



RESEARCH ARTICLE

Assessing the Potential of Organic Wastes through Vermicomposting: A Case Study with Cucumber (*Cucumis sativus*)

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Abstract Vermicompost is considered a good substitute for mineral fertilizers as an agricultural amendment capable of reducing the cost of cucumber production and the degradation of the atmosphere associated with mineral fertilizer. Poultry manure, maize straw, fresh leaves of *Gliricidia*, and dry leaf litter was collected and processed into vermicompost. Field experiments were performed to determine the potential of vermicompost (VC) for growth yield, proximate analysis, and soil properties and to determine the economic viability of cucumber. Cucumber (VC) (*Cucumis sativus* L.) were planted under the following organic fertilizers VC at 0, 80, 90, and 100 kgN ha⁻¹, NPK15-15-15 at 100 kgN ha⁻¹ and poultry manure at 100 kgN ha⁻¹. Fertilizer treatments were arranged and replicated three times in a randomized complete block design and repeated three times. The outcomes showed that application of VC at 90 kgN ha⁻¹ significantly improved cucumber growth and yield compared to the initial application of NPK and residual harvest. Proximate study of cucumber shoot and fruit showed that after comparison with cucumber plots treated with poultry manure, NPK and control, the cucumber cultivated with VC at 90 kgN ha⁻¹ differed significantly at $P < 0.05$ in P, N, Ca, K, crude fiber, moisture, ash, protein, fat and carbohydrate content. Application of vermicompost significantly improved

chemical soil properties and yields of cucumber fruit were significantly related to soil properties. Consequently, the use of vermicompost at a rate of 90 kg N ha⁻¹ was economically suitable for cucumber production on the basis of these findings.

Keywords Cucumber · Economic · Organic waste · Vermicomposting · Yield

Introduction

There is a pool of organic materials that are generated in our everyday life through many agricultural and other practices, including residues of crops in the form of straw, husk, weed species, residues of animals, and by-products such as bones, manure, dung, waste from fish processing, and residential waste such as sewage, municipal waste, sludge, etc. [1]. A general survey of organic manurial materials obtainable for local usage indicates the different crop stalks (guinea corn, maize, and sorghum), rice husks, wheat straws, potato peels, brewery waste, banana leaves, poultry dung, pigs, sheep and goats, and other organically rich crop residues have been used in various parts of Nigeria.

In Nigeria, due to high costs and scarcity of mineral fertilizer, it is remote in order to satisfy the demand of the farming population. The recycling of organic waste for the supply of plant nutrients is becoming more significant, the conservation of soil, the reduction of pollution and the employment opportunity generation, which is now increasingly recognized as a strategy for the development of organic crops. It is believed that vermicomposting offers a route through which organic waste can become significantly stable, turning it into a finished fertilizer [2].

Significance Statement Vermicompost enhanced the growth, yield of cucumber and improved the physicochemical properties of soil.

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Vermicomposting is a bio-oxidation process that intensively combines angleworms with micro-organisms in the decomposer culture, improving organic matter by stabilization with altered physical and biochemical properties. Research efforts have demonstrated the capacity of vermicompost for promoting plant crop growth through various greenhouse and field studies [3, 4]. Cucumber (*Cucumis sativus*) is an important vegetable fruit eaten raw, grilled, or used in salads. The crop serves as the main source of vitamins; due to several factors, this crop is still poor in productivity in Nigeria, with nutrients/water being the limiting factor. To date, however, little effort has been made to discover the ability of vermicompost use to increase cucumber production in Nigeria. Hence, the goal of the study was to evaluate the prospect of organic waste via vermicomposting and the effects of vermicompost on the development of first and residual cucumber crops, as well as a chemical analysis of the properties of soil and the economic viability of vermicompost in the production of cucumber.

Material and Methods

Experimental Location and Soil Characteristics

The study was carried out in the 2018/2019 cropping season, at the Teaching and Research farm of Kwara State University, Malete (08° 42' 48.5" N and 004° 26' 17.9" E) Nigeria, southern Guinea savanna region of Nigeria. The temperature of the region varies between 33 and 34 °C, with an annual rainfall of about 1200 mm and a dry spell during the December to March season. During the cropping season, the minimum and maximum temperatures differ between 18.9 and 31.8 °C. The land area of Kwara State University is part of the south-western zone of the Nigerian basement complex, a region of Pan-African orogeny recurrence and basement plutonism [5]. The Pan-African Orogeny manifests itself most prominently in Nigeria and areas of West Africa. The inherent soil potential, such as mineral components, structure, and water availability, as well as mineral and groundwater exploration, have a significant economic impact [6, 7]. Weathering of this rock, driven mostly by climatic circumstances, resulted in a wide range of colors, textures, and mineralogy composition in the soil. The soil characteristic was loamy sand, consisting of 15% silt, 3.0% clay, and 82.0% sand.

