Growth and yield response of tomato (*Solanum lycopersicum* L.) as influenced by compost, biochar and micronutrients on an alfisol

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In Nigeria tomato (*Solanum lycopersicum* L.) is known for its health benefits, but yields are low, due to poor soil fertility and paucity of information on fertiliser use. This, together with the detrimental impacts of synthetic fertilisers on soil fertility and productivity requires a critical search for eco-friendly alternatives. Studies were conducted on organic sources, such as compost, biochar and micronutrients in greenhouse pot and field trials. The pot experiment was a randomised block with three replications; treatments consisted of biochar and compost applied each at 15, 30, 45 and 60 kg N/ha, and micronutrients concentration at 1, 2 and 3 L/ha each applied one, two and three times after transplanting; each treatment had a control without any fertiliser application. The results of the pot experiment indicated 45 kg N/ha and 30 kg N/ha as the optimum application rates obtained from compost and biochar, respectively; while optimum micronutrient concentration was 1 L/ha applied twice. The field experiment consisted of a control together with the optimum rates (as determined from the pot experiment) of biochar, compost, micronutrients and their combinations; it was laid out in a randomised block design with three replications. The field experiment results indicated that the combined effects of biochar + compost enhanced plant height and number of leaves more than other fertiliser treatments, although, the effect was not significantly ($P > 0.05$), different, from that obtained, from biochar + compost + micronutrients. The combined effects of biochar + compost + micronutrients fertiliser, positively influenced early flowering and fruiting, produced the highest fruits weight, biomass yield, fruit yield, nutrient uptake and nutrient use efficiency ($P \leq 0.05$), more than the other treatments. The result established that for optimum growth and economically higher yield, the tomato crop may be fertilised with biochar at 30 kg N/ha and compost at 45 kg N/ha. Also, micronutrients optimum concentration of 1 L/ha applied twice should be used for growth and yield of tomato.

Keywords: Synthetic fertilisers, detrimental impacts, eco-friendly alternatives, nutrient use efficiency, fruit yield

Tomato (*Solanum lycopersicum* L.) is one of the most widely consumed vegetables in the world. It is an excellent source of vitamins, minerals and antioxidants which help improve the general health of humans (Antonio et al. 2004). Residue from processed tomato is the secondary raw material that is considered a potential source of dietary fiber and bioactive compounds (Inmaculada et al. 2011). In recent decades the consumption of tomatoes has been associated with the prevention of several diseases (Sharoni and Levi 2006), mainly due to the content of antioxidants, including carotenes, ascorbic acid and phenolic compounds (Periago et al. 2009). In Nigeria the major producing areas lie between latitudes 4° and 14° N and between 3° and 15° E (Umeh et al. 2002). Low yield is a major problem limiting the availability of tomato in Nigeria. This is primarily due to poor soil fertility and inappropriate fertiliser recommendations for producing higher yields (Mofuka et al. 2007). Inorganic fertiliser has been widely used by farmers to improve tomato yield, but there is increasing soil degradation, as well as contamination and pollution of water sources, because of the continuous use of inorganic fertilisers. Therefore the need to use organic based fertilisers such as compost, biochar and micronutrients is imperative. Organic inputs have several advantages in soil fertility management. Apart from providing essential plant nutrients, they contribute directly towards the build-up of soil organic matter and its associated benefits (Fairhurst 2012). Compost is considered to be an environmentally safe, agronomical advantageous and relatively cheap organic

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amendment which stimulates soil microbial activity and crop growth (Ros et al. 2006). Compost addition to soils can increase soil nutrient availability and thereby enhance nutrient uptake by plants (Poll et al. 2008). Biochar is a carbon-rich byproduct of biomass pyrolysis under oxygen-limited environments and when applied to the soil improves agronomic and environmental benefits (Kloss et al. 2014). The carboxylate groups found in black carbon provide cation exchange capacity, increase the oxygen carbon ratio and are the primary source of biochar's high nutrient retention ability (Glaser et al. 2001). Research efforts have shown that use of biochar as amendments can play a significant role in soil nutrients turnover specifically nitrogen (N), phosphorous (P) and potassium (K), directly due to its inherent nutrient concentrations, or indirectly by influencing soil properties and microbial population growth and activity (Jeffery et al. 2011). In addition, biochar application has been reported to increase plant productivity by 10 - 25% for above ground biomass (Biederman and Harpole 2013). Applications of micronutrients i.e. zinc and boron have been reported in increasing growth and fruit yield in tomato (Naga et al. 2013). Therefore, this research sought to determine the optimum application rates of compost, biochar and micronutrients and their combinations on the growth and yield of tomato.

