german cooperation
DEUTSCHE ZUSAMMENARBEIT

ግብርና ሚኒስቴር
MINISTRY OF AGRICULTURE

ETH-SOIL

2nd Soil Symposium

Conference reader

2nd Soil Symposium
13 February 2024 in Addis Abeba, Ethiopia

Implemented by:
DBFZ

2nd Soil Symposium: Soil amelioration – the cicular way!

Date and Time

13th February 2024, 8:15 – 5:00 p.m. (EAT)

Place

ILRI campus, 2R87+GPC, "Azage Hall", Addis Ababa, Ethiopia

Agenda

Time	Agenda	Speaker
8.15 a.m. – 8.45 a.m.	Meet and greet	
8.45 a.m.	Inaugural address	**Dr. Sophia Kassa**, State Minister for Agriculture and Investment Division, Ministry of Agriculture (solicited) **Dr. Volker Lenz**, Head of Department Thermo-chemical Conversion (DBFZ)
9.00 a.m. – 9.15 a.m.	Keynote: The role of biochar and COMBI-mix on soil properties, crop yield and carbon sequestration in tropical agricultural soils	**Dr. Getachew Agegnehu**, Researcher, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
	Research within the 1st ETH-Soil Call	
9.15 a.m. – 9.30 a.m.	Biochar based organic-fertilizers	**Dr. Milkiyas Ahmed**, Assistant Professor of soil fertility and agronomy, Jimma University
9.30 a.m. – 9.45 a.m.	Evaluation of biochar-treated amendments for their agronomic effectiveness in acidic soils: Production process and quality	**Dr. Yackob Alemayehu**, Assistant Professor of Soil Science, Dilla University
9.45 a.m. – 10.00 a.m.	Smallholder farmers involved preparation and evaluation of biochar-based fertilizers	**Mr. Wondimu Tamrat**, Assistant Professor of Agronomy, Wachemo University
10.00 a.m. – 10.15 a.m.	Integrated use of coffee husk biochar and vermicompost on smallholder farms	**Dr. Shimelis Gizachew**, Assistant Professor, Hawassa University
10.15 a.m. – 10.30 a.m.	Co-application of biochar and digestate in highly degraded acidic soils: Effect on crop production, soil quality, and nutrient uptake	**Dr. Abebe Nigussie**, Associate Professor of soil science, Jimma University
10.30 a.m. – 10.45 a.m.	Integrated effect of Biochar and Bio-slurry compost with NP Fertilizers on soil physic-chemical properties, climate change mitigation, yield components and yield of Sorghum	**Mr. Tilahun Abera**, Researcher, Batu Soil Research Center, Oromia Agricultural Research Institute
10.45 a.m. – 11.15 a.m.	Break	
11.15 a.m. – 11.30 a.m.	Keynote: Biochar in Sustainable Soil Management	**Prof. Sheleme Beyene**, Professor of Soil Sciene, Hawassa University

	Call for papers – Best presentation award	
11.30 a.m. – 11.45 a.m.	Aggregate size distribution, labile carbon fractions and litter decomposition after long-term application of biochar-based soil amendments in low-input acidic soils	**Mr. Getachew Mulatu**, Researcher, Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center
11.45 a.m. – 12.00 p.m.	Co-composting of biochar and humanure: a new path in improving soil quality and sustainable crop production	**Prof. Fantaw Yimer**, Lecturer at Wondo Genet College of Forestry and Natural Resources, Hawassa University
12.00 p.m. – 12.15 p.m.	Optimizing Soil Health and Agricultural Productivity with Biochar based Indigenous Organic Fertilizers in Acidic Soils: Insights from Northwestern Ethiopia	**Mr. Ewunetu Tazebew**, Researcher, University of Gondar
12:15 p.m. – 12.30 p.m.	Effect of biochar, farmyard manure, and lime on soil properties, and on growth and nutrient uptake of wheat on acidic soils in Southern Ethiopia	**Dr. Mekdes Lulu**, Assistant Professor, College of Agriculture, Wachemo University
12.30 p.m. – 2.00 p.m.	Lunch Break	
	Winning proposals within the 2nd ETH-Soil call	
2.00 p.m. – 2.15 p.m.	Farmers Participatory Biochar Production, Nutrient Loading, Characterization, and Evaluation	**Dr. Fanuel Laekemariam**, Associate Professor of soil science, Wolaita Sodo Univeristy
2.15 p.m. – 2.30 p.m.	Blending bioslurry with biochar: Effects on crop production, soil fertility and nutrient loss along varying soil types	**Dr. Esubalew Getachew**, Assistance Professor of agronomy / horticulture, Jimma University
2.30 p.m. – 2.45 p.m.	Biochar Based Fertilizer: Challenge and Opportunity for Widespread Uptake of the Technology by Ethiopian Small-scale Farmers for Increased Grain Productivity	**Dr. Ashenafi Nigussie**, Researcher, Ethiopian Institute of Agricultural Research / Wondo Genet Agricultural Research Center
2.45 p.m. – 3.00 p.m.	Participatory Evaluation of Biochar-Based Biofertilizers on Smallholder Farms	**Dr. Yackob Alemayehu**, Assistant Professor of Soil Science, Dilla University
3:00 p.m. 3:30 p.m.	Coffee break	
	Field experiences regarding biochar and biofertilizer production	
3:30 p.m. – 3.45 p.m.	Recovery of biofertilizers from residues of biogas production and their application on small holder farms – best practice, lessons learned and way forward.	**Mr. Carlos Bueso Varela**, SNV (solicited)
3.45 p.m. – 4.00 p.m.	Practical experience with the implementation of EBC-Artisan in rural Africa.	**Mr. Simon Lotz**, Ithaka Institute (solicited)
4.00 p.m. – 4.15 p.m.	The effect of solid and liquid bioslurry on soil fertility and crop productivity	**Mr. Zelalem Addis**, Adet Agricultural Research Center
4:15 p.m. – 5:00 p.m.	Closing session and Best Presentation Award	**Ms. Kerstin Wilde**, DBFZ **Dr. Getachew Eshete Beyene**, ETH-Soil Project Coordinator (DBFZ / GIZ InS)
5:00 p.m.	Closing of the Soil symposium	

Biochar in Sustainable Soil Management
ETH-Soil Symposium

Keynote Speech

By
Sheleme Beyene
Hawassa University
13 February 2024
Addis Ababa

Main points

- **Why sustainable soil management?**
  - Principal functions of soil
  - Principles of sustainable soil management
- **Biochar in sustainable soil management**
  - Characteristics and persistence
  - Effects
  - Application
- **Concluding points**

