International Journal of Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2024.6.6

Volume 10, Issue 6
June - 2024

Appraising the Effect of Biochar in Groundnuts(*Arachis hypogaea* L) Growth Parameters and Yield Under Screen House Conditions

Joshua J. Ibrahim*[1], Ernest Mbega[1], Angela Mkindi[1], Arnold Mushongi[2], Billes L. Nzilano[3]

[1]Department of Life Sciences and Bioengineering, The Nelson Mandela African Institution of Science and Technology(NM-AIST), Box 447, Arusha, Tanzania

[2]Tanzania Agricultural Research Institute (TARI) Ilonga Centre, P.O. Box 33, Kilosa, Morogoro, Tanzania

[3]Tanzania Agricultural Research Institute (TARI) Uyole Centre, P.O. Box 400, Mbeya, Tanzania

---

ABSTRACT

Biochar soil amendment is known to suppress the effect of pathogenic fungi and favour plant resistance against soil-borne pathogen effects. This study appraises the impact of biochar on groundnut yield planted in the slightly acidic sandy loam soil. The study was done at the Nelson Mandela African Institution of Science and Technology (NM-AIST) screen house, where groundnuts were planted in the 2L pots filled with soil mixed with biochar at different rates (2.5%, 5% and 7.5%) in April 2022. Groundnut's growth parameters were managed by measuring shoot length and root length, counting the number of leaves and taking leaf area once every week from the second week after planting to harvesting, where its yield was also measured. Analysis of variance showed a significant ($P < 0.05$) increase in groundnut growth parameters and yield when 5% Biochar was used. There was a strong positive correlation between biochar and some groundnut growth parameters. No significant ($P < 0.05$) difference was observed between Biochar and groundnut growth parameters and yield when 2.5% biochar was used. A slightly weak negative correlation was observed when a 7.5% Biochar rate was used. Biochar-amended soils indicated a dramatic increase in soil pH, CEC, Mn, P, K, Ca, B, Zn and Si. The current study indicates that the utilization of 5% maize cob biochar, pyrolyzed at 500°C, in acidic sandy loam soil, can lead to maximum enhancement in soil physical and chemical properties, as well as groundnut growth and yield parameters.

Keywords: Biochar, Groundnuts, Growth parameters, Soil, Soil nutrient.

---

1. INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the leguminous crops presented to Africa from Brazil in the 16th century (Daudi *et al*., 2018). It is the most significant crop for smallholder farmers in Tanzania for the provision of food, feed, and income (Mfaume *et al*., 2019). The crop is grown in different types of soils, preferably with more than fifty per cent sand, with pH range of 4.8 to 7 (Daudi *et al*., 2018). Heavy soils cause water logging and detachment of seeds during harvest. Nutritionally, groundnut is rich in fat, protein, carbohydrates, vitamins, and minerals (Abady *et al*., 2019). It is the world's 13th most consumed food crop, fourth for cooking oil, and third for essential proteins (Daudi *et al*., 2018). This crop is a native New World crop where early pioneers found it cultivated broadly in both Meso and South America (Abady *et al*., 2019; Alam *et al*., 2020; Daudi *et al*., 2018). It is described that groundnut remnant pericarp tissue recovered from archaeological sites in Peru dates its purposeful agricultural use to around 3900-3750 years ago (Mfaume *et al*., 2019). The domestication of this crop is supported by archaeological records between 300 and 2500 BC in Peruvian desert oases and likely first occurred in the valleys of the Paraguay and Parana rivers in the Chaco region of South America (Daudi *et al*., 2018). In Africa, the Portuguese presented groundnuts from Brazil in the 16th century (Mwatawala & Kyaruzi, 2019). Frank Samuel, head of the United Africa Company, came up with the idea in 1946 of cultivating groundnuts in Tanganyika for the production of vegetable oil (Katundu *et al*., 2014). Groundnut is consumed in many forms: uncooked, roasted, and grounded (Mfaume *et al*., 2019). Its seed cakes and straws were used for animal feeds and fertilizers (Daudi *et al*., 2018). These several uses brand groundnut as among the most treasured crops in the world.

Areas where groundnuts are grown in Tanzania include Dodoma, Tabora, Geita, Shinyanga, Songwe, Katavi, Singida, Rukwa, Lindi, Mtwara and Manyara regions (Figure 1).

Figure 1 Tanzania map showing groundnuts producing areas

The major producers of groundnuts are mainly smallholder farmers, and over 14 million people depend on groundnut cultivation (Mkandawire *et al*., 2021). Groundnut yields in Tanzania are low, standing between 500 kg/ha to 1,000 kg/ha compared with 1,500 kg/ha to 2,500 kg/ha reported in other African countries (Mfaume *et al*., 2019). For example, in Egypt, average production was 3,209.7 kg/ha; in Mauritius was 2,956 kg/acre; in Algeria was 2,774.4kg/ha; in Morocco was 2,541.5kg/ha; and in Kenya was 2,409.1kg/ha (Mfaume *et al*., 2019). Yields and productivity are highly variable among countries due to poor soil fertility, soil acidity and salinity, low soil calcium, drought, poor knowledge of good agronomic practices, unreliable rainfall, diseases and pests, including aphids, thrips, leaf minor, termites, earwigs, white grabs, groundnut bruchids and red flour beetles, low-yielding varieties, obsolete agricultural practices (Akpo *et al*., 2021). Major diseases of groundnuts are groundnut rosette, early leaf spot (*Cercospora arachidicola*), late leaf spot (*Phaeoisariopis personata*), Rusts (*Puccinia arachidis*) and aflatoxin (Alam *et al*., 2020; Horn, n.d.). Among all the constraints, drought and soil acidity are the main problems, especially in sub-Saharan Africa(Ngulube *et al.*, 2018). Soil acidity is inhibitive to nutrient availability, which has a suppressive impact on crop growth and yield (Rogers *et al*., 2022). Groundnut plants are more subtle to extreme salinity and acidity. It inhibits crop lateral branching and causes chlorosis, leading to stunted growth, poor root proliferation and low water absorption (Nte *et al*., 2022). The primary detrimental impact of soil acidity on groundnut yield is the inadequate supply of Calcium and Magnesium, resulting in poor pod filling and prolonged maturation (Nte *et al*., 2022). Achieving economical or break-even production of any crop necessitates soil conditions devoid of physical or chemical constraints (Rogers *et al*., 2022). Such soil quality demands effective management practices to attain the desired and targeted yields. One of these essential measures involves developing technology that is environmentally friendly, socially acceptable, accessible, and economically viable, specifically tailored to counteract the threat of soil acidity and fertility, ensuring profitable groundnut cultivation (Nte *et al*., 2022).

