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The benefits of biochar on soil nutrient retention and maize productivity.

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Simfukwe Paul
p_simfukkwe@yahoo.com
Mulungushi University, Zambia
P.O. Box 80415, Kabwe

Shitumbanuma Victor
University of Zambia, Zambia
P.O. Box 32379, Lusaka

Kalala Daniel
Kasisi Agricultural Training Centre, Zambia
P. O. Box 30652, Lusaka

Abstract

Poor soil fertility is one of the major factors contributing to low production and productivity among smallholder farmers mainly due to soil acidity, low nutrient reserves, low nutrient retention and low soil organic matter. The use of biochar technology in crop production has the potential to alleviate these problems. The study aimed at determining the benefits of biochar on soil nutrient retention and maize productivity. The biochar was produce from maize combs by Pyrolysis using the Top Lit updraft kiln. For the effects of biochar on nutrient retention in the soil profile, 50cm length, 8.3cm diameter soil columns, were used to collect soils from Kabwe, Mufulira, Choma and Mungu research stations. The treatments comprised: biochar+fertilizer, fertilizer alone, and control. Biochar and fertilizer application rates were: 2% wt/wt biochar/soil (≅40 t/ha) to the top 10cm and 9g (200kg/ha) "D" compound to the top 5 cm, replicated four times. Rainwater was used to leach the soil. The EC and the pH of the leachate was measured for 12 weeks. Biochar effect on maize grain yield, was conducted at the above sites with similar treatment as above. The soil profile samples were also collected at 0-15cm, 15-30cm and 30-50cm depths from control, fertilizer alone and biochar+fertilizer treatments. The results show that biochar effect on nutrient leaching was varied depending on the soil types. Biochar addition restricted the leaching of D compound nutrients but enhanced the leaching of Urea in Kabwe and Choma soils. The field profile samples revealed that biochar reduced leaching of nutrients. Furthermore, biochar amendment increases the CEC and soil pH thereby ameliorating soil acidity and improving the soil chemical characteristics. The retention of these nutrients ensures an efficient use of applied synthetic fertilizers by the plants thereby increased maize yields by 88% compared to fertilizer alone treatment in Choma, 28% in Kabwe, and 22% in Mufulira soils. The study showed that biochar applied to the soil significantly reduced the leaching of plant nutrients, increased soil pH, CEC, available phosphorus, mineral nitrogen, therefore offers great potential to enhance soil quality and improve crop yield.

Keywords

Introduction

Rural livelihoods and food security in Southern Africa are strongly linked to agricultural productivity derived from degraded and marginal soils. Poor soil fertility is one of the major factors contributing to low production and productivity among smallholder farmers in addition to unsustainable traditional farming practices like the chitemene (slash and burn agriculture) cultivation system. Among the soil fertility constraints responsible for the low productivity are soil acidity, low nutrient reserves, low soil organic matter (SOM) and low nutrient retention. Crop production constraints in Southern Africa have been exacerbated by changing climate that has induced persistent drought and low rainfall (Falkenmark and Rockström, 2008).Use ofbiochar technology isanalternative sustainable farming method to Chitemene system capable of restoring and maintaining soil fertility, reducing deforestation and gas emissions. Biochar is a carbon-based co-product that has value as a soil amendment, containing nutrients such as potassium (K), phosphorous (P), magnesium (Mg) and calcium (Ca). When placed in the soil, an increase in soil organic matter (SOM) is observed, along with increases in crop productivity, water retention, and soil biological activity as well as a decreased fertilizer requirement. The overall objective of the study was to investigate the use of biochar produced from maize combs (on-farm wastes) for improvement of soil fertility and maize yields. The beneficiaries of the technology were the small holder famersin the rural areas, extension workers and research staff.

Methodology

Biochar production – soil amendments

A field evaluation was undertaken involving Biochar produced from maize combs using the double drum method and the TLUD gasifier methods (fig. 1).

