Impact of Vermicompost and Its Residual Effect on Soil Properties, Nutrient Uptake and Yield Of Cucumber (*Cucumis sativus* L.)

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ABSTRACT

Application of vermicompost to soil has been found to play a vital role in soil nutrient augmentation and adequate maintenance of soil organic. Two pot trials were conducted to investigate impacts of vermicompost application and its residual on soil properties, nutrient uptake and yield of cucumber (*Cucumis sativus* L) in a screen house. Treatments were control (0 kg N ha^{-1}), vermicompost providing 70, 80, 90, 100 kg N ha^{-1} and NPK fertilizer (100 kg N ha^{-1}). Growth, yield and nutrient uptake of cucumber were improved by vermicompost at 90 kg N ha^{-1} in both cropping cycles. Cucumber applied with vermicompost at 90 kg N ha^{-1} gave the highest yield of 184.4 and 128.4 g/plant at first and residual harvest respectively. Result also showed that residual soil pH, organic C, P and K contents increased when vermicompost, 90 kg N ha^{-1} was applied. A significant positive correlation exists between cucumber fruit yield and nutrient uptake Vermicompost, 90 kg N ha^{-1} significantly improved nutrient uptake with higher nutrient residuals than other treatments.

Keywords: *Cucumis sativus*, mineral fertilizer, screen house, vermicompost

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INTRODUCTION

Cucumber productivity in Nigeria is low due to low native fertility status of the soil among other factors (Law-Ogbomo *et al.*, 2018). This crop required high amount of soil nutrients from seedling stage to maturity and highly sensitive to excessive water or waterlogs environment and adequate soil tillage for easy fragile root penetration, is required prior to sowing or planting (Nweke et al., 2014). Non-use of fertilizer, inappropriate plant population, varying amount of moisture, and low soil fertility contribute to low yields (Law-ogbomo and Osaigbovo, 2018).

Most Nigerian soils have low nitrogen and are supplemented with N fertilizer. Application of fertilizer is the easiest strategy for increasing cucumber yield (Agu *et al.*, 2015.). However, the production and the use of chemical fertilizers impact various negative effects on the agricultural ecosystems, such as degradation of the soil, loss of genetic diversity, reduction in soil microbial diversity, contamination of ground-water resources, and pollution of the atmosphere. (AdeOluwa *et al.*, 2021) One way of improving soil and water conditions is use of vermicomposting. Vermicompost is finely-divided mature material produced by a non-thermophylic process involving interactions between earthworms and microorganisms (Edwards and Burrows, 1988) leading to bio-oxidation and stabilization of organic material (Aira *et al.*, 2000). Vermicompost contains N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B, the uptake of which positively affects plant nutrition, photosynthesis, chlorophyll content of the leaves and nutrient content of plant tissues (Theunissen *et al.*, 2010). It increased nutrient uptake in plants, due to higher concentrations of humic acid (HA) and a larger population of microorganisms, was shown to result in improved germination, flowering and growth in plants (Arancon *et al.*, 2006; Hatamzadeh, 2011)

Vermicompost increases cucumber yield, improve soil properties, and reinforces the soil environment (Esmaielpour *et al.*, 2020). There is little or no information on the influence of vermicompost on the production of cucumber in Nigeria. The objective of the study was to determine the impact of vermicompost and its residual effect on soil properties, nutrient uptake and yield of cucumber.

MATERIALS AND METHODS

Pot experiments were carried out at Kwara State University, Faculty of Agriculture Screen House, (Latitude 80°71'N and Longitude 40°44'E) at Malete, Kwara State, Nigeria. Soil samples were randomly collected from Kwara State University Teaching and Research Farm, Malete, from a depth of 0-15 cm, air-dried and passed through a 2 mm sieve. Chemical and physical properties were determined in the laboratory by procedure described by Okalebo *et al*. (2002).