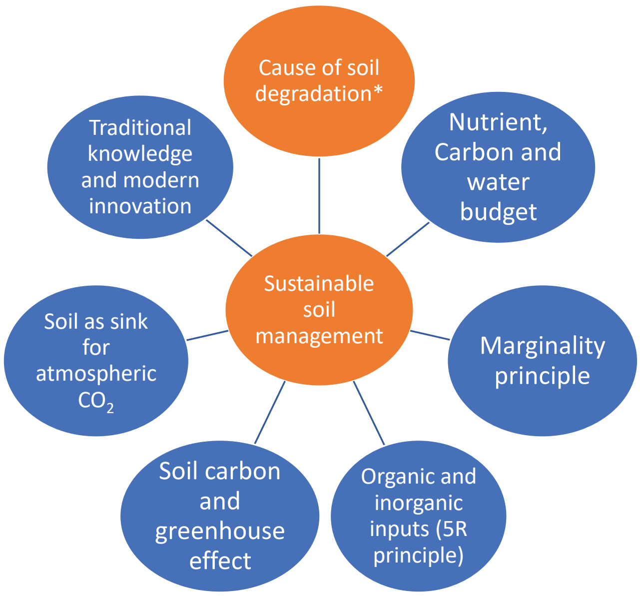
Why sustainable soil management?

The principal soil functions include:

- medium for plant growth,
- sequestering carbon to mitigate climate change,
- denaturing and filtering pollutants,
- being repository of germplasm and biodiversity, and
- maintaining cycles of nutrient elements and water.

- Sustaining and enhancing the net primary productivity (NPP) and agronomic yields, and
- mitigating climate change, maintaining water quality and biodiversity are the main concerns.

Principal components of sustainable soil management



Causes of soil degradation

Serious threats to soil function;

- Low OM contents of the soils and severe OM depletion due to complete removal of crop residues[1];
- High population growth[2]:
  - Erosion;
  - Nutrient mismanagement and depletion[3];
- Soil acidity[4];
- Soil fauna and flora depletion;

Removal of maize stover after harvest

Loss of soil by erosion in Boricha, Sidama

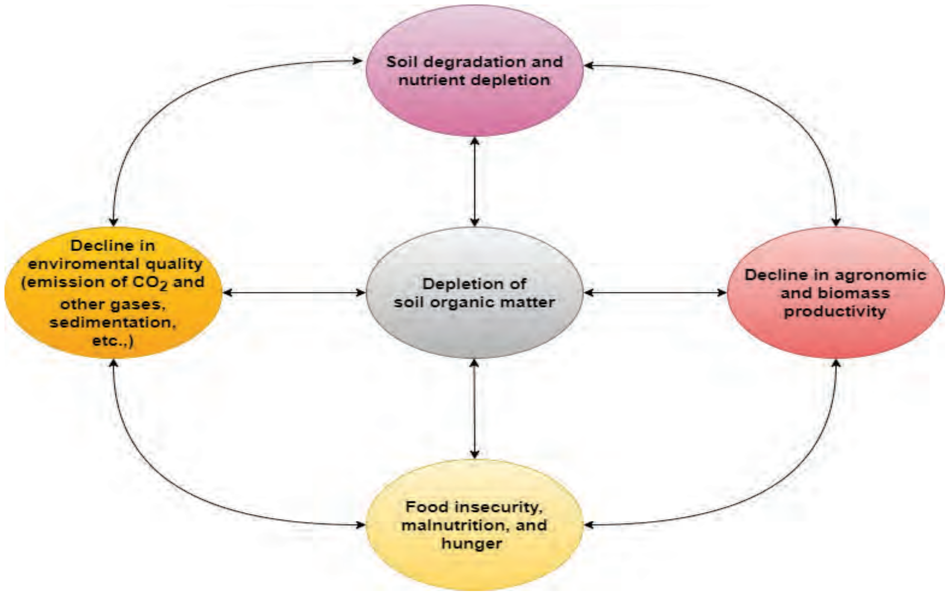
Causes of soil degradation *Cont'd*

- Soil salinity and sodicity[1];
- Soil structure deterioration and physical land degradation[2];
- Soil pollution[3];
- Waterlogging[4]

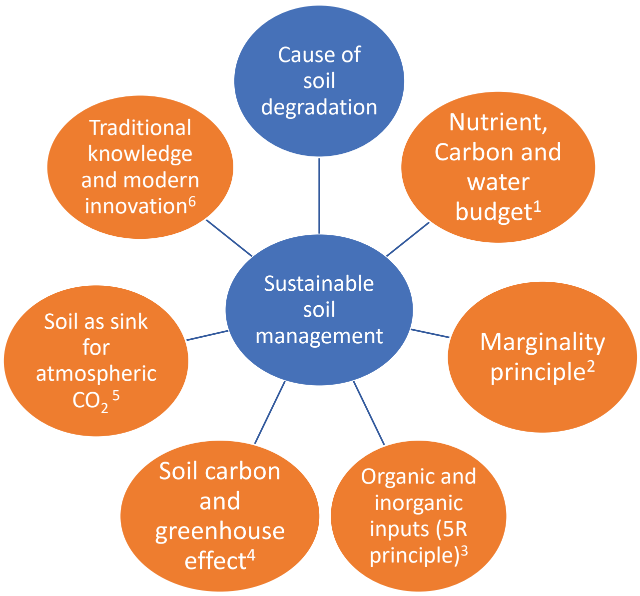
Abandoned land at Kessem Sugar Estate

Vertisol under waterlogging

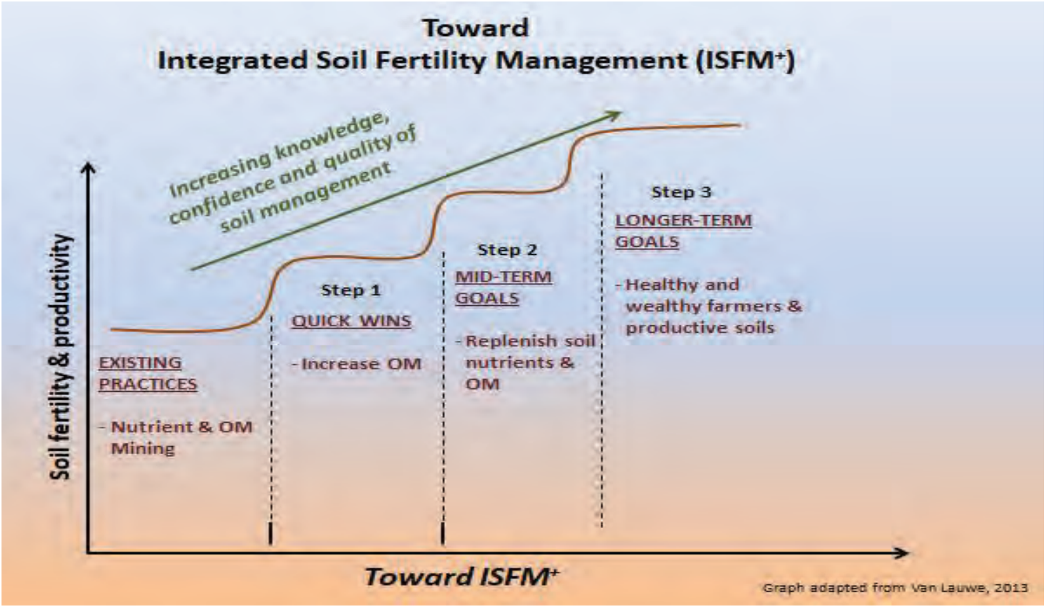
Vicious cycle of soil degradation/SOM depletion – low crop yield - food insecurity – environmental degradation (adapted from Lal, 2004)*



