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Influence of poultry manure and biochar on the performance and antioxidant properties of cucumber (*Cucumis sativus*)

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Abstract

Several works have shown that inorganic fertilizers increase crop yield but are also associated with soil acidity and nutrient imbalance. Organic nutrient sources have been suggested as an alternative to attaining food security and quality, however, the effect of these organic sources on the antioxidant properties of cucumber is scanty. Hence the study sets out to evaluate the effect of organic sources of poultry manure and biochar on the performance and antioxidant properties of cucumber plants. The experiment was laid out in a Randomized Complete Block Design (RCBD) with five treatments replicated three times. The treatments consist of various rates of poultry manure and biochar application as sole and in combinations. Six plants were tagged per treatment for growth parameters and laboratory analysis while the entire plot was used for yield estimation. Data collected included number of leaves. Vine length (cm), vine girth (mm), and number of branches. Yield Parameters included number of days to 50% flowering, number of fruits per plot, length of the fruits (cm), fruits diameter (mm), and weight of fruits per plot (kg). Free Radical Scavenging Power of the fruit was also assayed. Data collected were subjected to ANOVA and means were separated using Tukey HSD at probability of 5%. According to the results, 5t/ha poultry litter biochar x 2.5t/ha poultry manure performed best among the treatments for all parameters.

Keywords: Poultry manure; Biochar; Antioxidant; Cucumber; Free radical

1. Introduction

Cucumber (*Cucumis sativa* L.) belongs to the Cucurbitaceae family, it is regarded worldwide as an essential vegetable that is rich in vitamins, minerals, and antioxidants [20]. Cucumber is a low-calorie food, consisting of 90% water, which is why it provides superior hydration. Its eminent texture and flavor are the main reasons for its use in salads in fresh form and pickles in the processed form [23]. Its medicinal value is another distinguished property, which includes its antioxidant ability, and ability to lower glycemic and antimicrobial activity. Its intake regularly helps to boost metabolism and improve immunity [23]. The performance and antioxidant power of the crop are however dependent o n the nutrient status of the environment where it is grown [16].

Biochars are organic materials that are charred at temperatures between 300 and 700 °C with little or no oxygen concentrations [18]. Their properties may differ one from the other depending on the method used for pyrolysis and the feedstock used. Biochars improve specific surface area, soil aggregation, bulk density, total pore volume, available water content, and permeability of especially sandy soils [11, 19, 21]. It also improves soil chemical properties such as SOC, soil pH, available phosphorus, total N, cation exchange capacity, and exchangeable bases [1, 30, 3] thereby making the soil suitable for sustainable crop production [9].

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To obtain a high yield of cucumber there is the need to augment the nutrient status of the soil to meet the crop requirement and thereby maintain the fertility of the soil. One of the ways of increasing soil nutrients is by boosting it either through the use of materials from organic sources like poultry manure, and animal wastes from pigs, cattle, and goats, and the use of compost with or without inorganic fertilizers [9] or the use of integrated nutrient management which has been found to improve the performance of crops [12, 5].

The usage of organic materials, such as crop residues, sewage sludge, compost, and poultry manure, is well recognized as beneficial in soil resumption [26, 7]. In recent times technologies like hydroponics have also been used in crop production [6], but keeping in view the health benefits and nutritional significance, organically produced vegetables are still high demand these days.However, low yields are obtained in farmers' fields because of declining soil fertility as a result of continuous cropping and poor knowledge of soil amendment practices, which has led to several nutrients becoming deficient.

It is in an attempt to fill the gap in our present knowledge for the optimized production of cucumber in Nigeria through organic fertilizers such as poultry manure especially poultry litter biochar as it has not been explored in the study area. The study aims to evaluate the effect of poultry litter biochar and poultry manure on the performance and antioxidant of cucumber.

2. Material and methods

2.1. Experimental location, land preparation, experimental design, and treatments

The experiment was carried out at the Teaching and Research Farms of Lagos State Polytechnic, Ikorodu, Lagos State Nigeria. The site lies between latitude 5^{o}10N and longitude 3^{o}16E of the Greenwich meridian. It has an altitude of 50m above sea level with a temperature of 26oC and average annual rainfall of 1400m and relative humidity fluctuates between 25-31 degree Celsius, and 58-85% [14]. The experiment site has been under continuous cultivation for over three years without any form of soil amendment.