Vermicompost was produced in a vermicomposting bin. Organic materials used in production of vermicompost were fresh gliricidia leaves, poultry manure, maize straw and dry plant from which leaves were obtained which were chopped into pieces. The chopped maize straw was used as a bedding material, the mix of poultry manure, dry leaf litter and the fresh gliricidia leaves were used as worm feed. The quantity of material required to fill the bin was 2 kg of bedding materials and 4 kg of worm feed. This quantity was added based on the day-to-day ability of worms to decompose the organic matter. The organic materials were partially decomposed over a 2 week period before adding *Eudrilus euginea* earthworms, 100 earthworms·m^{-2}. The earthworms were introduced to initiate the vermicomposting process over a 30 day period. During vermicomposting moisture content was maintained at 80%. The vermicomposting bin was covered with a black cloth as shade. After 30 days, the ripe vermicompost was harvested and analyzed for nitrogen, phosphorous and potassium content in the laboratory.

Twenty-four pots were individually filled with 25 kg of soil. The treatments were 0 kg ha^{-1} N, vermicompost at 70, 80, 90, 100 kgN ha^{-1} and NPK fertilizer at the rate of 100 kgN ha^{-1} (Kuranga, 2014). The organic sources were applied 2 weeks before planting; mineral fertilizer was applied 2 weeks after planting. Each treatment was thoroughly mixed. Treatments were arranged in a completely randomized design with 4 replicates. Cucumber seed were sown in a pot and was watered immediately. Developing plants were staked when they reached a height of about 50 cm. The plants were watered to field moisture capacity every 3 days and weeding was carried out as required. The experiment was continued using the same pots without any fertilizer application at a second planting to determine its residual effect on soil properties, nutrient uptake and yield of cucumber.

Plant samples were randomly selected during the first and second cropping. Samples were oven dried in a laboratory oven at 70°C to a constant weight as dry matter yield. Dry samples were ground and analyzed for N, P and K contents based on procedures described by Okalebo *et al*. (2002).

Nutrient uptake was determined by multiplying total dry matter yield (g) with nutrient content (%). Chemical analysis of the soil was carried at first and second harvest to determine nutrient status. Data on growth and yield parameters collected include; vine length, vine girth, number of leaves, number of branches, number of days to 50% flowering, number of fruit/plant, fruit diameter and weight of fruit/plant. The data were subjected to analysis of variance and differences among means separated using Duncan's Multiple Range Test. Pearson correlation was performed on relationship of cucumber yield and nutrient uptake.

RESULTS

The textural class of the soil was a loamy sand, with pH (H_2O) 6.7 making it slightly acidic. Organic carbon, total N and available P values were 7.9, 0.82 ($g{\cdot}kg^{-1}$) and 2.77 $mg{\cdot}kg^{-1}$, respectively. Exchangeable K, Mg, Na and Mn were 0.28, 0.78, 0.43 $cmol{\cdot}kg^{-1}$ and 106 $mg{\cdot}kg^{-1}$, respectively.

Growth parameters of cucumber to application of vermicompost during the first and second cropping in the screen house were shown in Table 1. At first planting, cucumber plants grown with vermicompost at 90 kgN ha^{-1} produced the highest vine length and this was significantly ($p < 0.05$) higher than other treatments. The highest vine girth recorded in cucumber plant was from vermicompost at 90 kgN ha^{-1}. This was significantly ($p < 0.05$) higher than other treatments by 12.8% - 31.9%. Cucumber number of leaves influenced by the application of vermicompost at 90 kgN ha^{-1} was found to be significantly ($p < 0.05$) higher from that of control and other fertilizer treatments. At second planting, vermicompost at 90 kgN ha^{-1} produced the highest value of vine length closely followed by vermicompost at 80 kgN ha^{-1} and control produced the least vine length. Similarly, application of vermicompost at 90 kgN ha^{-1} produced plant with significantly higher vine girth than NPK fertilizer, vermicompost at 70, 80, 100 kgN ha^{-1} and control respectively. Number of leaves and number of branches produced from vermicompost at 90 kgN ha^{-1} resulted in highest values which were significantly ($P < 0.05$) different from value obtained from control, NPK fertilizer and vermicompost at 70, 80, 100 kgN ha^{-1} respectively. In this study, vermicompost application showed better results on growth parameters than inorganic fertilizer treatment during the two cropping cycle.