Principal components of sustainable soil management

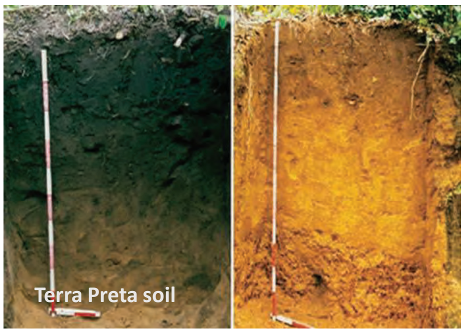


Integrated soil fertility and nutrient management



Biochar in sustainable soil management

- **Biochar:** a pyrogenic material derived from the thermo-chemical conversion of **biomass** in an oxygen-depleted environment.
- The first biochar is utilized in a great agricultural civilization fertilized poor forest soils with **Terra Preta.**
- Today, we are rediscovering the value of biochar* and building upon the traditional knowledge
- It has come into the limelight for its potential to foster soil C sequestration.
- The concept covers 5 SDGs* (2, 3, 7, 13 and 15)



Characteristics of biochar and its persistence

- Biochar is a renewable and environmentally friendly product from waste biomass products*
- The characteristics of biochar vary significantly depending on feedstock type and pyrolysis temperature.
- Biochar from manure, greenhouse waste and grasses are more effective for nutrient supplementation than wood-based biochar;
- Biochar has an alkaline pH, porous, contains fixed and available carbon, and contain some nutrients;
- Biochars can persist for long periods of time in the soil at various depths, thus has great potential to store carbon in the soil for thousands of years.

Effects of Biochar

Positive effects

- Soil fertility and health*
  - Increase CEC, retain nutrients, improve fertilizer use efficiency[1]
  - Improves N availability[2]
  - Improves soil structure[3]
  - Modifies biological properties[4]
  - Reduces soil acidity[5]
- Improves plant growth and enhances crop yields;
  - increasing food production and sustainability
    - ✓ in areas with depleted soils, limited organic resources, insufficient water and/or access to chemical fertilizers.

Effects of Biochar *Cont'd*

Positive effects *Cont'd*

- Adsorption of pollutants

  - Sorption of organic and inorganic pollutants;
  - Reduction of heavy metals (Pb, Cd) bioavailability;

  - Improves soil and water conservation
  - Reduce waterlogging

- Carbon sequestration:

  - Reduce increasing atmospheric carbon dioxide (CO_2) concentrations and mitigate climate change

- Reduce nitrous oxide (N_2O), and methane (CH_4) and CO_2 emissions*;
- Alleviates adverse effects of abiotic stress on microorganisms, particularly in saline soils;

Effects of Biochar *Cont'd*

Negative effects:

- All biochars are not equally created and do not perform the same.
- Many biochars have pH around 7.
- Use of alkaline biochar (with pH >7) on calcareous soils.
- Biochar may be a source of contamination by bringing polyaromatic hydrocarbons (PAHs), dioxins, Volatile Organic Compounds (VOCs), and heavy metals depending on its feedstock and production conditions.
- In some cases, detrimental effects of applying straight biochar (for example, causing temporary lockup of some nitrogen)

Application of Biochar

The properties of biochar determine its applications to soil.

Application may require the selection of certain feedstocks and pyrolysis temperature.

Manure: greater content of nutrients and CEC; higher EC (may increase soil salt concentration); low C content.

Crop and grass residue: higher K content; lower porosity; higher C content.

Wood waste: greater fixed C content and thus, more stable; greater porosity and thus higher water retention; biochar from conifer wood has a lower pH and would be better for alkaline soils.

Higher pyrolysis temperatures (500°C – 650°C): greater amount of micro-pores (better for adsorption of toxic substances and soil rehabilitation); higher pH; greater mineral content; lower cation exchange capacity.

Lower pyrolysis temperatures (350°C – 500°C): greater degradable C as source for soil micro-organisms; higher CEC.

Application of Biochar *Cont'd*

'Straight' biochars (non-enriched) are most suited for aeration of soils*

'Nutrient-enriched' or 'biologically-enriched' biochars have added nutrients or additional microbes including mycorrhizal fungi.

- **Soil properties**. Infertile, dense, acid soils tend to show greater positive effects than fertile well-structured soils.
- Sandy soils also benefit from the improved water retention and cation exchange capacities of biochar
- **Plant** species and cultivar: for instance, raising soil pH by adding alkaline biochar will be detrimental to the growth of acid-loving plants such as rhododendrons.

Application of Biochar *Cont'd*

The application should follow **5R principles**.

Right source: (organic, inorganic); Biofertilizers (Right strains of Rhizobia for legumes; Mycorrhizae)

Charging up your soil with biochar*

- When the soil is already very fertile, biochar can be directly added to the soil.
- Biochar brings the most benefits to soil when it is "charged" or inoculated to help prime the soil for improved fertility.
- Letting the charge progress at least 14 days, to allow beneficial soil biology to inoculate.

Incorporating biochar and compost

- The ratio between compost and biochar can be as high as 1:1
- The aim is balanced **carbon-to-nitrogen** ratio and ensure proper aeration and moisture levels in the compost pile.

Application of Biochar *Cont'd*

Right Rate:

Appropriate rate should be used depending on the soil and crop types

For instance, biochar application at a rate of 10 tons per acre raised soil pH and increased crop yield by almost 30%, in Oregon dryland wheat cropping system

Right Place:

- There are several methods of biochar application to the soil. These methods include:
  - band placement (surface and subsurface)
  - uniform topsoil mixing,
  - top dressing, and
  - use of planting holes (localized application) .

Right Time: beneficial effects of applying biochar to soil improve with time*,

Right Agronomic Practices[@]

Concluding points

- Awareness creation (farmers and policy makers);
- Demonstration and encouraging farmers to produce biochar at farm level;
- Determining site specific (soil and crop type) rate of biochar use taking into account the specific characteristics of the biochar material;
- Applying the 5R principles and targeted application to address specific concern;
- Use of nutrient enhanced or blended biochar;
- Using biochar with appropriate rhizobium strains for legumes as well as mycorrhizae;
- Proper regulatory mechanism to avoid possible risks of soil contamination;

Photo by Prof. Tesfaye Abebe

With proper use of Biochar

↓

Healthy soils + Environment

↓

Increased production of healthy plants

↓

Improved food security

↓

Healthy people*

THANK YOU!!