Preparation of Vermicompost

Vermicompost production was carried out as described by [8]. Vermicompost bin measuring 60 × 100 × 20 cm was used for vermicompost making. Maize straw, poultry

manure, dry leaf litter, and fresh *Gliricidia* leaves were materials used in making vermicompost. Dry leaf litter, maize straw, and *gliricidia* leaves were collected from the farm and cut into pieces measuring ± 5 cm. While worm feed was used as a combination of fresh *gliricidia* dry leaf litter and poultry manure leaves, maize straw served as bedding products. 2 kg of bedding material and 4 kg of worm feed were the amount of material needed to fill the bin (ratio 1:2). Before adding *Eudrilus euginea* earthworms at a rate of 100 earthworms / m², the organic waste was allowed to partially decompose naturally for 2 weeks. The earthworms were introduced after 2 weeks to begin the vermicomposting process that was allowed to take place for 30 days. During the vermicomposting process, the moisture content was kept up at 80%. There was a black cloth covering the vermicomposting bin to evade the light. The mature vermicompost was harvested 30 days later and analyzed in the laboratory for nitrogen, phosphorus, and potassium content, as stated by [9]. Table 1 summarizes the nutrient analysis of vermicompost and poultry manure.

Soil Analysis

Soil samples were taken between 0 and 15 cm deep at random in the field before the analysis, using a soil auger. The samples were collected and air-dried and brought to the laboratory. The particle size analysis was carried out using the hydrometer method [10]. Organic carbon was determined as described by [11] and total nitrogen by [12] by the Walkley–Black dichromate digestion process. P was carried out by using the Brays P1 method [13]. By leaching the soil with neutral ammonium acetate, exchangeable K, Na, Ca, and Mg was extracted (NH₄OAC). The flame photometer measured K and Na concentrations, while the atomic absorption spectrophotometer determined Mg and Ca. The pH of the soil was measured using a ratio of 1:2 (soil: water) with a glass electrode pH meter and electrical conductivity of 1:5 (w/v) in the deionized water suspension.

Table 1 Chemical composition of vermicompost on dry weight basis

Nutrient (%)			
	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Vermicompost	1.4	0.19	0.29
Poultry manure	1.14	0.41	2.09

Field Study

3.0×3.0 (9 m^2) was the size of each sub-plot, with an inter-plot space of 0.5 m. Using the hoe two weeks before planting, vermicompost (VC) and poultry manure were uniformly incorporated into the well-prepared plot, while at three weeks after planting, NPK was applied by ring method, 5 cm in radius around and 2 cm deep nearby the cucumber plant. The experimental design was laid out in a randomized complete block design (RCBD) with three replications. The planting distance was $75 \text{ cm} \times 75 \text{ cm}$ at two plants per stand. Nevertheless, after seedling emergence, cucumber plants were thinned to one. In this experiment, the treatments used were as follows: VC at 80, 90, and 100 kg N ha^{-1} , NPK fertilizer at 100 kg N ha^{-1} , poultry manure at 100 kg N ha^{-1} and control. Successive manual weeding was carried out at two weeks intervals up to maturity of the crop. Cucumber was harvested at 12 weeks after planting. Another experiment was conducted to study the residual effects of fertilizer use.

Proximate Analysis

The proximate analysis as defined in [14] and [15] was carried out using standard laboratory techniques. The study of proteins was carried out using the technique mentioned in [16]. The cucumber shoot mineral analysis was performed using the technique described in [9].

Economic Analysis

An economic analysis of the production of vermicompost, poultry manure, and NPK on the yield of cucumbers was performed. The benefit-cost analysis was obtained with the formula used by [17].

Data Collection and Analysis

The data collected includes: vine length (cm), vine circumference (mm), number of plants per leave, number of days before 50% flowering, fruit diameter (cm), fruit length (cm), fruit weight (g), and yield (t ha^{-1}). The data collected were subjected to the statistical analysis system (SAS) for analysis of variance (ANOVA) and the treatments were assessed using the Duncan multiple range test at a 5 percent significance level (DMRT). In order to evaluate the relationships between cucumber yield and soil physicochemical properties, Pearson correlation coefficient analysis was also performed.

Results and Discussion

Soil Analysis

The status of the soil was deficient in N, P, before the beginning of the experiment (Table 2) and adequate in K [18–20]. The low soil N and P status is required to take advantage of soil amendments.