DOI: 10.31695/IJASRE.2024.6.6

The application of Biochar (The material formed when organic matter undergoes pyrolysis in a low-oxygen environment, and it serves as a beneficial soil amendment) to soil has been observed to enhance various soil properties such as structure, porosity, aggregation, bulk density, and water transmissivity (Ijaz *et al*., 2022). Biochar plays a role in stabilizing organic matter content by facilitating nutrient mineralization (Manso *et al*., n.d.). This process results in increased availability of essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) in the soil(Kuppusamy *et al*., 2016). Furthermore, Biochar helps to reduce the solubility of aluminium (Al) and manganese (Mn) in the soil, thereby mitigating their toxic effects and improving cation exchange capacity (CEC) (Ijaz *et al*., 2022). Additionally, biochar exhibits liming effects, promoting nitrogen fixation while decreasing biological oxygen demand (BOD) and biochemical oxygen demand (COD)(Nte *et al*., 2022). These favourable conditions support the optimal functioning of beneficial microorganisms in the soil, ultimately benefiting crop growth (Nte *et al*., 2022).

Biochar possesses distinctive attributes that enable it to mitigate certain challenges posed by climate change and soil conditions (Ahmadou *et al*., 2019; Denyes *et al*., 2012; Kuppusamy *et al*., 2016; Yeboah *et al*., 2020). When applied to soil, Biochar enhances soil fertility by mitigating temperature variations, neutralizing acidity, boosting cation exchange capacity (CEC), enhancing base saturation, augmenting organic matter levels, sequestering carbon, and improving nutrient and moisture retention(Bonanomi & Scala, 2015; Elad *et al*., 2011; Eyles *et al*., 2015; Kapoor *et al*., 2022; Kuppusamy *et al*., 2016; Laghari *et al*., 2015; Yeboah *et al*., 2020).

The objectives of the research were to (1) assess the response of groundnuts to different levels of biochar and (2) determine the best biochar ratio as far as groundnut growth and production are concerned. Despite the abundance of literature on the impact of soil acidity on soil and groundnut productivity and the benefit of Biochar in the soil, no research has been conducted in the specific area of focus for this study. However, it is believed to be the primary factor contributing to unsatisfactory production in groundnut-dominant agroecology. The absence of this information indicates the need for further investigation.

2. MATERIALS AND METHODS

2.1 Study location

A study was conducted in March of the year 2022 at the NM-AIST screen house in Arusha, Tanzania. The area is located at latitude 3.40°14′20″ N, longitude 36.79°58′20″ E and altitude of 1199 m.a.s.l. The area has a temperature that ranges between 10 and 30 °C (50 and 86 °F) and an average annual rainfall of 1,180 millimetres (46.46 in). The humidity varies between 65 dries weather to 90% during the cool weather and main rain seasons.

2.2 Materials

Soil: A composite soil sample was collected from five sites in Magugu ward groundnut growing areas, then through halving, coning, and quartering, a representative 300 kg soil sample that was used for the pot experiment was obtained. Magugu is the groundnut growing area which is located in the Babati district-Manyara region, located at Latitude -3.9954° or 3° 59' 43" S; Longitude. 35.78172° or 35° 46' 54" E. Magugu has an average temperature of 27°C and relative humidity of 80%. Maize cobs: Maize cobs were collected from farmers around NM-AIST for preparing biochar due to the necessity of using locally available materials for easy accessibility. Groundnut seeds: high-yielding groundnut seed (Red Mwitunde variety) was taken from Tanzania Research Institute -Naliendele (TARI Naliendele).

2.3 Methods

2.3.1 Biochar production and characterization

(i) Biochar production

The collected maize cob samples were carried to the NM-AIST laboratory for pyrolysis. Pyrolysis was done using a macro furnace at the standard effective temperature of 500℃ for one hour, cooled by natural conversion, pulverized using a grinder, and sieved using a 2mm sieve.