VIELEN DANK!

The role of biochar on soil quality, crop performance, and carbon sequestration in tropical agricultural soils

Getachew Agegnehu
ICRISAT
ETH-Soil Symposium
GIZ – Ethiopia
February 13, 2024
Addis Ababa

Contents

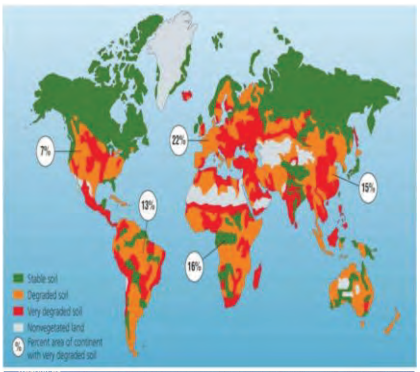
1. Introduction
   - General background
2. Role of biochar on agriculture and the environment
   - Plant growth and crop yield
   - Plant nutrient uptake and nutrient use efficiency
   - Soil quality
   - Greenhouse gases emissions
3. Conclusions and the way forward

What are the key challenges of agriculture?

- Increasing agric. production without exacerbating environmental problems, while coping with climate change (Pender 2009; Parry et al. 2007).
- Building food systems that meet increasing demand and remain profitable and sustainable in the face of climate change (Steiner et al., 2020).
- Multiple soil health issues affecting various areas to different extents: e.g., topsoil erosion, organic matter depletion, soil acidity, salinity, and deficiency of macro-and micro-nutrients (Lal, 2015; Sanchez et al. 1997; Zeleke et al. 2010).
- About half of Ethiopia's cultivated land (6.5 mln.) is severely degraded due to poor agricultural activities (FAO, 2018).

Major causes of land degradation and soil fertility depletion

- Overgrazing (35%)
- Deforestation (30%)
- Agricultural activities (28%)
- Overexploitation of land (7%)
- Significant decrease in cropland per capita

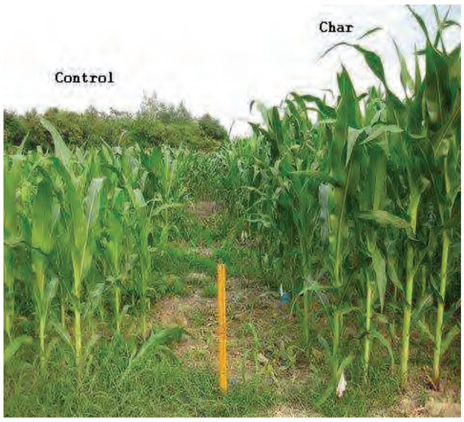


Competing use of resources

- 85% of total crop residues as feed, energy source, and thatching (Amare et al. 2005)
- Amount of nutrients in crop residues are higher than the amount applied as fertilizers (Agegnehu et al., 2012)
- Negative soil nutrient balance (Zeleke et al., 2010)
  - E.g. Ethiopia: -47, -7, and -32 kg NPK/ha/y

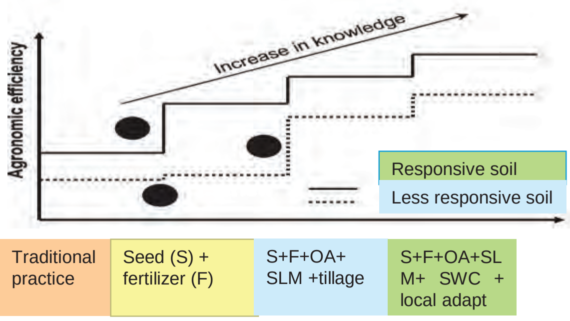
What are the main issues of sustainable agriculture?

- SA faces significant constraints due to:
  - enhanced SOM decomposition (Lal, 2015)
  - soil fertility depletion
- Fertilizer + seed technology reaching a point of diminishing returns (Barrow 2012).
- Low fertilizer use efficiency and environmental pollution
  - low N recovery efficiency of ~33% (Raun et al. 2002), with 67% (~$19 billion) global loss of N fertilizer per year (WB 2015).
  - Loss of nutrients via fixation, leaching, or gas fluxes
- High cost and need for continuous fertilizer application.



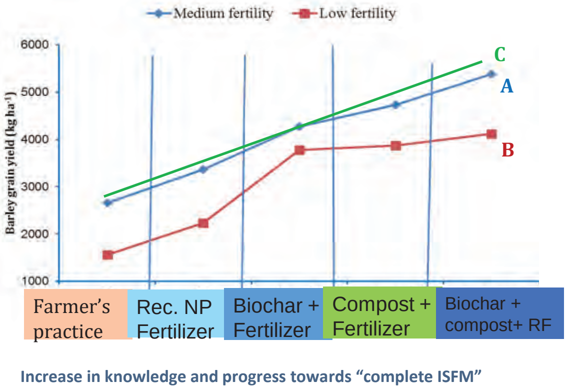
The relationship between fertilizers and organic amendments and implementation of various components of ISFM developing into complete ISFM towards the right side of the graph

Time to comprehensive ISFM depends on what is already taking place and extent of intervention



Source: Vanlauwe et al. (2010)

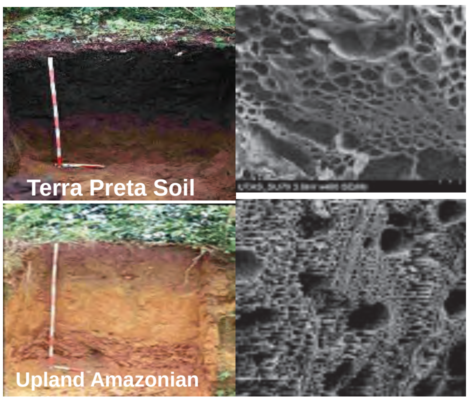
Efficient utilization of resources to achieve sustainable soil fertility management (ISFM)



Source: Agegnehu et al. (2017)

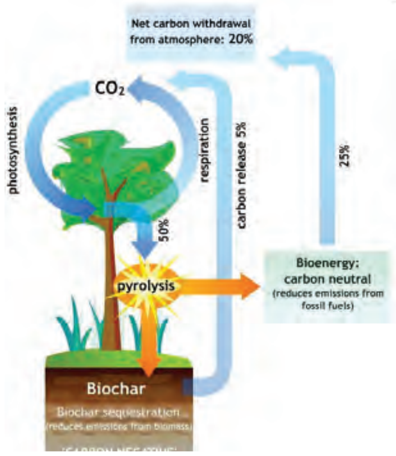
What is biochar?

