EFFECTS OF BIOCHAR AND NPK FERTILIZER ON SOIL CHEMICAL PROPERTIES, GROWTH AND YIELD OF CUCUMBER (*Cucumissativus*) IN AN ULTISOL, SOUTHEASTERN NIGERIA

***Abiola L.Akinmutimi and Cordelia C. Anyanwu**

Department of Soil Science and Land Resources Management,
College of Crop and Soil Sciences,
Michael Okpara University of Agriculture, Umudike.
P.M.B. 7267, Umuahia, Abia State, Nigeria.
Email: akinmutimi.abiola@mouau.edu.ng

Abstract

Field experiments were conducted in Michael Okpara University of Agriculture, Umudike, Nigeria in 2018 to determine the effects of biochar and NPK (15:15:15) fertilizer on chemical properties of soil, growth and yield of cucumber (*Cucumissativus*) in an Ultisol in southeastern Nigeria. The experiment was laid out in a randomized complete block design (RCBD), having six treatments in three replicates. The treatments comprised: T1- 1t/ha biochar, T2- 3 t/ha biochar, T3- 1t/ha biochar + 100 kg/ha NPK fertilizer, T4- 3t/ha biochar + 100 kg/ha NPK fertilizer, T5- 200 kg/ha NPK fertilizerand T6- control (no treatment application). From the results, soil pH, organic carbon, total nitrogen and available phosphorus were significantly improved by the application of the treatments that had a combination of biochar and NPK fertilizer. Also, exchangeable bases (Ca, Mg, K, Na), effective cation exchange capacity and base saturation were significantly($p<0.05$) improved by the same treatments, while exchangeable acidity was decreased significantly ($p<0.05$). From the growth and yield of cucumber, results showed that number of leaves, vine length, fruit yield and fruit girth were significantly increased by the treatments over the control. Treatment T4(3t/ha biochar + 100 kg/ha NPK fertilizer gave the best result in both soil properties and fruit yield of cucumber in the study area.

Key words: Biochar, NPK (15:15:15) fertilizer, soil chemical properties, growth and yield Ultisol

INTRODUCTION

Cucumber (*Cucumissativus*L.) is an annual vegetable crop that belongs to the family *Cucurbitaceae,* which comprises90 genera and 750 species (Onyia*et al.*, 2012). Cucumber is one of the monoecious annual crops in the *Cucurbitaceae* family that has been cultivated by man for over 3, 000 years

(Adetula and Denton, 2003; Okonmah, 2011). It is native to Africa and Asia where it has been consumed for over 3,000 years. It is one of the oldest vegetable crops grown for at least five thousand years (Okonmah, 2011). With respect to economic importance, it ranks fourth after tomatoes, cabbage and onion in Asia (Eifediyi *et al*., 2011). Cucumber is a very good source of vitamins A, C, K, B_6, potassium, pantothenic acid, magnesium, phosphorus, copper and manganese (Vimala*et al*., 1999). The ascorbic acid and caffeic acid contained in cucumber help to reduce skin irritation and swelling (Okonmah, 2011).

The application of different sources of fertilizer such as N.P.K, poultry manure, pig manure and biochar in soil is a suitable method for the maintenance of soil organic matter, improvement of soil quality and supply of nutrients needed by plants (Olasekan *et al*., 2019). Salehabadi*et al.* (2014) noted that excessive use of chemical fertilizers and pesticides in agricultural ecosystems causes some problems such as environmental pollution, soil erosion, food chain restriction, pest resistance to pesticides etc. Eifediyi and Remison (2010) also noted that the use of inorganic fertilizer has not been helpful under intensive agriculture because of the high cost, associated reduction in the crop yields, soil degradation, nutrient imbalance and soil acidity.

In spite of the increasing relevance of cucumber in Nigeria, low yields are obtained in farmers' fields because of declining soil fertility due to continuous cropping and disregard for soil amendment materials.

