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Research Application Summary

Assessment of the effect of shea nut cake biochar on tomato (*Solanum lycopersicon* L.) growth

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Abstract

This study was conducted to assess the effect of Shea nut cake biochar on tomato growth, evaluate the soil-biochar ratio necessary for enhanced tomato growth and assess the response of local and Petomech variety to soil-biochar treatment. Both varieties were raised in two set-ups (set-up A for local variety and set-up B for Petomech variety) comprising experimental pots of six treatments where soil level varied but amount of biochar was maintained constant; T1 (1S:1B), T2 (2S:1B), T3 (3S:1B), T4 (4S:1B), T5 (5S:1B), T6 (6S:1B) and control (only soil). Plants at T1, T2 and T3 all wilted and died five days after transplanting, leaving T4, T5, T6 and control on which data on growth parameters were taken and analysed. Results from the study revealed that Shea nut cake biochar in T6 of both set-ups significantly increased the performance of tomato. Plant height, stem girth, leaf area index and number of leaves increased as soil levels increased with biochar levels constant indicating that decreased soil levels at constant biochar levels decreased the performance of the tomato plants. Treatments T4 and T5 recorded lower tomato performance. Soil pH (6.55) increased as shea nut cake biochar treatments were applied. However, pH concentration decreased as soil levels were increased in treatments as T4 recorded the highest pH (8.39) and T6 recorded the least (8.13). Petomech variety performed better in all treatments as compared to the local variety following the growth parameters recorded and analyzed.

Keywords: Biochar, Petomech, Shea nut cake, tomato

Resume

Cette étude a été menée pour évaluer l’effet du biochar de tourteau de noix de karité sur la croissance de la tomate, évaluer le ratio sol-biochar nécessaire pour améliorer la croissance de la tomate et évaluer la réponse d’une variété locale et de la variété Petomech au traitement sol-biochar. Les deux variétés ont été plantées dans deux installations (installation A pour la variété locale et installation B pour la variété Petomech) comprenant des pots expérimentaux de six traitements où le niveau de sol a varié mais la quantité de biochar a été maintenue constante ; T1 (1S:1B), T2 (2S:1B), T3 (3S:1B), T4 (4S:1B), T5 (5S:1B), T6 (6S:1B) et le contrôle (seulement le sol). Les plantes de T1, T2 et T3 ont toutes flétri et sont mortes cinq jours après la transplantation, laissant T4, T5, T6 et le contrôle sur lesquels les données sur les paramètres de croissance ont été prises et analysées. Les résultats de l’étude ont révélé que le biochar de tourteau de noix de karité dans T6 des deux installations a augmenté de manière significative la performance de la tomate. La hauteur des plantes, la circonférence de la tige, l’indice de surface foliaire et le nombre de feuilles ont augmenté lorsque les niveaux de sol ont augmenté avec des niveaux de biochar constants, ce qui indique que des niveaux de sol réduits à des niveaux de biochar constants ont diminué la performance des plants de tomates. Les traitements T4 et T5 ont enregistré une performance plus faible des tomates. Le pH du sol (6,55) a augmenté avec l’application des traitements au biochar de tourteaux de karité. Cependant, le pH a diminué lorsque les niveaux de sol ont été augmentés dans les traitements, le T4 a enregistré le pH le plus élevé (8,39) et le T6 le moins élevé (8,13). La variété Petomech a donné de meilleurs résultats dans tous les traitements par rapport à la variété locale suivant les paramètres de croissance enregistrés et analysés.

Mots-clés : Biochar, Petomech, tourteau de noix de karité, tomate.

Introduction

Biochar is a solid material that is produced from the conversion of biomass under higher temperature with limited oxygen conditions (IBI, 2012). Its use in the Agricultural and Environmental sector distinguishes it from charcoal which is used in the Energy sector (Lehmann and Joseph, 2009). Shea nut cake is the residue obtained after extracting butter from shea nuts. Laboratory analysis of the cake has shown the presence of a reasonable amount of the following elements: N, P. K, Na, Ca, Mg, Cu and Mg, which highly support plant growth (Abdul-Mumeen *et al.,* 2013). Soil fertility is a great concern in the production of vegetables such as tomato. The continuous decline in soil fertility has led to the use of agrochemicals such as inorganic fertilizers which sometimes has left lethal residual soil effects. The input cost of chemical fertilizers however, scares peasant farmers who farm purposely to feed their families as well as those engaged in commercial production (Jansen *et al.,* 2004). Soil fertility enhancement is required to reverse the trend of declining agricultural productivity since its management holds the key to enhancing food production (Eghball, 2001). This paves way for the use of organic materials such as crop residues and some by-products from agro processing industries such as shea nut cakes to provide cheaper alternative as well as supply nutrients to the soil and improve soil properties (Awiti *et al.,* 2002). The preparation of biochar from shea nut cake following its proximate analysis holds a potential in effectively supporting plant growth. The aim of this study was therefore to assess the effect of shea nut cake biochar on tomato growth, evaluate the soil biochar ratio necessary for enhanced tomato growth and assess the response of local and Petomech variety to soil-biochar treatment.

