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Vermicompost efficacy in improvement of cucumber (*Cucumis sativus* L.) productivity, soil nutrients, and bacterial population under greenhouse condition

Sopheak Tith[1], Panida Duangkaew[1,*], Chaowanee Laosuthipong[1] and Sararat Monkhung[1]

[1]Faculty of Animal Science and Agricultural Technology, Silpakorn University, Phetchaburi IT Campus, Phetchaburi, Thailand
[*]Corresponding author: duangkaew_p@silpakorn.edu

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Abstract

Vermicompost is an organic residue derived from the aerobic and bio-oxidative process of wastes by the action of earthworms. Vermicompost has been known as a good material to boost soil nutrients, increases the availability of nutrients to plants, improves soil structure, promotes plant growth, and suppresses plant disease. This study aimed to investigate the efficacy of vermicompost on the productivity of cucumber (*Cucumis sativus* L.) planted in poor soil and its improvement of soil fertility. The experiment was laid out in Complete Randomized Design with 5 treatments: soil control, soil with chemical fertilizer application, and soil mixed with 10%, 20% and 30% vermicompost. The results clearly revealed that application of vermicompost had significant effect on promoting plant height, number of leaves, leave area, fruit yields, and suppression of disease incidence ($p \leq 0.05$). From the chemical analysis, mixing soil with vermicompost improved soil pH, electrical conductivity, total nitrogen, available nitrogen, total phosphorus, available phosphorus, total potassium, and available potassium. Analysis of bacterial populations demonstrated that vermicompost significantly increased the population of bacteria in the soil ($p \leq 0.05$). Based on the results, the application of 30% vermicompost showed the best positive effect on improving soil fertility, promoting cucumber growth, and improving yields in the poor soil. Therefore, application of vermicompost can be a vital choice in cucumber production for sustainable agriculture.

Keywords: Cucumber, Productivity, Soil nutrients, Vermicompost

1. Introduction

Agrochemicals including pesticides, insecticides, and fungicides have been widely used in the agronomic industry during the green revolution to boost food productivity [1]. However, the use of agrochemicals has shown their negative impact on the environment and that of the farmer's health [2]. Therefore, the adaptation of organic farming with the aid of various nutrients of biological origin such as compost or vermicompost are thought to be the answer for food safety and the security to improve food production while ensuring environmental sustainability [3].

Vermicompost is derived from organic wastes with the help of earthworms and microorganisms as converters [4,5]. The advantages of vermicompost are the enhancement of soil nutrients, increase the availability of nutrients to plants, improvement of soil structure and drainage, increase in plant growth, suppression of plant disease, and the enrichment of beneficial microorganisms [6]. Vermicompost plays roles in the increase of microbial activity in the soil and is believed to contain plant growth regulators by the action of beneficial microorganisms. Thus, vermicompost is considered as one of the efficient tools to solve environmental pollution problems in plant production [6].

Cucumber (*Cucumis sativus* L.), one of the popular fruits, belongs to the Cucurbitaceae or cucurbit family [7]. It is widely consumed fresh in a salad, fermented (pickles), or as a cooked vegetable [8]. However, the increase of cucumber production is dependent on the application of fertilizer which does not meet the food safety and environmental sustainability aspects. Thus, the nutrients from natural origin such as vermicompost may be the choice for improving soil condition to promote cucumber production and reduce the use of chemical fertilizer.

Therefore, in this present study, the effect of vermicompost application was investigated on the productivity of cucumbers planted in poor soil conditions and the improvement on soil fertility. Nutrient consumption and bacterial populations were determined in this study. We found that an application of vermicompost could increase nutrient resources and boost bacterial population in the soils, as well as improving cucumber yields.

2. Materials and methods

2.1 Materials

Cucumber seeds (East-West Seed International Ltd, Thailand) were purchased from a local store in Phetchaburi province. Cow dung vermicompost was purchased from a local farm in Nakorn Pathom province, Thailand. Chemical fertilizer (20-20-20) (Esteem Intertrade Co., Ltd., Thailand) was bought from a local store in Phetchaburi, Thailand. The soil used in this study was local non-fertilized soil purchased from a local supplier in Phetchaburi, Thailand.

2.2 Experiment design and plantation

The experiment was laid out in Complete Randomized Design (CRD) consisting of 5 treatments with 8 replications including soil control (T1), soil with chemical fertilizer application (T2), and soil mixed with 10%, 20%, and 30% vermicompost (T3, T4, and T5). Each pot (25 cm in diameter x 20 cm depth) contained 5 kilograms of soil or soil mixture. One cucumber seedling (7 days old) was planted to each pot. Water was applied on to the pot twice a day. Weeds and pests were monitored every day and removed by hand. There was no pesticide applied during the experiment. Twenty milliliters of 0.2% w/v chemical fertilizer were applied according to manufacturer suggestions on the package at two, four, and six weeks after planting (T2 only). The pots were maintained in the greenhouse at the Faculty of Animal Sciences and Agricultural Technology, Silpakorn University, Phetchaburi, Thailand from September to November 2020.