Cucumber Growth Parameters as Affected by Vermicompost, Poultry Manure, and Inorganic Fertilizer

The length of the vine, the diameter of the vine and the number of leaves of the cucumber plants increased significantly ($P < 0.05$) when vermicompost, poultry manure, and NPK were applied in both cropping cycles (Table 3). In the first trial, the length of the cucumber vine increased significantly ($P < 0.05$) when VC was applied at 90 kg N ha^{-1} . Application of vermicompost at 90 kg N ha^{-1} produced the longest vine (87.2 cm) and the control produced the shortest vine (56.8 cm). In the plot treated with VC, the maximum vine girth of 6.44 mm was observed at 90 kg N/ha and the control had the shortest vine girth of 3.24 mm. The difference in vine girth between VC at 80 kg N ha^{-1} , poultry manure at 100 kg N ha^{-1} , and VC at 100 kg N ha^{-1} was not significant. Among the treatments, the number of leaves per plant was significantly

Table 2 Physicochemical properties of experimental soil

Parameters	Soil test value
pH (H_2O)	6.7
Org.C (%)	7.9
Total N (%)	0.82
P (mg/kg)	2.77
Exchangeable bases (cmol/kg)	
Mg	0.78
Ca	0.58
Na	0.43
K	0.28
Extractable micronutrients (mg/kg)	
Cu	0.90
Fe	107
Mn	106
Zn	7.0
Sand (%)	82.0
Silt (%)	15.0
Clay (%)	3.0
Textural class	Loamy sand

Table 3 Effect of vermicompost, poultry manure and inorganic fertilizer on growth parameters of cucumber during first and residual planting

Treatments	Rate (kgNha ⁻¹)	Vine length (cm)	Vine girth (mm)	Number of leaves
First planting				
Control	0	56.8d	3.24d	29.7f
Poultry manure	100	74.8b	4.49c	88.5e
Vermicompost	80	64.5c	4.78c	158.3c
Vermicompost	90	87.2a	6.44 a	183.2a
Vermicompost	100	77.7b	4.59c	136.7d
NPK	100	76.5b	5.45b	174.7b
Residual planting				
Control	0	43.7e	2.53e	24.0e
Poultry manure	100	69.3b	3.86c	98.3c
Vermicompost	80	58.0d	4.62b	141.0b
Vermicompost	90	82.3a	6.10a	173.0a
Vermicompost	100	72.7b	3.09d	96.7d
NPK	100	65.0c	3.74c	98.3c

Means having the same letter along the columns indicate no significant difference using Duncan's Multiple Range Test at 5% probability level

Table 4 Effect of vermicompost, poultry manure and inorganic fertilizer on yield components of cucumber during first and residual planting

Treatments	Rate (kgNha ⁻¹)	Average fruit weight (g)	Fruit length (cm)	Fruit diameter	No of days before 50% flowering
First planting					
Control	0	148.3e	14.5e	41.5d	43.7d
Poultry manure	100	179.9c	18.4d	46.2c	37.0b
Vermicompost	80	169.2d	18.1d	45.3c	40.7c
Vermicompost	90	232.3a	30.4a	60.7a	35.6a
Vermicompost	100	166.5d	21.3c	44.4c	39.7b
NPK	100	190.2b	25.5b	50.6b	40.0c
Residual planting					
Control	0	100.2e	8.5d	30.5d	44.3f
Poultry manure	100	156.9b	12.4b	45.5b	36.0b
Vermicompost	80	129.2c	13.5b	43.3c	37.0c
Vermicompost	90	202.3a	22.0a	51.7a	35.3a
Vermicompost	100	111.3d	11.3c	43.6c	39.3d
NPK	100	112.6d	11.5c	32.6d	41.7e

Means having the same letter along the columns indicate no significant difference using Duncan's Multiple Range Test at 5% probability level

different ($P < 0.05$). Usage of VC with the highest number of leaves produced at 90 kg N ha⁻¹ (183.2) followed by NPK (174.7), the control resulted in the lowest number of leaves per plant (29.7). The maximum vine length of 82.3 cm was issued at VC 100 kg N ha⁻¹ during the second planting of the cucumber (residual) on the field. Residual application of vermicompost at 90 kg N ha⁻¹ of cucumber showed a substantial difference in vine girth and

number of leaves ($p < 0.05$) from poultry manure, NPK, and control values. At vermicompost 90 kg N ha⁻¹, residual output on the number of leaves generated 173, which was 43 and 86.1 percent higher than the NPK and control values, respectively. Vermicompost provided the best results with regard to vine length, number of leaves, and vine girth at 90 kg N ha⁻¹. This could be owed to the presence of high quantities of available nitrogen,

potassium, and micronutrients that improve photosynthesis, cell division, and cell enlargement, eventually improving the cucumber's growth-contributing properties [21]. Additionally, vermicompost plant growth hormones, such as auxin, gibberellin, and cytokinins, can also be linked to the growth, but also to their effect on soil physicochemical properties, humic acid content, and biology [22].