DOI: 10.31695/IJASRE.2024.6.6

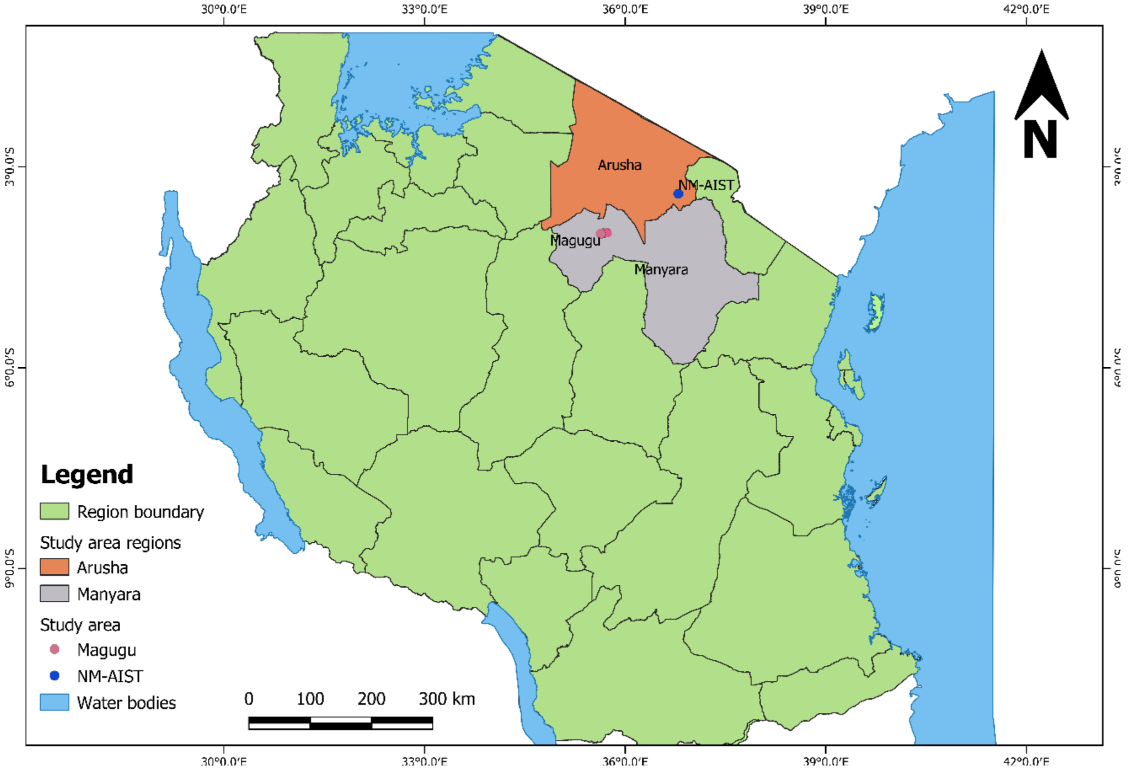

Figure 2. Map showing the study area

(ii) Biochar characterization

The microscopic analysis of biochar was carried out in Motlatsi Phari Institution-South Africa on 2 December 2023 at the magnification of 200^{xx} and Electrical heating temperature of 500 kV. A research microscope, Nikon Eclipse E-200, with fluorescence attachment, was used to know Biochar morphological characteristics using a Scanning Electron Microscope (SEM) (Fig 2). The porosity and pore size of Biochar were scrutinized using Brunauer-Emmett-Teller (BET). Characterization was done to understand the physical morphology for the determination of the ability of materials to hold moisture.

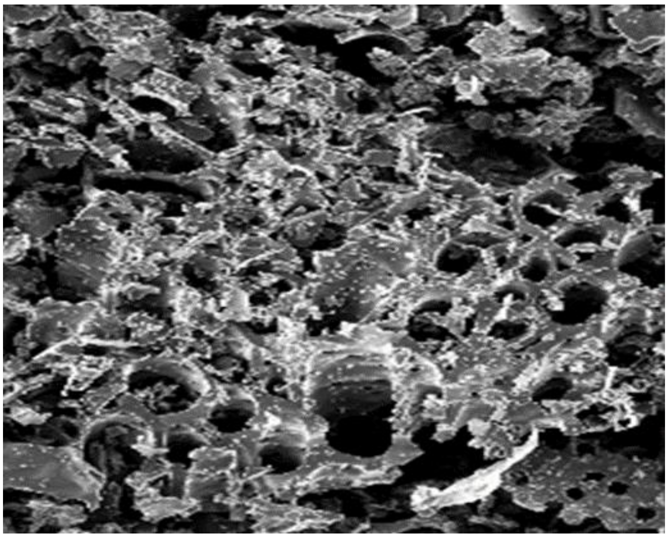

Figure 3. SEM image of maize cob Biochar taken by Motlatsi Phari institution (South Africa) showing micro and macro pores in maize cob Biochar.

Chemical characterization of Biochar was done at the Tanzania Research Institute Uyole (TARI-Uyole) laboratory.

(ii) Experimental design and layout

The screen house experiment was laid out in a completely randomized design with five replications and three observations per replication. A 2L plastic pots filled with sterilized soil were used to grow groundnuts whereby four

DOI: 10.31695/IJASRE.2024.6.6

seeds were sown and thinned to two plants per pot after two weeks. Treatments used were Biochar at the rates of (i) 2.5%, (ii) 5%, and (iii) 7.5%, and the negative control was soil without Biochar. Application of Biochar in each treatment was done before planting groundnut seeds by mixing it with soil. All the treatments were assigned at random (Figure 3), and irrigation was done regularly by using tape water. All the treatments receive the same agronomic practices.

Rep. 1	A	A	A	B	B	B	C	C	C
control							D	D	D
Rep. 2	C	C	C	B	B	B	A	A	A
control	D	D	D						
Rep. 3	A	A	A	C	C	C	B	B	B
control							D	D	D
Rep. 4	C	C	C	A	A	A	B	B	B
control	D	D	D						
Rep. 5	B	B	B	A	A	A	C	C	C
control							D	D	D

Figure 4. Figure showing the experimental design and treatments. The *Same Letter and Colour indicate observations per treatment level.* A=Pot with 2.5% biochar, B=Pot with 5% biochar, C= Pot with 7.5%, biochar and D= control (Pot with soil only). 1 to 5 is replications.

2.3.2 Soil analysis

Before the application of Biochar, the soil was taken at TARI Uyole Centre Soil Laboratory for nutrient analysis to know the initial soil fertility. Then, after harvest, sampling of soil for post nutrient analysis was done at the same laboratory. The measurement of the pH and exchangeable cations was done in 0.01 M $CaCl_2$ with a 1:2.5 soil: solution ratio (Van Reeuwijk, 1992) read on a pH meter (Hanna, HI2210-01 Benchtop pH/mV Meter) and in a 1:5 soil: solution ratio (Richards, 1954) using a conductivity meter (Hanna, HI98312 DiST® 6 EC/TDS/temperature Tester) respectively. A spectrophotometric machine was used to read the available P after analysing using the Bray 1 method; Total N was determined by the Kjeldahl method (Bremner and Mulvaney, 1982) and Organic matter by Walkley and Black's (1934) chromate reduction method. Exchangeable acidity (EA) and bases were determined by titration method (McLean 1965) and Atomic Absorption spectrophotometer (AAS) Perkin Elmer Analyst 400, respectively. Silicon (Si) content was determined by XRF and Cation exchange capacity (CEC) by the leaching method (Rowell, 1994). Soil texture was determined by the hydrometric method

2.3.3. Data collection

Data on growth parameters like shoot height (cm) was taken using a calibrated wooden ruler, leaf area (cm^2) was obtained by measuring leaf length and width using a 30 cm ruler, and the number of leaves was obtained by counting. All the growth parameters were measured once every week, starting from the second week to harvesting by randomly selected plants. At the end, all the data were recorded per treatment in an Excel sheet. Harvesting was done by hand after 120 Days from germination. The yield of each replicate in each treatment was measured and documented using a digital weighing balance. All the data was taken by randomly selecting three plants per replicate.