2.3 Plant growth, yield, and disease incidence determination

Vegetative growth of cucumber plant including plant height, number of leaves, and leaf area data were collected at the second, fourth, and sixth week after planting. Leaf area was recorded by Portable Leaf Area Meter 470-010/01 (CID Bio-Science, Inc, United States). Fertilized flowers and mature fruits were count and total yields were determined for each treatment at week eight and nine. Fruit characteristics were evaluated by randomly selecting five fruits from each treatment. These characteristics were fruit length, fruit weight, fruit circumference, and fresh fruit thickness. Leaf spot incidence and severity were investigated following the method of [9] during the late harvesting period at the ninth week.

2.4 Soil and vermicompost chemical nutrient analysis

Soil, vermicompost, and mixture of soil/vermicompost in each ratio was measured for soil pH, soil electric conductivity (EC), and macronutrients. The macronutrients measured were: total nitrogen (TN), total phosphorus (TP), total potassium (TK), available nitrogen (AN), available phosphorus (AP), and available potassium (AK). Soil pH and soil EC were measured by using a pH meter (Adwa, Hungary) following the method of [10] and EC measured using a meter (AZ Instrument, Taiwan) following the method of [11]. TP determined by the ashing colorimetric and ascorbic acid method using a spectrophotometer (Spectro SC, Labomed Inc, United States) for recording data [12]. TP was determined by ashing colorimetric method with data analysis by AAS/Flame Spectroscopy [13]. TN was determined by the micro Kjeldahl method (digestion, distillation and titration) [14]. AN was determined by the alkaline permanganate method [15]. AP was determined by Bray I extraction solution and ascorbic acid method using a spectrophotometer (Spectro SC, Labomed Inc, United States) for data recording [16]. AP was measured using the extraction method of ammonium acetate with pH 7.0 with data analysis by AAS/Flame Spectroscopy [17].

2.5 Determination of total bacteria

Soil and soil mixed with vermicompost samples were collected before and after planting. Serial dilutions of each sample were prepared in 0.85% sodium chloride (NaCl). A one hundred microliter aliquot of each dilution was plated onto nutrient agar (NA) plates in triplicate. After incubation at 27 ± 2°C for 24 hours, colonies were counted and calculated in CFU (colony forming unit) /mL unit [18].

2.6 Statistical analysis

Data were analyzed for analysis of variant (ANOVA) using R program version (4.0.3). The differences among means were tested by Duncan's multiple range tests at $p \leq 0.05$.

3. Results

3.1 Effect of vermicompost on growth, yields, and fruit characteristics

Plant heights were recorded using a meter stick and represented in centimeter (cm) (Table 1). The results demonstrated that treatment with 30% of vermicompost showed the highest plant height compared to other treatments, followed by vermicompost 20% and 10%, respectively. This may be because these treatments were the most enriched with essential nutrients. Furthermore, untreated control soil and chemical fertilizer treatment showed low plant height values compared to vermicompost treatments during six weeks of cucumber growing. Foliar application of chemical fertilizer showed a positive effect on plant height at week 6; however, the effect was less than vermicompost treatment. At the 6th week, the highest plant height obtained from application of 30% vermicompost was 205.69 cm and the lowest was in the control soil treatment at 54.80 cm (Table 1).

As demonstrated in Table 2, vermicompost treatment provided higher number of leaves compared to control soil. At 4th to 6th week of planting, application of 30% vermicompost significantly promoted the production of leaves (21.25 leaves) compared to other treatment (Table 2).

Table 1 Plant height (mean ± SD, cm) of cucumber plants using different potting materials with different vermicompost levels compared to control and chemical fertilizer.[1]

Treatment[2]	2nd week	4th week	6th week
T1	22.08 ± 0.80^d	45.59 ± 1.41^d	54.80 ± 4.07^e
T2	12.30 ± 0.45^e	43.32 ± 1.57^d	68.10 ± 0.22^d
T3	41.68 ± 0.68^c	82.39 ± 2.48^c	127.25 ± 0.50^c
T4	46.87 ± 1.92^b	107.47 ± 0.45^b	148.57 ± 2.79^b
T5	53.46 ± 0.29^a	126.22 ± 0.83^a	205.69 ± 1.08^a
CV value	3.00	1.74	1.49

Note: [1]Means in each column with different superscript letters ($^{a, b, c, \cdots}$) were significantly different by Duncan's Multiple Range Test ($p \leq 0.05$).
[2]The detail of each treatment code is soil control (T1), soil with chemical fertilizer application (T2), and soil mixed with 10%, 20%, and 30% vermicompost (T3, T4, and T5).

