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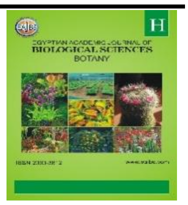

Effects of Sawdust Biochar Amendment and Watering Regime on Alfisol Chemical Properties and Amaranthus Growth Performance

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ABSTRACT

Amaranthus sp. is an important African indigenous vegetable that contributes to food security and income generation for small-scale farmers. However, its growth is often limited by soil fertility and water availability. This study investigated the effects of sawdust biochar and watering regimes on the growth and yield of Amaranthus. A 5 x 3 factorial experiment was conducted in a screenhouse, with five levels of sawdust biochar (0, 1, 2, 3, and 4 t/ha) and three watering regimes (200 ml of fresh water added once, twice, and thrice a week). The results showed that biochar application significantly increased plant height, stem diameter, number of leaves, and dry matter yield. The optimal watering regime also increased plant growth and yield parameters. The interaction between biochar and watering regimes was significant for some plant growth measurements. The study demonstrated that sawdust biochar can improve soil fertility and structure, and its application can be used to promote plant growth and yield in tropical regions. The findings of this study provide valuable insights into the potential of biochar as a soil amendment for improving soil fertility and promoting plant growth.

INTRODUCTION

Sub-Saharan Africa has experienced rapid growth and diversification of agricultural production, driven by domestic and global market demands. However, this shift towards export-oriented crops has led to a decline in native crop diversity and increased vulnerability to climate variability. African Indigenous Vegetables (AIVs), including Amaranthus, play a vital role in ensuring food security and health for underprivileged communities in urban and rural areas. Research has shown that AIVs are more profitable than exotic vegetables, particularly for small-scale farmers, especially women, who require minimal financial investment (Shackleton et al., 2009). The market potential for AIVs is promising, with studies highlighting their natural adaptability to local conditions (Nyarko and Quainoo, 2012).

Despite their importance, AIVs are understudied, particularly regarding their response to environmental stressors. Climate change is expected to exacerbate cropping conditions in sub-Saharan Africa, with more frequent dry spells. However, few studies have investigated the impact of soil moisture stress on AIVs (Olufolaji and Ojo, 2010), and even

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fewer have examined nutrient management (Ojo *et al.,* 2007). The success of AIVs depends on their sensitivity to environmental variables, such as water and nutrients. To enhance agro-sustainability, recovering nutrients and water from organic residues is crucial. Organic soil amendments, like compost and biochar, are essential for sustainable urban production systems, providing carbon and nitrogen sources (De Lucia *et al.,* 2013; Yadav *et al.,* 2011). Biochar, in particular has been shown to improve soil fertility, reduce leaching, and promote carbon sequestration (Yuan and Xu, 2012). This study aimed to investigate the response of Amaranthus to sawdust biochar, watering regime, and Alfisol soil properties, focusing on growth performance, leaching potential, and water use efficiency.

MATERIALS AND METHODS

The experiment was carried out in the screenhouse at the Soil and Tree Nutrition department, Forestry Research Institute of Nigeria (FRIN) located on the longitude 07 º 23’18” N to 07 º 23’43” N and latitude 03 º 51’20” E to 03 º 23’43”43E. The dry season usually commences from November to March while the rainy season starts from April to October. The average temperature is about 32ºC; annual rainfall ranges from 1400 -1500mm and an average relative humidity of about 65% (FRIN, 2018). Surface Alfisol samples were taken from the arboretum of FRIN and filled into a 2 kg capacity poly pot while a sub sample was taken for laboratory analysis. The study was a 5 X 3 factorial experiment fitted into a completely randomized design (CRD) with 4 replications having a total of 60 experimental units while each unit has 5 transplanted Amaranthus pre-germinated seedlings each at 2 leaves stage to make a total of 300 Amaranthus seedlings used in the study. Factor one consists of 0 (B0), 1 (B1), 2 (B2), 3 (B3) and 4 (B4) t/ha sawdust biochar (The sawdust was collected at the sawmill of Forest Products Development &Utilization Department, FRIN and pyrolyzed at 350^0c before being incorporated into the experimental soil in the polythene pots) while factor two was 200 ml of fresh water added to the soils once (W1), twice (W2) and thrice (W3) a week interval for a period of 6 weeks. Initial and post experimental routine soil analysis was carried out and the growth and yield parameters measured are plant height (cm), stem diameter, number of leaves and dry mater yield.