2.3.4. Harvesting

Decision to harvest was set at fourth months after the groundnut plants showed all symptoms of maturity by leaves yellowing. Harvesting was done by groundnut plants being separated with soil by pouring the pot contents on a clean table, and the pods were harvested by hands one by one. Shelling of the pods was done by hand. Shelled groundnut seeds were left dry to optimum moisture, packed and labelled properly as per treatment.

3. Data Analysis

Data on groundnut growth parameters (shoot length, leaf number and leaf area) and yield were checked for normality (Shapiro–Wilk's test) and homogeneity of variances (Levene's test) and analyzed using analysis of variance (ANOVA), followed by mean separation test using Tukey's honest significant difference test ($P < 0.05$) by the JAMOVI statistical

DOI: 10.31695/IJASRE.2024.6.6

package version 2.3.2(2022). Correlation analysis was also done with the same software to check for the strength of the linear relationship between treatments.

4. RESULTS AND DISCUSSION

Referring to the analysis, there is no significant (P <0.001) difference between 2.5% Biochar and control in groundnut plant growth parameters and yield, but there was a slight increase of shoot length, root length and leaf area by 9.3%, 9.7%, and 1.6%, respectively (Table 1). Statistically, a significant (P <0.001) difference was observed when 5% Biochar was applied, whereby shoot length, root length, leaf area, leaf counts and yield were increased by 29.3%, 16.3%, 35.3%, 10.5%, and 19.1%, respectively (Table 1). The correlation showed a weak positive relationship between Biochar and groundnut yield. Still, it showed a strong relationship with some growth parameters like shoot length, root length and number of leaves (Table 2). The present finding is consistent with that of Cong *et al.* (2023), who reported a significant increase in maize growth and yield when Biochar was applied to the field at the rate of 5t/ ha.

This finding might be attributed to several reasons, as stated below:

(i) Raised soil pH to the optimum level for groundnut production (Figure 7). The optimum pH for groundnut production is between 5.3 and 6.9 (Desk, 2019; Kapoor *et al*., 2022; Lehmann *et al*., 2011; Thomas *et al*., 2020). The soil used in this study was acidic (4.3 pH), which can impair plant nutrient uptake (Kapoor *et al*., 2022). Nutrients such as N, P and Mg, which are directly involved in chlorophyll production, tend to be low in acidic soils (Cong *et al*., 2023). A high quantity of total bases in Biochar and its large surface area (Figure 8) was reported to displace the H^+ ions on the soil colloids, thus levitating the low pH of the soil (Manso *et al*., n.d.).

(ii) Increased soil's total porosity due to Biochar porous structure and large specific surface area (Figure 3). This later condition was reported to enhance root system growth and soil water holding capacity (Ngulube *et al.*, 2018), improvement of plant nutrient absorption aptitude(Obia *et al*., 2016), and consequently encourage groundnut growth and yield (Figure 9). The application of Biochar in soil could also improve soil structure, enhance the accumulation of soil inorganic particles, and improve the steadiness of aggregates (Kochanek *et al*., 2022).

(iii) Increased cation exchange capacity(CEC) (Figure 7). High surface area and total pores increase the soil's ability to retain and supply nutrients to the plants, hence stabilizing their availability for plant growth (Cong *et al*., 2023). This study was synonymous with other studies which portray that the application of Biochar could significantly intensify soil nutrient contents, thus improving the growth of crops (Lu *et al*., 2016; Wiedner and Glaser, 2013). similarly, Biochar might reduce the leaching of soil nitrate, improve the soil's nitrate holding capability, and reduce the soil nitrate reductase activity, soil denitrification intensity, and soil nitrogen oxide flux so as to slow down the loss of soil nitrate nitrogen, thereby sustaining the nitrogen use efficiency of crops, and improving plant biomass (Cong *et al*., 2023).

(iv) Biochar effect on soil chemical properties (Figure 7). This scenario, apart from increasing crop available nutrients, may also affect soil microbiome and their activity by reshaping microbial community structure (Cong *et al*., 2023; Davis, 2017; Egamberdieva *et al*., 2016). Microbial modification could affect soil properties, such as the breakdown of organic matter and regulation of soil carbon dynamics and nutrient cycling, which in turn may affect plant growth and yield (Chen *et al*., 2018). Calcium and Phosphorus, which were the key elements in groundnut growth and yield, were radically increased in the soil amended with biochar (figure 7). Insufficient calcium in the soil can result in a significant number of seeds failing to develop properly, leading to empty pods or underdeveloped ones. It also causes issues such as shrivelled or malformed fruit and the production of pods without seeds (Daudi *et al*., 2018). Adequate calcium levels in the soil are crucial for achieving optimal yields and quality groundnut pods starting from the early flowering stage(Nte *et al*., 2022). Phosphorus, on the other hand, is essential for promoting root growth, improving nutrient and water uptake efficiency, and ultimately increasing yield, especially in leguminous plants that form nodules(Nte *et al*., 2022). The application of Biochar to phosphorus-deficient soil significantly boosts groundnut yield due to its vital role in various plant physiological processes (Daudi *et al*., 2018).