Yield and Components of Cucumber Yield

Table 4 shows the results of fruit weight, fruit length, fruit diameter, and number of days prior to 50 percent flowering in both cropping cycles. The first study indicated that the effects of vermicompost, poultry manure, and inorganic fertilizer varied significantly ($p < 0.05$) between the treatments. In all the parameters measured, the plots treated with vermicompost at 90 kg N ha^{-1} gave the maximum value, followed by NPK, except for the number of days before 50 percent of flowering, and the lowest value was obtained from the control plots. The direction of increment of all the yield components measured was VC at $90 \text{ kg N ha}^{-1} > \text{NPK} > \text{poultry manure} > \text{control}$. Similarly, the second trial outcome shows that the yield component values obtained from VC were significantly higher at 90 kg N ha^{-1} plot than the control, poultry manure, and NPK plots in fruit length, fruit weight, fruit diameter, and number of days before 50 percent flowering. As indicated by various yield parameters (fruit weight, fruit length, fruit diameter, number of days before flowering, and cucumber yield), the significant effects of vermicompost over control, poultry manure, and NPK is an indication that vermicompost is a storehouse for various nutrient elements for plant growth [23].

Figure 1 shows that cucumber yields varied significantly ($p < 0.05$) between first and residual planting of organic and mineral fertilizer treatments. Vermicompost at 90 kg N/ha produced the highest total grain yield (25.8 t/ha and 22.4 t/ha in first and residual planting, respectively) while the control had the least cucumber yield (6.2 t/ha and 6.1 t/ha , in first and residual planting, respectively). There was no substantial difference ($p < 0.05$) between the yield of poultry manure-derived cucumbers at 100 kg N ha^{-1} and the yield of VC at 80 and 100 kg N ha^{-1} in both periods, respectively. Compared to 100 kgN/ha , the greater impact of VC 90 kg N ha^{-1} on plant growth and yield and why VC 100 kg N ha^{-1} produced lower concentrations of soil nutrients could be as a result of better physical, chemical, and biological properties of vermicompost at 90 kg N ha^{-1} owed to humic acids [24]. Compared to the NPK plot during residual planting, the higher yield values of the cucumber plant components recorded in poultry manure could be credited to a higher level of nutrients, in particular nitrogen and phosphorus, and to the

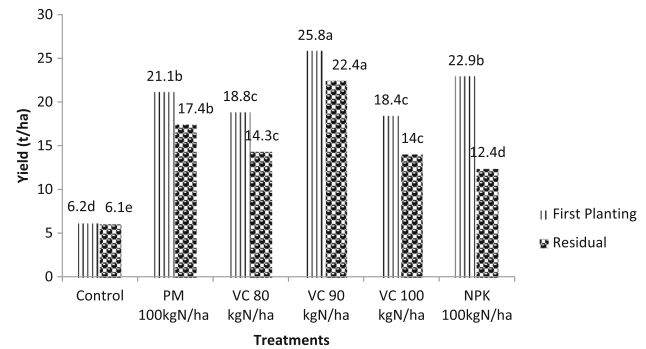


Fig. 1 Yield of cucumber as influenced by vermicompost, NPK and poultry manure at first and residual planting. Means having the same letter along the columns indicate no significant difference using Duncan's multiple range test at 5% probability level

harmonization of nutrients released during the cucumber plant growth period in poultry manure [25].

Mineral and Proximate Analysis

Table 5 indicates the average result of the chemical composition of the cucumber shoot during initial and residual cropping. Nitrogen ranged from 0.14 to 1.34 percent, with P content ranging from 0.10 to 0.95 percent, while K content ranged from 0.19 to 0.80 percent. In the cucumber shoot, the application of 90 kg N ha^{-1} of vermicompost significantly improved the amount of N, P, K and Ca. Cucumber plants with 90 kgN ha^{-1} of VC had higher P levels (0.95%), K (0.8%) and Ca (0.78%). Control had the least nutrient content on its own. Table 6 shows the proximate values of cucumber plants grown with vermicompost, poultry manure, and NPK fertilizer. In the cucumber plant grown with all the treatments, it showed that carbohydrate had the highest proximate content compared to fat, protein, crude fiber, ash, and moisture contents. Fat content is very similar among all treatments except control. Crude protein also shows an interesting effect when compared between treatments. The application of 90 kg N ha^{-1} of vermicompost holds a positive impact on proximate cucumber analysis. Compared to control, vermicompost increased the carbohydrate, moisture, fat, crude fiber, and ash content of the cucumber. This was in line with the report of [21]. Vermicompost was found to increase *Triticum aestivum*'s protein, fat, moisture, carbohydrate, dietary fiber, and ash content compared to control and recommended chemical fertilizer doses.