- A carbon-rich product produced from biomass by controlled pyrolysis, or under oxygen-limited environment (Lehmann & Joseph, 2009).
- Emerged in conjunction with soil management and C-sequestration.
- Terra Preta soils contain up to 70 times more C than adjacent soils (Lehmann et al. 2009; Glaser et al. 2002)
- Recalcitrant (half-lives of 100-900 years). Pyrolysis makes biomass recalcitrant and can be sequestered in the soil.
- Carbon species in biochar can be classified as carbonate and bicarbonate in the inorganic phase and aliphatic, aromatic and functionalized carbon in the organic phase.



Carbon sequestration using biochar

- 10.2 Gt C/yr. fixed by photosynthesis used by humans (Haberl 2007).
- 8 Gt C/yr - current fossil-C emissions
- Biochar is C negative -reduces GHG emission from biomass via C sequestration (Lehmann & Joseph, 2015).
- Soils have a great potential to sequester carbon.

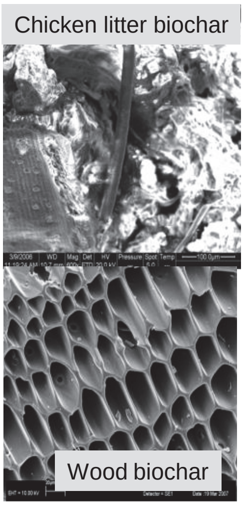


Composting with biochar

- Provides both stable and labile carbon.
- Increases rate of carbon mineralization reducing bulk.
- Increases nitrogen retention.
- Provides nutrients and a mechanism for retention in the soil.
- Accelerates biochar 'aging' and hence improves soil function and microbial habitat faster.
- Use of biochar as a bulking agent could reduce N2O emissions by up to 52% during composting (Steiner et al. 2010).

Characteristics of biochars

- All biochars are not created equal.
- The physicochemical properties of biochar vary according to biomass type used and temperature.
- Pore size and distribution is determined by the feedstock structure.
- Mineral contents vary among



Characterizing biochar

According to structure

Physicochemical characteristics

According to Function

Ability to improve plant growth and microbial processes

Ability to store carbon

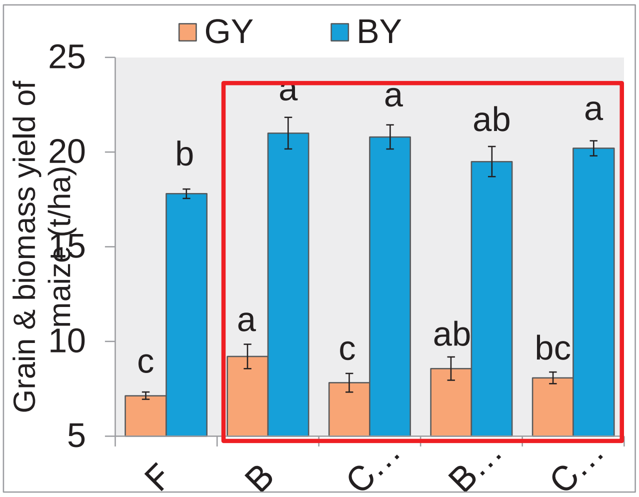
Images from www.airterra.com and "Biochar: Environmental Management" (Lehmann and Joseph, 2009)

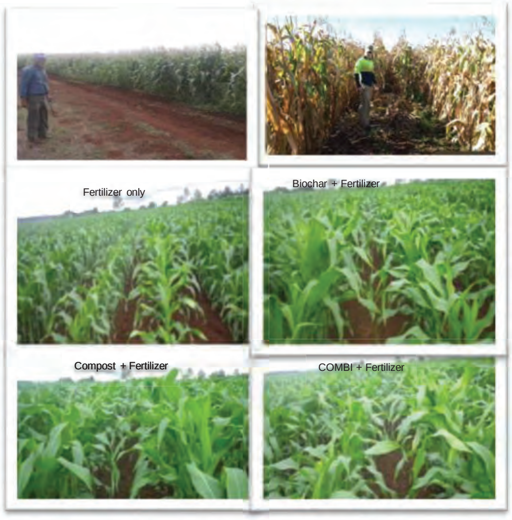
Nutrient content of biochar, compost and COMBI-mix

Some Key Research Findings on the Significance of Biochar and COMBI-mix

Element	Unit	Biochar	Compost	COMBI
pH (H2O)		8.8	7.5	7.7
OC	%	59.2	23.9	19
Nitrogen	%	0.38	0.95	0.94
Sulfur	%	0.02	0.014	0.012
Colwell P	mg kg^{-1}	79.5	917	1104
Potassium	cmol(+)/kg	7.25	20.7	19.1
Calcium	cmol(+)/kg	2.20	25.8	22.3
Magnesium	cmol(+)/kg	1.45	18.3	16.0
CEC	cmol(+)/kg	11.2	70.4	61.9
Copper	mg kg^{-1}	2.55	11.9	9.5
Zinc	mg kg^{-1}	83.5	74.1	79.2
Iron	mg kg^{-1}	0.04	246	218
Boron	mg kg^{-1}	9.25	4.8	4.3
Molybdenum	mg kg^{-1}	<0.3	<0.2	<0.2

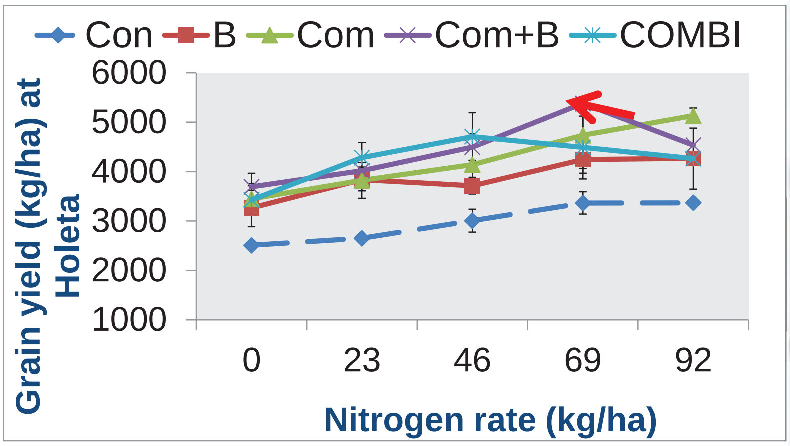
1. Biochar and COMBI-mix increase plant growth and yield relative to inorganic fertilizer alone.