Table 2 Leaf number (mean ± SD) of cucumber plants using different potting materials with different vermicompost levels compared to control and chemical fertilizer.[1]

Treatment[2]	2nd week	4th week	6th week
T1	3.50 ± 0.53^b	6.80 ± 0.45^c	6.00 ± 0.00^d
T2	3.16 ± 0.35^b	5.75 ± 0.46^c	8.00 ± 0.00^d
T3	5.00 ± 0.63^a	10.75 ± 0.96^b	12.86 ± 0.38^c
T4	5.40 ± 0.55^a	12.50 ± 0.58^b	16.17 ± 0.98^b
T5	5.72 ± 0.49^a	16.75 ± 1.26^a	21.25 ± 2.43^a
CV value	11.54	7.68	9.86

Note: [1]Means in each column with different superscript letters ($^{a, b, c, \cdots}$) were significantly different by Duncan's Multiple Range Test ($p \leq 0.05$).
[2]The detail of each treatment code is soil control (T1), soil with chemical fertilizer application (T2), and soil mixed with 10%, 20%, and 30% vermicompost (T3, T4, and T5).

Along with plant height and leaf number, application of vermicompost had a positive impact on the leaf area. The cucumber plant showed larger leaves in 10%, 20%, and 30% vermicompost treatments compared to untreated controls and application of chemical fertilizer. From the 2nd to 6th week of planting, soil mixed with 30% vermicompost showed the highest leaf area (Table 3). However, application of chemical fertilizer showed a better result compared to untreated vermicompost control soil at 6th week of the planting (Table 3).

Table 3 Leaf area (mean ± SD, cm^2) of cucumber plants using different potting materials with different vermicompost levels compared to control and chemical fertilizer.[1]

Treatment[2]	2nd week	4th week	6th week
T1	67.06 ± 2.84[d]	87.96 ± 0.62[d]	95.42 ± 1.50[d]
T2	56.28 ± 0.43[e]	85.65 ± 0.92[d]	104.08 ± 2.89[c]
T3	126.68 ± 0.15[c]	146.20 ± 2.17[b]	117.32 ± 0.50[b]
T4	128.29 ± 0.35[b]	152.69 ± 2.39[c]	117.06 ± 2.89[b]
T5	134.92 ± 0.39[a]	227.16 ± 2.85[a]	166.85 ± 2.06[a]
CV value	1.45	1.36	1.64

Note: [1]Means in each column with different superscript letters (a, b, c, …) were significantly different by Duncan's Multiple Range Test ($p \leq 0.05$).
[2]The detail of each treatment code is soil control (T1), soil with chemical fertilizer application (T2), and soil mixed with 10%, 20%, and 30% vermicompost (T3, T4, and T5).

Cucumber plants started producing flowers at around week 5 and became fertilized fruit. The cumulative number of cucumber fruits were shown in Table 4. Based on the result, untreated control treatment showed the lowest number of fertilized flowers but pots with the vermicompost added produced a greater number (95, 87, and 83 fruits for 30%, 20%, and 10% vermicompost, respectively) (Table 4). Mature fruits were harvested from week 8 to 9. However, not all fruits were harvested, only some of them grew to maturity because many fertilized flowers fell due to the heavy rain during the experiment. As shown in Table 4, 30% of vermicompost promoted the production of fruits better than other treatments, with the highest total yield of 1108.27g. Unfortunately, there is no fruit was harvested in the control treatment.

Table 4 Cumulative numbers of fertilized flowers and fruit yields in each treatment.

Treatment[1]	Total number of fertilized flowers	Total number of harvested fruits	Total yield (g)
T1	18	0	0
T2	70	5	159.52
T3	83	6	232.51
T4	87	11	689.41
T5	95	13	1108.27

Note: [1]The detail of each treatment code is soil control (T1), soil with chemical fertilizer application (T2), and soil mixed with 10%, 20%, and 30% vermicompost (T3, T4, and T5).

Physical characteristics of cucumber fruits were measured on average fruit weight, fruit length, fruit circumference, and fresh fruit thickness (Table 5). Fruit shape as a longitudinal cut are shown in Figure 1. The results show that cucumber fruits from 30% vermicompost had higher fruit weight (158.32 g) and fruit length (11.24 cm) than other treatments (Table 5). Fruit circumference and fresh fruit thickness of 30% and 20% vermicompost treatment showed the best values compared to 10% vermicompost and chemical fertilizer (Table 5).

