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Potentials of Jatropha Seed Cake in Soil Fertility: A Case Study with Cucumber (*Cucumis Sativa .L.*)

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ABSTRACT

An attempt to mitigate rapid soil fertility and productivity decline has led to the application of organic and inorganic fertilizers. However, the availability of inorganic fertilizers for crop production is a challenge to many farmers in developing countries. Thus, the use of organic fertilizers is becoming more popular among farmers in recent decades. In this study, a two-year field experiment was conducted to compare the efficacy of Jatropha seed cake (JSC), Tithonia (*Tithonia diversifolia*), compost, and the most common compound inorganic fertilizer in Nigeria – NPK. 15:15:15 on growth, yield, and some soil physico-chemical parameters and yield of cucumber (*Cucumis sativus L.*). The treatments were laid out in Randomized Complete Block Design, with three replicates and were applied at the rates of 80 and 120 kg N ha^{-1}. Two-way ANOVA was used to determine the effects of fertilizer, rate, and year on some soil macro and micronutrients. Structural equation model (SEM) was used to reveal the direct and indirect effects of fertilizer and rate of application on soil physicochemical properties and the performance of cucumber. The results showed that organic amendments (JSC and Compost) significantly increased the yield of cucumber, JSC improved the soil pH, available nitrogen (AN), and available phosphorus (AP), while Compost better improved organic carbon (OC) than the NPK. 15:15:15. The SEM showed that fertilizer had direct significant positive effects on the yield of cucumber, magnesium, and sodium and a direct significant effect on the yield of cucumber. Also, organic carbon had direct and significant effects on both available phosphorous and total nitrogen. Jatropha seed cake and compost proved to be better than mineral fertilizers NPK 15–15-15, thus proving these organic wastes as better alternatives to NPK fertilizer in producing cucumber.

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Introduction

In tropical agriculture, the use of agricultural wastes as soil amendments is becoming increasingly utilized as soil fertility improvers in recent years. In the sub-Saharan tropical Africa, soil productivity maintenance remains an issue due to poor unsustainable practices, coupled with the fragile nature of most arable soils (Oyetunji, Ekanakaye, and Osonubi 2001). Bationo et al. (2006) described soil fertility depletion as the single most important constraint to food security in West Africa. The use of organic fertilizers as a cultural means of solving soil fertility problems over the years has the potential of reducing the use of chemical fertilizers which is often limited in many developing countries by its high cost and scarcity (Giannakis et al., 2014; Leip et al. 2014; Mensah and Frimpong, 2018; Toungos 2019). Although chemical fertilizers directly enhance crop yield because plants directly and indirectly

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assimilate the nutrients provided by ready mineralization of these inorganic fertilizers. However, the production and the use of these 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 (Akbariyeh et al., 2018; Chaudhry et al. 2009; Kaur, Brar, and Dhillon 2008; Mahal et al., 2019; Nan et al., 2016). Hence, there is a need to further explore the fertilizer potential of organic wastes to supply crop nutrients. Tithonia leaves (*Tithonia diversifolia*), *Jatropha Curcas* (Jatropha seed cake), and composted organic market wastes could be good alternatives as fertilizers in crop production (Akanbi et al. 2007; Olowoake and Ojo 2014; Shivani 2011).

Jatropha curcas is drought-resistant oil-bearing multipurpose shrub/small tree, belonging to the family of Euphorbiaceae (Baroi, Yanful, and Bergougnou 2009; Mulpuri, Carels, and Bahadur 2019; Vaknin et al., 2018). The *Jatropha curcas* seed cake which is the by-product of the biodiesel transesterification process can be used as a rich organic fertilizer as reported by Srinophakun et al. (2012). In the production of biodiesel from *Jatropha curcas*, about 4 kg of fresh Jatropha seeds can yield only 1 kg of Jatropha oils, thus generating a large amount of solid waste after the oil extraction. An investigation by Kumar and Sharma (2008), showed that Jatropha seed cake is reported to contain 3.2–4.55 nitrogen (N), 1.4–2.1%, phosphorus (P) and 1.2–1.7% potassium (K). Although *Jatropha curcas* is known to contain phorbol esters, a toxic chemical to human and animals, a study by Devappa, Makkar, and Becker (2010) proved that no residue of the toxin was found in the soil as well as in the fruit of tomato, Chinese Kale leaves, and sweet potato tuber planted using organic fertilizer from Jatropha seed cake. This necessitates the usage of JSC as a soil amendment in crop production and for sustaining soil fertility, owing to the fact that JSC is cheap, readily available, and environment friendly as fertilizer.