(v) Biochar unique structure (high surface area and many micro/macropores) (Figure 3). Osmoregulation is a vital plant physiological mechanism for fighting plant stress (Cong *et al*., 2023). Plants regulate their

DOI: 10.31695/IJASRE.2024.6.6

cellular osmotic balance via the accumulation and synthesis of osmoregulators (Soluble sugar, proline, and soluble protein) during their normal metabolic process so as to lessen the stress-induced damage in plants(Cong *et al.,* 2023). The biochar application could change the osmoregulatory condition in groundnut leaves to adapt to the soil environmental changes due to its properties of increasing soil water holding capacity, which may assure maintenance of plant water uptake and consequently increase the relative water content of the leaves (Hossain *et al*., 2020). Plant stress was reported to increase Reactive Oxygen Species (ROS), which may cause serious damage to plants if not solved in time. For example, drought conditions could increase Reactive Oxygen Species (ROS) production in plants and cause plant damage due to protein oxidation, lipid peroxidation, chlorophyll degradation, enzyme inhibition, and cell death (Kamali *et al*., 2022). The biochar amendment was reported to reduce ROS content in plants, which consequently promotes plant growth and yield (Cong *et al*., 2023).

(vi) Alteration of plant physiological status, especially root exudates. Root exudates are important hormones for the recruitment of Plant Growth Promoting Hormones (PGPR) (Feng *et al*., 2021). It is an important source of nutrients and signalling molecules for rhizosphere microbial communities, which plays a vital role in the conscription of PGPR (Cong *et al*., 2023). Biochar improves plant growth and yield by directly affecting their physiological status and indirectly through the alteration of soil physiochemical characteristics and promotion of PGPR (Loi *et al*., 2020). Its single application may achieve a long-term effect since it can exist in soil for thousands of years (Cong *et al*., 2023).

The analysis also shows that when biochar was applied to above 5%, groundnut growth and yield were reduced compared to 5% biochar (Figure 6). Similar findings were documented by Cong *et al.* (2023), who reported a decrease in crop yield due to nutrient uptake inhibitory effect in soil amended with a high amount of Biochar. The results show raised soil pH to 7.9 when a 7.5% Biochar rate was used (Figure 7). Munsanda *et al*., (2018) reported a dramatic reduction in bean yield planted in the soil amended with Biochar compared to the control. A higher Biochar application rate leaves less space in the soil pores to hold more water at each irrigation and causes anaerobic conditions in the soil, thus poor soil aeration hence low yield. Biochar contains pollutants that may induce phytotoxicity and cytotoxicity compounds due to its production process (high-temperature pyrolysis under an oxygen-limited environment) (Lu *et al*., 2016). These compounds play a substantial role as plant growth promotors in low dosages, but they are detrimental to plants and soil microbiomes when used in higher quantities (Bonanomi and Scala, 2015; Jaiswal *et al*., 2014, 2018). Moreover, the application of Biochar in high quantity could adsorb cationic nutrients due to its negatively charged surface, which may lead to incomplete utilization by plants and negatively impact plant growth and yield (Cong *et al*., 2023). The effectiveness of Biochar is the function of raw materials, soil properties, pyrolysis temperature and climate (Elad *et al.*, 2011; Frenkel *et al*., 2017; Jaiswal *et al*., 2014; Jaiswal and Graber, 2017; Luigi *et al*., 2022); hence, further research is needed for the verification and optimization of this technology in other conditions, as explained in the present study, to achieve its potential benefits.

Figure 5. Picture showing groundnut at blooming stage with different biochar levels. (A) 90 Days groundnut with zero Biochar, (B) 90 Days groundnut with 2.5%Biochar, (C) 90 Days groundnut amended with 5%Biochar, and (D) 90 Days groundnut amended with 7.5% Biochar.

DOI: 10.31695/IJASRE.2024.6.6

Table 1. ANOVA table showing the effect of different levels of biochar on groundnut growth parameters and yield

Treatment	Shoot length	Leaf area	No. of leaves	Root length	Yield
7.5BCH	21.72a	6.55a	23.80a	8.16a	8.87a
NCTR	24.16b	8.86b	34.20b	11.63b	10.70b
2.5BCH	27.42c	9.01b	34.22b	13.28c	11.90b
5BCH	31.20d	10.25c	37.80c	15.67d	15.74c
cv	3.1	5.1	3.2	6.1	6.2
p-value	<.001	<.001	<.001	<.001	<.001
df	16	16	16	16	16

The same letters indicate no statistical difference within or/and between the treatments

Table 2. Kendall's rank correlation coefficient between biochar and aflatoxin

No.leaves(cm)	**1.000**				
Root_Lth(cm)	0.638	1.000			
shoot_Lth(cm)	0.7034	0.7474	1.000		
Bch	0.1412	0.0118	0.118	1.000	
Yield_(g)	0.6489	0.7684	0.7895	0.1	1.000
	No. leaves(cm)	R.Lth_(cm)	S. Lth_(cm)	Bch	Yield (g)

No. leaves=Number of leaves, Root Lth=Root length, S. Lth=shoot length, Bch=Biochar, cm=Centimeter, g=gram

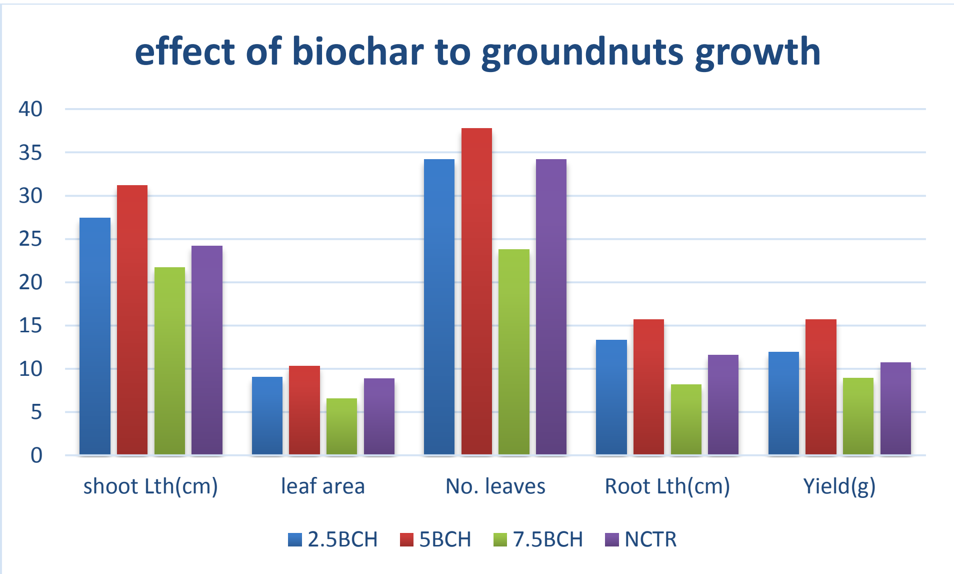

Figure 6. Effect of Biochar levels on groundnut growth parameters and yield.