Materials and methods

Experimental site. The study was carried out at the University for Development Studies Plant House on Nyankpala Campus located Latitude 9^{0} 25^{0} 41^{0}N and Longitude 0 ^{0} 58 ^{0} 42 ^{0}W and 183m above sea level. The soil is an Alfisol under USDA classification, and Savanna Ochrosol under the Ghanaian system of classification (NAES Annual report, 1984). The entire study took place between January and May 2019.

Source of study materials. Local tomato seeds were obtained from a local farmer in Nyankpala located within the Tolon district while Petomech variety was purchased from an agro chemical shop within the Tamale metropolis. Shea nut cake was obtained from SEKAF Co. LTD., a shea processing company off Nyankplala-Tamale road. Black soil samples were randomly taken from a field outside the plant house.

Shea cake biochar preparation. Shea nut cake samples obtained were dried at the glasshouse to expel moisture and later divided into proportions to be burnt in batches. Using an improvised barrel pyrolyser, a small quantity of dry grasses was placed at its bottom. First batch of the cake biomass was spread on the dry grasses in the pyrolyser and a second layer of dry grasses placed on it. A starter was then used to initiate the burning process. The whole unit was then set ablaze to begin burning of the shea nut cake into biochar. The pyrolyser was then covered with a lid with a hole created at its centre and a chimney placed on it to cover the hole and aid the process of pyrolysis (slow burning in the presence of limited oxygen). The biomass was allowed to burn for about 3-6 hours until it was charred. Frequent checks were conducted to ensure efficient process control. Charred hot red biomass was then discharged and cooled down using sprinkled water. The process was repeated to burn the batch of shea nut cake left.

Soil preparation, nursing and transplanting of tomato seedlings. Soils obtained were sterilized using an improvised barrel steam sterilization method. A barrel was placed on a four concrete blocks laid to provide anchorage, stability as well as space for burning firewood. Soil samples obtained were screened for sticks, metals, plastics, twigs and gravels after which they were placed in a jute sack. The barrel was then filled with water and the firewood set ablaze beneath the barrel to provide heat for steaming the soil as the water heats up. A metallic stand was placed in the water and the jute sack of soil placed on top of it thus, creating a little space between the sack and the water. The barrel was covered by a lid and soil sterilized for 2 hours. The process was repeated to sterilize the batch of soil left.

The nursery was set up in the planthouse using improvised nursery containers cut out from "yellow gallons". Holes were perforated beneath the container to ensure proper aeration and drainage. Emerged seedlings were watered morning and evening and weeds controlled manually by hand picking to reduce competition for air, moisture and nutrients. Seedlings were hardened occasionally and uniform ones transplanted after three weeks.

Experimental design and treatments. Two experimental set ups were established and data were collected on growth parameters of the tomato plants in each pot. Set-up A consisted of plants grown from the local seeds whilst Set-up B consisted of plants grown from the purified seeds obtained (PETOMECH variety). The experiment was laid out in a complete randomized design in 7 L buckets with six treatments and control and five replicates each with two plants per pot where biochar ratio remained unchanged as soil ratio varied. Treatments included T1 (1S:1B), T2 (2S:1B), T3 (3S:1B), T4 (4S:1B), T5 (5S:1B), T6 (6S:1B) and Control (only soil) where "S" stands for parts of soil, and "B" stands for parts of biochar at 500g.

Data were collected on pH of soil, biochar and treatments using a pH meter. Plant growth parameters including plant height, number of leaves, stem girth and leaf area index (LAI) were measured at 2, 4 and 6 weeks after transplanting (WATP).

Data taken were subjected to Analysis of Variance (ANOVA) using GENSTAT discovery Edition 4, to indicate significant treatment differences. Treatment means were separated using Least Significant Difference (LSD) at 5 % level of significance to ascertain if the treatments were statistically different from each other.