Many previous studies have documented the influence of JSC on the growth of wheat (*Triticum aestivum L.*) and soil health indices in sandy and calcareous. Similarly, studies of Olowoake, Ojo, and Osunlola (2015) and Olowoake (2017) reported that JSC improved crop yields (Amaranth (*Amaranthus caudatus) and* okra (*Abelmoschus esculentus L.*), respectively) and soil properties in an Alfisol. Also, previous studies have documented the efficacy of Tithonia as an important nutrients source in maize production (Amhakhian, Oyewole and Isitekhale 2010; Endris 2019) and other crops like *Brassica oleraceae* (Okalebo et al., 2002), *Amaranthus cruentus* (Sajo et al., 2016), okra (*Abelmoschus esculentus L.*) (Anderson 2002). Compost application has been reported in many soils to contribute to sustainable agriculture and ultimately improve crop yield (AdeOluwa and Bello 2017; D'Hose et al., 2012; Giannakis et al., 2014). Despite many studies being conducted on JSC, Tithonia, and compost, there is little information on the influence of these amendments on cucumber growth and yield in an Alfisol.

Cucumber (*Cucumis sativus L.*) is an essential vegetable and a famous member of the Cucurbitaceae family. It is a very good source of vitamins (A, C, K, B6), provides dietary fibers, pantothenic acid, magnesium, phosphorus, copper, and manganese (Vimala et al. 1999). A major limitation of cucumber production in most tropical soils is low nutrient status. Therefore, the aim of this study was to evaluate the soil fertility effectiveness of JSC, NPK, and other organic amendments on the growth and yield of cucumber and their effects on some soil properties.

Materials and methods

Site description

A two-year (2011–2013) field trial on the same site was conducted to assess the effects of JSC, Tithonia (*Tithonia diversifolia*), compost, and inorganic fertilizer (NPK. 15:15:15) application on the growth and fruit yield of cucumber and the fertilizer effects on soil physico-chemical properties was also examined. The JSC was obtained from a local Jatropha processing factory located at Olodo, Ibadan, Nigeria. Fresh biomass Tithonia was obtained from the Department of Agronomy (now split into Departments of Aoil Resources Management and Crop and Horticultural Sciences) experimental plot,

Parry road, the University of Ibadan. Compost and NPK. fertilizers were purchased from a fertilizer outlet at Bodija, Ibadan; the compost was produced from market organic wastes. The study was conducted at the experimental plot (longitude 7° 25" N and latitude 3° 52" E) of National Horticultural Research Institute (NIHORT) Ibadan, Nigeria in the derived savannah of South West Nigeria.

Experimental design

Tilling was manually done and beds were prepared in size of 2 m × 2 m with space of 50 cm between plants and 50 cm between rows, resulting in 16 plants per bed (4 plants/m^2). Data were collected on the four plants at the center of each bed; this was done to eliminate any border effects. Rain-fed farm practice was adopted in this study. The treatments tested were JSC, Tithonia (*Tithonia diversifolia*), Compost, NPK. 15:15:15 and control (zero addition). Except for control, each treatment was applied at the rate of 80 and 120 kg N ha^{-1}. Market more, a common cucumber variety among local cucumber producers in Nigeria was used in this study. The experimental design was a randomized complete block design (RCBD) with 3 replicates. The organic fertilizers were incorporated into the soil two weeks before sowing to give room for mineralization, while inorganic fertilizer was applied in drills at two weeks after sowing at 3 cm away from both sides of the plant; the drills were covered immediately to prevent nitrogen loss.