Presently, the addition of biochar to soils is attaining universal attention due to the potential of it in improving water holding capacity, soil nutrient retention capacity and sustaining carbon storage, thereby reducing greenhouse gas emissions and as such can concurrently act in both soil modification and as carbon sequestration medium, giving a high prospect that could help decrease atmospheric carbondioxide in the near future (Amonette and Joseph, 2009). This study was designed to determine the effect of biochar and N.P.K (15:15:15) fertilizer on growth and yield of cucumber and soil chemical properties in an Ultisol of Southeastern Nigeria.

.MATERIALS AND METHODS

Description of Experimental Site

A field experiment was carried out in Michael Okpara University of Agriculture, Umudike (Western Farm) in 2018, located between the following coordinates: Latitude 05°29’ North and Longitude 07°33’ East, elevated 122 meters above the sea level. Located in the tropical rain forest, this area has a mean annual rainfall of 2117mm distributed over 9 to 10 months in a bimodal rainfall pattern. Monthly average air temperature ranges from 20°C to 24°C and 28°C to 35°C for minimum and maximum temperatures respectively, while the soil temperature ranges from 23.0°C to 24.6°C. Relative humidity varies from 51% to 87% (NRCRI, 2013).

Soil Sampling and Preparation

Pre-planting soil samples were collected from the experimental field to determine the inherent soil characteristics before treatment incorporation and soil samples were also taken per plot at the end of the experiment. Soil samples were collected with a soil auger at a depth of 0 – 15cm. The samples were air dried, gently crushed with a wooden roller and sieved with 0.5mm for total nitrogen and organic carbon while 2mmsizesieve was used for other chemical properties determinations.

Laboratory Analyses

Soil samples were analyzed for selected physical and chemical properties. These include: Particle size analysis; this was determined using the Bouyoucos hydrometer method (Bouyoucos, 1951), 5% of a dispersing agent (calgon: sodium hexametaphosphate was used to separate sand, silt and clay particles. Soil pH was determined electrometrically using pH-meter in a soil: liquid rato of 1:2.5 (Thomas, 1996). Soil exchangeable acidity ($Al^{3+,}$ and H^+) was determined by titration method (Mclean, 1982). Exchangeable bases (K, Na, Ca and Mg) were extracted with 1N ammonium acetate (NH_4OAc) buffered at pH 7, afterwards sodium (Na^+), and potassium (K^+) were read using flame photometer, while magnesium and calcium were determined using the ethylenediaminetetracetic acid (EDTA) titration method as described by Page *et al.* (1982).

Total nitrogen was determined by the micro kjeldahl digestion method (Bremner and Mulvaney, 1996). Organic carbon was determined by Walkley and Black (1934) wet oxidation method. Available phosphorus was extracted using Bray II extractant as described by Olsen and Sommers (1982).

Field Experiment and Design

The field experiment was carried out in Umudike. The farm site was slashed, ploughed and harrowed and the surfacebrought into fine tilth and marked out. The experiment was laid out in Randomized Complete Block Design (RCBD), replicated three times with six (6) different treatment rates of biochar.

The treatments were:

Treatment 1 I ton /ha biochar

Treatment 2 3 tons/ha biochar

Treatment 3: I ton/ha biochar + 100kg/ha NPK (15:15:15)

Treatment 4: 3 tons/ha biochar + 100kg/ha NPK (15:15:15)

Treatment 5: 200kg/ha of NPK (15:15:15)

Treatment 6: Control (no fertilizer).

The farm was made into beds; each plot size was 3m x 3m (9 m^2). A planting distance of 75 cm x 75 cm, and inter row spacing of 1m between experimental units and 2m distance between the experimental plots was used. Biochar treatments were applied one week before sowing the cucumber seeds. Two seeds of cucumber were sown per hole; weeds were controlled manually by using weeding hoe. The experiment lasted for three months in the field.

Data collection

Data collection commenced at 2 weeks after planting and continued at 2 weeks interval till harvest for number of leaves and vine length while the fruit girth, length and weight were taken at harvest.

Number of leaves per plant was obtained by counting all the fully opened leaves. Vine length was measured using a measuring tape. Fruit girth and length were measured at harvest with the use of a measuring tape. Fruit weight per plant and total fruit weight per treatment were measured by using a weighing balance.