Table 5 Chemical composition of cucumber shoot

Treatments	Rate (kgNha ⁻¹)	N %	P %	K %	Ca %
Control	0	0.14c	0.10c	0.19c	0.21d
Poultry manure	100	0.27b	0.28b	0.39b	0.43c
Vermicompost	80	0.25b	0.20b	0.33b	0.42c
Vermicompost	90	1.34a	0.95a	0.80a	0.78a
Vermicompost	100	0.20b	0.20b	0.30b	0.45c
NPK	100	0.27b	0.27b	0.34b	0.60b

Means having the same letter along the columns indicate no significant difference using Duncan's multiple range test at 5% probability level

Table 6 Proximate results of *Cucumis sativus* grown with vermicompost

Treatments	Rate (kgNha ⁻¹)	Ash (%)	Crude protein (%)	Crude fiber (%)	Fat (%)	Moisture (%)	Carbohydrate (%)
Control	0	0.52 ± 0.02	1.84 ± 0.04	6.11 ± 0.09	0.24 ± 0.03	7.11 ± 0.11	32.20 ± 2.30
Poultry manure	100	1.50 ± 0.08	2.45 ± 0.06	10.3 ± 0.06	1.10 ± 0.05	10.0 ± 0.5	40.34 ± 0.57
Vermicompost	80	1.61 ± 0.10	2.44 ± 0.44	9.40 ± 0.40	1.12 ± 0.10	9.6 ± 0.60	39.8 ± 0.80
Vermicompost	90	1.70 ± 0.03	3.20 ± 0.13	12.50 ± 0.68	1.40 ± 0.03	11 ± 0.29	44.69 ± 1.94
Vermicompost	100	1.58 ± 0.08	2.40 ± 0.20	8.2 ± 0.30	1.29 ± 0.29	9.30 ± 0.30	40.31 ± 1.01
NPK	100	1.62 ± 0.50	2.55 ± 0.50	9.60 ± 1.10	1.32 ± 0.33	10.02 ± 1.01	42.60 ± 1.00

Result is the mean of triplicate study during first and residual cropping ± SEM

Effects of Vermicompost on Soil Physicochemical Properties during the First and Residual Planting at Harvest

Table 7 indicates the analysis of soil following the cucumber harvest during the first and residual planting periods. The two cropping cycles show that vermicompost at 90 kg N ha⁻¹ exceeded all other treatments for increasing soil nutrients; nitrogen, phosphorus, potassium, calcium, magnesium, soil organic carbon (OC), and pH, although control treatment had the lowest values for both. Vermicompost has also been revealed to enhance soil physicochemical properties, plant development, and productivity, in addition to the release of higher nutrient elements into the soil [26]. pH, organic carbon, available P, N, Ca, Mg, K, and available nitrogen were higher from use of vermicompost at 90 kg N ha⁻¹ on soil than for chemical fertilizers applied to soil after first and residual harvesting. This may be due to the comparatively higher concentration of vermicompost nutrients, and the nutrients present in organic materials are released more slowly and retained in the soil for a longer period of time, thereby ensuring a long residual effect [21]. According to report from [27], the use of organic amendment for example vermicompost was

reported by [17], that it is a source of organic matter that increases soil fertility by including the required and important plant nutrients, in addition to organic matter that enhances soil moisture and nutrient retention. The nutrient added from NPK was, however, consumed after the first planting; a smaller amount of nutrients left behind could support good harvesting during residual cropping. The rise in soil pH owing to the application of vermicompost at 90 kg N ha⁻¹ could be due to its high basic cation and pH content, which, by replacing the exchange site acid cation, could decrease soil acidity, exchangeable acidity, and aluminum content. This is in line with the findings of [28] who pointed out that, as a result of the application of vermicompost, the direction of change in soil pH reflected the initial VC pH. The use of NPK fertilizer decreased the soil pH during the second harvest. These results were consistent with the findings of other studies that showed that soil pH was also reduced by NPK fertilizer supplementation [29]. Compared to the initial soil properties after first harvest, soil amended with vermicompost has shown an increase in soil organic carbon content.