Laboratory Analysis:

The subsamples of soil collected were air dried, and latter sieved with a 2 mm diameter sieve. These were later analyzed for selected soil physical and chemical properties following the procedures outlined by Amhakhian and Achimugu (2011). Particle-size analysis was done using the hydrometer method with sodium hexametaphosphate as the dispersing agent (Gee and Or, 2011). Percent sand silt and clay, the soil textures were determined using USDA textural triangle. Soil organic with 50 ml ammonium acetate at pH 7. The exchangeable K in the extract was determined with a flame photometer, and exchangeable Na, Ca and Mg was determined using an absorption spectrophotometer (Bremner, 1996; Nelson and Sommers,1996; Okalebo *et al.,* 2002). Soil pH was determined in 1:2 soil-water medium using a digital electronic pH meter.

Statistical Analysis:

Data collected was subjected to analysis of variance (ANOVA). Means were separated using the least significant different (LSD) at 5% probability level.

RESULTS

The initial and post experimental analysis of the physico-chemical properties of the soils were shown in Tables 1 and 2. The pH of the soil before experiment was found to be slightly acidic (6.10) while post analysis revealed the soil to be neutral (7.62 – 8.04). The Total Nitrogen was 1.53g/kg, Organic carbon was 13.80g/kg and available Phosphorus was

14.24g/kg. The exchangeable cation was Na (0.37cmol/kg), K (0.51 cmol/kg), Mg (0. Cmol/kg) and Ca (3.00 cmol/kg). The Particle size distribution shows Sand (82.0), Silt (13.0) and Clay (5.0). It is therefore classified as Sandy loam. Extractable micronutrients were also found to be 56.00 mg/kg for Mn, 99.40mg/kg for Fe, 1.04 mg/kg for Cu and 1.19 mg/kg for Zn. Manganese and iron contents were relatively high, while copper and zinc were relatively low.

Table 1: Initial soil physicochemical properties analysis.

Soil parameters	Content in soil
pH (H_2O 1:1)	6.10
Organic Carbon (gKg^{-1})	13.8
Total nitrogen (gKg^{-1})	1.53
Available phosphorus ($mgKg^{-1}$)	14.24
Exchangeable cat ions ($Cmolkg^{-1}$)	
Na	0.37
K	0.51
Mg	0.59
Ca	3.00
Extractable micronutrients ($mgKg^{-1}$)	
Mn	56.0
Fe	99.40
Cu	1.04
Zn	1.19
Particle size distribution g/kg	
Sand	82.0
Silt	13.0
Clay	5.0
Textural class	**Sandy loam**

Table 2: Post experimental soil analysis.

Sample	Ph (H20)1:2	O.C (%)	T.N (%)	Avail. P. (mg/kg)	Na (cmol/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Mn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
B0 W1	7.99	2.09	0.18	30.97	0.36	0.07	22.90	2.56	339.00	350.00	6.0	48.00
B0 W2	7.66	2.03	0.17	34.10	0.27	0.11	26.10	2.93	383.00	670.00	7.0	49.00
B0 W3	7.62	2.51	0.21	53.41	0.29	0.16	26.55	2.79	381.00	330.00	7.0	46.00
B1 W1	7.95	2.29	0.19	33.58	0.33	0.06	23.50	2.23	396.00	330.00	7.0	49.00
B1 W2	7.80	2.39	0.21	19.83	0.26	0.05	24.30	2.26	352.00	340.00	6.0	46.00
B1 W3	7.8	2.93	0.21	5.05	0.11	0.11	26.14	2.50	398.00	540.00	6.0	49.00
B2 W1	7.86	2.51	0.21	18.79	0.33	0.08	37.10	2.56	332.00	330.00	8.0	46.00
B2 W2	7.66	2.89	0.25	67.86	0.34	0.12	23.20	2.50	400.00	350.00	6.0	48.00
B2 W3	7.67	2.43	0.2	19.31	0.31	0.12	25.15	2.99	350.00	340.00	6.0	49.00
B3 W1	7.88	2.31	0.2	27.84	0.40	0.04	17.80	2.36	320.00	330.00	5.0	45.00
B3 W2	7.89	2.17	0.18	7.30	0.29	0.13	23.20	2.40	348.00	360.00	8.0	50.00
B3 W3	7.73	2.53	0.22	32.01	0.41	0.17	34.70	3.15	368.00	340.00	7.0	46.00
B4 W1	8.04	2.51	0.18	27.49	0.26	0.13	26.90	2.82	343.00	310.00	6.0	46.00
B4 W2	7.86	2.55	0.22	20.53	0.46	0.06	32.90	2.66	338.00	350.00	6.0	43.00
B4 W3	7.84	2.61	0.19	25.92	0.39	0.06	36.22	2.66	410.00	380.00	6.0	64.00