Statistical analysis

All data collected were subject to Analysis of Variance (ANOVA) using GenStatsoftware. The means separation was done according to Obi (2002), using Fisher's Least Significant at 5% level of probability.

RESULTS AND DISCUSSION

Some selected properties of pre-cropping soil sample

The results of the pre-cropping soil sample analysis are shown in Table 1. The result showed that the soil was predominantly sandy loam with 65.8% of sand, 18.2% of silt and 16% of clay. The soil pH showed that the soil was strongly acidic with a pH of 5.1. According to Hazelton and Murphy

(2011), the soil was moderately low in organic carbon (1.24%) and organic matter (2.14%),the total nitrogen was low (0.110%) while the available phosphorous content was moderate (15.3 mg/kg) according to the ratings of Akinrinde and Obigbesan (2000).The results obtained from exchangeable bases (Ca-3.60, Mg-1.20, K-0.23 and Na-0.10cmol/kg) were generally low; this could be as a result of heavy rainfalls usually experienced in the study area, capable of washing the exchangeable cations down the soil profile (Rengel, 2011).

Effect of biochar and NPK fertilizer on some selected soil properties after harvest

The result on Table 2shows mean effect of treatment on soil properties after harvest. The result showed that sand particles dominate the soil with a range of 65.8 and 66.13% across the treatments (T1-T6). The silt (18.2-17.53%)and clay (16.33-15.67%)particles followed the same trend. There was no significant difference ($P>0.05$) in the particle size distribution of the soil as a result of applying the treatments on the soil. The values of soil pH ranged from 4.83 -6.83. The result showed a significant ($P\leq0.05$) increase in soil pH due to treatment application. The highest pH value (6.83)was recorded on T4 (3t/ha biochar+100 kg/ha NPK) followed by T3 (1t/ha biochar + 100kg/ha NPK) which had a value of 6.43 while the lowest value (4.83) was obtained on the control plot (T6). Soil pH in KCl followed the same trend, where T4 had the highest value (5.86) followed by T3 (5.43), while the control gave the lowest value (3.90). The result obtained on soil pH is in accordance with the report of Spokas (2012) who reported an increase in soil pH due to combined application of biochar and mineral fertilizer.

The available phosphorous (Av. P) ranged from 14.37-25.97 mg/kg. There was a significant difference ($P\leq0.05$) on Av.P values due to treatment application. The highest value of Av.P (25.97 mg/kg) was recorded in T4 (3 t/ha biochar + 100 kg NPK) followed by T3 (1t/ha biochar + 100kg NPK) which had a value of 23.17 mg/kg.

The lowest value of Av.P (14.37 mg/kg) was obtained from T6 (control). The increase in Av.P may be attributed to the increase in pH by the treatments (biochar and NPK). The result obtained on Av.P. is in agreement with Atkinson *et al.*(2010), Barrow (2012) and Xu*et al.* (2012) where they reported increase in soil phosphorous contents as a result of applying biochar and NPK fertilizers.

The values of total nitrogen (TN) ranged from 0.074-0.316 %. The result showed a significant ($P \leq 0.05$) increase with the application of treatments. The highest value of TN (0.316%)was recorded on the plot with 3t/ha biochar + 100kg/ha NPK (T4) followed by T5 (200kg/ha NPK) (0.284%) while the control (T6) gave the lowest value of TN (0.074%). The increase in TN recorded on T4 may be attributed to increase in nutrient reaction from combined application of biochar and NPK fertilizer. While the increase recorded on the plot with NPK fertilizer alone may be attributed to mineralization of the inorganic fertilizer added to the soil. The result is in accordance with the report of Botiano and Mokwunye (1991) where they observed an increase in nitrogen due to application of NPK and biochar in Sahelian and Sudanian zones of West Africa.

The results of organic carbon (OC) and organic matter (OM) ranged from 0.83-2.46% and on 1.43-4.23%, respectively. There was a significant ($P \leq 0.05$) increase in OC and OM over the control. The highest value of OC and OM was recorded on T4; OC (2.46%), OM (4.23%) followed by T2 (3t/ha biochar) with OC of 2.38% and OM of4.10 % while the lowest value of OC (0.83%)and OM (1.43 %)was obtained from T6 (control). The increase in OC and OM may be attributed to the high content of stable carbon in the biochar.