Materials and methods

Laboratory analysis

Surface soil samples (0 – 15 cm depth) were collected from the University of Ibadan, Teaching and Research farm. The soil samples were bulked, air dried, crushed, thoroughly mixed, passed through a 2 mm sieve and subjected to routine laboratory analysis (IITA 1979), as described by Moormann et al. (1975). Soil pH (1:1 soil/water suspension ratio) was measured using a pH meter with glass electrode; particle size analysis was by the hydrometer method (Bouyoucus 1962); total N by the micro-Kjeldahl method (Jackson 1958); organic C by the wet dichromic acid oxidation (Walkley and Black 1934) and organic matter was estimated by multiplying organic C with a factor of 1.729. Available-P was extracted using the method of Bray and Kurtz (1945). K and N were determined by flame photometry and Ca, Mg and extractable micro-nutrients (Mn, Fe, Cu and Zn) by atomic absorption spectrophotometry.

Pyrolysis of biochar

The equipment used for the production of biochar had three compartments; an insulated outer metal box with a cover, an inner cylinder with a separate cover and a lower lid where the charred product comes out. The dried feedstocks were fed into the inner cylinder and tightly sealed. A prepared burning charcoal was then fed into the space around the cylinder after which the reactor was covered. The timer was set at this stage to determine how long the biomass would take to char in the reactor. The charring process took about 5 hours from start to completion. The materials remaining in the cylinder after the contents were smoldered and charred are referred to as biochar. The biochar was released into the lower lid, drawn out from the bottom, after which water was sprinkled on the hot char to prevent complete combustion. The biochar was air dried for 1 week before use.

Compost preparation

Collected feedstocks (maize stovers, cow dung and moringa leaves) were chopped into small sizes to reduce the surface area, so as to hasten bio-degradation. Feedstocks were piled, moistened and uniformly mixed together with a shovel and allowed to undergo biological decomposition under aerobic condition in heaps. The pile was turned weekly and mixed with adequate water until it finally yielded a more stable dark coloured humified material after 3 months. The compost was left to cure for 3 weeks and bagged.

Greenhouse pot experiment

The first phase, conducted at the University of Ibadan, Department of Agronomy, was a pot experiment carried out to determine the optimum application rate of biochar, micronutrients fertiliser and compost for the growth and yield of tomato. 108 polythene bags of 5 kg capacity were filled with soil and then placed in pots. Tomato seedlings (F1 Cobra 26) were raised in a nursery tray for 3 weeks, two viable seedlings were then transplanted into each of 108 pots and thinned to one plant per pot after 2 weeks. There were three replicates of a completely randomised design. Biochar was applied at control (no application), 15, 30, 45 and 60 kg N/ha, compost at control (no application), 15, 30, 45 and 60 kg N/ha, and MNF liquid micronutrients fertiliser sprays were applied at control (no spray), 1, 2, and 3 L/ha (i.e. 3.6, 7.2 and 10.8 ml/plant), and micronutrient fertiliser concentration (MNC) frequency of sprays; no spray, 1, 2 and 3 times at 2 weeks interval after transplanting. Thus, in each replicate there were five each of biochar and compost treatments (30 pots). MNF sprays were at four levels (three replicates 12 pots), MNC frequency of sprays four levels (3 replicates 12pots). At each stand in each replicate two pots were placed there were two pots with similar treatments.