F = Fertilizer; B = Biochar; Com = Compost; COMBI = Co-composted biochar-compost

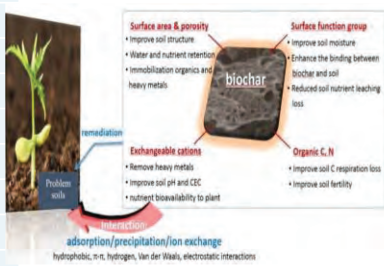
Response of barley grain yield to OAs and N fertilizer



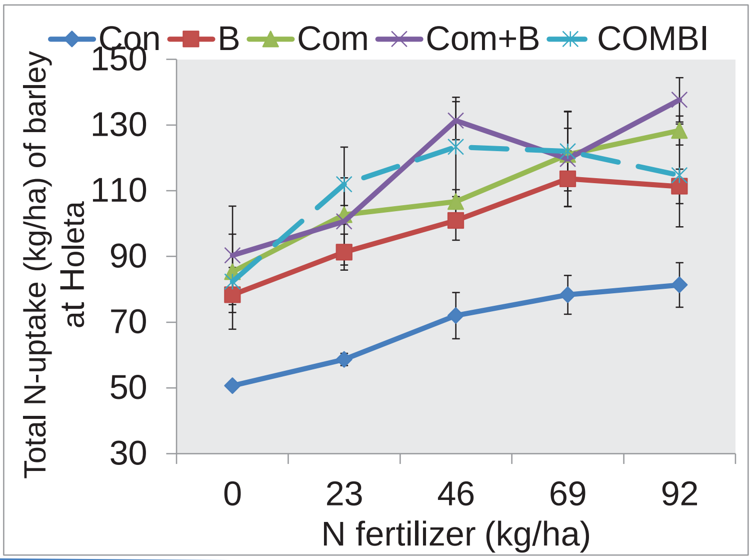
Con=Control; B=Biochar; Com=Compost; COMBI=Co-composted biochar

Amendment effect of different biochar types on grain yield in problematic soils

Soil type	Biochar type	Crop type	Yield increase (%)	Reference
Acid soil	Wood	Maize	28-140	Major et al. (2010)
Acid soil	Acacia	Barley	30-78	Agegnehu et al. (2016)
Sandy soil	Wood	Rice	20	Asai et al. (2009)
Acid soil	Sewage sludge	Rice	149–175	Khan et al. (2013)
Saline soil	Bamboo	Rice	20	Dong et al. (2014)
Heavy clay soil	*Gliricidia sp.*	Maize	43-50	Obia et al. (2018)
Waterlogged paddy soil	Rice husk	Rice	12	Wang et al. (2012)
Cd, Pb	Wheat straw	Rice	17–18	Bian et al. (2014)
Poor sandy loam soil	Rice straw	Rice	12	Kamara et al. (2015)
Saline-sodic paddy soil	Wheat straw	Rice	13	Jin et al. (2018)
Saline-sodic paddy soil	Peanut shell	Rice	22-24	Ran et al. (2019)

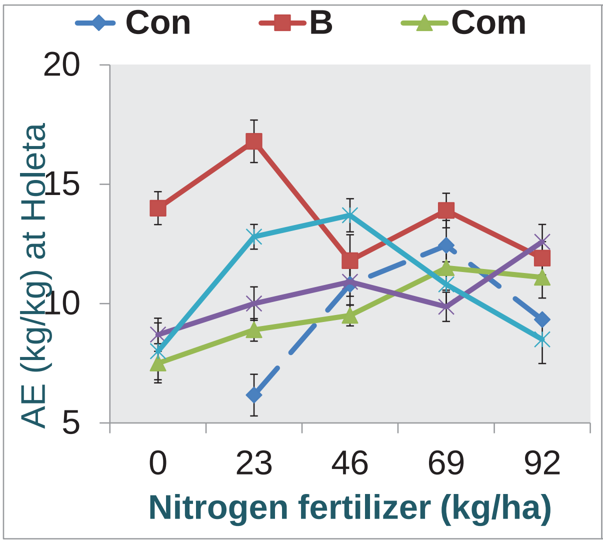


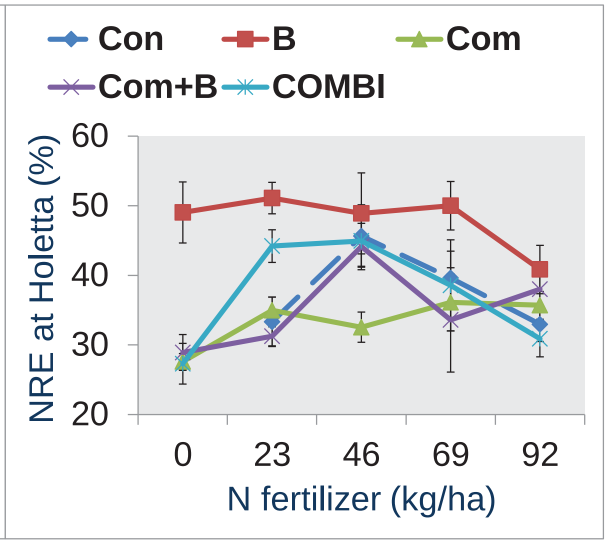
2. Biochar and COMBI-mix improve plant nutrient uptake and use efficiency.