DOI: 10.31695/IJASRE.2024.6.6

key: 2.5BCH= Soil amended with 2.5% Biochar, 5BCH= Soil amended with 5% Biochar, 7.5BCH=Soil amended with 7.5% Biochar. Lth= Length, No.=Number, cm=Centimeter, g=Gram

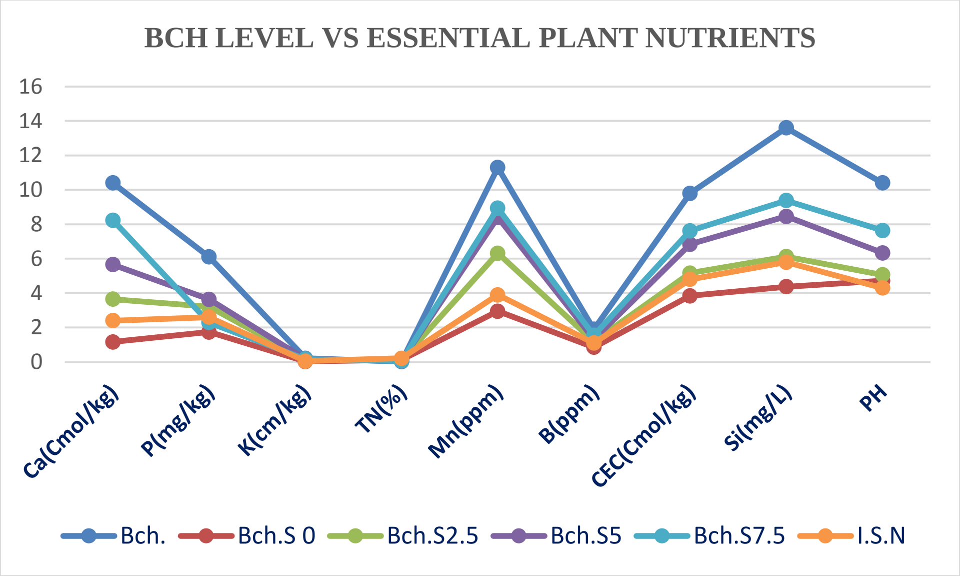

Figure 7. Effect of Biochar levels on soil nutrients under controlled experiment.

Note: Bch= Biochar, Bch.S 0= Soil without Biochar, Bch.S2.5= Soil amended with 2.5% Biochar, Bch.S5=Soil Amended with 5% Biochar, Bch.S7.5= Soil amended with 7.5% Biochar and I.S.N=Initial Soil Nutrient. Bo=Boron, Ca=Calcium, CEC=Cation exchange capacity, =K=Potassium, Mn=Manganese, P=Phosphorus, Si=Silicon, N=Nitrogen.

5. CONCLUSION

A sound management strategy to enhance crop yield is by amending the soil to maintain optimal conditions. Inadequate soil fertility and low pH levels negatively impact groundnut productivity, posing challenges amid climate change and worsening land degradation. The drawbacks outweigh any perceived benefits. Applying biochar derived from maize cobs to the soil demonstrates remarkable efficacy in improving both its physical and chemical properties. Significant enhancements in groundnut growth and yield parameters were observed in pots treated with biochar compared to untreated ones. This study provides valuable insights for groundnut farmers and other stakeholders, highlighting the potential to mitigate soil degradation and enhance productivity through the application of maize cob biochar. The efficacy of biochar depends on factors such as the raw materials used, soil characteristics, pyrolysis temperature, and climatic conditions. Therefore, additional research is necessary to verify and optimize this technology under various conditions, as outlined in the current study, in order to fully realize its potential benefits to other crops and the environment.

6. COMPETING INTERESTS

The authors declare that they have no competing interests

Funding

This research was funded by the Tanzania Initiative for Preventing Aflatoxin Contamination (TANIPAC) under the Tanzania Ministry of Agriculture.

Availability of Data and Materials

Data will be available upon reasonable request to the corresponding author

Acknowledgement

I acknowledge the Tanzania Initiative for Preventing Aflatoxin Contamination (TANIPAC) project under the Tanzania Ministry of Agriculture for funding my studies, the TARI UYOLE laboratory and all laboratory scientists who helped in soil analysis, NM-AIST for giving me screen houses for doing my experiments and all other people who contributed to this study in one way or another to accomplish this work.

REFERENCES

Abady S, Shimelis H, Janila P, Mashilo J. (2019). Groundnut (Arachis hypogaea L.) improvement in sub-Saharan Africa: A review. *Acta Agriculturae Scandinavica Section B: Soil and Plant Science*, *69*(6), 528–545. https://doi.org/10.1080/09064710.2019.1601252

Ahmadou A, Napoli A, Durand N, Montet D. (2019). *High physical properties of cashew nut shell biochars in the adsorption of mycotoxins*. *6*, 18–28.

Akpo E, Bakari H, Lukurugu GA, Daudi H, Muricho G, Minja A, Nzunda J, Ojiewo C, Varshney R. (2021). *Comparative advantage of newly-released varieties of groundnut in Tanzania*. *September*, 1–7.