Table 7 Effects of vermicompost on soil chemical and physical properties at harvest during the first and second field cropping

Treatment	Rate (kgNha ⁻¹)	pH (H ₂ O)	Available P mg kg ⁻¹	OC N g kg ⁻¹	Ca Mg K cmol kg ⁻¹				Clay	Silt (%)	Sand
First harvest											
Control	0	6.80d	8.36b	0.39f	0.10f	2.30f	0.38e	0.40f	6.0d	13.8a	80.2a
Poultry manure	100	7.69b	23.3e	1.55c	0.14d	2.97e	0.46c	0.56e	6.0d	13.0b	81.0a
Vermicompost	80	7.68b	29.7d	1.04d	0.17c	3.61d	0.38d	0.63d	6.0d	12.7c	81.3a
Vermicompost	90	7.71a	44.5a	1.89a	0.20a	5.94a	1.36a	0.86a	7.0a	11.5e	81.5a
Vermicompost	100	7.70a	36.0c	0.94e	0.12e	4.16c	0.44c	0.73b	6.8b	12.0d	81.2a
NPK	100	7.36c	41.5b	1.74b	0.16b	5.30b	1.12b	0.68c	6.4c	12.0d	81.6 a
Residual harvest											
Control	0	6.91d	9.62d	0.46e	0.05c	2.34e	2.70d	0.12d	3.6b	14.0a	82.4a
Poultry manure	100	7.70b	15.4b	1.05b	0.12b	5.43b	3.90b	0.18c	4.0a	13.8a	82.2a
Vermicompost	80	7.71b	11.26c	0.94c	0.15b	2.98d	3.10c	0.19b	3.9a	13.8a	82.3a
Vermicompost	90	7.79a	17.12a	1.17a	0.18a	5.93a	5.76a	0.27a	4.1a	13.7a	82.2a
Vermicompost	100	7.71b	14.66b	0.67d	0.12b	3.10c	3.50c	0.21b	4.0a	13.8a	82.2a
NPK	100	7.03c	12.66c	0.53d	0.08c	3.11c	2.95d	0.15c	4.0a	13.8a	82.2a

Mean having the same letter along the columns indicate no significant difference using Duncan's multiple range tests at 5% probability level

Table 8 Pearson correlation coefficients between cucumber yield and soil chemical properties after first harvest

Parameters	Yield	pH	OC	N	P	Ca	Mg	K
Yield	1							
pH	0.783**	1						
OC	0.949**	0.746**	1					
N	0.889**	0.674**	0.915**	1				
P	0.898**	0.873**	0.888**	0.918**	1			
Ca	0.880**	0.658**	0.902**	0.980**	0.861**	1		
Mg	0.960**	0.765**	0.899**	0.771**	0.816**	0.769**	1	
K	0.820**	0.909**	0.795**	0.583**	0.782**	0.559**	0.875**	1

* Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level

Relationship after First and Residual Harvest Between Cucumber Yield and Soil Chemical Properties

The correlation coefficients between the cucumber yield and the chemical characteristics of the soil are shown in Tables 8, 9, respectively, after the first and residual harvests. pH, OC, N, P, Ca, Mg, and K was positive and significantly ($p < 0.05$) correlated with cucumber yield after first harvest (Table 8).

The highest positive correlation was $r = 0.960^{**}$ with magnesium, while pH was associated with P and K positively ($r = 0.873^{**}$, $r = 0.909^{**}$). The OC to N relationship was highly and positively correlated ($r = 0.915$). P and K were correlated positively ($r = 0.782$). In addition, the

cucumber yield after residual harvest was positive and important ($p < 0.05$) for pH, organic carbon, nitrogen, phosphorus, calcium, magnesium, and potassium, the cucumber yield after residual harvest was positive and important ($p < 0.05$). (Table 9). The highest positive correlation was with P, $r = 0.854^{**}$. Other soil chemical properties were positively correlated with pH, including cucumber yield. Positive linear correlations found after first and residual harvest between cucumber yield and soil chemical properties suggest that these properties have been closely associated with cucumber yield [30], they found that there is a positive relation between tomato yield, K, pH, organic matter, available nitrogen and available phosphorus content in soils. The significant and affirmative association between organic carbon and nitrogen in both

Table 9 Pearson correlation coefficients between cucumber yield and soil chemical properties after residual harvest

Parameters	Yield	pH	OC	N	P	Ca	Mg	K
Yield	1							
pH	0.816**	1						
OC	0.617**	0.800**	1					
N	0.636**	0.722**	0.961**	1				
P	0.854**	0.913**	0.759**	0.744**	1			
Ca	0.799**	0.984**	0.746**	0.645**	0.927**	1		
Mg	0.786**	0.916**	0.746**	0.695**	0.897**	0.928**	1	
K	0.759**	0.774**	0.813**	0.879**	0.834**	0.729**	0.878**	1

*Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level

Table 10 Economic Analysis of introducing vermicompost

Treatment	Rate (kgNha ⁻¹)	Variable cost N	Fixed cost N	Total cost N	Revenue N	Net farm income N	Benefit cost ratio
Control	0	512, 598	17,400	529, 998	688, 888	158, 900	1.29
Poultry manure	100	1,584,488	17,400	1 601,888	2, 344,444	742, 556	1.46
Vermicompost	80	1,417,377	17,400	1,434,777	2,011,111	576, 334	1.40
Vermicompost	90	1,875,266	17,400	1,892,666	2,866,666	974, 000	1.51
Vermicompost	100	1,401,933	17,400	1,419,333	2,044,444	625, 111	1.44
NPK	100	1,709,377	17,400	1,726,777	2,544,444	817, 667	1.47

Average of 2 cropping seasons; N365 = \$1 (As at December 2019)

cropping cycles can be due to the release of mineralizable nitrogen from soil organic matter in proportional quantities and to the adsorption of $\text{NH}_4\text{-N}$ by soil humus complexes.