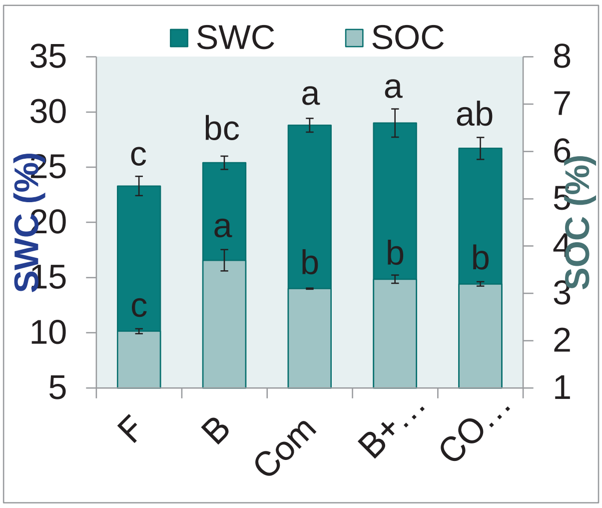
Agronomic efficiency of barley

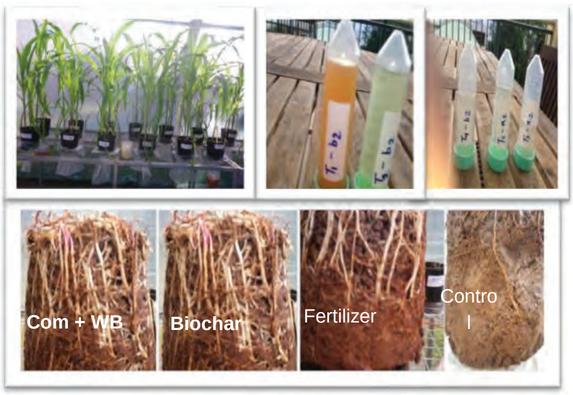
Nitrogen recovery efficiency of barley



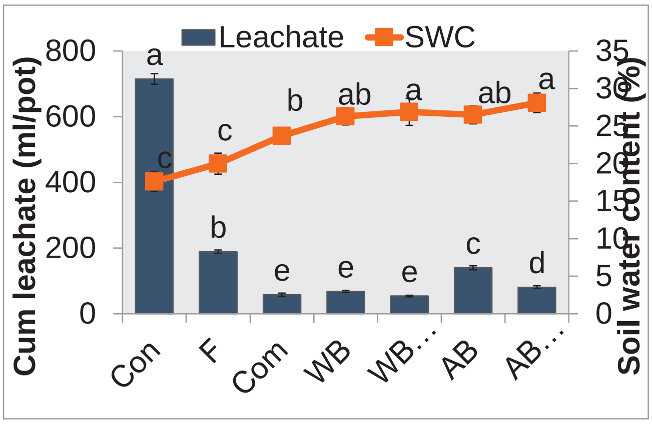


3. Biochar and COMBI-mix amendments increase properties and reduce nutrient leaching





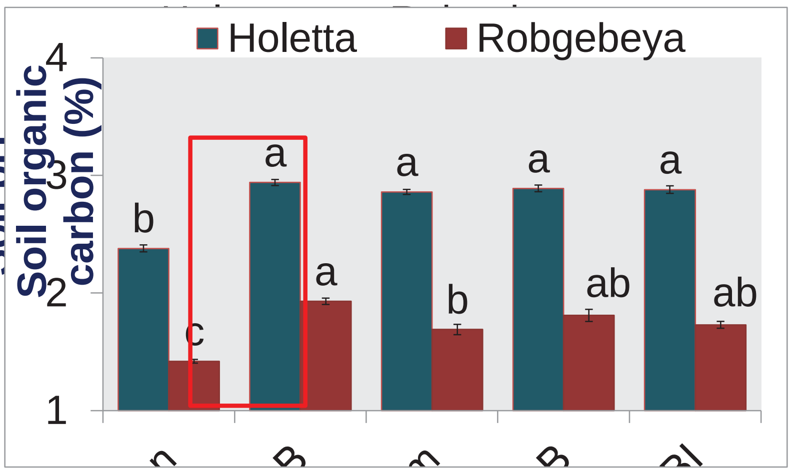
Cumulative leachate and soil water content



Treatment	Nutrient leaching (mg pot[-1]) NO$_3$-N	P	K
Control	102.1 b	0.37 d	22.8 a
Fertilizer (F)	133.6 a	1.23 a	20.7 b
F + Com	85.7 c	0.18 f	10.8 c
F + WB	44.7 ef	0.26 e	6.5 e
F + WB +Com	35.6 f	0.14 g	6.4 e
F + AB	69.4 d	0.46 c	11.0 c
F+ AB + Com	47.9 e	0.63 b	8.4 d
p level	***	***	**
LSD $_{(0.05)}$	10.1	0.04	1.7

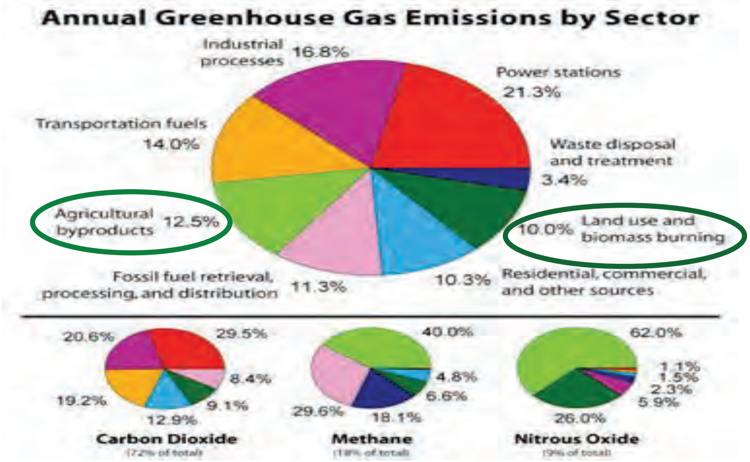
Con=Control; F= Fertilizer; Com= Compost; WB=Willow biochar; AB=Acacia biochar

Application of biochar and biochar-compost improved soil pH and SOC after barley harvest



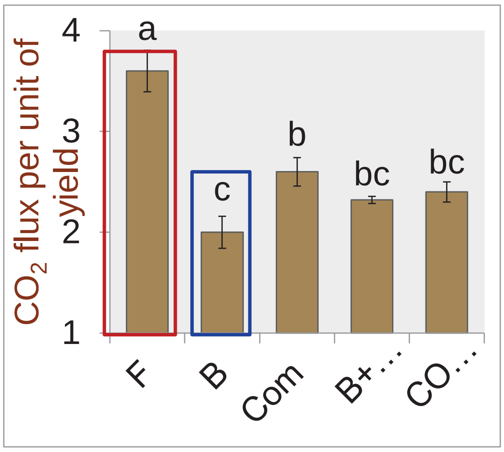
F=Fertilizer; B=Biochar; Com=Compost; COMBI=Co-composted biochar-com

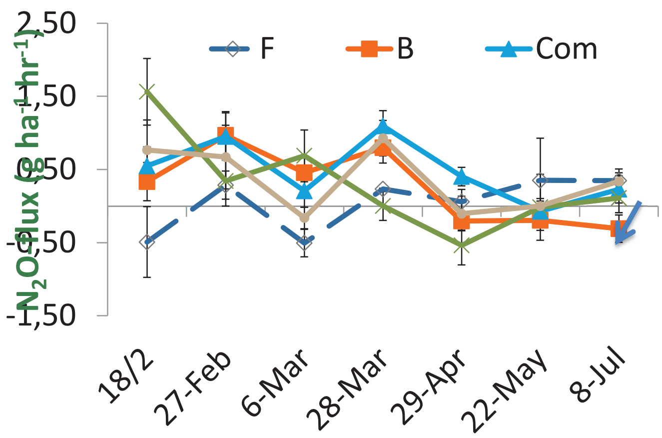
4. Organic amendments reduce greenhouse gas emissions



Units of CO_2 produced per unit of maize yield (kg CO_2 ha^{-1}/kg yield ha^{-1})

N_2O flux from organic amendments compared to fertilizer only in maize field





Conclusions: Biochar, Biochar + Compost mixture and COMBI-mix

Increase:

