significant difference in K2O values and an increase of 0.5 times compared to the formula without PB in each formula. For potassium (K_2O), the results were similar to P_2O_5 but also had a high value above the standard value of 0.5%, exceeding the value of K_2O in organic fertilizers but still at a high level and increased from the fertilizer formula without PB by 0.5 times compared with reported by Syha *et al*. (2023) in using beneficial microorganisms in soil improvement which increased the value of K_2O by 3.04 mg/kg.

Table 6 K_2O value of compost fermented with photosynthetic bacteria

No	Treatment	K_2O value of compost	
		K_2O value (%)	Standard value of K_2O
1	T_1	1.18[d]	≤ 0.2 (Very low) 0.2-0.5 (Medium) ≥0.5)High(
2	T_2	1.11[e]	
3	T_3	1.07[f]	
4	T_4	1,10[e]	
5	T_5	1.20[c]	
6	T_6	1.22[b]	
7	T_7	1.23[b]	
8	T_8	1.29[a]	
F-prob		0.000	
CV (%)		0.54	

Note: The results of the above analysis show that different letters in the table indicate a statistical difference at 95% ($p<0.05$) using Duncan's Multiple Range Test (DMRT) analysis.

3.6. Electrical conductivity (EC)

The EC value with the addition of PB resulted in a gradual decrease in the electrical conductivity (EC) value according to each group, and there was a statistical difference at 95% ($p<0.05$). Moreover, the EC value with the addition of PB: T_5-T_8 was lower than the standard value (<4), which is slightly lower, and the EC value was lowest in T_8 (2.58 ds/m) followed by T_7 (2.76 ds/m) and T_5 (2.14 ds/m), respectively, and there was a difference at 95% ($p<0.05$). It can be said that the bio-fertilizer with the addition of PB resulted in a statistically significant difference and was reduced by 2 times when compared to the formula without PB, namely T_1-T_4 (Table 7). In conclusion, the electrical conductivity (EC) of this compost is below the standard threshold (< 4 ds/m), which is beneficial as it ensures the fertilizer is safe for use and not excessively saline.

Table 7 EC value of compost fermented with photosynthetic bacteria

No	Treatment	EC value of compost	
		EC value (dS/m)	Standard value of EC
1	T_1	3.98[a]	≤ 4
2	T_2	3.20[c]	
3	T_3	3.14[d]	
4	T_4	3.28[b]	
5	T_5	3.14[d]	
6	T_6	2.93[e]	
7	T_7	2.76[f]	
8	T_8	2.58[g]	
F-prob		0.000	
CV (%)		0.40	

Note: The results of the above analysis show that different letters in the table indicate a statistical difference at 95% ($p<0.05$) using Duncan's Multiple Range Test (DMRT) analysis.

4. Discussion

The results of the study on the chemical composition changes of the bio-fertilizer, with the addition of photosynthetic bacteria (PB) mixed with other agricultural waste raw materials such as rice husk, teak sawdust, corn kernels, coconut kernel, and cattle manure, the result showed that the chemical composition of the bio-fertilizer was increased, especially with the addition of PB. Almost all chemical compositions were high in T_8, which increased the value of organic matter (OM), nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O), respectively. In addition, the value of electrical conductivity (EC) was at a good level when compared with the specified standard value. Therefore, from this study, it is clear that the introduction of PB into the formulation of bio-fertilizer has different effects; there was a significant relationship, especially when compared with the standard values of each bio-fertilizer, and all of the chemical compositions were in the medium to high range. Therefore, it can be concluded that the bio-fertilizer formula with the addition of PB had an effect on the chemical composition, with the greatest effect in the addition of PB, and was highest in T_8.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. Funding Declaration No funding was allocated for this article.

Author Contribution

Phengchanh Keodouangkham conceived the idea and designed the experiments. Phengchanh Keodouangkham, Khantavanh Phomlasaboud, and Anousith Vannaphon conducted the experiments. Phengchanh Keodouangkham analyzed the research data. Phengchanh Keodouangkham, Phonesavanh Phouthaxay, and Vongpasith Chanthakhoun wrote the manuscript. All authors read and agree to the submission of the manuscript to the journal.

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