The land was cleared, plowed, harrowed, and made into seed beds with traditional hoe. The experiment was laid out to the required plot size of 3m x 3m for the sowing of cucumber seeds with a spacing of 75cm by 75cm.

The experiment was laid out in a Randomized Complete Block Design (RCBD) because of the heterogeneity of the experimental location. The experiment was laid out on a total area of land measuring 198m^2 which was divided into 3 blocks of 18m x 11m (198m^2) each plot size is 3m x 3m (9m^2) with a discard of 0.5m to a total number of 15 plots. The trial consisted of five (5) treatments which were replicated thrice, they include; Poultry litter biochar 7.5 tons.ha-1, Poultry manure 7.5 tons/ha, 2.5 tons/ha Poultry litter biochar x 5 tons/ha Poultry manure, 5 tons/ha poultry litter biochar x 2.5 tons/ha Poultry manure and the control (no application). In addition, the treatments (biochar) were crushed and incorporated into the beds at a depth of 0.20m during tillage.

2.2. Crop establishment and maintenance

Cucumber seeds were obtained from an agro-allied company in Lagos state. Planting was done at two seeds per hole, transplanting was done to supply missing stands. Manual weeding was carried out weekly with the use of a hoe. Spraying of insecticides and fungicides was done at a weekly interval to ensure effective chemical control of insect and fungi attacks at the seedling stage

2.3. Pre-cropping and post-harvest Soil analysis

Composite soil samples were randomly collected with an auger from ten (10) different locations in the study area and were composited, air-dried, and sieved through a 5mm sieve. The soils were analyzed using standard laboratory procedures to assess the physical and chemical properties of the soil, exchangeable cations (cmol/kg), available P (mg/kg), OC%, OM%, total N, Mn, Zn, Fe, pH (H_2O) of the soil.

2.4. Determination of Soil pH

pH of each soil sample was determined with a pH meter in accordance with ASTM D4972. Prior to sample analysis, the meter was calibrated according to manufacturer instruction with buffer solution 4, 7 and 9. The pH measurement involved inserting the probe of the pH meter into a 1:1 ratio suspension of the sample in distilled water.

2.5. Nitrogen determination

1g of the dried samples was converted to ammonium sulphate by digestion with concentrated H_2SO_4 and in the presence of $CuSO_4$ and Na_2SO_4. These were heated and the ammonia evolved was steam distilled into boric acid solution. The nitrogen from ammonia was deduced from the titration of the trapped ammonia with 0.1M HCl with Tashirus indicator (double indicator) until a purplish pink color was obtained.

2.6. Total Organic Carbon (TOC)

TOC was determined by the rapid wet-oxidation method based on Walkley -Black procedure. This is a titrimetric method which involves initial oxidation of the carbon content in the samples followed by a rapid back-filtration with ammonium Ferro sulphate solution.

2.7. Determination of TOM

Organic matter was determined using gravimetric method by measuring weight change associated with high temperature. After initial oven drying at 105^0C.the samples were ignited in a muffle furnace for two hours at 360^0C. The total organic matter is calculated as the percent weight loss during ignition

2.8. Digestion of Soil for Metal/Mineral Determination

One gram of pulverized and oven dried (50^oC) soil sample was weighed into a 100ml conical flask and Moistened with distilled water, 10ml aqua regia HNO_3: HCl (3:1) was added then boiled with steady heat to almost dryness. It was cooled and filtered; the filtrate was made up to 100ml with distilled water and was subjected to metal analysis. Calcium, Potassium, magnesium and Sodium then were determined using Jenway Digital Flame Photometer (PFP7 Model) using the filter corresponding to each mineral element. While the Atomic Absorption Spectrometer (AAS) Buck Scientific model 211 VGP was used to determine the metal content (Mn, Fe and Zn) of the soil samples in accordance with APHA 20th Edition 3111B and 3111D, ASTM D3561 and ASTM D5198. The method requires direct aspiration of the digested liquid sample in an acidic medium into an air/acetylene or nitrous oxide/acetylene flame at specified wavelengths for each of the metals under investigation. The equipment was calibrated prior to use with working standards of known concentration to obtain a calibration curve. The concentrations of the metals in the sediment samples were obtained by aspirating the digested samples directly into the flame.