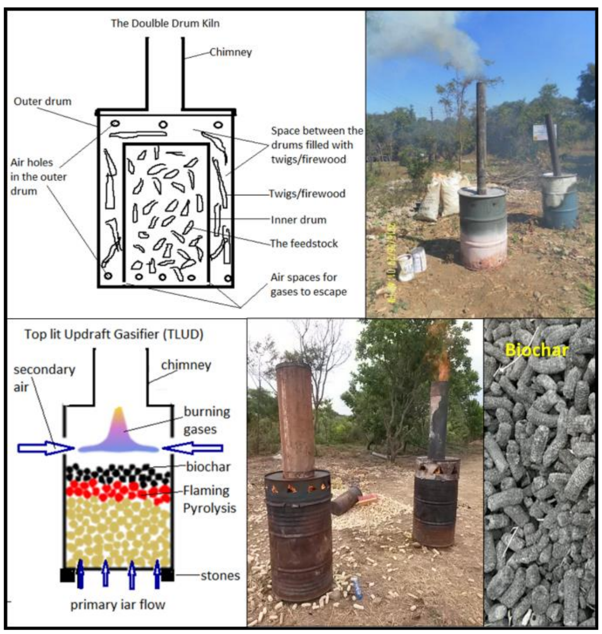

Figure 1. The double drum kiln, the TLUD gasifier and the biochar material

Two experiments (i) Leaching experiment and (ii) field trials were carried out. In the leaching experiment, the effects of biochar on nutrient retention in the soil profile was determined using 50cm soil columns (8.3cm diameter) and benchmark soils sampled from Kabwe, Mufulira, Choma and Mongu. The treatments were: biochar + fertilizer, Biochar alone, fertilizer alone, and control replicated 4 times. Where biochar and fertilizer was applied, the soils were mixed with biochar at the rate of 20g/kg soil to the top 10 cm. 9g D compound was added to the top 5 cm. These were leached with rain water and the EC and the pH of the leachate was measured for 12 weeks.

Figure 2. Leaching experiment on benchmark soils of Zambia

The field trial to evaluate the effect of biochar on maize grain yield was conducted for two seasons as multilocation trialat Kabwe, Mufulira, Choma and Mongu Research Stations in RCBD replicated 4 times. The treatments were: T1=control, no fertilizer no manure, T2=fertilizer alone, T3=fertilizer + biochar, T4=chicken manure alone, T5= chicken manure + biochar and T6= farmer practice.

The application rates for fertilizer was at 200kg/ha "D" compound and 200kg/ha Urea, Biochar application rate was at 2% wt/wt biochar to soil (≅40 t/ha). Manure application rate was 40.5t/ha basal dressing and 69t/ha top dressing. This was calculated from the nutrient (NPK) content of manure. The rates were the equivalent of the 200kg/ha of 'D' compound and urea fertilizers. The farmer practice consisted of basal fertilizer application two weeks after planting and urea top dressing four weeks after planting.

Classification of Soils.

The soil were classified using the World Reference Base for soil resources 2006 edition.The field sites had highly variable soil characteristics namely: (1) Choma soil - Haplic Acrisol (Epiarenic, Chromic); moderately leached, loamy sand and clay illuviation developed on mag-matic and metamorphic rocks and Basement Complex; coordinates- S16^0 50.000'; E 27^0 03.883'; (2) Mufulira- Haplic Acrisol, (Chromic), highly leached, acidic sandy loams and clay illuviation developed from Schist parent material; coordinates S 12^0 36.583', E 28^0 08.817'; (3) Kabwe- PlinthicAcrisol,laomy sand of quartzite/sandstone origin, Coordinates S 14^0 23.367', E 28^0 29.700'. (4) Mongu–Haplic Arenosol, (Aridic), excessively drained sandy soil developed on Kalahari sands of aeolian origin; coordinates S 15^0 09.361', E $23^0$33.170'. All sites were on flat terrain of less than 2% slope.