The calcium (Ca) values ranged from 2.60-8.20 cmol/kg (Table 2). The result showed a significant ($P \leq 0.05$) increase in Ca value as a result of biochar and NPK fertilizer application. The highest value of Ca was recorded on T4, (8.20cmol/kg) followed by T3 (6.26 cmol/kg) while the lowest value (2.60cmol/kg)was obtained from T6 (control) The other exchangeable bases (Mg, K, and Na) followed the same trend where the highest value of Mg (4.33 cmol/kg), K (0.694cmol/kg) and Na (0.337 cmol/kg) were obtained from the T4 (3 t/ha biochar + 100kg NPK). The exchangeable bases were significantly increased ($P \leq 0.05$) in treated soils over the control (T6).

The result obtained on Exchangeable Acidity (EA) showed a significant decrease ($P \leq 0.05$) on EA as a result of applying biochar and NPK fertilizer. The EA values ranged from 0.42-1.69cmol/kg. The highest value of EA (1.69cmol/kg) was recorded in control plot (T6) while the lowest value of EA (0.42cmol/kg) was recorded on T4. The increase in EA of the control may be attributed to the low organic matter content and low pH, while the decrease in EA observed on the plot treated with 3t/ha of biochar may be attributed to release of Mg and Ca ions from the biochar which served as liming agents. The values of effective cation exchange capacity (ECEC) and base saturation (BS) ranged from 5.22-13.98 cmol/kg and 67.45-96.99 %, respectively. The results showed a significant increase ($P \leq 0.05$) over the control which had the lowest value of 5.22cmol/kgfor ECEC and 67.45% for BS. Treatment T4 gave the highest value of ECEC (13.98 cmol/kg) as well as the highest value for BS (96.99%). The increase in most of the chemical properties of the soil as a result of applying biochar and NPK fertilizer is in agreement with Atkinson *et al.* (2010); Barrow (2012) who observed a similar increase in soil pH, Ca, Mg and CEC after application of biochar and NPK fertilizer.

Effect of biochar and NPK fertilizer on Vine Length (VL) of Cucumber

The effect of treatments on the vine length of cucumber is as shown in Table 3.The length of the vines increased steadily from 2 WAP till the 6th week after planting. At 2 weeks after planting, T5 (200kg/ha NPK) gave the longest vine (6cm), followed by T4 (3t/ha biochar + 100kg NPK) which had 5.5cm. The shortest vine was recorded from T6 (control) which gave a vine length of 3cm. At 4WAP, the highest value of VL was recorded on T3 (52.2cm), followed by T2 (46.6cm).The least value was obtained from the control (T6) which gave VL of 14.20 cm. At 6WAP the vine length values ranged from 136.2-190.9cm. The highest value was recorded on T2 (190.9cm) followed by T3 (190.2cm) while the lowest value was recorded on T6 (136.20 cm). The increase in vine length may be attributed to improved soil pH as a result of biochar application, thus releasing basic cations in the soil (Shetty and Prakash, 2020).

Effect of biochar and NPK fertilizer on Number of Leaves (NL) of Cucumber

The effect of treatments on the number of leaves (NL) of cucumber is as shown in Table 4. The result showed that number of leaves increased steadily from 2 WAP till the 6thWAP.In each week measured, the increase did not follow a regular pattern. However, at 6WAP, the result showed a significant ($P \leq 0.05$) increase on NL, the highest value was obtained on T3 (27.83) followed by T2 (26.6) while the lowest was recorded on T6 (16.33).The increase in leaf growth may be related to the highest nutrient release from biochar in soil and the greater availability of these nutrients to plant roots (Uzoma*et al.*, 2011).