Sampling and processing

Collection of data started three weeks after sowing when the plants were well established and was done weekly until the 6th week. The parameters measured were vine girth, number of leaves, vine length, fruit length, fruit diameter, and fruit weight. Surface soil samples (0–20 cm depth) were collected from the experimental field to determine the chemical compositions of the soil before and after fertilizer application. The soil samples were air-dried and sieved (<2 mm). Particle size analysis was determined by the hydrometer method of Bouyocus (1951) as described by Tel and Hargerty (1984). Soil pH in was determined potentiometrically using a glass electrode in a 1:1 soil: water (Peech 1965). Organic carbon (OC) was determined using the dichromate wet oxidation method (Walkey and Black 1934) and the organic matter value was obtained by multiplying the Organic carbon value by a factor of 1.724. Total nitrogen was determined by the macro Kjeldahl procedure (Jackson 1967). Available phosphorus was determined by the method of Bray and Kurtz (1945) and determined colourimetrically using Molybdenum Blue Method, while Potassium (K), Sodium (Na), Calcium (Ca) and Magnesium (Mg) were extracted using 1 M NH40Ac 7.0 pH. After the extraction, flame photometry was used to estimate K and Na values, while Atomic Absorption Spectrophotometer was used to estimate Ca and Mg values. Micronutrients such as Manganese (Mn), Iron (Fe) and Copper (Cu)) were extracted with Mehlich III extractant and their values were determined using Buck Scientific Atomic Absorption Spectrophotometer.

Statistical analysis

Statistical analyses were performed using the GenStat 12.1 program for Windows. To examine the interaction among fertilizers types, fertilizer rate, and year of experiment on some soil macro- and micronutrients elements, a two-way analysis of variance (ANOVA) were conducted. The least

Table 1. Chemical analysis for organic fertilizer.

Nutrient element (g kg^{-1})	Jatropha seed cake (JSC)	Tithonia leaves	Compost
Total N	52.0	37.0	35.0
Total P	2.0	2.0	10
Total K	13.0	27.1	12.0

Table 2. The first- and second-year preplanting soil properties.

Treatment (kg N ha^{-1})	pH	TN gkg^{-1}g kg^{-1}	Org.C g kg^{-1}	Avai.Pmg/kg	Ca	Mg cmol kg^{-1}	K	Na	Mn	Fe mg kg^{-1}	Cu	Zn
First season pre-planting soil properties												
Initial soil	5.2	1.0	7.0	3	1.0	0.1	0.2	0.5	132	20	7	2
First season post-planting soil properties												
Control	5.0	1.0	7.3	3	0.1	0.2	0.2	0.9	161	85	2	2
JSC 80	5.8	1.7	13.2	6	0.1	0.2	0.2	1.1	164	88	2	2
JSC 120	6.0	1.6	11.2	6	0.1	0.2	0.2	0.9	179	97	2	2
Compost 80	6.1	1.7	13.8	7	0.1	0.2	0.3	0.8	174	88	3	2
Compost 120	5.8	1.6	10.3	7	0.1	0.1	0.2	1.8	172	88	2	2
Tithonia 80	5.7	1.5	12.9	6	0.2	0.2	0.2	0.9	168	87	2	3
Tithonia 120	5.9	1.5	8.6	6	0.1	0.1	0.3	0.9	182	93	2	2
NPK 80	5.4	1.0	7.2	5	0.1	0.1	0.3	0.8	153	84	2	2
NPK 120	5.2	1.1	7.4	5	0.1	0.1	0.4	1.0	186	100	3	3

Avai. N =
Total nitrogen, Avai.*P* = available phosphorus, Org.C = organic carbon JSC = Jatropha seed cake

significant difference (LSD) was used to compare treatment means at $p \leq 0.05$significance level. A normality test was performed for all the data prior to variance analysis. Structural equation model (SEM) was used to analyze the direct and indirect effects of fertilizer and rate of application on soil physicochemical properties and the performance of cucumber. Model adequacy was determined by χ^2 tests ($p > .05$), goodness-of-fit index (GFI > 0.9), Akaike Information Criteria (AIC), and root square mean errors of approximation (RSMEA < 0.05) (Hooper, Coughlan, and Mullen 2008). The SEM analyses were performed using AMOS 24.0 (AMO IBM, USA).