Results and discussion

Death of plants. Tomato plants for both varieties under T1(S1:B1), T2(S2:B1) and T3(S3:B1) all wilted and died after five days of transplanting into their various treatment pots. This was chiefly attributed to the presence of Pb in shea nut cake as reported by Abdul-Mumeen *et al.* (2013). Akinci *et al.* (2010) similarly reported the negative impact of lead concentrations in tomato as root, shoot and leaf were negatively affected. Obroucheva *et al.* (1998) also reported retarded root growth in maize as Pb arrested cell divisions and decreased the final lengths of the elongating cells. Survival of plants at T4, T5 and T6 suggests decreasing alkalinity and insignificant effect of Pb on the plants. This also indicates significant plant growth as a result of nutrients present in shea nut cake in addition to that of the soil. Control survived due to the suitability of the soil for tomato growth at 6.27 pH.

pH effect on soil treatments post-experiment. pH concentrations of treatments decreased with increased soil ratio. The T6 recorded the least alkaline concentration while T4 recorded the highest alkaline concentration. Control however had an acidic concentration. Lehmann *et al.* (2011), Alburquerque *et al.* (2014) and Cui *et al.* (2015) similarly reported an increase in pH with decreased soil level. Chirenje and Ma (2002) attributed this to ash accretion while Jeffery *et al.* (2011) indicated that the high surface area and porous structure of biochar may increase the cationic exchange capacity of the soil.

Table 1. Mean pH of soil treatments at the end of the experiment

Treatment	pH concentration	Description
T4 (4S:1B)	8.388	Alkaline
T5 (5S:1B)	8.366	Alkaline
T6 (6B:1B)	8.134	Alkaline
Control (only soil)	6.270	Acidic
LSD	0.149	
F pr.	< .001	

Plant height. There were significant differences between treatments at 5 % level of significance for both varieties. It was observed that treatment levels (T4-T6) increased plant height of tomato for both local and Petomech varieties throughout the six weeks. Shea nut cake biochar had a significant effect on tomato plant height for both varieties. The T6 (six parts of soil: one part of biochar) recorded the highest mean plant height for both varieties while T4 (four parts of soil: one part of biochar) and control (only soil) recorded the least for Petomech and local varieties, respectively. This could be attributed to a decrease in alkalinity at T6 and the presence of major nutrients in shea nut cake in addition to that of the soil. This is in accordance with Grabber *et al.* (2010) who similarly reported an increase in plant height of tomato at lower biochar application. However, Howard (2011) also reported a decrease in plant height of maize and soybean as a result of higher biochar application rates.

Number of leaves. Shea nut cake biochar amendment had a significant effect on the leaf number of tomato. At six weeks, T6 recorded the highest leaf number for both varieties while T4 recorded the least. It was observed that tomato plants with highest leaf number stemmed from the high soil ratio while those with least leaf number from low soil ratio. This agreed with the findings in a study conducted by Graber *et al.* (2010) which indicated significant greater numbers of leaf nodes on pepper plants in biochar treatments as compared to the control. Viger *et al.* (2015) similarly reported increased leaf number in lettuce and *Arabidopsis thaliana*. A study conducted by Noguera *et al.* (2012) in rice also revealed that the biochar treated soil also significantly increased the number of leaves as compared to earthworm treated soil.

Table 2. Effect of shea nut cake biochar on tomato plant height

	Mean plant height (cm)					
	Local variety			Petomech variety		
Treatment	2 WATP	4 WATP	6 WATP	2 WATP	4 WATP	6 WATP
T4 (4S:1B)	10.10	20.00	36.78	11.77	27.00	54.00
T5 (5S:1B)	9.44	20.34	41.74	13.23	30.86	61.72
T6 (6S:1B)	12.04	25.22	50.64	16.25	34.30	68.60
Control (only soil)	7.98	17.18	36.00	16.63	28.70	57.40
LSD (0.05)	3.41	4.92	5.00	2.78	1.73	3.46
F pr.	0.13	0.03	< .01	0.01	< .01	< .01

WATP= Weeks after transplanting

Table 3. Effect of shea nut cake biochar on tomato leaf number

	Mean number of leaves					
	Local variety			Petomech variety		
Treatment	2 WATP	4 WATP	6 WATP	2 WATP	4 WATP	6 WATP
T4 (4S:1B)	4.40	7.80	11.20	3.40	6.80	11.56
T5 (5S:1B)	5.60	9.80	14.00	4.60	7.20	12.24
T6 (6S:1B)	6.40	10.20	15.40	5.20	8.40	15.98
Control (only soil)	4.60	7.40	11.40	5.00	7.40	12.58
LSD (0.05)	1.18	1.90	1.36	1.01	1.21	2.06
F pr.	0.01	0.02	< .01	0.01	0.00	0.00

WATP= Weeks after transplanting

Stem girth. There was a significant effect of Shea nut cake biochar on stem girth of both tomato varieties. As soil ratio increased and biochar amount remained constant, the stem girth of both plant varieties increased. The T6 recorded the highest stem girth for both varieties while T4 and control recorded the least for both varieties, respectively. This agreed with the study conducted by Situmeang *et al.* (2015) who reported on dose bamboo biochar amended medium which had a significant effect on maize stem girth as compared to untreated fertilizer medium. Viger *et al.* (2015) also observed similar trends in *Arabidopsis thaliana* and lettuce.