Field experiment

The experimental field measuring 21.2 × 13 m was divided into three blocks, each of which comprised of eight plots of three beds giving a total of 24 beds in a block. Healthy seedlings of uniform heights were transplanted on the raised beds at four plant stands per bed at a spacing of 60 × 60 cm. The optimum application rates determined from the first experiment were used for the second experiment. Treatments consisted of sole and combined levels of compost, biochar and micronutrients fertiliser. They were replicated three times in a randomised complete block design. The fertiliser treatment combinations were:

(1) Control (no fertiliser application)
(2) Biochar (100%) i.e. 1.54 kg biochar per plot (plot size was 7.2 m^2)
(3) Compost (100%) i.e. 3.26 kg compost per plot
(4) Micronutrients fertiliser 1 L/ha i.e. 3.6 ml/plant applied twice
(5) Biochar + compost (50%: 50%) i.e. 0.77kg per plot: 1.63kg per plot
(6) Biochar (100%) + micronutrients fertiliser (1 L/ha applied twice)
(7) Compost (100%) + micronutrients fertiliser (1 L/ha applied twice)
(8) Biochar + Compost (50%: 50%) + micronutrients fertiliser (1 L/ha applied twice)

Compost, biochar and micronutrients were applied using the optimum application levels obtained from experiment 1: i.e. biochar at 30 kg N/ha, compost at 45 kg N/ha and micronutrients concentration of 1 L/ha applied twice.

Data collection

Data on plant height, stem girth, number of leaves, flowers and fruits, fruit and biomass yields, nitrogen uptake (NU) and nitrogen use efficiency (NUE) were collected.

NU was calculated by multiplying N content by the respective weights and NUE (kg yield kg^{-1} N), was calculated by the formula reported by Jothimani et al. 2007:

$$NUE = (Y_f - Y_0)/(N_f - N_0)$$

Where: Y_f is the yield with N fertiliser, Y_0 is the yield of control, N_f is the amount of fertiliser added, N_0 is the amount of native N (all units are in kg/ha).

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using SAS (1992) and means were separated by Duncan's Multiple Range Test at $P \leq 0.05$.

Results

Characteristics of soil used for the studies

Based on established nutrient critical levels by (Oluleye et al. 2008; Oluleye and Akinrinde 2017) on the soil used for the studies (Table 1), it was evident that the exchangeable cations (0.3 – 0.6 c mol/kg) were low, total N was low, with moderate amounts of organic carbon and available P; soils were strongly acidic with sandy textural classification.

Table 1: Characteristics of soil used for the studies

Properties	**Values**
pH (1:1, H_2O)	5.2
Org. C (g kg^{-1})	11.57
Soil organic matter (g kg^{-1})	107.49
Total N (g kg^{-1})	1.21
Av. P Bray 1(mg kg^{-1})	11.0
Exchangeable cations (c mol kg^{-1})	
K	0.19
Ca	1.96
Mg	0.65
Na	0.24
Exchangeable acidity	0.58
Extractable micronutrients (mg kg^{-1})	
Cu	3.36
Zn	4.01
Mn	4.86
Fe	1.55
Particle size (g kg^{-1})	
Sand	918
Silt	34
Clay	48
Textural class	**Sand**

Composition of biochar and compost and concentration of micronutrients

Table 2 indicates the chemical compositions of biochar and compost Tables 3 and 4 show the application levels of amounts of nitrogen, phosphorus and potassium contained in biochar and compost at the various biochar, compost and micronutrients used in the greenhouse pot experiment.

Table 2: Chemical compositions of biochar and compost

Properties	**Biochar**	**Compost**
Organic carbon (g/kg)	22.21	20.11
Total N (%)	0.89	0.95
Total P (%)	0.19	1.44
Macronutrients (%)		
K	3.20	0.60
Ca	0.22	0.17
Mg	0.07	0.30
Na	0.17	0.004
Micronutrients (mg/kg)		
Mn	206	392
Fe	135	38
Cu	22.3	24.2
Zn	431	1620

Table 3: Amounts of nitrogen, phosphorus and potassium contained in biochar and compost at the various application levels in the greenhouse experiment

Application (kg N/ha)	**Nutrient composition**		
	N (g/5kg soil)	**P (g/5kg soil)**	**K (cmol g/5kg soil)**
Biochar			
15	0.04	0.06	0.13
30	0.08	0.12	0.26
45	0.12	0.18	0.39
60	0.16	0.24	0.52
Compost			
15	0.04	0.01	0.03
30	0.08	0.02	0.06
45	0.12	0.03	0.09
60	0.16	0.04	0.12

Table 4: Concentration of each of the micronutrients in the liquid micronutrient fertiliser in the greenhouse experiment