Results

Constituent of organic fertilizers used and its influence on soil properties

The nutrient composition of the organic amendments used (Jatropha seed cake, Tithonia, and Compost) are presented in Table 1. The analysis revealed that N ranged from 35.0 g kg^{-1} – 52.0 g kg^{-1}, P ranged from 2.0 g kg^{-1} – 10 g kg^{-1}, while K ranged from 12.0 g kg^{-1} – 27.1 g kg^{-1}. As shown in Table 2, the results of year one and year two pre-planting soil chemical analysis revealed that the pH was slightly acidic. N, P, Ca, Mg, K, OC and Na were observed to be lower than the critical level required for optimal performance of most crops in Nigeria; which implies that the soil fertility is

Table 3. Two-way ANOVA examining the effects of fertilizer, rate, and year on some growth and yield parameters.

Parameter		Number leaves	Vine girth	Vine length	Yield t/ha
Year	1	13.60	0.45	83.10	22.70
	2	13.74	3.19	47.80	35.50
	Lsd (≤0.05)	ns	0.0923	10.44	3.29
Rate	80 kgN/ha	13.18	1.80	58.80	27.10
	120 kgN/ha	14.16	1.84	72.10	31.10
	Lsd (≤0.05)	ns	ns	10.44	3.29
Fertilizer	Control	9.05 c	1.15d	30.10 c	7.00 c
	JSC	15.96a	2.24a	76.70ab	56.00a
	Compost	13.21b	1.80bc	57.80b	30.75b
	Tithonia	13.01b	1.92 c	61.70b	26.00b
	NPK	17.09a	2.00b	101.00a	25.75b
Interaction	Year*Rate	ns	ns	0.036	<0.001
	Rate*Fertilizer	ns	0.007	ns	ns
	Fertilizer*Year	<0.001	<0.001	<0.001	<0.001
	Rate*Fertilizer*Year	ns	0.023	ns	<0.001

Means having the same letters implies nonsignificantly different between the mean at 5% probability level, using Duncan's Multiple Range Test (DMRT). ns = not significant. LSD = least significance difference.
JSC = Jatropha seed cake

inherently low and is expected to show a positive response to soil amendment. By the end of the first planting season, the treated plots showed improved pH, while the pH of the control plot was more acidic (pH 5.0). There was an increase in N, P, OC, and K on the treated plots, while their values remained unchanged on the control plot. A similar trend was observed in both the initial and post-harvest soils during the second planting season.

Influence of year, fertilizer rate, and type on growth parameters of cucumber

Except for a number of leaves, two-way ANOVA analysis indicated that vine girth and vine length were significantly *(P < .05)* influenced by fertilizer rate and year (Table 3). The application of different fertilizers significantly improved cucumber growth parameters, compared to the control. The NPK fertilizer produced a higher vine length (101.00 cm), but the value was not different from that obtained from JSC (76.70 cm). However, the NPK was different from tithonia and compost of 61.70 cm and 57.80 cm, respectively, while the control had the least value (30.10 cm). A similar trend was observed in the number of leaves of cucumber. In the case of vine girth, all the fertilizer treatments examined enhanced vine girth of cucumber compared to the control which had the lowest value.

Yield of cucumber as influenced by year, fertilizer rate, and type application

The influences of year, rate, and fertilizer application on yield are summarized in Table 3. A higher yield of cucumber was recorded in the second year, compared to first-year one. Applied fertilizer rates also differed with years in this study. The application of different fertilizers significantly affected the yield of cucumber ($p < .05$). The highest yield (56.00 t/ha; fresh weight) was obtained from JSC, while no difference was observed among compost, NPK, and Tithonia yields. Except for fertilizer × rate, the interactive effects among the various factors significantly affected the yield. Also, the interaction of fertilizer × year affected the number of leaves, vine girth, and vine length, while rate × fertilizer interaction affected vine girth.