Alam T, Anco DJ, Rustgi S. (2020). *Management of Aflatoxins in Peanut*. https://doi.org/10.34068/report7

Bonanomi, G., & Scala, F. (2015). *A " black " future for plant pathology? Biochar as a new soil amendment for controlling plant diseases BIOCHAR AS A NEW SOIL AMENDMENT FOR CONTROLLING PLANT DISEASES*. *November*. https://doi.org/10.4454/jpp.v97i2.3381

Chen H, Ma J, Wei J, Gong X, Yu X, Guo H, Zhao Y. (2018). Biochar increases plant growth and alters microbial communities via regulating the moisture and temperature of green roof substrates. *Science of the Total Environment*, *635*, 333–342. https://doi.org/10.1016/j.scitotenv.2018.04.127

Cong M, Hu Y, Sun X, Yan H, Xu W, Jia H. (2023). *Long-term effects of biochar application on the growth and physiological characteristics of maize*. *June*, 1–15. https://doi.org/10.3389/fpls.2023.1172425

Daudi H, Shimelis H, Laing M, Okori P, Mponda O. (2018). Groundnut production constraints, farming systems, and farmer-preferred traits in Tanzania. *Journal of Crop Improvement*, *32*(6), 812–828. https://doi.org/10.1080/15427528.2018.1531801

Davis DD. (2017). Biochar as a soil amendment: Effects on heat and water movement in soil. *Journal of Geology & Geophysics*, *06*(06), 8719. https://doi.org/10.4172/2381-8719-c1-015

Denyes MJ, Langlois VS, Rutter A, Zeeb BA. (2012). The use of biochar to reduce soil PCB bioavailability to Cucurbita pepo and Eisenia fetida. *Science of the Total Environment*, *437*, 76–82. https://doi.org/10.1016/j.scitotenv.2012.07.081

Desk S. (2019). *Effect of pyrolysis temperature on ochratoxin A adsorption mechanisms and kinetics by cashew nut shell biochars*. 877–888. https://doi.org/10.25177/JFST.4.7.RA.565

Egamberdieva D, Wirth S, Behrendt U, Allah EFA. (2016). *Biochar Treatment Resulted in a Combined Effect on Soybean Growth Promotion and a Shift in Plant Growth Promoting Rhizobacteria*. *7*(February), 1–11. https://doi.org/10.3389/fmicb.2016.00209

Elad Y, Cytryn E, Meller Harel Y, Lew B. (2011). The Biochar Effect: plant resistance to biotic stresses. *Phytopathologia Mediterranea*, *50*(3), 335–349. https://doi.org/10.2307/26556455

Eyles A, Bound SA, Oliver G, Corkrey R, Hardie M, Green S, Close DC. (2015). Impact of biochar amendment on the growth , physiology and fruit of a young commercial apple orchard. *Trees*. https://doi.org/10.1007/s00468-015-1263-7

Feng H, Hou X, Lv Y, Zhang N, Liu Y, Xu Z, Miao Y, Krell T, Shen Q, Zhang R. (2021). Chemotaxis of beneficial rhizobacteria to root exudates: The first step towards root–microbe rhizosphere interactions. *International Journal of Molecular Sciences*, *22*(13). https://doi.org/10.3390/ijms22136655

Frenkel O, Jaiswal AK, Elad Y, Lew B, Kammann C, Graber ER. (2017). *The effect of biochar on plant diseases : what should we learn while designing biochar substrates ?* *6897*(June).

https://doi.org/10.3846/16486897.2017.1307202

Horn BW. (n.d.). *Colonization of wounded peanut seeds by soil fungi: selectivity Colonization of wounded peanut seeds by soil fungi: selectivity for species from for species from Aspergillus Aspergillus section section Flavi Flavi CORE View metadata, citation and similar papers at core.ac.uk provided by DigitalCommons@University of Nebraska*. https://digitalcommons.unl.edu/usdaarsfacpub/1565

Hossain MZ, Bahar MM, Sarkar B, Donne SW, Ok YS, Palansooriya KN, Kirkham MB, Chowdhury S, Bolan N. (2020). Biochar and its importance on nutrient dynamics in soil and plant. In *Biochar* (Vol. 2, Issue 4). Springer Singapore. https://doi.org/10.1007/s42773-020-00065-z

Ijaz M, Afzal A, Ali SR, Nawaz HH, Altaf R, Jannat FT, Syed S. (2022). Aflatoxin: Can Be Managed By Soil Amendments in Groundnut? *Pakistan Journal of Phytopathology*, *34*(1), 65–70. https://doi.org/10.33866/phytopathol.034.01.0749

Jaiswal AK, Elad Y, Graber ER, Cytryn E, Frenkel O. (2018). Soil-borne disease suppression and plant growth promotion by biochar soil amendments and possible mode of action. *Acta Horticulturae*, *1207*, 69–76. https://doi.org/10.17660/ActaHortic.2018.1207.9

Jaiswal AK, Frenkel O, Elad Y, Lew B, Graber ER, Lew B. (2014). *Non-monotonic influence of biochar dose on bean seedling growth and susceptibility to Rhizoctonia solani : the " Shifted R max -Effect ."* https://doi.org/10.1007/s11104-014-2331-2

Jaiswal A K, Graber R. (2017). *Linking the Belowground Microbial Composition , Diversity and Activity to soilborne Disease suppression and Growth promotion of tomato Amended with Biochar*. *October 2016*, 1–17. https://doi.org/10.1038/srep44382

Kamali M, Sweygers N, Al-salem S, Appels L, Aminabhavi TM, Dewil R. (2022). Biochar for soil applications-sustainability aspects , challenges and future prospects. *Chemical Engineering Journal*, *428*(July 2021), 131189. https://doi.org/10.1016/j.cej.2021.131189

Kapoor A, Sharma R, Kumar A, Sepehya S. (2022). Biochar as a means to improve soil fertility and crop productivity : a review. *Journal of Plant Nutrition*, *0*(0), 1–9. https://doi.org/10.1080/01904167.2022.2027980

Katundu BM A, Mhina ML, Arbogast G, Kumburu NP. (2014). Socio-economic factors limiting smallholder groundnut production in Tabora Region. In *Policy Research for Development* (Issue September).