Table 5 Average fruit weight, fruit length, fruit circumference and fresh fruit thickness (mean ± SD) of each treatment.[1]

Treatment[2]	Fruit weight (g)	Fruit length (cm.)	Fruit circumference (cm.)	Fresh fruit thickness (cm.)
T1	n. a.	n.a.	n.a.	n.a.
T2	31.90 ± 6.30[b]	6.17 ± 0.76[c]	10.48 ± 0.47[b]	0.53 ± 0.01[b]
T3	58.13 ± 8.69[b]	6.61 ± 0.19[c]	10.75 ± 0.40[b]	0.60 ± 0.02[b]
T4	137.88 ± 32.84[a]	8.82 ± 0.31[b]	12.45 ± 0.37[a]	0.92 ± 0.04[a]
T5	158.32 ± 32.80[a]	11.24 ± 1.26[a]	13.57 ± 0.62[a]	0.86 ± 0.07[a]
CV Value	24.56	9.30	4.03	5.79

Note: [1]Means in each column with different superscript letters ([a, b, c, …]) were significantly different by Duncan's Multiple Range Test ($p \leq 0.05$).
[2]The detail of each treatment code is soil control (T1), soil with chemical fertilizer application (T2), and soil mixed with 10%, 20% and 30% vermicompost (T3, T4, and T5).

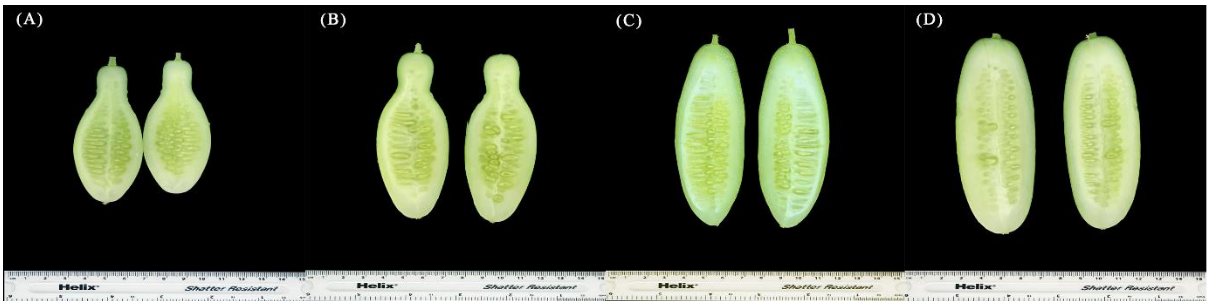

Figure 1 Longitudinal cut of cucumber fruit of (A) T2: chemical treatment, (B) T3: 10% vermicompost, (C) T4: 20% vermicompost, and (D) T5: 30% vermicompost treatment.

Leaf spot incidence was significantly different among treatments (Table 6). Control and chemical treatments were not significantly different from each other (82.11% in control and 83.81% in chemical treatment). Whereas, application of 20% vermicompost showed the lowest disease incidence at 51.67%. This may be because vermicompost consists of beneficial microbes that contributed to the soil resulting in preventing the diseases. However, disease severity showed no significant difference between all treatment groups (Table 6).

Table 6 Leaf spot disease incidence and severity (mean ± SD) of cucumber plants at 9th week after plantation.[1]

Treatment[2]	Disease incidence (%)	Disease severity (%)
T1	82.1 ± 1.83[a]	50.00 ± 0.00
T2	83.8 ± 3.30[a]	48.78 ± 2.92
T3	62.24 ± 1.21[b]	48.50 ± 2.60
T4	51.67 ± 2.89[c]	47.41 ± 2.63
T5	66.34 ± 1.80[b]	45.38 ± 3.87
CV Value	3.39	5.68

Note: [1]Means in each column with different superscript letters (a, b, c, …) were significantly different by Duncan's Multiple Range Test ($p \leq 0.05$).
[2]The detail of each treatment code is soil control (T1), soil with chemical fertilizer application (T2), and soil mixed with 10%, 20%, and 30% vermicompost (T3, T4, and T5).

3.2 Macronutrient chemical analysis

Chemical nutrients of soil and vermicompost are compared in Table 7. Soil showed lower values in soil pH, soil EC, and all nutrients compared to vermicompost. These results demonstrated that vermicompost has more nutrients than the soil used in this study.

Table 7 Chemical characteristics of soil and vermicompost (means ± SD).