Effect of biochar and NPK fertilizer on

Cucumber Fruit Girth (FG)

The effect of treatments on cucumber fruit girth at harvest is as shown in Table 5. The values ranged from 2.5-3.76cm. T4 gave the highest value (3.76 cm), followed by T5 (3.73 cm), T3 (3.36 cm), T1 (3.40 cm), T2 (2.83 cm) and T6 gave the lowest value (2.50 cm). Treatments T1, T3, T4 and T5 fruit girth values were significantly ($P \leq 0.05$) higher than the control. The increase in fruit girth may be attributed to the mineralization of nitrogen in the NPK fertilizer. The result obtained from this experiment is similar to the report of Magalhaes and Huber (1991) where they observed increase in cucumber girth and yield as a result of organic manure and NPK fertilizer application. Muhammad *et al.* (2023) also experienced a similar result as a result of applying biochar and NPK fertilizer.

Effect of biochar and NPK fertilizer on Fruit Weight and Length of Cucumber

The effects of treatments on fruit weight and length of cucumber at harvest are as shown in Tables 6 and 7. Treatment T4 gave the highest mean weight of cucumber(3.63 kg) which was significantly ($p \leq 0.05$) higher than T1, T3 and the control (Table 6).

Fruit length of cucumber (Table 7) was in this order: the highest length of fruit was recorded on T4 (12.23 cm) which was significantly ($p<0.05$) higher than the control, followed by T1 (10.97cm), while the lowest value was obtained from T6 (5.47cm). The results obtained from most of the plant parameters were in accordance with the report of Grubben*et al.* (2004) who reported that biochar and NPK helps cucumber foliage to grow strong and produce more fruits.

CONCLUSION AND RECOMMENDATION

The results obtained from this study showed that soil chemical properties were significantly improved by biochar and NPK fertilizer application. The application of biochar and NPK also improved growth and yield parameters of cucumber; the application of 3t/ha + 100kg/ha NPK (15:15:15) fertilizer gave best results for chemical properties of soil and yield parameters of Cucumber.

Based on the above findings, farmers in Umudike are advised to use 3t/ha + 100kg/ha NPK fertilizer for optimum yield of cucumber and maintenance of soil fertility.

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Table 1: Pre-cropping soil properties

Parameters	**Values**

Sand (g kg^{-1})	658.00
Silt (g kg^{-1})	182.00
Clay (g kg^{-1})	160.00
Texture	Sandy Loam
Soil pH (H_2O)	5.10
Soil pH (KCl)	4.30
Available Phosphorus (mg/kg)	15.30
Total nitrogen (%)	0.11
Organic carbon (%)	1.24
Organic matter (%)	2.14
Exchangeable Calcium (cmol/kg)	3.60
Exchangeable Magnesium (cmol/kg)	1.20
Exchangeable Potassium (cmol/kg)	0.23
Exchangeable Sodium (cmol/kg)	0.10
Exchangeable Acidity (cmol/kg)	1.38
Effective Cation Exchange Capacity (cmol/kg)	6.51
Base Saturation (%)	78.80

Table 2: Effect of **biochar and NPK fertilizer** on selected properties of soil after harvest

Treatments	Sand %	Silt %	Clay %	Texture	pH (H_2O)	pH (KCl)	Av. P (mg/kg)	TN (%)	OC (%)	OM (%)	Ca	Mg	K (cmol/kg)	Na	EA	ECEC	BS (%)
T1	65.8	18.2	16.0	SL	5.73	4.7	17.4	0.12	1.73	2.97	4.40	1.60	0.29	0.17	1.17	7.64	84.64
T2	65.8	18.53	15.67	SL	6.06	4.96	19.57	0.17	2.38	4.10	5.56	2.26	0.38	0.23	0.78	9.22	91.34
T3	66.13	17.53	16.33	SL	6.43	5.43	23.17	0.24	1.85	3.13	6.26	3.26	0.51	0.27	0.64	10.96	94.14
T4	66.13	17.87	16.00	SL	6.83	6.83	25.97	0.32	2.46	4.23	8.20	4.33	0.69	0.34	0.42	13.98	96.99
T5	65.8	18.20	16.00	SL	5.9	5.9	21.40	0.28	1.26	2.17	4.46	1.45	0.43	0.24	1.22	7.81	84.36
T6	65.8	18.20	16.00	SL	4.83	4.83	14.37	0.07	0.83	1.43	2.60	0.60	0.19	0.14	1.69	5.22	67.45
Mean	**65.91**	**18.09**	**16.00**		**5.96**	**4.95**	**20.31**	**0.20**	**1.75**	**3.01**	**5.25**	**2.25**	0.41	0.23	0.98	9.13	86.48
LSD (0.05)	**NS**	**NS**	**NS**		**0.14**	**0.42**	**0.77**	**0.08**	**0.07**	**0.13**	**0.41**	**0.29**	0.02	0.05	0.07	0.60	2.15
CV (%)					**1.50**	**1.30**	**0.80**	**21.10**	**1.90**	**1.40**	**3.10**	**4.10**	2.70	7.30	5.50	1.90	0.70
SE					**0.09**	**0.06**	**0.17**	**0.04**	**0.03**	**0.04**	**0.16**	**0.09**	0.01	0.02	0.05	0.17	0.57