Results and Discussion

For the biochar production, the TLUD gasifier method was found to be more efficient as it produced less smoke and did not need extra fuel to char the feedstock. Even though, biochar production produces greenhouse gasses, the TLUD method ensures complete burning of all the volatile organic compounds (VOC) particles guaranteeing little or no CO emissions during biochar production.

From the leaching experiments, the electrical conductivity and pH were measured from the evaluated four soils typesdescribed above. TheChoma and Mufulira soils showed no evidence of biochar effect on soil electrical conductivity. The Kabwe soils showed biochar reducedleaching.The Mongu soil showed enhanced leaching of nutrients. The results show that biochar effect on nutrient leaching was varied depending on the soil types see figure 3 below.

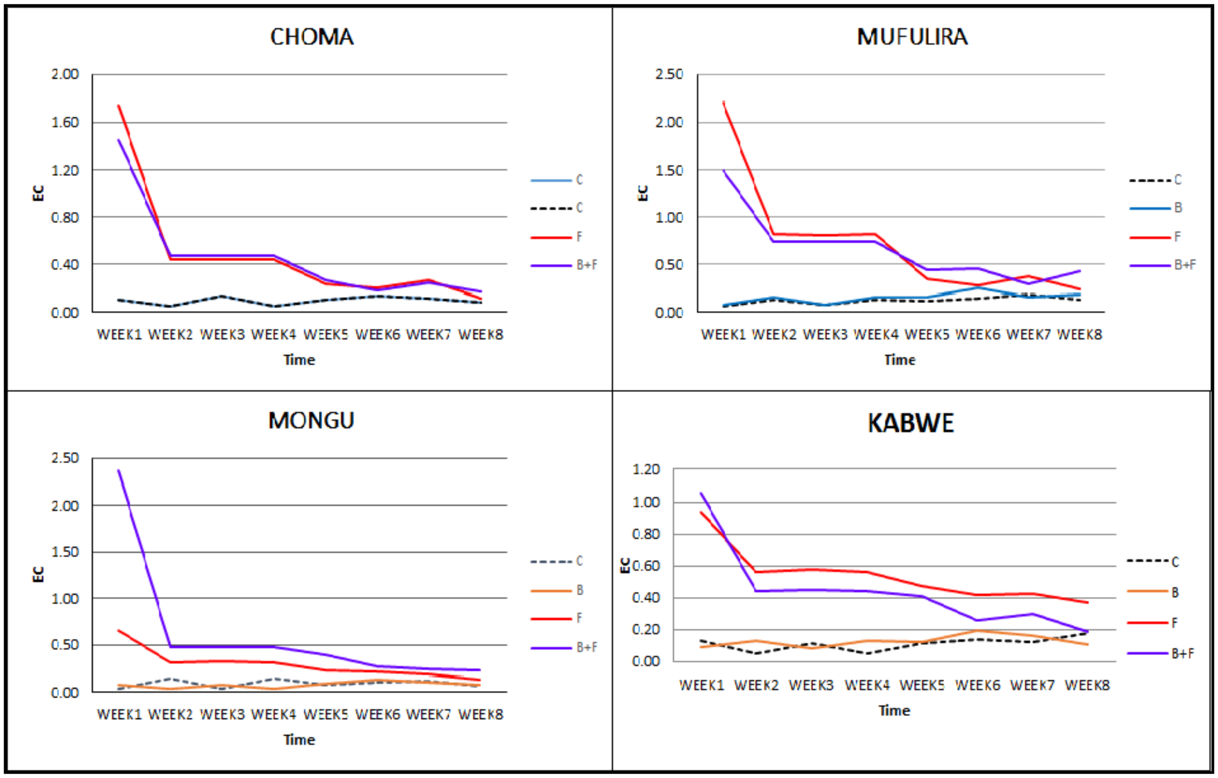

Fig 3 Electrical conductivity (EC) of leachate from the four soil types treated with biochar and fertilizer. The treatments C = control, B = biochar amended soils, F= fertilizer amended soils and B+F= biochar + biochar amended soils