Table 1: Response of cucumber growth parameters to vermicompost application

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

Response of yield parameters of cucumber as influenced by vermicompost

The yield components of cucumber as influenced by application of vermicompost and NPK during the first and second cropping in the screenhouse were shown in Table 2. According to first planting results, there were significant different among fertilizers on days to attained 50% of flowering. There were no significant differences between treatments comprised of vermicompost at 80 and 90 kgN ha^{-1}, including vermicompost at 100 and NPK at 100 kgN ha^{-1}. However, control took the highest number of days to achieve 50% flowering.

At second planting, there were no significant differences between treatments comprised of vermicompost at 70, 80, 90 and 100 kgN ha^{-1}. NPK fertilizer and control took the highest

Treatment	Rate of N ($kg\ ha^{-1}$)	Vine length (cm)	Vine girth (mm)	Number of leaves	Number of branches
		First planting			
Control	0	43.3e	5.68d	11.09e	12.7e
NPK	100	75.0b	7.63b	18.8b	18.1b
Vermicompost	70	56.4d	6.22c	14.5d	15.1c
Vermicompost	80	57.3d	6.98c	16.4c	14.3d
Vermicompost	90	89.5a	8.34a	22.1a	21.6a
Vermicompost	100	72.6c	7.27b	17.4b	17.1b
		Second planting			
Control	0	36.4d	3.53d	8.8d	7.3d
NPK	100	38.1d	3.66c	9.4c	9.4c
Vermicompost	70	43.4c	3.64c	9.9c	9.8c
Vermicompost	80	48.3b	4.55b	10.8b	10.5b
Vermicompost	90	53.4a	5.02a	15.0a	12.5a
Vermicompost	100	45.4c	4.49b	10.1b	9.4c

number of days respectively. Concerning fruit diameter per plant, at first planting, vermicompost at 90 kgN ha^{-1} produced the highest fruit diameter per plant as compared to other treatments, while the least fruit diameter was recorded from control. The result also showed that there was no significant difference ($p<0.05$) between vermicompost at 100 and NPK at 100 kgN ha^{-1} in terms of fruit diameter per plant. There was significant difference between fruit diameter/plant from vermicompost at 70 and 80 kgN ha^{-1}. At second planting, application of vermicompost at 90 kgN ha^{-1} resulted in significantly higher fruit diameter/plant than NPK and others vermicompost, while the control had the smallest fruit diameter. At first planting, application of vermicompost significantly ($p< 0.05$) pose variation in cucumber fruit weight per plant and the highest of cucumber fruit weight was recorded for the plants which were treated with vermicompost at 90 kgN ha^{-1} which was significantly different from Vermicompost at 70, 80, 90, 100 kgN ha^{-1}, NPK and control respectively. At second planting, results from Table 2 indicated that fruit weight / plant produced from vermicompost at 90 kgN ha^{-1} resulted in highest values which was significantly ($P< 0.05$) different from value obtained from NPK and others vermicompost. Lowest weight was recorded from control pot.

Treatment	Rate (kgN ha^{-1})	Days to 50% flowering	Fruit diameter (mm)	Fruit weight/ plant (g)
		First planting		
Control	0	42.0d	24.8e	78.1f
NPK	100	35.0b	51.5b	169.0b
Vermicompost	70	38.0c	48.8c	93.5e
Vermicompost	80	38.0c	46.5d	107.4d
Vermicompost	90	33.0a	66.6a	184.4a
Vermicompost	100	36.0b	55.2b	128.0c
		Second planting		
Control	0	43c	18.7d	62.3e
NPK	100	41b	40.1c	90.3c
Vermicompost	70	39a	42.7b	70.6d
Vermicompost	80	39a	41.3c	92.8c
Vermicompost	90	39a	50.2a	128.4a
Vermicompost	100	39a	43.6b	102.5b

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

Plant nutrient uptake

N, P and K uptake of the first cucumber cropping was significantly ($p<0.05$) affected by the vermicompost and mineral fertilizer applications, whereas vermicompost at 90 kg·ha^{-1} of N provided the highest N uptake, while the residual effect on the second plant, the highest N uptake was also found in vermicompost at 90 kgN ha^{-1} (Figures 1 and 2). Vermicompost at 90 kgNha^{-1} increased N uptake more than NPK and other vermicompost treatments.