Sawdust biochar t/ha: 0 (B0), 1 (B1), 2 (B2), 3 (B3) and 4 (B4). fresh water added to the soils once (W1), twice (W2) and thrice (W3) a week interval for a period of 6 weeks. O.C – Organic Carbon, T.N – Total Nitrogen

The Table 3, shows the analysis of variance results of response of plant height to effects of sawdust biochar (B) and the watering regime. It was observed that there were significant differences (p<0.05) across the weeks after transplanting. Both the individual effects of biochar and watering regime were significant, while the interaction effect was not. However, at 6 weeks after transplanting, the treatment B4 /W2 had the highest height (34.7cm) which is comparable to the treatments B1/W1, B2/W1, B2/W2 and B4/W1. While the lowest was treatment B3/W3 (17.79cm).

Table 3: Effects of Saw dust biochar and watering regimes on Plant height.

BIOCHAR	WATER	1WAP	2WAP	3WAP	4WAP	5WAP	6WAP
B0	W1	7.775ad	11.36be	17.96ac	21.63ae	26.18ad	31.73ab
	W2	6.5de	8.62df	12.66ce	16.95df	23.07cf	29.07ab
	W3	6.3de	7.79ef	10.86de	15.83ef	20.15df	18.5cd
B1	W1	8.4ad	13.53ac	22.19a	27.02a	34.02a	33a
	W2	9.85ab	13.82ac	20.74ab	25.55ac	31.35ab	32.07ab
	W3	7ce	9.96cf	13.29ce	19.43bf	25.5bf	30.37ab
B2	W1	10.225a	15.77a	22.46a	26.7a	31.75ab	33.1a
	W2	10.15a	14.26ab	21.13ab	26.44ab	33.88a	33.38a
	W3	5.85de	7.79ef	10.33de	12.62f	22.95cf	27.41ac
B3	W1	7.85ad	11.21be	17.46ac	23.36a-d	29.85ac	32.12ab
	W2	9.3ac	9.31df	15.69bd	18.6cf	21.89df	25.25ad
	W3	4.95e	5.55f	8.36e	10.9f	16.55f	17.79d
B4	W1	8.05a-d	12.48ad	20.96ab	25.61ac	32.9ab	32.83a
	W2	7.35b-e	11.83ae	18.11ac	21.6ae	31.18ab	34.7a
	W3	5.05e	6.24f	8.59e	11.64f	18.2ef	22.6bd
LSD (0.05)							
B		1.338*	2.124*	2.885*	3.596*	3.926*	4.912*
W		1.037*	1.645*	2.234*	2.786*	3.041*	3.804*
BXW		2.318	3.678	4.996	6.229	6.8	8.507

Means with different alphabets in the same column are significantly different from each other at * = p<0.05. Sawdust biochar t/ha: 0 (B0), 1 (B1), 2 (B2), 3 (B3) and 4 (B4), fresh water added to the soils once (W1), twice (W2) and thrice (W3) a week interval for a period of 6 weeks**.**

Table 4, shows the stem diameter of the Amaranthus to the treatments. There were significant effects (p<0.05) from 1 to 5 weeks after transplanting, with week 6 not significantly affected. However, the interaction between biochar and watering regime was significant. At week 4 after transplanting, the treatment B4/W1 had the largest stem diameter (6.945mm) while the lowest stem diameter (2.64mm) was observed at B3/W3.

The result of number of leaves was shown on the Table 5, with both the biochar and the watering regime showing significance differences (p<0.05) in their individual effects. However, biochar effect was significantly higher than other effect with the treatment B4/W3 having the largest number of leaves (11.375) at 6 weeks after transplanting which was comparable to the effect of B1/W1, while B0/W3 gave the least number of leaves (4.392).