Parameters	Soil	Vermicompost
pH	5.09 ± 0.03	6.25 ± 0.01
EC (mS)	0.06 ± 0.00	4.56 ± 0.02
AN (%)	0.01 ± 0.00	0.06 ± 0.00
TN (%)	0.10 ± 0.01	1.85 ± 0.02
AP (%)	< 0.01 ± 0.00	0.08 ± 0.00
TP (%)	0.20 ± 0.00	0.45 ± 0.00
AK (%)	0.06 ± 0.00	1.39 ± 0.00
TK (%)	0.23 ± 0.00	0.47 ± 0.01

Soil or a mixture of soil and vermicompost in each treatment were collected and analyzed for pH, EC, and chemical macronutrients comparing between, before, and after planting (Table 8). The soil pH values were increased after mixing the soil with vermicompost and slightly increased after planting except for the application of chemical fertilizer. Similarly, mixing with vermicompost made the soil EC values higher based on the ratio of mix. However, the soil EC values were decreased in all treatments after planting.

As shown in Table 8, the levels of both available and TN and potassium levels were increased when vermicompost was mixed with soil ($p \leq 0.05$). Reduction of nitrogen and potassium content was decreased after planting due to plants absorbing nutrients for their growth. Note that AP of T1 and T2 were not changed. The levels of total and AP were found slightly increased when using vermicompost (Table 8). Since it showed a very low level of phosphorus in our treatment, the usage of phosphorus was not clearly seen. However, the TP levels were found to increase after planting when the soil was mixed with 10%, 20%, and 30% vermicompost but not the control soil and chemical fertilizer treatment (Table 8).

Table 8 Comparison of chemical parameters and nutrients (mean ± SD) among each treatment[1] before and after planting.[2]

Parameter	Time	T1	T2	T3	T4	T5
pH	Before	5.09 ± 0.03^c	5.09 ± 0.03^c	6.00 ± 0.08^b	6.14 ± 0.02^a	6.22 ± 0.03^a
	After	5.26 ± 0.12^b	4.88 ± 0.05^c	6.46 ± 0.01^a	6.51 ± 0.02^a	6.59 ± 0.01^a
EC (mS)	Before	0.06 ± 0.00^d	0.06 ± 0.00^d	0.75 ± 0.05^c	1.26 ± 0.00^b	2.10 ± 0.03^a
	After	0.04 ± 0.00^c	0.03 ± 0.00^c	0.12 ± 0.00^d	0.18 ± 0.00^b	0.27 ± 0.00^a
AN (%)	Before	0.01 ± 0.00^b	0.01 ± 0.00^b	0.02 ± 0.00^b	0.02 ± 0.00^b	0.03 ± 0.00^a
	After	0.01 ± 0.00^b	0.01 ± 0.00^c	0.01 ± 0.00^c	0.01 ± 0.00^b	0.01 ± 0.00^a
TN (%)	Before	0.10 ± 0.01^d	0.10 ± 0.01^d	0.23 ± 0.01^c	0.32 ± 0.01^b	0.67 ± 0.01^a
	After	0.08 ± 0.00^d	0.07 ± 0.00^d	0.17 ± 0.00^c	0.23 ± 0.00^b	0.36 ± 0.01^a
AP (%)	Before	0.00 ± 0.00^d	0.00 ± 0.00^d	0.01 ± 0.00^c	0.02 ± 0.00^b	0.02 ± 0.00^a
	After	0.00 ± 0.00^e	0.00 ± 0.00^d	0.01 ± 0.00^c	0.01 ± 0.00^b	0.02 ± 0.00^a
TP (%)	Before	0.20 ± 0.00^b	0.20 ± 0.00^d	0.19 ± 0.01^b	0.20 ± 0.00^b	0.23 ± 0.00^a
	After	0.03 ± 0.00^d	0.03 ± 0.00^d	0.20 ± 0.00^c	0.65 ± 0.01^b	1.17 ± 0.03^a
AK (%)	Before	0.06 ± 0.00^d	0.06 ± 0.00^d	0.11 ± 0.00^{cd}	0.16 ± 0.01^b	0.32 ± 0.00^a
	After	0.07 ± 0.00^d	0.06 ± 0.00^d	0.09 ± 0.00^{cd}	0.10 ± 0.00^b	0.15 ± 0.00^a
TK (%),	Before	0.23 ± 0.00^c	0.23 ± 0.00^c	0.26 ± 0.01^b	0.26 ± 0.01^b	0.37 ± 0.01^a
	After	0.17 ± 0.01^c	0.17 ± 0.00^c	0.22 ± 0.01^b	0.21 ± 0.01^b	0.24 ± 0.01^a

Note: [1]The detail of each treatment code is soil control (T1), soil with chemical fertilizer application (T2), and soil mixed with 10%, 20%, and 30% vermicompost (T3, T4, and T5).
[2]Means in each column with different superscript ($^{a, b, c, \cdots}$) were significantly different by Duncan's Multiple Range Test ($p \leq 0.05$).