Kochanek J, Soo RM, Martinez C, Dakuidreketi A, Mudge M. (2022). Resources , Conservation & Recycling Biochar for intensification of plant-related industries to meet productivity , sustainability and economic goals : A review. *Resources, Conservation & Recycling*, *179*(December 2021), 106109. https://doi.org/10.1016/j.resconrec.2021.106109

Kuppusamy S, Thavamani P, Megharaj M. (2016). *Agronomic and remedial bene fi ts and risks of applying biochar to soil : Current knowledge and future research directions*. *87*, 1–12.

Laghari M, Mirjat M S, Hu Z, Fazal S, Xiao B, Hu M, Chen Z, Guo D. (2015). Effects of biochar application rate on sandy desert soil properties and sorghum growth. *Catena*, *135*, 313–320. https://doi.org/10.1016/j.catena.2015.08.013

Lehmann J, Rillig MC, Thies J, Masiello CA, Hockaday WC, Crowley D. (2011). *Soil Biology & Biochemistry Biochar effects on soil biota e A review*. *43*, 1812–1836. https://doi.org/10.1016/j.soilbio.2011.04.022

Loi M, Paciolla C, Logrieco AF, Mulè G. (2020). Plant Bioactive Compounds in Pre- and Postharvest Management for Aflatoxins Reduction. *Frontiers in Microbiology*, *11*(March). https://doi.org/10.3389/fmicb.2020.00243

Lu Y, Rao S, Huang F, Cai Y, Wang G, Cai K. (2016). Effects of Biochar Amendment on Tomato Bacterial Wilt Resistance and Soil Microbial Amount and Activity. *International Journal of Agronomy*, *2016*. https://doi.org/10.1155/2016/2938282

DOI: 10.31695/IJASRE.2024.6.6

Luigi M, Manglli A, Dragone I, Antonelli MG, Contarini M, Speranza S, Bertin S, Tiberini A, Gentili A, Varvaro L, Tomassoli L, Faggioli F. (2022). *Effects of Biochar on the Growth and Development of Tomato Seedlings and on the Response of Tomato Plants to the Infection of Systemic Viral Agents*. *13*(May), 1–15. https://doi.org/10.3389/fmicb.2022.862075

Manso FA. (n.d.). *Use of Corn Cob and Rice Husk Biochar as Liming Materials in Acid Soils*.

Mfaume J, Matemu A, Mbega ER. (2019). *Distribution and occurrence of indigenous strains of atoxigenic and toxigenic Aspergillus section Flavi in groundnut producing areas of Southern Tanzania*. *14*(2), 14–20.

Mkandawire LM, Mhango W, Saka VW, Kabambe VH, Juma S, Goodman J, Brandenburg RL, Jordan DL. (2021). Influence of Plant Population and Harvest Date on Peanut (Arachis hypogaea) Yield and Aflatoxin Contamination . *Peanut Science*, *48*(1), 33–39. https://doi.org/10.3146/ps20-30.1

Munsanda N, Alice MM, Elijah P, Samuel CM, Hendrix C, Victor S, Rick LB. (2018). Effects of biochar and gypsum soil amendments on groundnut (Arachis hypogaea L.) dry matter yield and selected soil properties under water stress. *African Journal of Agricultural Research*, *13*(21), 1080–1090. https://doi.org/10.5897/ajar2018.13123

Mwatawala H, Kyaruzi P. (2019). An exploration of factors affecting groundnut production in Central Tanzania: Empirical evidence from Kongwa District, Dodoma Region. *International Journal of Progressive Sciences and Technologies (IJPSAT)*, 122–130.

Ngulube M, Mweetwa AM, Phiri E, Muriu SC, Chalwe H, Shitumbanuma V, Brandenburg RL. (2018). *Effects of biochar and gypsum soil amendments on groundnut (Arachis hypogaea L .) dry matter yield and selected soil properties under water stress*. *13*(21), 1080–1090. https://doi.org/10.5897/AJAR2018.13123

Nte NJ, Sunday IT, Solomon AO, Onyeogoziri EC, Uguru NS, Nwangele MB, Ebuka OJ. (2022). Response of groundnut to lime sources on acid sandy loam. *Asian Journal of Agriculture and Biology*, *2022*(3), 1–11. https://doi.org/10.35495/ajab.2020.08.452

Obia A, Mulder J, Martinsen V, Cornelissen G, Børresen T. (2016). In situ effects of biochar on aggregation, water retention and porosity in light-textured tropical soils. *Soil and Tillage Research*, *155*, 35–44. https://doi.org/10.1016/j.still.2015.08.002

Rogers PM, Yanda PZ, Pauline NM, Haikola S, Hansson A, Fridahl M. (2022). Effects of Biochar on Soil Fertility and Crop Yields: Experience from the Southern Highlands of Tanzania. *Tanzania Journal of Science*, *48*(2), 256–267. https://doi.org/10.4314/tjs.v48i2.3

Thomas E, Borchard N, Sarmiento C, Atkinson R, Ladd B. (2020). Key factors determining biochar sorption capacity for metal contaminants : a literature synthesis. *Biochar*, *0123456789*. https://doi.org/10.1007/s42773-020-00053-3

Wiedner K, Glaser B. (2013). Biochar Impact on Plant Resistance to Disease. *Biochar and Soil Biota*, *May 2020*, 49–76. https://doi.org/10.1201/b14585-4

Yeboah E, Asamoah G, Ofori P, Amoah B, Agyeman KO. (2020). Method of biochar application affects growth, yield and nutrient uptake of cowpea. *Open Agriculture*, *5*(1), 352–360. https://doi.org/10.1515/opag-2020-0040

*Corresponding Author. E-mail**:** **joshua.ibrahim@nm-aist.ac.tz,**

DOI: 10.31695/IJASRE.2024.6.6