In addition, organic carbon showed a positive and important association with phosphorus in our study; similar findings have been reported by. The pH was strongly and significantly correlated with OC. The worker proposed that the rise in soil OC following manure application was associated with a general improvement in soil conditions. In **conclusion**, vermicompost was discovered to have greater residual properties than NPK fertilizer on soil nutrients.

Economic Analysis

Table 10 describes the economic evaluation of introducing vermicompost in cucumber production using the benefit-cost ratio (BCR). The BCRC calculates and sums up the equivalent money value of any investment's benefits and costs. The net profit (N974, 000) was highest at 90 kgN/ha for vermicompost. For NPK and poultry manure, this was accompanied by N 817, 667 and N742, 556, respectively. The net profit under control (N158, 900) was the lowest. In this study, the highest benefit–cost ratio (1.51) was found

in vermicompost at 90 kg N ha⁻¹. NPK, poultry manure, vermicompost at 100 kg N ha⁻¹, 80 kg N ha⁻¹ and control were followed by 1.47, 1.46, 1.44, 1.40, and 1.29, respectively. The economic benefits of fertilizer usage are determined by fertilizer rates, seed prices and, eventually, how the plant responds to fertilizer application. The study of economic returns showed higher net revenues compared to other amendments on the cucumber-treated plot with vermicompost at 90 kg N ha⁻¹. Vermicompost supply of a more secure proportion of essential nutrients could justify its highest return.

Conclusions

For length of cucumber vine, vine girth, number of leaves, average weight of fruit, length of fruit, diameter of fruit, yield of fruit, and proximate properties, vermicompost applied at 90 kg N ha⁻¹ was superior to that of NPK fertilizer and poultry manure in both cropping cycles. VC provides vital nutrients to the soil at 90 kg N ha⁻¹ and increases the physicochemical characteristics of the residual soil. Correlation studies showed that, as shown by the correlation coefficient, cucumber yield had a positive

significant correlation with all chemical soil properties in the sample. Highest net farm income was reported with application of vermicompost at 90 kg N ha⁻¹. From the economic gain point of view, it can be inferred that, as an organic fertilizer, vermicompost receives greater prospects for cucumber growth and yield, thereby acting as an alternative to synthetic fertilizers.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