Table 4. Effect of shea nut cake biochar on tomato stem girth

	Mean stem girth (cm)					
	Local variety			Petomech variety		
Treatment	2 WATP	4 WATP	6 WATP	2 WATP	4 WATP	6 WATP
T4 (4S:1B)	0.92	1.32	1.76	1.12	1.48	1.82
T5 (5S:1B)	1.12	1.50	2.60	1.30	1.68	2.04
T6 (6S:1B)	1.30	1.50	2.64	1.32	1.74	2.50
Control (only soil)	1.20	1.50	1.88	1.14	1.52	1.82
LSD (0.05)	0.22	0.26	0.27	0.14	0.14	0.22
F pr.	0.02	0.00	< .01	0.01	0.01	< .01

WATP= Weeks after transplanting

Leaf area index. There was significant effect of Shea nut cake biochar on the leaf area index of varieties of the tomato plants under study. Leaf area index of both varieties increased as soil levels were increased while biochar was constant throughout the six weeks. The T6 recorded the highest leaf area index for both varieties while the control recorded the least. This may be as a result of decreased alkalinity at T6 and the presence of major nutrients in shea nut cake in addition to that of the soil. This is in accordance with a research carried out by Alburquerque *et al.* (2010) who reported a significant positive effect of biochar on leaf area, specific leaf area and leaf area ratio as compared to control. Graber *et al.* (2010) also reported similar findings on pepper and tomato plants as leaf area index showed significant responses to biochar treatments at all levels. Harel *et al.* (2012) also reported significant effect of biochar-sand treatment on leaf area index in pepper.

Table 5. Effect of Shea nut cake biochar on tomato Leaf area index

	Mean leaf area index (cm^2)s					
	Local variety			Petomech variety		
Treatment	2 WATP	4 WATP	6 WATP	2 WATP	4 WATP	6 WATP
T4 (4S:1B)	8.33	23.33	102.10	11.51	50.70	105.70
T5 (5S:1B)	9.61	24.61	156.40	15.91	76.50	168.30
T6 (6S:1B)	10.28	25.28	171.90	17.89	83.90	182.70
Control (only soil)	8.74	23.74	78.10	22.08	57.40	95.40
LSD	1.38	1.38	12.10	4.40	9.55	19.23
F pr.	0.04	0.04	< .01	0.02	< .01	< .01

WATP= Weeks after transplanting

Soil-biochar ratio necessary for enhanced tomato growth. Results from the study revealed that plants may perform better with the ideal soil-biochar ratio. Plants from T1 to T3 died leaving those in T4 to T6. Data analyzed showed that plants under T6 performed better as compared to T5, T4 and control. As soil ratio increased tomato plants recorded enhanced growth indicating that the 2:1 soil- biochar combination was not effective hence, could not support tomato plant growth. The 2:1 soil-biochar combination may be dependent on the type of material used to prepare biochar. It was therefore projected that soil ratio when increased beyond T6 may produce significant positive effects in tomato growth, however, there may be possible thresholds as well. This agreed with a study conducted by Chamkha *et al.* (2002) as plants in pot experiment showed decreased growth with increasing shea nut cake application rate and suggested decomposition may be due to the presence of tannins. Roger *et al.* (1999) also reported that the antimicrobial action of shea nut cake could have negative effect on organic matter breakdown and lethal substances to growth of plants is capable of being released at the early stages of the decomposition (Van Scholl and Nieuwenhuis, 2007).

Response of local and petomech varieties to soil-SNC biochar treatments. Results from the study revealed that the petomech varieties performed better under all soil- biochar treatments as compared to the local varieties. This was reflected in the significant effect of shea nut cake biochar on the Petomech varieties as observed in all the growth parameters analyzed throughout the six weeks. The Petomech varieties are known to possess good growth qualities such as higher purity and germination rate, enhanced vegetative and yield parameters which may account for better response to Shea nut cake biochar treatments as compared to the local varieties. Ahmad *et al.*

(2007) similarly reported on the comparative performance of 11 tomato cultivars in the Northern area of Pakistan and recommended Petomech as one of the commercial cultivars following its enhanced performance.

Conclusion

Shea nut cake biochar had a significant effect on tomato growth as reflected by the significant increase in plant height, stem girth, number of leaves and leaf area index of tomato. The 2:1 standard soil-biochar combination may be dependent on the type of material used to prepare biochar as Shea nut cake biochar at that rate did not support tomato plant growth. Tomato Petomech variety performed better in shea nut cake biochar treatments than the local variety. It is recomended the the pH of soils should be controlled to provide conducive environment for plants to thrive and future research should examine presence and effect of heavy metals present in shea nut cake.

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