Note: Av. P=Available phosphorous, TN= Total nitrogen, OC= Organic carbon, OM= Organic matter, Ca= Calcium, Mg= Magnesium, K= Potassium, Na= Sodium, EA= Exchangeable acidity, ECEC= Effectivecation exchange capacity, BS= Base saturation, LSD= Least significant difference, CV= Coefficient of variation, SE= Standard error

Treatment 1 (T1) 1 ton /ha biochar
Treatment 2 (T2) 3 tons/ha biochar
Treatment 3 (T3) 1 ton/ha biochar + 100kg NPK (15:15:15)
Treatment 4 (T4) 3 tons/ha biochar + 100kg NPK (15:15:15)
Treatment 5 (T5) 200kg/ha of NPK (15:15:15)
Treatment 6 (T6) Control (no fertilizer).

Table 3: Effect of biochar and NPK fertilizer on vine length of Cucumber (cm)

Treatments	2 WAP	4 WAP	6 WAP
T1	4.17	42.30	158.00
T2	4.17	46.60	190.90
T3	4.00	52.20	190.20
T4	5.50	39.70	147.00
T5	6.00	28.70	160.50
T6	3.00	14.20	136.20
Mean	4.47	37.28	163.80
LSD (0.05)	2.27	31.77	26.68

Note: VL= Vine length, WAP= Weeks after planting, LSD= Least significant difference

Treatment 1 (T1) 1 ton /ha biochar
Treatment 2 (T2) 3 tons/ha biochar
Treatment 3 (T3) 1 ton/ha biochar + 100kg NPK (15:15:15)
Treatment 4 (T4) 3 tons/ha biochar + 100kg NPK (15:15:15)
Treatment 5 (T5) 200kg/ha of NPK (15:15:15)
Treatment 6 (T6) Control (no fertilizer).

Table 4: Effect of biochar and NPK fertilizer on Number of Leaves (NL)

Treatments	2 WAP	4 WAP	6 WAP
T1	3.50	9.83	24.20
T2	3.33	10.83	26.60
T3	3.50	9.17	27.83
T4	3.16	7.83	18.50
T5	3.50	10.83	22.50
T6	3.33	8.17	16.33
Mean	3.38	9.44	22.66
LSD (0.05)	0.73	NS	3.62

Table 5: Effect of biochar and NPK fertilizer on Fruit girth

Treatments	Fruit girth (cm)
T1	3.40
T2	2.83
T3	3.36
T4	3.76
T5	3.73
T6	2.50
Mean	3.26
LSD (0.05)	0.70

Table 6: Effect of biochar and NPK fertilizer on Weight of Cucumber

Treatments	Weight of cucumber/plot (kg)
T1	1.67
T2	2.80
T3	2.17
T4	3.63
T5	3.17
T6	1.57
Mean	2.40
LSD $_{(0.05)}$	0.94

Table 7: Effect of biochar and NPK fertilizer on Length of Cucumber

Treatments	Fruit length (cm)
T1	10.97
T2	10.03
T3	9.43
T4	12.23
T5	10.20
T6	5.47
Mean	9.72
LSD $_{(0.05)}$	3.32