The results of the effect of biochar and watering regimes on the dry matter yield was displayed on Table 6. There were significant differences (p<0.01) in the leaf and stem dry matter yield at biochar and watering regime individual effect, while the root dry matter was only significant at watering regime effect. Treatment B4/W1 was observed to have given the highest number of leaves (44.63), while B3/W3 gave the lowest number of leaves (5.19). In the same vein, the root dry matter was significant (p<0.05) at watering regime effect with the treatment B2/W1 giving highest root dry matter yield (2.85g) and the B3/W3 which gave the lowest root dry matter yield (0.347g).

Table 4: Effects of Saw dust biochar and watering regimes on Stem diameter.

Biochar	Water	1WAP	2WAP	3WAP	4WAP	5WAP	6WAP
B0	W1	1.604ab	2.776bd	3.6ab	5.22be	4.1ab	4.403a
	W2	0.958cd	2.036de	2.251df	5.603ae	4.603a	3.972a
	W3	0.885cd	1.516e	1.768ef	3.872ef	3.819ab	3.569a
B1	W1	1.645a	3.378ab	3.647a	4.843be	5.501a	5.493a
	W2	1.635a	3.375ab	3.268ad	4.147df	4.433ab	5.126a
	W3	1.02cd	2.144ce	2.536b-e	4.79bf	4.703a	4.737a
B2	W1	1.752a	3.808a	4.021a	6.401ab	4.42ab	4.803a
	W2	1.654a	3.457ab	3.54ab	5.26ae	4.976a	4.594a
	W3	0.92cd	1.364e	1.72ef	3.159f	4.358ab	5.077a
B3	W1	1.348ac	3.102ac	3.189ad	5.947ac	4.926a	4.842a
	W2	1.579ab	2.256ce	2.425ce	5.032be	4.762a	4.544a
	W3	0.795cd	1.254e	1.214f	2.646f	2.625b	3.577a
B4	W1	1.558ab	3.084ac	3.466ac	6.945a	5.38a	5.369a.
	W2	1.18ad	2.863ad	2.962ad	5.705ad	4.95a	4.862a
	W3	0.654d	1.217e	1.013f	4.607cf	4.424ab	5.006a
LSD (0.05)							
B		0.3074*	0.505*	0.554*	0.862*	0.958	1.026*
W		0.2381*	0.3911*	0.4291*	0.668*	0.742*	0.794
BXW		0.5324	0.8746	0.9595	1.493*	1.66	1.776

Means with different alphabets in the same column are significantly different from each other at * = p<0.05. Sawdust biochar t/ha: 0 (B0), 1 (B1), 2 (B2), 3 (B3) and 4 (B4), fresh water added to the soils once (W1), twice (W2) and thrice (W3) a week interval for a period of 6 weeks**.**

Table 5: Effects of Saw dust biochar and watering regimes on Number of leaves.

Biochar	Water	1WAP	2WAP	3WAP	4WAP	5WAP	6WAP
B0	W1	6.25bd	7.95ab	9.05ab	10.488ab	9.28bc	9.838ab
	W2	6.35bd	5.575de	7.333bd	9.575ab	10.29ac	8.979ac
	W3	5.7bd	5.3e	8.267ad	9.067ab	8.34c	4.392c
B1	W1	7.7ab	8ab	9.95a	11.5a	13.15a	11.25a
	W2	7.75ab	7.5ac	9.6ab	10.65ab	10.17ac	10.1ab
	W3	6.6bc	5.95ce	8ad	9.004ab	10.33ac	10.183ab
B2	W1	8a	8.75a	8.713ac	9.142ab	12.5ab	9.483ab
	W2	7.4ab	8.062ab	9.8ab	11.033a	11.62ac	9.146ac
	W3	4.95cd	5.05e	6.3ce	7.058b	9.46ac	8.25ac
B3	W1	7.35ab	7.188ad	9.975a	10.15ab	11.68ac	7.587ac
	W2	7.45ab	6.9be	8.354ad	9.637ab	10.94ac	9.354ab
	W3	3.975d	4.3e	4.958e	6.979b	8.96bc	6.146bc
B4	W1	7.25ab	7.4ac	9.688ab	10.025ab	12.38ab	9.562ab
	W2	6.5ce	7.75ab	8.267ad	7.8ab	8.75bc	7.85ac
	W3	4.471d	4.55e	5.95de	9ab	11a-c	11.375a
LSD (0.05)							
B		1.053*	0.886*	1.247	1.886	1.866	2.41*
W		0.816*	0.686*	0.966*	1.461*	1.446*	1.867
BXW		1.824*	1.535*	2.16	3.267	3.233	4.174