The comparison between treatments from cumulative ECs overtime in Choma and Kabwe soils showed that biochar addition restricted the leaching of D compound nutrients but enhanced the leaching of Urea as seen from figure 4. In both soils, the biochar + D treatment curve is below D compound alone curve while the Biochar + Urea curve is above the urea alone curve. This opposite effect on these nutrients can be attributed to the charge of the predominant nutrients involved. Phosphorus (P_2O_5) in D compound is sparingly leachable in the soil and has various mechanisms by which it is made insoluble (Brady, 1984). The K+ in D compound is very soluble and very leachable but with the addition of biochar, which has a large negative charge, adsorbs it to its exchange complex rendering it unavailable for leaching. Thus the EC readings for the biochar + D compound read lower that the D compound alone. Contrariwise the biochar + Urea treatment, the nitrogen (NH_3^-) a negatively charged ion will be repelled by the negatively biochar exchange complex rendering it susceptible for leaching. Thus the biochar + Urea treatment shows more leaching than the Urea alone treatment. The difference between the rates

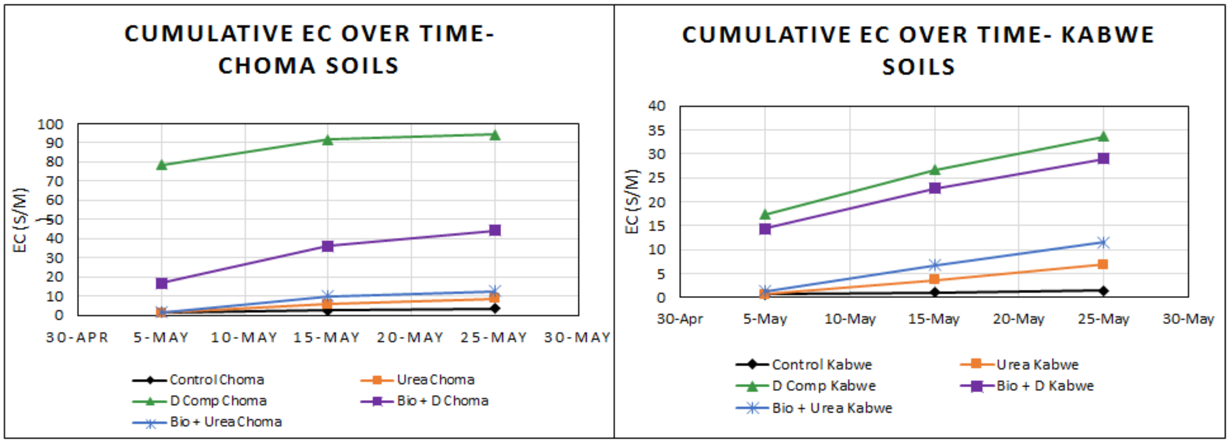

Fig 4 Cumulative electrical conductivity of leachate over time it two soils treated with fertilizer and Biochar

The field experiments investigating the effect of Biochar on nutrient leaching (or retention) in the field showed that biochar reduced leaching of nutrients. Higher concentrations of phosphorus, potassium, magnesium and sulphur in the 15-30cm soil depth compared to the control and the fertilizer alone treatments.Biochar had a positive effect in soil nutrient retention (see figure 5).

Biochar amendment was also observed to increase the soil pH thereby ameliorating soil acidity. Biochar increased the CEC of the soil, which further improved the soil chemical characteristics. The retention of these nutrients ensures an efficient use of applied synthetic fertilizers by the plants

Table 1: Means (+ or - Standard Deviation) of Soil Chemical characteristics of 36 soil samples at Soil depths of 0-15cm,15-30cm and 30-50cm from Kabwe ,Zambia