Soil post chemical properties

Postharvest soil chemical properties are shown in Table 4. Two-way ANOVAs revealed that pH, N, P, Mg, Na, K, Cu, Fe, Zn, and Mn were significantly ($p < .05$) affected by year and rate. Application of different fertilizers significantly influenced post-harvest soil quality, compared to the control. The JSC fertilizer application significantly improved the pH, N, and P with values 6.48, 1.00 g/kg, and 14.75 mg/kg, respectively, compared with other treatments. In contrast, compost application showed a higher OC (6.48 g/kg,) while Tithonia showed higher K (0.4 cmol kg^{-1}). The concentrations of Mg (6.9 cmol kg^{-1}), Na (4.3 cmol kg^{-1}), Ca (4.4 cmol kg^{-1}), Fe (129 mg/kg), and Mn (227 mg/kg) were generally higher under NPK fertilizer application. Overall, control had the lowest post-harvest soil chemical values except for pH (6.40) and Cu (5.50 mg/kg) where higher values were observed than some of other fertilizer application treatments

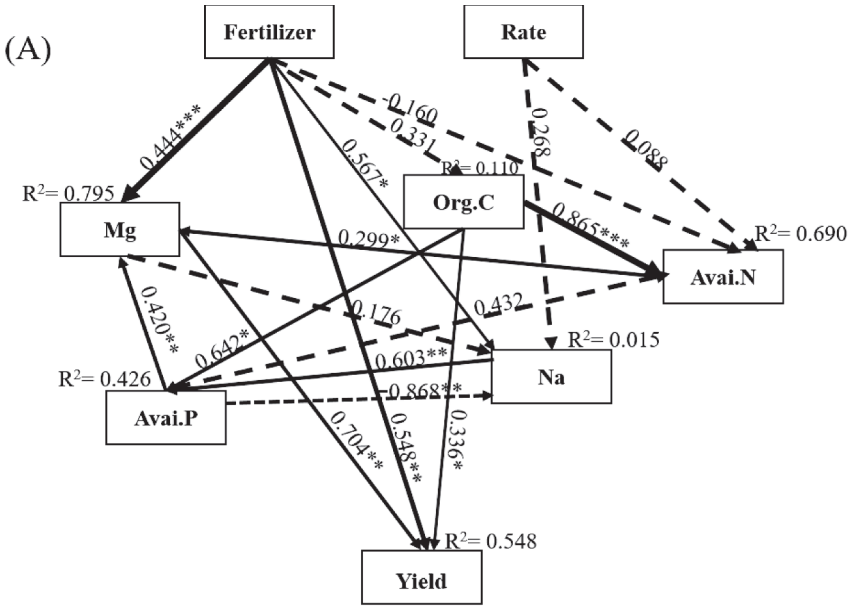
Direct and indirect relationships between fertilizer application, fertilizer rate, soil chemical properties, and some selected cucumber parameters

Two-way ANOVA test results showed that fertilizer rate and type enhanced the post-harvest soil properties of some selected soil parameters and yield of cucumber. The final SEM models corroborated the significance criteria ($\chi 2 = 4.814$, df = 11, $P = .940$, RMSEA = 0.000, GFI = 0.947, ACI = 56.121) and this explained 11% of organic carbon, 69% of the available nitrogen, 42.6% of the available phosphorous, 2% of sodium, 79.5% of magnesium, and 55% of yield (Figure 1). Fertilizer application showed direct positive effects on Mg ($\lambda = 0.444$), Na ($\lambda = 0.567$), and direct effects on yield ($\lambda = 0.548$). The fertilizer indirect effects were mediated via Mg and OC. Organic carbon showed

Table 4. Two-way ANOVA examining the effects of fertilizer, rate, and year on some postharvest soil macro- and micronutrients.