Compound	**Content (g/L)**		
	1	**2**	**3**
Fe	18.2	36.4	54.6
Mn	15.8	31.6	47.4
Zn	8.45	16.90	25.35
Cu	12.6	25.2	37.8
Co	0.5	1.0	1.5
B	2.2	4.2	6.6
Mo	0.1	0.2	0.3

Relative growth index (%) of tomato as influenced by nitrogen levels applied using biochar and compost in the greenhouse experiment

Table 5 shows the relative growth index (%) of tomato, as influenced by nitrogen levels in biochar and compost. Tomato grew best at 30 kg N/ha biochar application level with a relative growth index of 100%, while the control had the least growth (82.2%). However, compost applied at 45 kg N/ha gave the best tomato growth with a relative growth index of 100%, while the least growth was observed for the control (73.4%).

Table 5: Relative growth index (%) of tomato as influenced by nitrogen levels applied using biochar and compost in the greenhouse experiment

Biochar application level (kg N/ha)	**Relative growth index (%)**	**Compost application level (kg N/ha)**	**Relative growth index (%)**
0	82.2	0	73.4
15	90.1	15	87.7
30	100.0	30	88.7
45	93.3	45	100.0
60	88.0	60	92.9
LSD (P = 0.05)	NS		NS

NS: not significant

Relative growth index (%) of tomato when treated with the commercial micronutrients fertiliser (with respect of the concentration and application times) in the field experiment

Table 6 shows the relative growth index (%) of tomato treated with micronutrients fertiliser, with respect to the concentration and application times, over a period of 6 weeks after transplanting; 1 L/ha of micronutrients fertiliser, applied twice, gave the best tomato relative growth index of 100%; the control gave 96.0%.

Table 6: Relative growth index (%) of tomato when treated with micronutrients fertiliser (with respect to concentration and application times) over a period of 6 weeks after transplanting in the field experiment

Micronutrients fertiliser concentration (L/ha)	**Relative growth index (%)**	**Micronutrients fertiliser application times**	**Relative growth index (%)**
0	86.5	0	96.0
1	100.0	1	98.1
2	90.0	2	100.0
3	87.7	3	99.5
LSD (P = 0.05)	NS		NS
NS: not significant			

Effects of nitrogen levels when using biochar and compost on some yield and yield components of tomato in the field experiment.

The effects of biochar application were not significant (Table 7). However, biochar applied at the rate of 30 kg N/ha produced a higher number of flowers (10) per plant and the highest fruit weight (74.8 g/plant) when compared with other application levels. Compost applied at 30 kg N/ha had the highest dry biomass, while compost applied at 45 kg N/ha gave the highest number of tomato fruits (5) per plant, leading to highest fruit weight (98.2 g/plant) which was significantly different from other application levels. Biochar applied at the rate of 30 kg N/ha resulted in highest fruit yield (26.3 t/ha) while biochar applied at the rate of 15 kg N/ha gave the lowest fruit yield (17.7 t/ha). Compost applied at the rate of 45 kg N/ha was significantly different from other application levels and gave the highest fruit yield (39.3 t/ha), while control gave the lowest fruit yield (18.8 t/ha).

Table 7: Effects of nitrogen levels applied using biochar and compost on some yield and yield components of tomato in the field experiment

Fertiliser source	Application levels (kg N/ha)	Dry biomass (g/plant)	Number of flowers /plant	Number of fruits /plant	Fruit weight (g/plant)	Fruit yield (t/ha)
Biochar	0	6.5	6.7	2.0	48.3	19.3
	15	5.9	7.7	2.7	44.3	17.7
	30	8.2	10.0	3.3	74.8	26.3
	45	7.8	8.0	3.0	54.9	22.0
	60	9.4	7.7	3.0	61.1	24.4
	LSD (0.05)	NS	2.2	NS	21.5	NS
Compost	0	2.3	7.3	2.0	47.0	18.8
	15	7.7	8.7	3.0	62.0	24.8
	30	12.3	9.3	3.7	69.8	27.9
	45	11.7	9.7	5.0	98.2	39.3
	60	11.1	8.7	4.0	78.9	31.6
	LSD (0.05)	5.5	NS	0.5	10.3	4.1
NS: not significant						

Predictive dry matter yield (g/plant) as a function of treatment applications in the greenhouse experiment

The regression equations giving the predictive dry matter yield as a function of application rates are shown in Table 8. The regression equations were calculated by plotting fertiliser application rates against dry biomass (g/plant). The results showed that the optimum application rates for compost, biochar and micronutrients fertiliser concentrations were 45 kg N/ha, 30 kg N/ha and 1 L/ha, respectively. In addition, application of micronutrients fertilizer, twice at 6 weeks after transplanting, gave the optimum application rate for tomato.