2.9. Phosphorus determination

1g of sample obtained was treated with 2 MHCL solution. 10ml of the filtrate solution was pipetted into 50ml standard flask and 10ml of vanadate yellow solution was added and the flask was made up to mark with distilled water, stoppered and left for 10 minutes for full yellow development. The concentration of phosphorus was obtained by taking the optical density (OD) or absorbance of the solution on a Spectronic 20 spectrophotometer or colorimeter at a wavelength of 470nm.

The percentage phosphorus was calculated from using the formula:

$$\%\text{Phosphorus} = (\text{Absorbance x Slope x Dilution factor})/10000$$

2.10. Cation Exchange Capacity determination (CEC)

The ammonium acetate method was used for the determination of CEC, 2.5g of soil sample was weighed and a 1 mol/L ammonium acetate solution (75ml) was percolated through it. The excess reagent is eliminated with several rinsing with ethanol. After drying in air, the solid phase was agitated in 50ml of 1 mol/L solution of sodium chloride. The exchanged ammonium was measured spectrocolorimetry, which permits the measurement of CEC.

2.11. Data Collection on Cucumber Plant

Growth and yield parameters were collected on each experimental plot from six plant stands randomly tagged as samples for easy data collection, the parameters collected were as follows;

Growth Parameters; number of leaves which was counted. Vine length (cm) using a meter rule, vine girth (mm) using venier caliper, and number of branches which was also counted. Yield Parameters; number of days to 50% flowering, number of fruits per plot (counted), length of the fruits (cm) usind a ruler, fruits diameter (mm) using venier caliper, weight of fruits per plot (kg) using an electrical weighing balance.

2.12. Free Radical Scavenging Power of the Fruits

The Free radical scavenging ability of the extract was determined using the DPPH (1, 1- diphenyl-2- picryhydrazyl) according to Gyamfi*et al*., (1999). 1ml of the extract was mixed with 0.4mM of methanoic solution of DPPH. The mixture was then left in the dark for 30 minutes before measuring the absorbance at 516nm using a UV spectrophotometer. Blank was prepared in similar way excluding sample. The free radical scavenging prowess of the sample was then calculated using the formular

$$\text{Antioxidant Power} = \frac{\text{Ablank} - \text{Asample}}{\text{Ablank}} \text{X } 100$$

Where Asample is absorbance of test solution; Ablank is absorbance of blank.

2.13. Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA), and means of treatments were compared using Tukey HSD at a 5% level of probability using ASSISTAT 11 statistical software.

3. Results

3.1. Pre-Experimental soil physio-chemical properties

Table 1 shows the pre-experimental soil physio-chemical analysis results. The pre-soil analysis revealed the site to be slightly alkaline (pH of 8.69), low in Organic Carbon (2.62%), Total N (0.16%), and Available P (5.28 PPM) as well as low in exchangeable bases Na (0.15 cmol/kg), K (0.17 cmol/kg), Ca (2.45 cmol/kg) and Mg (1.96 cmol/kg). The soil was observed to have a CEC of 4.76 and the particle size percentage of sand, silt, and clay (62.78%, 20.10%, and 17.12% respectively) with soil textural class of sandy loam.

Table 1 Pre-Experimental soil physio-chemical properties analysis results

Soil physiochemical properties	Values
pH	8.69
OM (%)	2.62
N (%)	0.18
P (PPM)	5.28
K (Cmol/kg)	0.17
Ca (Cmol/kg)	2.45
Mg (Cmol/kg)	1.96
Na (Cmol/kg)	0.18
CEC	4.76
Sand (%)	62.78
Silt (%)	20.10
Clay (%)	17.12
Texture	Sandy Loam

3.2. Effect of poultry litter biochar and poultry manure on the Free radical scavenging power of cucumber fruits

Significant difference ($p \leq 0.01$) was observed in the free radical scavenging power of cucumber fruits as influenced by poultry litter biochar and poultry manure application (Table 2), 5 t/ha poultry litter biochar + 2.5 t/ha poultry manure performing best (55.03%) followed by the control (50.36%) then 7.5 t/ha poultry manure (45.66%) with the poorest performance observed in 7.5 t/ha poultry litter biochar.