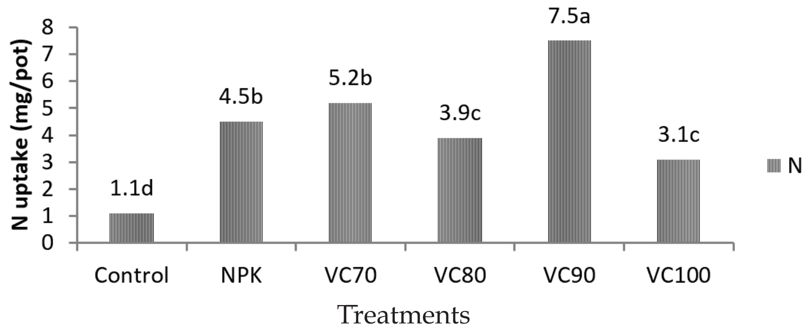

Figure 1. Nitrogen uptake by cucumber as influenced by application of vermicompost during first cropping

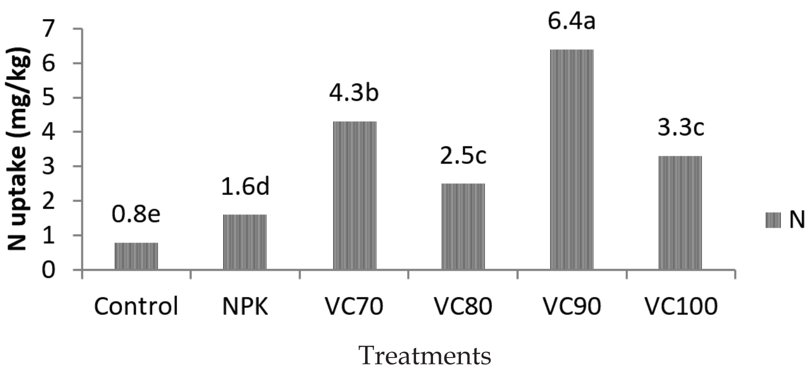

Figure 2. Nitrogen uptake by cucumber as influenced by application of vermicompost during residual cropping

Legend
Control = 0 kg·ha^{-1} N; NPK = 100 kg·ha^{-1} N; VC 70 = Vermicompost at 70 kg·ha^{-1} N; VC 80 = Vermicompost at 80 kg·ha^{-1} N; VC 90 = Vermicompost at 90 kg·ha^{-1} N, and VC 100 = Vermicompost at 100 kg·ha^{-1} N. Bars with the same letter are not significantly different, $p<0.05$, Duncan's Multiple Range Test.

The P uptake of cucumber was influenced by the NPK and vermicompost applications. However, the different rate of vermicompost significantly affect P uptake of the cucumber where the highest P uptake was found in vermicompost at 90 kgN ha^{-1}. The residual effect of vermicompost on the P uptake of the second cucumber was found on the pot treated with vermicompost at 90 kgN ha^{-1}(Figures 3 and 4).

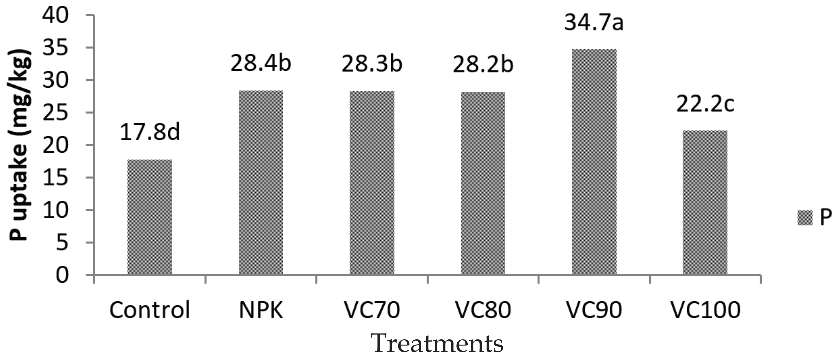

Figure 4. Phosphorus uptake by cucumber as influenced by application of vermicompost during residual cropping

lLegend

Control = 0 kg·ha-1 N; NPK = 100 kg·ha-1 N; VC 70 = Vermicompost at 70 kg·ha-1 N; VC 80 = Vermicompost at 80 kg·ha-1 N; VC 90 = Vermicompost at 90 kg·ha-1 N, and VC 100 = Vermicompost at 100 kg·ha-1 N. Bars with the same letter are not significantly different, $p<0.05$, Duncan's Multiple Range Test.