3.3 The effect of vermicompost on bacterial population

As shown in Figure 2, application of vermicompost significantly increased bacterial population in the planting materials ($p \leq 0.05$). The bacteria population number was increased in relation to the amount of vermicompost used in the mixture. The maximum bacteria population was obtained from 30% vermicompost (before plantation = 9×10^5 CFU/mL; after planting = 2.33×10^6 CFU/mL). In comparison to the vermicompost treatment, control soil and soil treated with chemical fertilizer showed low microbial populations. Besides being low in nutrients, these results indicated that the soil was also low in bacteria.

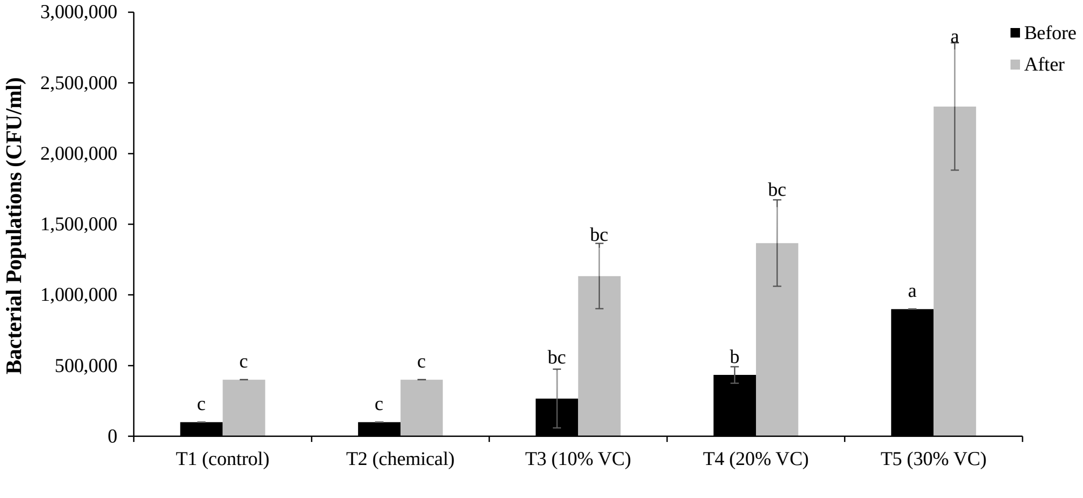

Figure 2 Comparison of bacterial population among treatments, before and after plantation. The detail of each treatment code is soil control (T1), soil with chemical fertilizer application (T2), and soil mixed with 10%, 20%, and 30% vermicompost (T3, T4, and T5). Means of each treatment within the group of before or after planting with different letters (a, b, c, …) were significantly different by Duncan's Multiple Range Test ($p \leq 0.05$).

4. Discussion

In recent years, the interest in using organic fertilizers such as compost or vermicompost as a potting medium has grown, particularly their use as an environmentally-friendly efficient medium for plant cultivation. Due to its high composition of organic matter and many beneficial microorganisms, vermicompost can be an advantage to agriculture both as a fertilizer and as a biocontrol agent. It has been widely reported to improve soil fertility, plant growth, and also reduce plant disease infections.

As indicated, the application of vermicompost significantly increased the plant height, the number of leaves, and the leaf area. It also improved soil fertility and increased soil microbial population before and after cultivation. Application of vermicompost at 30% showed the greatest results compared to the untreated vermicompost control. Previous study reported that the application of vermicompost at 10% and 20% improved cucumber plant growth and yield compared to the control [19]. However, [19] also revealed that up to 30% to 60% of vermicompost cucumber does not produce more fruit yield and plants become shorter. We have found that 30% of vermicompost was the best for plant growth and fruit yield. Particularly, pots treated with 10% and 20% did not give the highest productivity as it had been previously reported. In addition, we found that the fertilized flowers in all treatments were not strong enough to resist the harsh environment as shown by most flowers falling during the heavy rain. This may be due to the contribution of soil properties and nutrition in our experiment. In this study, soil chemicals showed very low nutrients compared to [19], thus a higher ratio of vermicompost must be required to obtain the best cucumber productivity. Our results clearly showed that the application of vermicompost can promote the growth of cucumber plants.

Disease occurrence was significantly lower in vermicompost treatment ($p \leq 0.05$). Many studies have demonstrated the effectiveness of vermicompost in providing protection against various plant diseases [20,21]. According to [21], the application of vermicompost induced a significant reduction in leaf miners and fungal infections in ladies' finger plants in comparison to the control soil. The suppression mechanisms may be due to high nutrient availability, presence of antimicrobial compounds such as flavonoids, phenolics, and humic acids and/or the action of beneficial microorganisms in vermicompost that produce plant growth promoting compounds. It is possible that beneficial microorganisms have an antagonistic effect to pathogens and compete for pathogen infection sites, or destroy pathogen propagules [22].