Parameter		pH	Org.C	Avai.N	Avai.P	Mg	Na	Avai.K	Ca	Cu	Fe	Zn	Mn
			g kg^{-1}		mg/kg		cmol/kg				mg/kg		
Year	1	6.22	3.28	0.18	9.61	5.59	3.51	0.31	3.84	6	89.3	2.17	150.7
	2	6.1	5.76	0.95	11.3	6.13	2.72	0.24	3.96	3.3	102.8	2.39	179.9
	Lsd (≤0.05)	0.1189	0.4032	0.07	0.439	0.225	0.3087	0.05	ns	0.3177	4.06	0.1577	8
Rate	80 kgN/ha	6.25	4.5	0.51	9.9	5.61	2.93	0.22	4.15	4.2	94.9	2.36	169.8
	120 kgN/ha	6.07	4.54	0.62	11.01	6.11	3.3	0.33	3.65	5.1	97.2	2.2	160.8
	Lsd (≤0.05)	0.1189	ns	0.07	0.439	0.225	0.3087	0.05	0.2501	0.32	ns	0.1577	8
Fertilizer	Control	6.40a	1.25d	0.10d	3.50e	3.85 c	3.15b	0.10 c	2.70 c	5.50a	25.00d	2.00 c	121.00d
	JSC	6.48a	5.23b	1.00a	14.75a	6.18b	3.10bc	0.25b	3.98b	4.25 c	105.20bc	2.48b	185.00b
	Compost	6.00b	6.48a	0.70a	13.00b	6.23b	2.38 c	0.28b	3.78b	4.76b	113.00b	2.75a	142.50 c
	Tithonia	5.97b	5.23b	0.63b	10.01d	6.13b	2.68bc	0.43a	4.63a	4.00d	107.50 c	2.00 c	150.80 c
	NPK	5.94b	4.43 c	0.40 c	11.02 c	6.93a	4.28a	0.33b	4.43a	4.75bc	129.50a	2.17 c	227.20a
Interaction	Year*Rate	0.033	0.021	<0.001	Ns	<0.001	0.047	ns	<0.001	0.062	<0.001	0.032	0.003
	Rate*Fertilizer	ns	<0.001	<0.001	0.001	ns	0.005	<0.001	0.002	0.016	0.002	<0.001	<0.001
	Fertilizer*Year	ns	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.033	0.0664	<0.001	<0.001	<0.001
	Rate*Fertilizer*Year	<0.001	0.003	<0.001	0.002	0.008	ns	<0.001	0.043	<.001	<0.001	ns	<0.001

Avai. N = available nitrogen, Org.C = organic carbon. Mean having the same letters implies non-significantly different between the mean at 5% probability level, using Duncan's Multiple Range Test (DMRT). ns mean not significant. LSD = least significance difference. JSC = Jatropha seed cake



(B)

	Path coefficient					
	Direct path		Indirect path		Total path	
Variable	F	R	F	R	F	R
Org. C	0.331	0.000	0.000	0.000	0.331	0.000
Avai.N	-0.160	0.088	0.287	0.000	0.127	0.088
Avai.P	0.000	0.000	0.412	0.107	0.412	0.107
Na	0.311	0.201	-0.101	-0.100	0.209	0.101
Mg	0.444	0.000	0.162	0.057	0.690	0.057
Yield	0.548	0.000	0.598	0.040	0.051	0.040

F= Fertilizer, R= Rate

Figure 1. Structural equation models (SEM) illustrating the direct and indirect effects of fertilizer application and rate on available nitrogen, available phosphorus, organic carbon, magnesium, sodium, and yield. Values above the line represent the path coefficients and values above the box represent the residuals. Solid lines and dashed lines indicate significant and nonsignificant pathways, respectively. Width of arrows indicates strength of the standardized path coefficient *(***P < .001; ** P < .01; * P < .05)*.

higher direct positive effect on available nitrogen (λ = 0.865), than available phosphorous (λ = 0.642) and yield (λ = 0.336). Similarly, the indirect effects of organic carbon on Mg were mediated through N and P. Both N and P registered direct effects on Mg in this study with λ = 0.299 and 0.420, respectively. Rate showed no significant effect on Na and N in this model.

Discussion

Results from this study show that JSC and other organic amendments enhanced pH, organic carbon, available N, available P, and K values of post cropping soils, which corroborated previous studies by AdeOluwa and Bello (2017) and Olowoake and Ojo (2014). This observed increase in OC, N, P, and K contents could be attributed to the nature of nitrogen in the JSC and compost used, coupled with the ability of organic amendments to slowly release nutrients in the soils (Ayeni et al. 2008). However, it is important to note that excessive use of organic soil amendments as substitutes for inorganic

N fertilizers may result in yield reduction, as well as P and K accumulation in soil, which could result in endangering the ecosystem (Geng et al. 2019).