Table 8: Regression equations, optimum application rates and coefficients of determination in relation to dry matter yield (g/plant)

Fertiliser treatment	**Regression equation**	**R^2**	**Optimum rate**
Compost	$y = -0.0055x^2 + 0.4732x + 2.2163$	0.68	45 kg N/ha
Micronutrients fertiliser (frequency)	$y = -0.395x^2 + 1.787x + 2.722$	0.81	2.0
Micronutrients fertiliser (concentration)	$y = -0.6175x^2 + 1.9075x + 2.3125$	0.98	1 L/ha
Biochar	$y = -0.0005x^2 + 0.019x + 6.2403$	0.79	30 kg N/ha

Effects of fertiliser treatments on plant height, number of leaves, stem diameter, number of flowers and number of fruits in the field experiment

The effects of fertiliser treatments on plant height, number of leaves, stem diameter, number of flowers and number of tomato fruits are presented in Table 9. The results showed that fertiliser treatments were significant for plant height, number of leaves/plant, number of flowers/plant and number of fruits/plant. Biochar + compost produced the tallest plants (69.33 cm) though not significantly different from biochar + compost + micronutrients (67.33 cm). The control produced the shortest plants (46.67 cm). Plants treated with biochar + compost produced the highest number of leaves (87.00), while the control produced the least number of leaves (60.00). The effect of fertiliser treatments was not significant for stem diameter, however, biochar + compost + micronutrients produced the highest stem diameter (24.02 cm), while the control produced the shortest stem diameter (20.61 cm). The tomato plants treated with biochar + compost, as well as biochar + compost + micronutrients and solely compost produced the highest number of flowers with each having 14.00, while the control produced the least flowers (8.67). The combination of biochar + compost resulted in the production of highest number of tomato fruits (10.00), while control produced the lowest number of fruits (3.00).

Table 9: Effects of fertiliser treatments on number of flowers, number of fruits and weight of fruits in the field experiment

Treatments	**Plant height (cm)**	**Number of Leaves**	**Stem diameter (cm)**	**Number of flowers /plant**	**Number of fruits /plant**
Control	46.67d	60.00e	20.61	8.67c	3.00d
Compost	57.00b	77.67b	21.19	14.00a	9.00ab
MNF	50.33c	62.67de	21.06	9.67bc	4.33cd
B + C	69.33a	87.00a	22.05	14.00a	10.00a
B + MNF	57.00b	67.67d	21.77	12.00ab	8.33ab
C + MNF	59.67b	72.67c	22.74	12.33a	7.00bc
B + C + MNF	67.33a	80.67b	24.02	14.00a	9.00ab
SED	1.63***	2.26***	1.58NS	1.168***	1.249***

MNF: micronutrients fertiliser, B + C: biochar + compost, B + MNF: biochar + micronutrients fertiliser, C+ MNF: compost + micronutrients fertiliser, B + C + MNF: biochar + compost + micronutrients fertiliser.

NS: not significant at P = 0.05; ***: significant at $P \leq 0.001$. Means with the same letter(s) in the same column are not significantly different (Duncan's Multiple Range Test P > 0.05)

Effects of fertiliser treatments on fruit (t/ha) and biomass (g/plant) yield in the field experiment

The effects of fertiliser treatments on tomato fruit yield (t/ha) and biomass (g/plant) yield are shown in Table 10. The results showed that the effects of fertiliser treatments were significant on fruit and biomass yield. Tomato plants treated with biochar + compost + micronutrients produced the highest fruit yield (2.09 t/ha), while the lowest fruit yield was obtained from the control (0.82 t/ha).The biochar + compost + micronutrients treatment, produced the highest dry biomass (10.47 g/plant), while the control produced the lowest dry biomass (1.36 g/plant).