TREATMENT		CONTROL			FERTILIZER ALONE			FERTILIZER + BIOCHAR		
	DEPTH	**0-15**	**0-15**	**0-15**	**15-30**	**15-30**	**15-30**	**30-50**	**30-50**	**30-50**
VARIABLE	**TREAT Units**	**Control**	**Fertilizer +Biochar**	**Fertilizer alone**	**Control**	**Fertilizer +Biochar**	**Fertilizer alone**	**Control**	**Fertilizer +Biochar**	**Fertilizer alone**
pH		4.46±0.21	5.77±0.30	4.38±0.25	4.44±0.95	5.59±0.94	4.33±0.27	4.41±0.28	5.07±0.28	4.32±0.54
OM	**%**	4.64±0.97	2.38±0.68	2.54±0.63	3.87±0.24	2.28±2.36	2.78±0.14	4.32±0.17	2.6±0.48	4.54±0.30
P	**mg/kg**	13.1±2.88	15.8±11.58	15.0±7.67	20.9±5.30	20.9±7.68	10.6±1.70	13.9±2.75	10.2±1.88	24.0±5.22
S		3.51±2.01	0.73±0.59	0.37±0.16	1.99±0.11	0.55±0.14	0.34	0.99±0.12	0.28±0.09	0.54±0.13
Ca	**cmol/kg**	3.63±0.36	1.86±0.48	2.59±0.27	3.04±1.32	2.34±0.45	2.57	3.27±0.56	2.52±0.64	2.8±0.56
Mg		0.6±0.16	0.8±0.15	0.6±0.18	0.9±0.05	0.9±0.12	0.8	0.7±0.16	0.6±0.11	0.9±0.10
K		1.17±0.19	0.98±0.18	1.19±0.13	1.13±0.12	1.12±0.05	1.17	1.15±0.17	0.34±0.22	1.07±0.29
CEC		23.4±1.40	19.9±3.22	20.1±0.57	19.8±1.22	22.4±0.62	22.04	20.6±0.83	19.2±0.80	19.0±2.41
Total N	**%**	0.07±0.07	0.07±0.10	0.04±0.06	0.09±0.07	0.08±0.08	0.06±0.04	0.06±0.04	0.04±0.06	0.06±0.06
Nitrates	**(mg/kg)**	142.8±44.16	114.8±26.37	134.4±18.77	131.6±31.06	100.8±21.00	95.2	86.8±42.87	86.8±29.90	117.6±15.26
Nitrites		117.6±40.06	112±18.85	126±40.82	140±20.41	117.6±24.50	120.4	78.4±9.02	92.4±35.82	128.8±25.48