K uptake of the first cucumber cropping was influenced by the direct effects of NPK fertilizer and vermicompost applications where the vermicompost at 90 kg·ha-1 of N provided the highest K uptake (Figure 5). The highest residual effect of the vermicompost on K uptake of the second cucumber was found in vermicompost at 90 kgN ha-1 (Figure 6).

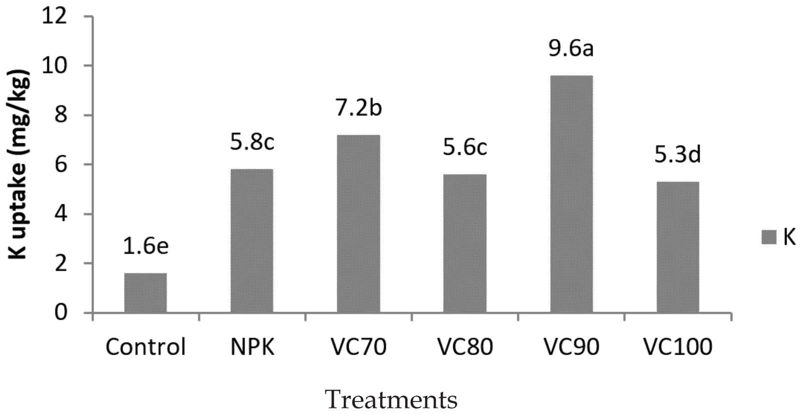

Figure 5. Potassium uptake by cucumber as influenced by application of vermicompost during first cropping

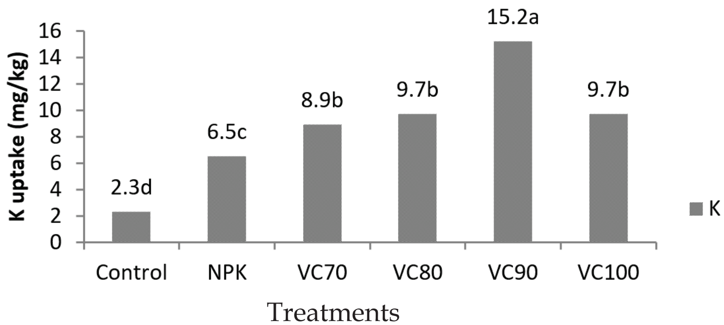

Figure 6. Potassium uptake by cucumber as influenced by application of vermicompost during residual cropping

Physico-chemical analysis of the soil after the harvesting

The effects of application of different rates of vermicompost and NPK on the experimental pot after first and residual harvesting are presented in Tables 3. At first harvesting stage of *Cucumis sativus,* nitrogen application of vermicompost at 90 kgNha-^{1} increased soil pH value than other treatments including control. Soil available P content vermicompost at 90 kgNha-^{1} was higher than the pot treated with other vermicompost and NPK. There is a general increase in the values of organic C from control to other vermicompost. Total N varied between 0.82 g kg^{-1} in control and 3.16 g kg^{-1} in 90 kgNha-^{1} vermicompost pot. The soil in control pot had available K content of 0.27 cmol kg^{-1}, while that of pot treated with vermicompost increased from 0.50 to 0.64 cmol kg^{-1}. Results from the physical analysis of the soil after harvesting, shows that control pots had the lowest contents of clay and silt. Residual harvest pots treated with vermicompost at 90 $kgNha^{-1}$ had higher pH, P and OC, N and K contents when compared with other fertilizer treatments and control respectively. After residual harvest, the result of physical and chemical analysis shows that control pots had the lowest contents of clay and silt.