References

- Islam MA, Talukder MS, Islam MS, Hossian MS, Mostofa MG (2018) Recycling of organic wastes through the vermicomposting process of cow dung and crop residues. *J Bangladesh Acad Sci* 42(1):1–9
- Edwards CA, Norman QA, Sherman R, (2011) *Vermiculture Technology. Organic Waste and Environmental Management*, CRC Press, Boca Raton, FL, USA, Earthworms, pp 17–19
- Arancon NQ, Edwards CA, Bierman P, Welch C, Metzger JD (2004) Influences of vermin composts on field strawberries: Effects on growth and yields. *Biores Technol* 93:145–153. <https://doi.org/10.1016/j.biortech.2003.10.014>
- Gutiérrez-Miceli FA, Santiago-Borraz J, Molina JAM, Nafate CC, Abud-Archila M, Llaven MAO, Rincón-Rosales R, Dendooven L (2007) Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersicon esculentum*). *Bioresour Technol* 98(15):2781–2786
- Olowoake AA (2017) Nutrient Release Pattern from Compost Supplemented with *Jatropha* Cake on Alfisol of Ilorin, Nigeria. *Int J Plant Soil Sci* 15(5):1–11
- Oyedele AA, Adelusi OA, Oyedele T (2005) Determination of Aquifer units using the vertical electrical sounding technique: A case study of Federal Low-Cost Housing Estate, Okeho, South-western, Nigeria. *J Pure Appl Physic* 4:60–67
- Mbits K, Musa AI (2018) Petrographic and structural analysis of exposed rocks of Musawa Bayero. *J Pure Low-Cost Sci* 11(1):189–196
- Nurhidayati N, Machfudz M, Murwani I (2018) Direct and residual effect of various vermicompost on soil nutrient and nutrient uptake dynamics and productivity of four mustard Pak-Coi (*Brassica rapa* L) sequences in organic farming system. *Int J Recycling Organic Waste Agri* 7:173–181
- Ngo PT, Rumpel C, Ngo QA, Alexis M, Velasquez Vargas G, Mora Gil Mde L, Dang DK, Jouquet P (2013) Biological and chemical reactivity and phosphorus forms of buffalo manure compost, vermicompost and their mixture with biochar. *Biore-sources Technol* 148:401–407
- Bouyococcus GJ (1951) Direction for making mechanical analysis by the hydrometer method. *Soil Sci* 42:225–229
- Nelson DW, Sommers LE (1982) Total carbon, organic carbon and organic matter. In: Page AL, Miller RH, Keeney DR (eds) *Methods of Soil Analysis Part 2: Chemical and Microbiological*. ASA and SSSA, Madison, Wisc pp, pp 539–577
- Bremner JM, Mulvancy CS (1982) Total Nitrogen. In: Page AL et al. (ed) *Methods of soil analysis part 2, Agron Monogr. 9* (2nd edition) ASA and SSSA, Madison Wsc pp 403–430
- Bray RH, Kurtz LT (1945) Determination of total and organic of phosphate in the soil. *Soil Sci J* 59:45–49
- AOAC (1990) *Official Methods of Analysis*. 15th (ed) Association of Official Analytical Chemists Washington DC, USA.
- James CS (1995) *Experimental procedures for estimation of major food constituent*. Chapman and Hall, New York, USA, pp 71–99
- Chang SKC (2003) *Protein analysis in food analysis* (3rd ed) Kluwer Academic Plenum Publishers New York, USA. pp. 131–142.
- Harphool O, Sharma L, Kumar R (1996) Economics of nitrogen and phosphorous fertilization in isabgol (*Plantago ovata* Forsk). *Crop Res* 11(2):246–247
- Aduloju MO (2004) Acid Extractable Micronutrients (Mn and Zn) in Selected soils of vegetables producing Areas of Kwara State, Nigeria. *Nigeria J Horticultural Sci* 9:116–199
- Adeoye GO (1986) Comparative studies of some extractants for sedimentary soil of South Western Nigeria. Ph.D. Thesis, University of Ibadan, Ibadan. 201pp
- Adeoye OA, Agboola AA (1985) Critical level of soil plant available P, K, Zn, Mn, Cu and Mn on maize leaf content in sedimentary soil of Southwestern Nigeria. *Fert Res* 6:60–71
- Joshi R, Singh J, Vig AP (2014) Vermicompost as an effective organic fertilizer and biocontrol agent: effect on growth, yield and quality of plants. *Rev Environ Sci Biotechnol*. <https://doi.org/10.1007/s11157-014-9347-1>
- Atiyeh RM, Lee S, Edwards CA, Arancon NQ, Metzger JD (2002) The influence of humic acids derived from earthworm-processed organic wastes on plant growth. *Bioresour Technol* 84:7–14
- Fernandez-Luqueno F, Reyes-Varela V, Martinez-Suarez C, Salomon-Hernandez G, Yanez-Meneses J, Ceballos-Ramirez JM, Dendooven L (2010) Effect of different nitrogen sources on plant characteristics and yield of common bean (*Phaseolus vulgaris* L). *Bioresour Technol* 101(1):396–403
- Lim SL, Wu TY, Lim PN, Shak KPY (2015) The use of vermicompost in organic farming: overview, effects on soil and economics. *J Food Sci Agric* 95:1143–1156
- Ghanbarian D, Youneji S, Fallah S, Farhadi A (2008) Effect of broiler litter on physical properties, growth and yield of two cultivars of cantaloupe (*Cucumis melo* L.). *Int J Agric Biol* 10:697–700
- Pathma J, Sakthivel N (2012) Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. *springerPlus* 1:26. <https://doi.org/10.1186/2193-1801-1-26>
- Canatoy RC (2018) Effects of Vermicompost on the Growth and Yield of Sweet Corn in Bukidnon, Philippines. *Asian J Soil Sci Plant Nutrition* 3(2):1–8

28. Angelova VR, Akova VI, Artinova NS, Ivanov KI (2013) Effect of organic amendments on soil chemical characteristics. *Bulgarian J Agr Sci* 19(5):958–971
29. Brar BS, Singh J, Singh G, Kaur G (2015) Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize-wheat rotation. *Agronomy* 5:220–238
30. Fu H, Zhang G, Zhang F, Sun Z, Geng G, Li T (2017) Effects of Continuous Tomato Monoculture on Soil Microbial Properties and Enzyme Activities in a Solar Greenhouse. *Sustainability* 9:317. <https://doi.org/10.3390/su9020317>

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