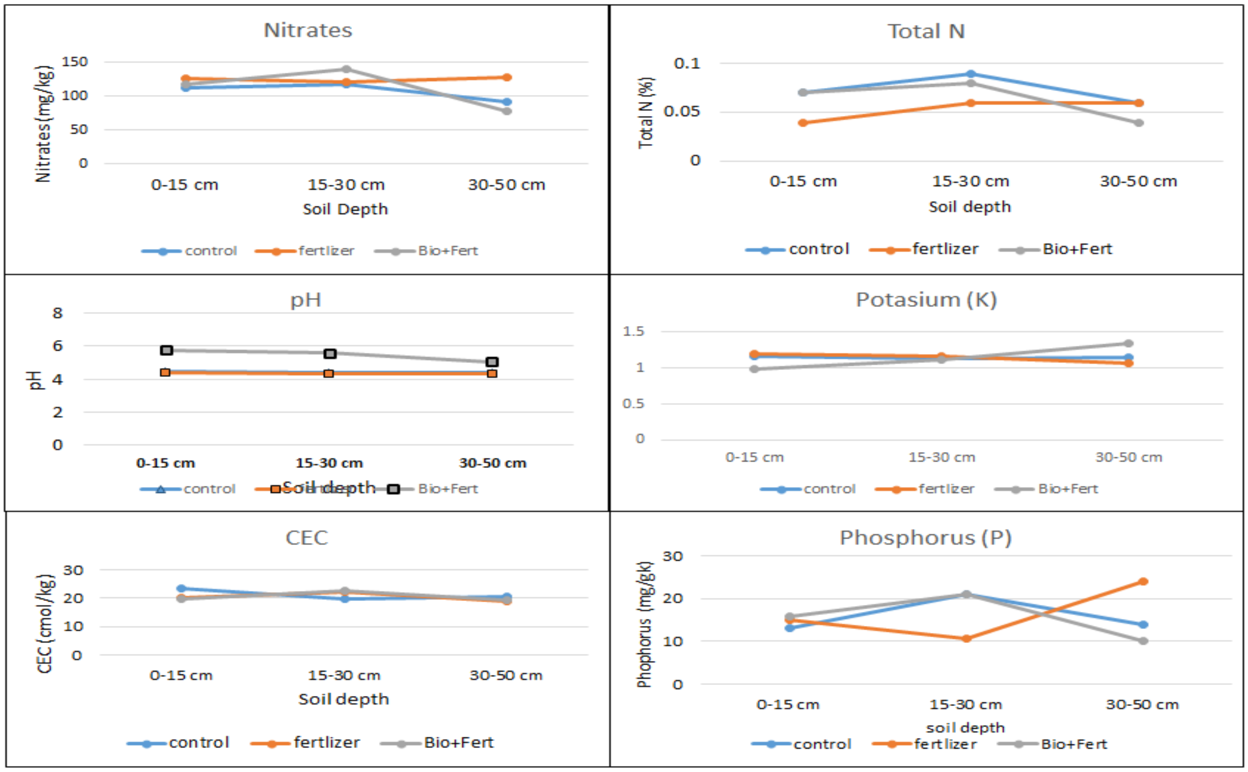

Fig 5 the soil profile measurements of soil characteristics

The effect of biochar on maize yield

On the effect of biochar on crop yields, the results showed that the addition of biochar of approximately 40 t/ha increased the maize yields in all soil types. The increase was by 88% in comparison to fertilizer alone treatment in Choma soils, 28% in Kabwe soils, and 22% in Mufulira soils (See figure 6).

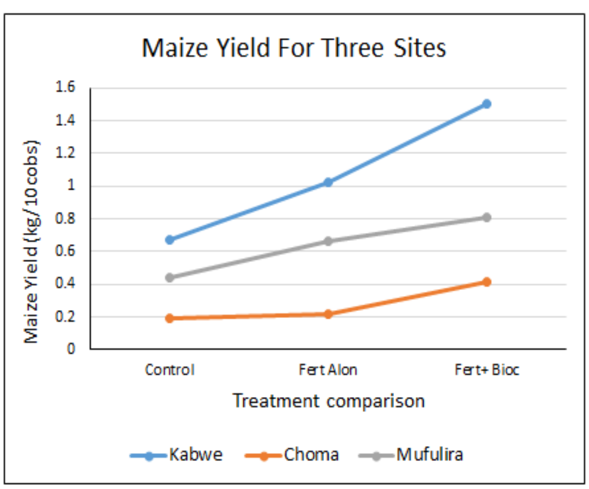

Fig 6Maize yield response curves to fertilizer and biochar treatments for Choma, Mufulira and Kabwesoils

Conclusions and Recommendation

The study showed that biochar applied to the soil significantly reduced the leaching of plant nutrients, increased soil pH, CEC, available phosphorus, mineral nitrogen. The study demonstrated that biochar applied to soil offers great potential to enhance soil quality and improve crop yield.

1. This is being a preliminary finding. We recommend a longer-term study to examine the long-term effects of the treatments on soil physicochemical properties and yield responses.

2. There is need to come up with the biochar kiln that can be made by local farmers from local materials. TLUD gasifier concept should be refined for production of biochar for agricultural use as well as for energy production for cooking. This can be a post project activity worth investing in, as this technology enhance soil fertility, sequestering carbon to the soil when applied to the soil, thereby mitigating climate change as well as meeting energy needs of the farmers

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