Table 4: Effects of vermicompost on soil chemical and physical properties at harvest during the first and second cropping

Treatment	Rate	pH	Available P	OC	N	K	Clay	Silt	Sand
	($kgNha^{-1}$)	(H_20)	mg kg^{-1}	g kg^{-1}		cmol kg^{-1}	(%)		
				First harvest					
Control	0	6.1d	10.40c	0.60c	0.82d	0.27d	5.0b	9.2b	85.5a
NPK	100	6.5c	33.75b	1.41b	3.08b	0.59b	6.6a	9.4b	84.0b
Vermicompost	70	6.5c	32.33c	1.28b	2.50c	0.52c	6.6a	9.5b	83.9b
Vermicompost	80	6.6b	29.26d	1.22b	2.26c	0.50c	6.6a	9.4b	84.0b
Vermicompost	90	6.8a	34.99a	1.63a	3.16a	0.64a	6.6a	10.0a	83.4b
Vermicompost	100	6.5c	32.58c	1.41b	2.41c	0.54c	6.6a	9.4b	84.0b
				residual harvest					
Control	0	5.8d	16.50e	0.91e	1.0c	0.80d	5.2b	12.0c	82.8a
NPK	100	6.4c	26.10d	1.33d	2.0b	1.36c	5.6b	12.2b	82.2a
Vermicompost	70	7.1b	29.70c	2.12c	1.9b	1.40c	5.8a	12.5b	81.7b
Vermicompost	80	7.2b	20.20d	1.80d	1.8b	1.10d	6.0a	12.5b	81.5b
Vermicompost	90	7.6a	37.90a	2.83a	2.8a	2.20a	6.1a	13.8a	80.1b
Vermicompost	100	7.1b	33.60b	2.40b	1.7b	1.80b	6.0a	12.1c	81.9b

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

Correlation of fruit yield to NPK uptake at first and residual harvest

Pearson correlation coefficients between cucumber fruit yield and N P K uptake were positively correlated after first and residual harvest respectively (Table 5 and 6). At first harvest, positive relationships exist between yield and N (R^2= 0.1175); P (R^2= 0.7114) and K uptake (R^2= 0.4524). The residual harvest also show that N (R^2= 0.5933); P (R^2= 0.8655) and K (R^2= 0.7937) were positively correlated with cucumber fruit yield.

Table 5: Pearson correlation coefficients between cucumber yield and nutrient uptake after first harvest.

Parameters	N	P	K
P	0.8523**		
K	0.9592**	0.8704**	
Yield	0.1175*	0.7114**	0.45241*

*Significant at the 0.05 level. ** Significant at the 0.01 level.

Table 6: Pearson correlation coefficients between cucumber yield and nutrient uptake after second harvest

Parameter	N	P	K
P	0.6788**		
K	0.7647**	0.9354**	
Yield	0.5933**	0.8655**	0.7937**

*Significant at the 0.05 level. ** Significant at the 0.01 level

Discussion

The pre-planting soil analysis indicated the soil was low in soil nutrients. Values of total nitrogen and available phosphorus, calcium and magnesium were below critical levels (Olowoake, 2019).

The high values of vine length, vine girth, number of branches and number of leaves of cucumber plant grown in the pot treated with vermicompost at 90 kgN ha^{-1} could be attributed to presence of plant growth regulators and humic acid in vermicompost, which are produced by increased activity of microbes such as fungi, bacteria, yeasts, actinomycetes and algae (Arancon *et al*., 2004; Joshi *et al*., 2014;).

The application of vermicompost at 90 kgN ha^{-1} recorded shorter periods in number of days to 50% flowering. This is in line with finding of Kawthar et al. (2010) that fertilizers treated plants could be attributed to acceleration of the vegetative phase through the stimulating effect of the absorbed nutrients during photosynthetic process which reflected on both vegetative growth and flower initiation. Cucumber plants in pots treated with vermicompost at 90 kgN ha^{-1} showed increase in yield parameters than with pots receiving inorganic fertilizer only. This may be due to the presence of high amount of available nitrogen, potassium, and micronutrients that enhance photosynthesis, cell division, and cell enlargement, ultimately improving the growth contributing characteristics content of cucumber (Joshi *et al*., 2014). Furthermore, it may also probably be due to the occurrence of plant growth hormones like auxin giberlins and cytokinins in vermicompost but also its effect on soil physiochemical properties, humic acid content and biology (Atiyeh *et al*., 2002: Opara *et al*., 2012).'The values of yield parameters of cucumber were observed to be low in the pot without any treatment. This might be as a result of low nutrients status of the soil especially N and P.