Table 10: Effects of fertiliser treatments on fruit (t/ha) and biomass (g/plant) yield in the field experiment

Treatments	**Fruit yield (t/ha)**	**Biomass yield (g/plant)**
Control	0.82e	1.36d
Biochar	1.02de	1.86cd
Compost	1.34bcd	5.25bc
MNF	1.23cd	2.21cd
B + C	1.72b	7.96b
B + MNF	1.41bcd	5.42bc
C + MNF	1.58bc	1.85cd
B + C + MNF	2.09a	10.47a
SED	0.17***	1.63***

MNF: micronutrients fertiliser, B + C: biochar + compost, B + MNF: biochar + micronutrients fertiliser, C+ MNF: compost + micronutrients fertiliser, B + C + MNF: biochar + compost + micronutrients fertiliser.
***: significant at $P \leq 0.001$. Means with the same letter(s) in the same column are not significantly different (Duncan's Multiple Range Test $P > 0.05$)

Effects of fertiliser treatments on nutrient uptake and nutrient use efficiency by tomato plant Nitrogen uptake in the field experiment

The tomato plants treated with biochar + compost + micronutrients fertiliser had the highest N-uptake (4.49 g/kg) when compared to the other fertiliser treatments (Table 11). The lowest N-uptake was observed for the control (0.43 g/kg) although not significantly different from the plants treated with micronutrients fertiliser alone (0.67 g/kg).

Nitrogen Use Efficiency

The tomato plants treated with biochar + compost + micronutrients fertiliser had the highest nitrogen use efficiency (55.70 g/g) when compared to the other fertiliser treatments **(**Table 11). In addition, plants treated with compost, biochar and compost + micronutrients fertiliser had similar nitrogen use efficiency, while the control and tomato plants treated with micronutrients fertiliser alone, had the lowest nitrogen use efficiency (0 g/g and 0 g/g, respectively).

Table 11: Effects of fertiliser treatments on nutrient uptake and nutrient use efficiency by tomato plant in the field experiment

Treatments	**N-uptake (g/kg)**	**NUE (g/g)**
Control	0.43c	0.00d
Biochar	0.96bc	34.10c
Compost	2.55abc	29.65c
MNF	0.67c	0.00d
B + C	3.20ab	45.93b
B + MNF	2.71abc	47.07ab
C + MNF	0.79bc	35.07c
B + C + MNF	4.49a	55.70a
SED	1.02*	4.31***

N: nitrogen, NUE: nitrogen use efficiency MNF: micronutrients fertiliser, B + C: biochar + compost, B + MNF: biochar + micronutrients fertiliser, C+ MNF: compost + micronutrients fertiliser, B + C + MNF: biochar + compost + micronutrients fertiliser.

*: significant at $P \leq 0.05$ ***: significant at $P \leq 0.001$. Means with the same letter(s) in the same column are not significantly different (Duncan's Multiple Range Test $P > 0.05$)

Discussion

The soil used for this study, exchangeable cations, total N, organic carbon and available P, are low based on established critical levels (Oluleye et al. 2008; Oluleye and Akinrinde 2017); this makes the soils amenable to amendments, hence the response to application of treatments. The optimum application rate of 45 kg N/ha obtained from compost application could be attributed to the fact that compost (low C: N ratio) releases the nutrients slowly and therefore its effect is slow. This agrees with the report of Bilal et al. (2016), that compost organic materials release nitrogen at rates considered to be slow. In addition, the optimum application rate of 30 kg N/ha, obtained from biochar application, could be ascribed to biochar high surface area for nutrient retention and sorption capacity when added to soil, which is in line with the report by Nigussie et al. (2012), that high surface area and porous nature of biochar increases nutrient uptake of biochar treated soils. Furthermore, 1 L/ha micronutrients fertiliser at two application times, showed that micronutrients, though usually required in minute quantities, are vital to the growth of tomato. These results agree with the findings of Das and Dash (1977), that micronutrients spray in tomato enhanced higher plant growth and development, compared to the control.