Means with different alphabets in the same column are significantly different from each other at * = p<0.05. Sawdust biochar t/ha: 0 (B0), 1 (B1), 2 (B2), 3 (B3) and 4 (B4), fresh water added to the soils once (W1), twice (W2) and thrice (W3) a week interval for a period of 6 weeks**.**

Table 6: Effects of Saw dust biochar and watering regimes on dry matter yield

Biochar	Water	Leaves	Stem	Root
B0	W1	18.48	24.4	2.39
	W2	18.25	22.92	1.61
	W3	7.61	17.16	0.482
B1	W1	24.79	35.94	2.38
	W2	33.89	33.1	2.638
	W3	14.55	27.34	0.71
B2	W1	22	32.41	2.85
	W2	30.45	25.33	2.79
	W3	6.87	24.17	0.8
B3	W1	19.92	26.02	1.92
	W2	9.85	17.22	1.412
	W3	5.19	8.58	0.347
B4	W1	44.63	48.8	2.455
	W2	20.04	34.44	2.565
	W3	5.27	11.04	1.92
LSD (0.05)				
B		8.01*	10.33*	1.16
W		6.21**	8.00**	0.90*
BXW		13.88*	17.89	2.00

Means with different alphabets in the same column are significantly different from each other at * = $p<0.05$. Sawdust biochar t/ha: 0 (B0), 1 (B1), 2 (B2), 3 (B3) and 4 (B4), fresh water added to the soils once (W1), twice (W2) and thrice (W3) a week interval for a period of 6 weeks.

DISCUSSION

The soil pH was found to be slightly acidic (6.10), which was later increased to 8.0 which made the soil to become neutral and tending towards being alkaline. This was as a result of the addition of sawdust biochar while invariably serve as a liming material which causes the increase in the pH value of the soil (Yuan and Xu 2012). The Particle size distribution showed that the textural class is Sandy loam according to the USDA textural classification, which is well-drained and suitable for many crops. The total Nitrogen, organic carbon was observed to be reasonably high. This indicates good soil fertility and structure. The total nitrogen content is 1.53 g/kg, which is moderate. The available phosphorus content is 14.24 mg/kg, which is relatively low. This may limit plant growth, and phosphorus fertilization may be necessary. The exchangeable cations were generally very low; however, Na and K were within the critical range. This study demonstrated that the biochar significantly increased the content of available phosphorus and calcium in the soil which has helped to neutralize the acidity (Table 2), which was in variance with the results of previous studies (Liang *et al.,* 2014; Yin *et al.,* 2014). Micronutrients Fe, Mn Zn and Cu were extremely high and (Alloway, B. J. 2004; Lee Jacobs, 2008).

Biochar can adsorb soil organic molecules and promote organic molecule polymerization to form organic matter through surface catalytic activity (Van Zwieten *et al.,* 2010). In addition, the slow decomposition of biochar contributes to the development of humus and promotes soil fertility (Joseph *et al.,* 2010). The increase of available potassium in soil may also be due to the interaction and reaction of biochar with soil in the short term, such as adsorption and desorption, dissolution, precipitation and redox reactions (Joseph *et al.,* 2010).

It was observed that biochar had little effect on the content of alkali nitrogen and available phosphorus (Table 2), which may be due to the low content of mineral nitrogen and available phosphorus in the sawdust biochar. Previous studies have proved that the contents of mineral nitrogen and available phosphorus in some plant biochar were extremely low (Chan *et al.,* 2008).

Biochar application has been shown to increase plant height in various studies. For example, a study by Zhang *et al.* (2012) found that biochar application increased maize plant height by 15.6% compared to the control. Similarly, a study by Major *et al.* (2010) found that biochar application increased plant height in a soybean crop. Increasing watering regimes has also been shown to increase plant height. A study by Hsiao *et al.* (2007) found that optimal irrigation increased plant height in a wheat crop. Another study by Abdel-Fattah *et al.* (2014) found that increasing watering regimes increased plant height in a wheat crop. The interaction between biochar and watering regimes on plant height has also been studied. A study by Zhang et al. (2012) found that the interaction between biochar and irrigation was significant for plant height. Similarly, a study by Abdel-Fattah *et al.* (2014) found that the interaction between biochar and watering regimes was significant for plant height.