Regarding soil chemicals, nitrogen and potassium were improved by vermicompost. The vermicompost made these more available for plants to absorb during their growth. Our results showed that TP increased after cultivation. The increase of phosphorus had been previously reported [23,24]. The release of orthophosphates was largely due to the activity of microorganisms [25]. This could be implied that the continuous inputs of orthophosphates to the soil were probably slowly released from the vermicompost. It could be noted that in our results the AP was at a low level in the beginning and seemed not to change after planting. This may be due to the plants not being able to absorb phosphorus well. On the other hand, this may be affected by the unsuitability of soil pH [26]. The low-level of phosphorus availability might result in less resistance to diseases, low photosynthesis, low fruit yield, flowers, and less seeds [27].

The analysis of total bacterial population in the planting materials revealed that vermicompost improved the microbial population in the soil. Use of vermicompost led to the increase of bacterial population. Our result was in agreement with [28] which reported the enrichment of the microbial communities by application of vermicompost. In addition, the study of vermicompost application in continuous tomato cropping in a greenhouse also found that microbial functional diversity was higher in the vermicompost treatment than in the application of chemical fertilizer and poultry manure compost treatments. The number of bacteria population was 8.6 x 10^6 CFU/mL in zero-year cropping and 9.68 x 10^6 CFU/mL in 5 years cropping was obtained from vermicompost treatment [29]. Similar to our results, several researchers reported that the application of chemical fertilizer does not improve the bacterial population, but the organic residues are important in increasing the beneficial bacterial populations [30,31]. This phenomenon can be attributed to the humic substances present in vermicompost may serve as a source of nutrients for microorganisms that may promote the indigenous microbial communities, thus increasing overall microbial growth and population [32].

In addition, the results demonstrated a strong correlation of increasing plant growth and yield together with increasing of the bacteria population. This phenomenon may be attributed by plant growth-promoting bacteria (PGPB) that can enhance plant growth and protect plants from disease and abiotic stresses through a wide variety of mechanisms [33]. According to [34], the Plant growth-promoting rhizobacteria (PGPR) isolated from vermicompost have been showed greater plant growth promoting traits such as improved germination rate (43%) and turnip yield (30%) along with increased number of leaves, leaf length, diameter, fresh/dry weights of plant shoot/root compared with control. This may be due to vermicompost having growth regulators such as indole-3-acetic acid (auxin). These reports matched with our results, as shown by the correlation of increased bacteria and improvement in growth and yields of cucumber in vermicompost treatment when compared to chemical application and control soils.

5. Conclusion

In the present study, the application of 30% vermicompost showed the best positive effect on improving soil fertility and promoting cucumber plant growth, yields, and bacteria population in poor soil conditions. However, a higher level of vermicompost should be further investigated. Therefore, an application of vermicompost can be a vital choice instead of chemical fertilizer or pesticides in cucumber production for sustainable agriculture without harm to the environment.