Table 2 Effect of poultry litter biochar and poultry manure on the Free radical scavenging power of cucumber fruits

Treatments	**Free radical scavenging power of fruit (%)**
7.5 t/ha poultry litter biochar	14.12e
7.5 t/ha Poultry manure	45.66c
2.5 t/ha poultry litter biochar + 5 t/ha poultry manure	35.55d
5 t/ha poultry litter biochar + 2.5 t/ha poultry manure	55.03a
Control (no application	50.36b
Significance	**

Means with similar letter(s) in the same column are not significantly different at 5% TUKEY HSD** means Highly significant

3.3. Effect of poultry litter biochar and poultry manure on the number of leaves of cucumber

A significant difference (p≤0.05) was observed in the number of leaves of cucumber at 6 Weeks After Planting (WAP) as influenced by poultry litter biochar and poultry manure (Table 3). The highest number of leaves (28.44) was observed in 7.5 t/ha poultry litter biochar followed closely by 2.5 t/ha poultry litter biochar + 5 t/ha poultry manure (27.28) and 5 t/ha poultry litter biochar + 2.5 t/ha poultry manure (27.22) and the lowest was observed in 7.5 t/ha poultry manure (23.05) and control (22.11). No significant difference (p≥0.05) was observed in the number of leaves of cucumber as influenced by poultry litter biochar and poultry manure at 2WAP and 4WAP (Table 4).

Table 3 Effect of poultry litter biochar and poultry manure on the number of leaves of cucumber

Treatments	**Week After Planting (WAP)**		
	2	**4**	**6**
7.5 t/ha poultry litter biochar	4.06	11.22	28.44a
7.5 t/ha Poultry manure	4.00	10.78	23.05b
2.5 t/ha poultry litter biochar + 5 t/ha poultry manure	4.00	10.78	27.28ab
5 t/ha poultry litter biochar + 2.5 t/ha poultry manure	4.00	10.39	27.22ab
Control (no application	4.00	10.17	22.11b
Significance	ns	ns	*

Means with similar letter(s) in the same column are not signific**antly different at 5% Tukey HSD** ns means not significant.* means significant

3.4. Effect of poultry litter biochar and poultry manure on the vine length (cm) of cucumber

Table 4 Effect of poultry litter biochar and poultry manure on the vine length (cm) of cucumber

Treatments	**Week After Planting (WAP)**		
	2	**4**	**6**
7.5 t/ha poultry litter biochar	4.36	21.96a	79.78a
7.5 t/ha Poultry manure	4.54	17.23b	66.87b
2.5 t/ha poultry litter biochar + 5 t/ha poultry manure	4.33	19.36ab	77.07ab
5 t/ha poultry litter biochar + 2.5 t/ha poultry manure	4.49	18.71ab	76.87ab
Control (no application)	3.83333	15.51c	63.98c
Significance	ns	*	*

Means with similar letter(s) in the same column are not signific**antly different at 5% Tukey HSD** ns means not significant * means significant

Poultry litter biochar and poultry manure significantly (p≤0.05) influenced the vine length of cucumber at 4WAP and 6WAP (Table 4). The longest vines at 4WAP and 6WAP were observed in 7.5 t/ha poultry litter biochar (21.96 cm and

79.78 cm respectively) followed by 2.5 t/ha poultry litter biochar + 5 t/ha poultry manure (19.36 cm and 77.07 cm respectively) and 5 t/ha poultry litter biochar + 2.5 t/ha poultry manure (18.71 cm and 76.87 cm respectively) then 7.5 t/ha poultry manure (17.23 cm and 66.87 cm respectively) while the shortest vine was observed in control (15.51 cm and 63.98 cm). No significant difference ($p \geq 0.05$) was observed in the vine length of cucumber at 2WAP (Table 4).

3.5. Effect of poultry litter biochar and poultry manure on the vine girth (cm) of cucumber

A significant difference ($p \leq 0.05$) was observed in the vine girth of cucumber at 2WAP (Table 5). The thickest vines were observed in 7.5 t/ha poultry manure (3.65 cm), 5 t/ha poultry litter biochar + 2.5 t/ha poultry manure (3.62 cm) and 7.5 t/ha poultry litter biochar (3.42 cm) while vines with the least girth were observed in 2.5 t/ha poultry litter biochar + 5 t/ha poultry manure (2.97 cm) and control (2.67 cm). The significant difference ($p \geq 0.05$) however diminished as the crop ages at 4WAP and 6WAP (Table 5).