The results obtained under the field experiment indicated that the combined effects of biochar + compost enhanced plant height and number of leaves more than the other fertiliser treatments, although the effect was not significantly different from that obtained for biochar + compost + micronutrients. Similar to the observations in the present study, Fischer and Glaser (2012) also observed that application of biochar and compost could lead to enhanced soil fertility, improved plant growth and carbon sequestration potential. The results also revealed that the combined effects of biochar + compost + micronutrients significantly influenced early fruiting, produced the highest fruit weight, biomass yield and fruit yield compared to the other fertiliser treatments. These results agree with the findings of Liu et al. (2012), that the combined application of compost and biochar had a synergistic positive effect on soil organic matter, nutrient contents and water holding capacity of soil under field conditions. The observed better performance of biochar +

compost + micronutrients, in terms of DM yield, and N uptake is probably because the treatment had high nutrient retention capacity which increases its ability to retain and supply nutrients and also reduce nutrient loss through leaching.

Recommendations and conclusion

For optimum growth and economically higher yield, the tomato crop may be fertilised with biochar at 30 kg N/ha, compost at 45 kg N/ha, as observed in this location under study. Also, micronutrients optimum concentration of 1 L/ha applied twice (optimum application time) should be used for growth and yield of tomato. The enrichment of biochar with compost and micronutrients fertiliser makes the combined application to effectively improve growth, yield and quality of tomato, this application could be recommended in this location.

Conflict of Interest

There was no conflict of interest

Authors' contributions

Martin Adekunle Adetayo, Research Student: Professor Ezekiel Akinkunmi Akinrinde, research project major supervisor and Dr Anthony Kehinde Oluleye, reviewer of the manuscript.

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References

Antonio, I., F. Nigro, and L. Schenna. 2004. "Control of Post-harvest Diseases of Fresh Vegetable by Application of Antagonistic Micro-Organism. Crop Management and Postharvest Handling of Horticultural Products, edited by Randane Dris, Raina Niskanen and Shri Mohan Jai. 1-30.

Biederman, L.A., and S.W. Harpole. 2013. "Biochar and its Effects on Plant Productivity and Nutrient Cycling: A Meta-Analysis." *GCB Bioenergy* **(5)**:202–214.

Bilal, B., M. Al-bataina, Y. Thomas, and R. Ezio. 2016. "Effects of Compost Age on the Release of Nutrients." *International Soil and Water Conservation Research* **4(3)**: 230–236.

Bouyoucos, G.J. 1962. "Hydrometer Method Improved for Making Particle-Size Analysis Of Soils. *Agronomy Journal* **(54)**: 464–465.

Bray, R.H., and L.T Kurtz. 1945. "Determination of Total Organic and Available Forms of Phosphorus in Soils." *Soil Science* **(59)**:39–45.

Das, R.C., and G. Dash. 1977. "Effect of Micronutrients with Without Urea on Growth, Development and Quality of Tomato Variety. Pusa Ruby." M.Sc Thesis submitted to Orissa University of Agriculture and Technology, Bhubaneswar.

Fairhurst, T. 2012. *Handbook for Integrated Soil Fertility Management.* Africa Soil Health Consortium: Wallingford, UK.

Fischer, D., and B. Glaser. 2012. "Synergisms between Compost and Biochar for Sustainable Soil Amelioration." *Management of Organic Waste*, edited by S.E. Kumae, 167–198.

Glaser, B., L. Haumaier, G. Guggenberger, and W. Zech. 2001. "The 'Terra Preta' Phenomenon: a Model for Sustainable Agriculture in the Humid Tropics." *Naturwissenschaften* **(88)**: 37–41.

IITA, 1979. *Selected Methods of Soil and Plant Analysis. Monograph 1*. International Institute for Tropical Agriculture, Ibadan, Nigeria.

Inmaculada, N.G. Verónica, G. Javier, and M. Jesús periago. 2011. "Chemical Profile, Functional and Antioxidant Properties of Tomato Peel Fiber." *Food Research International* **(44)**:1528–1538.

Jackson, M.L. 1958. *Soil Chemical Analysis*. Prentice-Hall Inc., Englewood Cliff.

Jothimani, S., B.J. Pandian, and T.M. Thiygarajan. 2007. "Nutrient use Efficiency in Crop Plants." *Agrobias Newsletter*. *Plant Physiology*. **(8)**: 28 – 31.

Jeffery, S., F.G. Verheijen, M. Van der velde, and A.C. Bastos. 2011. "A Quantitative Review of the *Literature Cited* Effects of Biochar Application to Soils on Crop Productivity Using Meta-Analysis." *Argic. Ecosyst Environ*. **(144)**:175–187.