This study also revealed that vermicompost at 90 kgN ha^{-1} gave the best residual effect on nutrient uptake. Jat and Ahlawat (2006) reported that vermicompost contains high available nutrients, allowing not only a short supply of plant nutrient but also increasing reserves for the succeeding crops. In the study reported here, investigations of the N uptake showed that a higher rate of vermicompost at 100 kgNha-^{1} did not result in a significantly greater N uptake. The higher uptake of N obtained from vermicompost at 90 kgNha-^{1} may have attributed to increased biological activity caused by the vermicompost which resulted to higher availability of N in the soil and consequently enhanced N uptake (Ehsan *et al*., 2019). Plant nutrient uptake highly hinge on the nutrient release from the soil solid phase in the form of mineral and organic materials to the soil solution. The release of nutrients from organic matter occurs biochemically through the balance of mineralization and immobilization processes, while from mineral materials occurs physico-chemically through adsorption and desorption, and precipitation and dissolution. The mineralization controls the soil solution concentration directly when the soil mineral does not release nutrient into the soil solution (Nurhidayati *et al.*, 2017). Vermicompost as an organic fertilizer also undergoes mineralization releasing nutrients into the soil solution. In this study total nitrogen uptake, phosphorus, and potassium by cucumber were significantly enhanced by the application of vermicompost. Similar result was recorded by Nardi *et al.*, (2002).

The increase in the soil pH level of the pots after the first and second crop's harvest might be attributed to high content of basic cations in vermicompost which could reduce soil acidity and the contents of exchangeable acidity and Al through replacing the acidic cations from the exchange sites. 'This is in agreement with the findings of Bekele *et al*, (2018) who pointed out that the direction of the change in soil pH as a result of vermicompost application reflected the initial pH of vermicompost. The application of the vermicompost at 90 kgNha-^{1} significantly (P <0.05) increased soil available P more than NPK fertilizer applied at both first and second harvest. This was because the organic material reduced soil P sorption making both the soil native P and the applied fertilizer available for plant uptake. Similar results were reported by Opala *et al*. (2010).

Soil organic carbon increased with application of vermicompost from first to residual harvest. These results are in line with other studies, showing that addition of exogenous organic matter such like vermicompost results in an enhancement of OC storage in addition to improvement of many other soil functions related to the presence of organic matter (Lashermes *et al*., 2009). A decrease of OC contents was observed from first to residual harvest on pot amended with mineral fertilizers. This finding may be related to sieving, which led to breakdown of aggregates and exposure of occluded organic matter to microbial decomposition (Six *et al.*, 2000). Pot treated with vermicompost increased the N and K contents of the initial and residual harvest compared to pot treated with inorganic fertilizer. This could be attributed to the relatively higher nutrient concentration in the vermicompost and nutrients contained in organic materials are released more slowly and are stored for a longer time in soil, thereby ensuring a long residual effect (Sharma and Banik 2014). The positive relationship between yield and NPK explains the importance of nitrogen, phosphorus and potassium to the growth and yield of cucumber, more explicitly. Alcantara and Gonzaga (2019) reported that plant required nitrogen, phosphorus and potassium in high quantity and these elements played a key role in green colouration of leaves, vegetative growth, promote metabolism and transport processes, turgor regulations and fruit development.

Conclusion

This study confirmed that the application of vermicompost significantly increased cucumber growth and yield parameters, higher NPK uptake more than mineral fertilizer. Furthermore, vermicompost at 90 $kgNha^{-1}$ improved physical and chemical properties of soil and is an excellent organic fertilizer.

Acknowledgment: The authors thank the Tertiary Education Trust Fund (TetFund) Abuja and the Management of Kwara State University, Malete, Ilorin, Nigeria, for providing funds for conducting this research.

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