Table 5 Effect of poultry litter biochar and poultry manure on the vine girth (cm) ofcucumber

Treatments	**Week After Planting (WAP)**		
	2	**4**	**6**
7.5 t/ha poultry litter biochar	3.42a	7.61	8.73
7.5 t/ha Poultry manure	3.65a	7.05	8.22
2.5 t/ha poultry litter biochar + 5 t/ha poultry manure	2.97 b	6.8	8.79
5 t/ha poultry litter biochar + 2.5 t/ha poultry manure	3.62a	7.52	8.24
Control (no application	2.67b	6.63	7.55
Significance	**	ns	ns

Means with similar letter(s) in the same column are not significantly different at 5% Tukey HSDns means not significant * means significant

3.6. Effect of poultry litter biochar and poultry manure on the number of days to 50% flowering of cucumber

Poultry litter biochar and poultry manure application significantly ($p \leq 0.05$) affects the number of days to 50% flowering of cucumber (Figure 1), with 2.5 t/ha poultry litter biochar + 5 t/ha poultry manure and 7.5 t/ha poultry litter biochar flowering first (28.33 and 28.67 days respectively) followed by 5 t/ha poultry litter biochar + 2.5 t/ha poultry manure and 7.5 t/ha poultry manure (both flowered at 29.33 days) while the control flowered late (30.00 days).

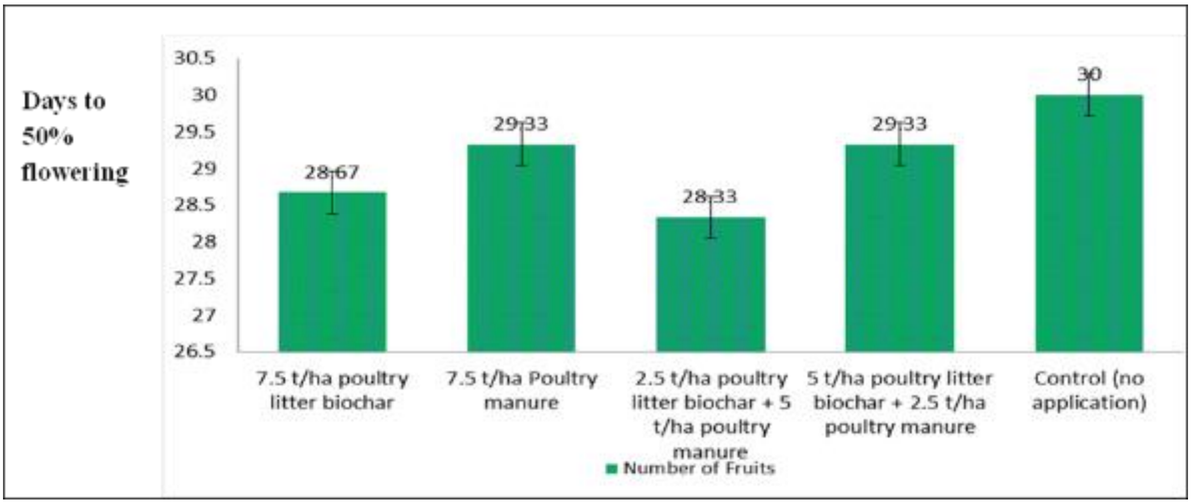

Figure 1 Effect of poultry litter biochar and poultry manure on the number of days to 50% flowering of cucumber

3.7. Effect of poultry litter biochar and poultry manure on number of fruits, length of fruits (cm), fruit diameter (cm)and weight of fruits

A significant difference (p≤0.05) was observed in the number of fruits of cucumber (Figure 2), with 7.5 t/ha poultry litter biochar having the highest number of fruits (19.00) followed by 5 t/ha poultry litter biochar + 2.5 t/ha poultry manure and 2.5 t/ha poultry litter biochar + 5 t/ha poultry manure (14.00 and 13.67 respectively) then 7.5 t/ha poultry manure (9.67) while the lowest number of fruits (7.67) was observed in the control.

Poultry litter biochar and poultry manure applications significantly (p≤0.05) influence the fruit weight of cucumber (Figure 2). The best fruit weight (6.29 kg) was observed in 7.5 t/ha poultry litter biochar followed by 2.5 t/ha poultry litter biochar + 5 t/ha poultry manure (4.48 kg) then 5 t/ha poultry litter biochar + 2.5 t/ha poultry manure (3.46 kg) and 7.5 t/ha poultry manure while the poorest fruit weight (2.54) was observed in control. No significant (p≥0.05) difference was observed in length of fruits and fruit diameter (Figure 2).