Biochar application has also been shown to increase stem diameter. A study by Major *et al.* (2010) found that biochar application increased stem diameter in a soybean crop. Similarly, a study by Zhang *et al.* (2012) found that biochar application increased stem diameter in a maize crop. Increasing watering regimes has also been shown to increase stem diameter. A study by Hsiao *et al.* (2007) found that optimal irrigation increased stem diameter in a wheat crop. The interaction between biochar and watering regimes on stem diameter has also been studied. A study by Zhang *et al.* (2012) found that the interaction between biochar and irrigation was significant for stem diameter.

Biochar application has also been shown to increase the number of leaves. A study by Major *et al.* (2010) found that biochar application increased the number of leaves in a soybean crop. Similarly, a study by Zhang *et al.* (2012) found that biochar application increased the number of leaves in a maize crop. Increasing watering regimes has also been shown to increase the number of leaves. A study by Hsiao *et al.* (2007) found that optimal irrigation increased the number of leaves in a wheat crop. The interaction between biochar and watering regimes on the number of leaves has also been studied. A study by Zhang *et al.* (2012) found that the interaction between biochar and irrigation was significant for the number of leaves.

Biochar application has also been shown to increase dry matter yield. A study by Zhang *et al.* (2012) found that biochar application increased dry matter yield in a maize crop. Similarly, a study by Major *et al.* (2010) found that biochar application increased dry matter yield in a soybean crop. Increasing watering regimes has also been shown to increase dry matter yield. A study by Hsiao et al. (2007) found that optimal irrigation increased dry matter yield in a wheat crop. The interaction between biochar and watering regimes on dry matter yield has also been studied. A study by Zhang *et al.* (2012) found that the interaction between biochar and irrigation was significant for dry matter yield.

CONCLUSION

The study investigated the effects of sawdust biochar on soil properties and plant growth. The results showed that biochar application significantly increased soil pH, available phosphorus, and calcium content, while also improving soil fertility and structure. This study provides new insights into the role of sawdust biochar in improving soil fertility and plant growth under different watering regimes. While previous studies have examined the benefits of biochar, this research specifically demonstrates how sawdust biochar enhances soil pH, available phosphorus, and calcium content, leading to improved soil structure and fertility. Moreover, the observed increase in plant height, stem diameter, number of leaves, and dry matter yield highlights the effectiveness of biochar under optimal water conditions. These findings contribute to a deeper understanding of biochar's potential as a sustainable soil amendment, particularly in water-limited environments, where optimizing soil moisture can further maximize its benefits.

It is therefore recommended sawdust biochar and optimal watering regimes can be used to improve plant growth and soil properties, particularly in acidic soils. Then, further research is needed to investigate the long-term effects of sawdust biochar and other sources of biochar, such as those derived from different feedstocks or production methods, should be explored for their potential effects on soil properties and plant growth.

Declarations:
Ethical Approval: The study strictly adhere to ethical principles, standards and guidelines.
Conflict of interest: The author declares no conflict of interest.
Author's Contributions: I hereby verify that the author mentioned on the title page has Contributed significantly to the idea and planning of the research, has carefully read the work, attested to the veracity and correctness of the data and its interpretation, and has given their approval for submission. This is to assert that the study is original. it has not been published elsewhere, all sources have been properly cited and all authours have contributed to the work and agreed to the submission.
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REFERENCES

Abdel-Fattah, M. A., El-Haddad, M. E., & Abo-Sedera, S. A. (2014). Impact of biochar and irrigation regimes on growth and productivity of wheat. *Journal of Soil Science and Plant Nutrition,* 14(2), 241-253.

Alloway, B. J. (2004). Zinc in Soils and Crop Nutrition. International Zinc Association. Brussels, 1-116.

Amhakhian, S. O and Achimugu, A. (2011). Effects of different soil textures on the growth and yield of maize (Zea mays L.). *Journal of Agriculture and Rural Development*,9(1),13-23.

Bremner, J. M. (1996). Nitrogen-Total. In D. L. Sparks (Ed.), Methods of Soil Analysis. Part 3.Chemical Methods (pp. 1085-1121). Soil Science Society of America.

Chan, K. Y., Van Zwieten, L., Meszaros, I., Downie, A and Joseph, S. (2008). Using poultry litter biochars as soil amendments. *Australian Journal of Soil Research,* 46(5), 437-444.