Improvement in the soil pH as influenced by JSC and compost might be due to improved soil cations' availability in the soil. In consonance with this result, Iren et al. (2012) attributed the improvement in soil pH to the ability of organic material amended soil to the supply of basic elements such as K, Ca, and Mg. The least soil pH recorded in NPK amended plots could be due to quick nutrient release, leading to leaching of cations and absorption of nutrients by the plant (Olowoake, Ajayi and Adeoye 2013; Vašák et al. 2015). Soil organic carbon improvement by applied organic materials in this study compared to the control and mineral fertilizer (NPK 15–15-15) treatments may be due to decomposition and mineralization of the applied organic amendments which might have resulted in the OM build-up. This confirms the reports of Massoud et al. (2017); Mbewe et al. (2018); Sajo et al. (2016) and AdeOluwa and Bello (2017) that organic materials as soil amendments enhance the soil organic carbon. The postplanting total nitrogen of all the soils in this study was below the critical levels of 1.5 g/kg N, while the K of control, compost, and JSC soils were below the critical level of 0.3 cmol/kg K (FFD -Federal Fertilizer Department 2012). This could be as a result of higher nutrients uptake by crops and/or loss through leaching (Ayoola 2006). The observed significant interactive effects of fertilizer and year on the growth and fruit yield parameters of cucumber indicates variability across the growing period which may be due to better rainfall distribution in 2013 and hence resulted in better yield. A similar year effect had been documented on chili pepper (*Capsicum annuum L.*) yield by Khaitov et al. (2019); it was observed that dynamics in climatic variables particularly rainfall, temperature, and relative humidity could result in yield differences. The observed direct significantly positive effect of fertilizer on Mg, Na, and yield in the final SEM models confirmed that fertilizers play crucial roles in improving the yield, maintaining soil fertility and productivity (Yousaf et al. 2017). Similarly, organic carbon direct effects on both available nitrogen and available phosphorous might be due to its potential to retain nutrients, improves soil structure, moisture retention, and availability, especially in the arid and semiarid environments of the tropics (Bationo et al. 2006; Olowoake 2017). The observed non-significant *P* value of the final model indicated that the model structure and data structure did not differ significantly. Hence, the model might accurately depict the relationships among the variables. Additionally, the $\chi 2$ to the degrees of freedom (df) ratio being less than 3, indicates that the structure and parameters of the model were satisfactory (Hoe 2008; Zhu et al. 2016). The higher yield obtained in organic amended plots compared to NPK plots may be due to the fact that most organic fertilizers can improve soil organic matter which is closely associated with soil water availability, structural stability, cation exchange, mineralizable nutrient supply, buffer capacity, and ultimately crop productivity (Ademiluyi and Omotosho 2007; Akanbi et al. 2007; Olabode et al. 2007; Wang, Yan, and Gong 2015). In contrast, the lower yield obtained from the mineral fertilizer (NPK 15–15-15) treated soil probably could be due to leaching and volatilization of nitrogen from the mineral fertilizer (AdeOluwa, Aworuwa, and Ogunsanya 2016). This confirmed the reports of Moral et al. (2005) and Donn et al. (2014) that applications of organic materials are fundamental to improving crop yields and soil fertility. The cucumber fruit yield obtained from JSC in this study was within the range of some documented average yield of 20–50 t/ha reported by De Lannoy (2001) in Mauritania and Niger; this might be due to JSC ability to quickly decompose and release nutrients for plant use (Olowoake, Ojo, and Osunlola 2015; Mbewe et al., 2018; Massoud et al. 2017). Also, Selanon, Saetae, and Suntornsuk (2014) and Elbl et al. (2016) documented that the high protein content of JSC could serve as a source of protein hydrolyzate, which helps plants' growth stimulation.

Conclusion

This study revealed that Jatropha seed cake and compost fertilizer improved the postharvest soil fertility and also resulted in a better yield of cucumber (*Cucumis sativus L.*), compared to NPK 15–15-15. The structural equation models (SEM) and path coefficient showed that fertilizer application had

direct significant positive effects on magnesium, sodium, and fruit yield of cucumber, while organic carbon had direct and significant effects on both available phosphorous, available nitrogen, and yield. This study revealed organic material as a key fertility variable mediating soil fertility and productivity. The results obtained indicated that Jathropha seed cake and compost positively influenced the soil chemical indices and yield of cucumber in Alfisol; JSC and compost proved to be better fertilizers compared to mineral NPK. Thus, these organic wastes could be a better alternative to NPK fertilizer for producing cucumber.

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