6. Acknowledgements

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7. References

[1] Adhikary S. Vermicompost, the story of organic gold: a review. J Agric Sci. 2012;3:905-917.
[2] Theunissen J, Ndakidemi P, Laubscher C. Potential of vermicompost produced from plant waste on the growth and nutrient status in vegetable production. J Phys Sci Int. 2010;5:1964-1973.
[3] Singh B, Jagdeep S, Gurbir S. Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize-wheat rotation. J Agron. 2015;52:220-238.
[4] Blouin M, Barrere J, Meyer N. Vermicompost significantly affects plant growth: a meta-analysis. Agron Sustain Dev. 2019;39(4):34.
[5] Sharma K, Garg V. Conversion of a toxic weed into vermicompost by *Eisenia fetida*: nutrient content and earthworm fecundity. Bioresour Technol Rep. 2020;11:100530.
[6] Alwaneen WS. Cow Manure composting by microbial treatment for using as potting material: an Overview. Pak J Biol Sci. 2016;191:1-10.
[7] Ogbonna P, Chukwudi U. Evaluation of sixteen cucumber (*Cucumis sativus* L.) genotypes in derived savannah environment using path coefficient analysis. Not Sci Biol. 2016;8(1):85-92.
[8] Sotiroudis G. Chemical analysis, antioxidant and antimicrobial activity of three Greek cucumber (*Cucumis sativus*) cultivars. J Food Biochem. 2010;34:61-78.
[9] Mridha U, Jabbar F, Bhuiyan M. The severity and cause of leaf spot disease of *Pongamia pinnata* L. and fungicidal control of the pathogen. J For Res. 2007;18:236-240.
[10] Mclean EO. Soil pH and lime requirement. In Page AL, et al. editors. Methods of soil analysis, Part 2. Chemical and microbiological properties - Agronomy Monograph no. 9 (2nd edition), Wisconsin: Soil Sciences Society of America and American Society of Agronomy Inc; 1982, p. 199-225.
[11] Rayment GE, Higginson FR. Australian laboratory handbook of soil and water chemical methods. Port Melbourne: Inkata Press; 1992.
[12] Bailey L, McHargue J. Ashing procedures for the determination of copper in plant material. Plant Physiol. 1945;20(1):79-85.
[13] Wright RJ, Stuezynski TI. Atomic absorption and flame emission spectrometry. In: Sparks DL, editor. Methods of Soil Analysis, part 3, chemical methods, Madison WI: Soil science society of America:, 1996, Book Series 5, p. 65-90.
[14] AOAC. Official Methods of Analysis. 16th ed. Washington DC: Association of Official Analytical Chemists; 1995.
[15] Subbiah B, Asija G. A rapid procedure for the estimation of nitrogen in soils. Curr Sci. 1956;25:259-260.
[16] Olsen S, Cole C, Watanabe F, Dean L. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Washington DC: USDA Circular Nr 939, US Govt. Print. Office; 1954.
[17] Jackson ML. Soil Chemical Analysis. Englewood Cliffs, NJ: Prentice-Hall Inc; 1958.
[18] Florez-Márquez J. Isolation and characterization of rhizobacteria associated with rice crops (*Oryza sativa* L.) in Norte de Santander (Colombia). Agrocienc Urug. 2017;51(4):373-391.
[19] Esmaielpour B, Einizadeh S, Pourrahimi G. Effects of vermicompost produced from cow manure on the growth, yield and nutrition contents of cucumber (*Cucumis sativus*). J Cent Eur Agric. 2020;21(1): 104-112.
[20] Yatoo AM, Baba Z. Sustainable management of diseases and pests in crops by vermicompost and vermicompost tea. Agron Sustain Dev. 2021;41(1):1-26.
[21] Hussain N, Abbasi T, Abbasi SA. Evaluating the fertilizer and pesticidal value of vermicompost generated from a toxic and allelopathic weed ipomoea. J Saudi Soc Agric Sci. 2020;19(1):43-50.

[22] Matteoli FP. Genome sequencing and assessment of plant growth-promoting properties of a *Serratia marcescens* strain isolated from vermicompost. BMC Genom. 2018;19(1):1-19.

[23] Mahmud M, Abdullah R, Yaacob J. Effect of vermicompost amendment on nutritional status of sandy loam soil, growth performance, and yield of pineapple (*Ananas comosus* var. MD2) under field conditions. J Agron. 2018;8(9):183.

[24] Natsheh B, Mousa S. Effect of organic and inorganic fertilizers application on soil and cucumber (*Cucumis sativa* L.) plant productivity. Int J Agric For. 2014;4(3):166-170.

[25] Arancon N, Edwards C, Bierman P. Influences of vermicomposts on field strawberries: part 2. Effects on soil microbiological and chemical properties. Bioresour Technol. 2006;97(6):831-840

[26] Margenot AJ, Sommer R, Parikh SJ. Soil phosphatase activities across a liming gradient under long-term managements in Kenya. Soil Sci Soc Am. 2018;82(4):850-861.

[27] Farag A, Abdrabbo M, Hassanein MJ. Response of cucumber for mulch colors and phosphorus levels under greenhouse. Egypt J Agric Res. 2010;(37):53-64.

[28] Sun M, Chao H, Zheng X, Deng S, Ye M, Hu F, et al. Ecological role of earthworm intestinal bacteria in terrestrial environments: a review. Sci Total Environ. 2020;740:140008.

[29] Zhao F, Zhang Y. Vermicompost improves microbial functions of soil with continuous tomato cropping in a greenhouse. J Soils Sediments. 2020;20(1):380-391.

[30] Ammaan M, Akila A, Muthukrishana MA, Rahul A. Effect of organic manures and biofertilizers on soil microbial population in amaranth (*Amaranthus blitum*). Int J Curr Microbiol Appl Sci. 2019;8:700-704.

[31] Maheshwari DK, Saraf M, Dheeman S. Plant growth-promoting rhizobacteria (PGPR) as protagonists of ever-sustained agriculture: an introduction, in field crops. Sustainable Management by PGPR. Springer Sci Rev. 2019;23:1-10.

[32] Pathma J, Sakthivel NJ. Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. Springerplus. 2012;1(1):1-19.

[33] Grappelli A, Tomati U, Galli E, Vergari B. Earthworm casting in plant propagation. HortScience. 1985;20(5):874-876.

[34] Zahra MT, Afzal A, Asad SA, Sultan T, Tabassum T, Muhammad A, et al. Vermicompost augmented with plant growth promoting rhizobacteria improved soil fertility and growth of *Brassica rapa*. Int J Agric Biol Eng. 2019;22(6):1645-1654.