De Lucia, M., Panettieri, M and Rinaldi, M. (2013). Effects of organic amendments on soil properties and plant growth. *Italian Journal of Agronomy,* 8(3), 235-244.

Forestry Research Institute of Nigeria (FRIN). (2018). FRIN Annual Report on Meteorological data, Environmental Management and Biometric Department.

Gee, G. W and Or, D. (2011). Particle-size analysis. In R. Lal & R. H. Miller (Eds.), Soil Testing and Analysis (pp. 83-104). Marcel Dekker.

Hsiao, T. C., Steduto, P., & Fereres, E. (2007). A systematic and quantitative approach to improve water use efficiency in agriculture. *Irrigation Science,* 25(2), 209-231.

Joseph, S. D., Camps-Arbestain, M., Lin, Y., Munroe, P., Chia, C. H and Van Zwieten, L.(2010). An investigation into the reactions of biochar in soil. *Australian Journal of Soil Research,* 48(6-7), 501-515.

Lee Jacobs, L. (2008). Soil Fertility Decline in the Tropics: A Review of the Literature. *Journal of Sustainable Agriculture,* 32(2), 159-184.

Liang, B., Solomon, D., Kinyangi, J., Grossman, J. M., O'Neill, B., Skjemstad, J. O., Thies, J. E., Luizão, F. J., Petersen, J and Neves, E. G. (2014). Quantitative assessment of soil organic matter transformations using 13C CP/MAS NMR spectroscopy. *Journal of Environmental Quality,* 43(5), 1547-1555.

Major, J., Lehmann, J., Rondon, M., & Goodale, C. (2010). Fate of soil-applied black carbon: Downward migration, leaching and soil respiration. *Global Change Biology,* 16(4), 1366-1379.

Nelson, D. W and Sommers, L. E. (1996). Total Carbon, Organic Carbon, and Organic Matter. In D. L. Sparks (Ed.), Methods of Soil Analysis. Part 3. Chemical Methods (pp.961-1010). Soil Science Society of America.

Nyarko, G and Quainoo, A. K. (2012). Effects of different rates of poultry manure on growth and yield of maize. *Journal of Agricultural Science and Technology,* 12(3), 277 287.

Ojo, D. O., Adebayo, A. and Afolabi, C. G. (2007). Effects of organic and inorganic fertilizers on soil properties and maize yield. *Journal of Sustainable Agriculture,* 30(2),147-157.

Okalebo, J. R., Gathua, K. W and Woomer, P. L. (2002). Laboratory Methods of Soil and Plant Analysis: A Working Manual. 2nd Edition, Tropical Soil Fertility and Biology Program, TSBF-CIAT and SACRED Africa, Nairobi, 128 p.

Olufolaji, A. O and Ojo, D. O. (2010). Effects of different levels of poultry manure on soil physical properties and maize yield. *Journal of Agricultural Science and Technology,* 10(3), 251-261.

Shackleton, C. M., Shackleton, S. E., Gambiza, J and Nel, E. (2009). Livestock production and household livelihoods in the Eastern Cape, South Africa. *Journal of Arid Environments,* 73(9-10), 970-979.

Van Zwieten, L., Kimber, S., Morris, S., Chan, K. Y., Downie, A., Rust, J., Joseph, S. and Cowie, A. (2010). Effects of biochar from wheat straw and bagasse on soil fertility. *Soil Research,* 48(7), 555-566.

Yadav, R. K., Sharma, S. K. and Singh, R. (2011). Effect of organic manures on soil physical properties and maize yield. *Journal of Environmental Science and Health, Part B,* 46, 154-160.

Yin, Q., Zhang, Y., Liu, J. and Liu, X. (2014). Biochar and its impacts on soil microbial community: A review. *Journal of Integrative Agriculture,* 13(8), 1792-1802.

Yuan, J. H. and Xu, R. K. (2012). Effects of biochars on soil fertility and crop yield. *Journal of Integrative Agriculture,* 11(8), 1244-1254.

Zhang, A., Liu, Y., Pan, G., Hussain, Q., Li, L., Zheng, J and Zhang, X. (2012). Effect of Biochar Amendment on Maize Yield and Greenhouse Gas Emissions from a Soil Organic Carbon Poor Calcareous Loamy Soil from Central China Plain. *Plant and Soil,* 351, 263-275. https://doi.org/10.1007/s11104-011-0957-x