Kloss S., F. Zehetner, B. Wimmer, J. Buecker, F. Rempt, and G. Soja. 2014. "Biochar Application to Temperate Soils: Effects on Soil Fertility and Crop Growth under Greenhouse Conditions." *Journal of Plant Nutrition and Soil Science* **(177)**: 3–15.

Liu, J., H. Schulz, B. Huwe, and B. Glaser. 2012. "Short-Term Effect of Biochar and Compost on Soil Fertility and Water Status of a Dystric Cambisol in NE Germany under Field Conditions." *Journal of Plant Nutrition and Soil Science* **(175)**: 698–707.

Mofuka, M.M., M. Nsomb, C. Nkasa, K. Ibwenzi, and K. Taba. 2007. "Effect of Combining Organic Biomass and Inorganic Fertilizer on Tomato Yield and Nematode Control in Arenosal in Kinshasha." *Advances in Integrated Soil Fertility Management in Sub-Saharan African* 359–363.

Moormann, F.R., R. Lal, and A.S.R. Juo. 1975. *The Soils of IITA*. IITA Technical Bulletin. No **(3).** https://hdl.handle.net/10568/109318

Naga, S.K., S.K. Swain, S.V. Verma, and B. Raju. 2013. "Effect of Foliar Application of Micronutrients on Growth Parameters in Tomato (*Lycopersicon esculentum* Mill.)." *Discourse Journal of Agriculture and Food Science* **1(10)**: 146–151.

Nigussie, A., E. Kissi, M. Misganaw, and G. Ambaw. 2012. "Effect of Biochar Application on Soil Properties and Nutrient Uptake of Lettuces (*Lactuca sativa*) Grown in Chromium Polluted Soils." *American-Eurasian Journal of Agriculture and Environmental Science* **12 (3)**: 369–376.

Oluleye, A.K., E.A. Akinrinde, and G.O. Obigbesan. 2008. "Phosphorus Dynamics in Forest and Savannah Agro-Ecological Alfisols Incubated with Different Phosphorus Fertilizers." *Journal of Food, Agricultures & Environment* **6 (3&4):** 534–537.

Oluleye, A.K., and E.A. Akinrinde. 2017. "Transformation of Phosphorus in Forest and Savannah Agro-Ecological Alfisols Incubated with Different Phosphorus Fertilizers." *Journal of Plant Nutrition***.** DOI. 10.1080/ 01904167.2017.1384009.

Periago, M. J., J. Garcia-alonso, K. Jacob, A.B. Olivares, A. J., Bernal, and M.D. Iniesta. 2009. "Bioactive Compounds, Foliates and Antioxidant Properties of Tomatoes (*Lycopersicum esculentum* Mill.) during Vine Ripening." *International Journal of Food Science and Nutrition* **60 (80)**: 694–708.

Poll, C., S. Marhan, J. Ingwersen, and E. Kandeler. 2008. "Dynamics of Litter Carbon Turnover and Microbial Abundance in a Rye Detritusphere." *Soil Biology & Biochemistry* **(40)**: 1306–1321.

Ros, M., S. Klammer, B. Knapp, K. Aichberger, and H. Insam. 2006. "Long-Term Effects of Compost Amendment of Soil on Functional and Structural Diversity and Microbial Activity." *Soil Use and Management* **22(2)**: 209–218.

Sharoni, Y., and Y. Levi. 2006. "Cancer Prevention by Dietary Tomato Lycopene and its Molecular Mechanisms." In *Tomatoes, Lycopene and Human Health Barcelona*, edited by A. V. Rao. Caledonian Science Press Ltd. 111–125.

Umeh, V.C., F.O. Kuku, E.I. Nwanguma, O.S. Adebayo, and A.A. Manga. 2002. "A Survey of the Insect Pests and Farmers Practices in the Cropping of Tomato in Nigeria." *Tropicultura*. **(20)**:181–186.

Walkley, A., and L.A. Black. 1934. "An Examination of the Degtjareff Method for Determining Soil Organic Matter and Proposed Modification of the Chromic Acid Titration Method." *Soil Science* **(37)**:29–38.