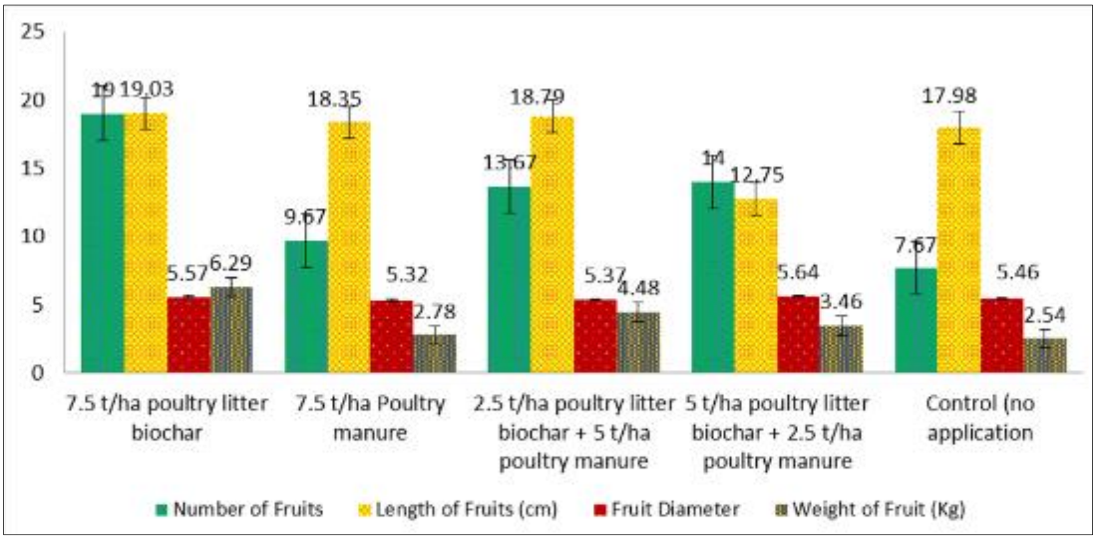

Figure 2 Effect of poultry litter biochar and poultry manure on Yield Parameters ofCumcumber

4. Discussion

The presented results demonstrate the impact of poultry litter biochar and poultry manure application on various growth and yield parameters of cucumber plants. The significant difference in free radical scavenging power indicates that the combination of 5 t/ha poultry litter biochar + 2.5 t/ha poultry manure performed best in enhancing the antioxidant activity of cucumber fruits. The observed differences may be attributed to the nutrient content, microbial activity, and organic matter provided by the specific combination of biochar and manure, influencing the plant's ability to scavenge free radicals. Plants contain a wide variety of free radical scavenging molecules; such natural products are rich in antioxidant activities. The production of these natural products and metabolites is enhanced by the availability of elements like carbon, nitrogen, phosphorus, copper, calcium, and manganese [25, 12, 15, 27]. All of these elements are being supplied by organic nutrient sources like biochar and poultry manure.

The higher number of leaves in treatments with poultry litter biochar suggests a positive influence on vegetative growth. This may be due to improved nutrient availability, water retention, or microbial activity in the soil as influenced by the application of poultry litter biochar. This agrees with the findings of [29] who also reported that the application of biochar increases leave number of leafy vegetables.

The longer vines in treatments with poultry litter biochar may be linked to enhanced nutrient availability [17], improved aggregate stability, water holding capacity, and improved soil structure [13, 4], which promoting better root development and overall plant growth.

The thicker vines in treatments with poultry manure may be attributed to the higher nutrient content supporting early-stage growth, while the impact diminished as the crop aged [17]. The earlier flowering in treatments with poultry litter biochar may be associated with improved soil conditions, nutrient availability, and overall plant health, which can accelerate the flowering process. The higher number of fruits and greater fruit weight in treatments with poultry litter biochar suggest improved plant productivity, possibly due to enhanced nutrient uptake and water retention in the soil. This is in agreement with the findings of Brandstaka *et al*. [8], Vishwanatha-Shetty *et al*. [28], Adane [2], and Sanni *et al*. [22] who reported increased crop performance with biochar application.

5. Conclusion

The observed results can be attributed to the complex interactions between soil amendments (poultry litter biochar and poultry manure) and their effects on soil properties, nutrient availability, and overall plant health. Based on the result of this experiment, 5 t/ha poultry litter biochar x 2.5 t/ha poultry manure best improved the soil as well as the growth and yield of Cucumber, and the radical scavenging power of the cucumber fruits as compared to all other treatments.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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