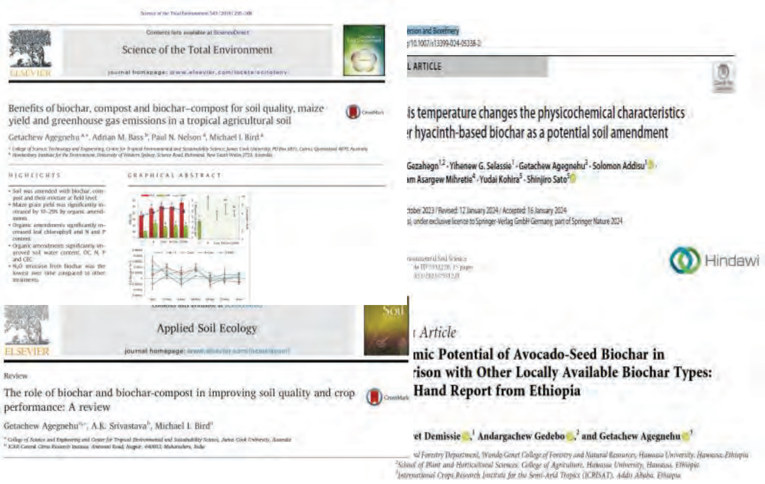
- Plant growth and crop yields
- Soil organic matter
- Soil pH and P availability
- Soil fertility and nutrient retention
- Soil microbial biomass
- Soil water holding capacity

Decrease:

- Soil bulk density
- Al saturation and soil acidity
- Fertilizer needs
- Nutrient leaching
- Greenhouse gas emissions

Way Forward

- Long-term effects of biochar application, beyond the first year.
- Factors which determine the magnitude and direction of the response.
- Impacts of biochar on C sequestration, soil quality, crop yield, and GHG emission.
- Interaction effects of biochar and fertilizers on soil properties and crop yield.
- Optimal application rates, amount of fertilizer that can be reduced, and long-term re-application practice.
- Develop the mechanistic understanding of interactions between biochar, soil, nutrients, water, microorganisms, and crops that underpin improvements in crop yield and soil quality.
- The quality of biochar as a soil amendment varies significantly with the feedstock and the production conditions.
- Policy on the use of biochar (standards; mapping feedstock source, amount and source, preparation, economics, etc.)


Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Benefits of biochar, compost and biochar–compost for soil quality, maize yield and greenhouse gas emissions in a tropical agricultural soil

Getachew Agegnehu[a,*], Adrian M. Bass[b], Paul N. Nelson[a], Michael I. Bird[a]

HIGHLIGHTS

- Soil was amended with biochar, compost and their mixture at field level.
- Maize grain yield was significantly increased by 10–29% by organic amendments.
- Organic amendments significantly increased leaf chlorophyll and N and P content.
- Organic amendments significantly improved soil water content, OC, N, P and CEC.
- N_2O emission from biochar was the lowest over time compared to other treatments.

GRAPHICAL ABSTRACT

Applied Soil Ecology

Review

The role of biochar and biochar-compost in improving soil quality and crop performance: A review

Getachew Agegnehu[a,*], A.K. Srivastava[b], Michael I. Bird[a]

L ARTICLE

is temperature changes the physicochemical characteristics
r hyacinth-based biochar as a potential soil amendment

Gezahegn[1,2] · Yihenew G. Selassie[1] · Getachew Agegnehu[3] · Solomon Addisu[1] ·
am Asargew Mihretie[4] · Yudai Kohira[3] · Shinjiro Sato[5]

tober 2023 / Revised: 12 January 2024 / Accepted: 16 January 2024
s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2024

Hindawi

Article

mic Potential of Avocado-Seed Biochar in
rison with Other Locally Available Biochar Types:
Hand Report from Ethiopia

et Demissie,[1] Andargachew Gedebo,[2] and Getachew Agegnehu[3]

[2]School of Plant and Horticultural Sciences, College of Agriculture, Hawassa University, Hawassa, Ethiopia
[3]International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Addis Ababa, Ethiopia

Thank You

48

Biochar based indigenous fertilizers for enhanced soil fertility, crop productivity and mitigate climate change: a local solution for global challenge.

Milkiyas Ahmed (PhD)

February 13, 2024

Addis Abeba, Ethiopia

Introduction

- Most Ethiopian farming households are
  - Resource-poor
  - practice subsistence level, low-input, rain-fed crop production systems
  - with very low crop productivity.

Land degradation and soil fertility decline

The limited capacity of resource-poor smallholder farmers to adopt the large-scale use of imported, expensive conventional fertilizer

suggest that there is a need for locally available resource-based approaches to restore soil fertility

DBFZ ETH-SOIL

- Many agricultural and urban wastes that would make superb fertilizers, pose great threats to safety and health

- Use of biochar and biochar-compost mixtures from different alternative organic sources can be an option for improving soil fertility and restoring degraded land.

Objective

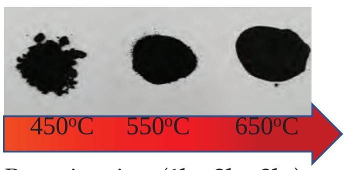
- ➢**Develop indigenous and low-cost alternative fertilizer** from non-competitive residues.
- ➢To provide a proof-of-concept for a **recapitalization of soil fertility using local nutrient sources**

Biochar Production

- **Biochar** is a carbon-rich solid material produced by heating biomass in an oxygen-limited environment.

Coffee husk biomass

Pyrolysis Unit



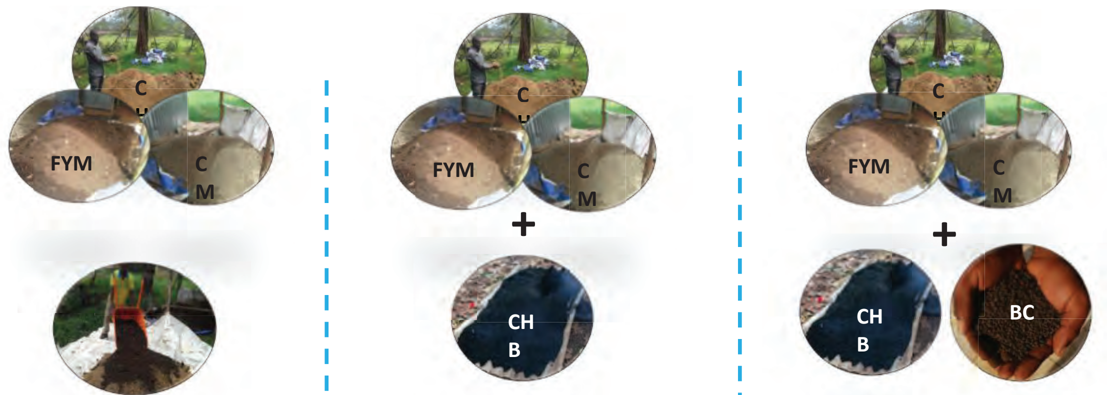
Retention time (**1hr, 2hr, 3hr**)

Biochar quality test

List of 16 indicator PAHs	T450 R1	T450 R2	T450 R3	T550 R1	T550 R2	T650 R1	T650 R2
Naphthalene	4.5	4.3	4.1	1.5	**0.7**	0.7	3.5
Acenaphthylene	<0.1	<0.1	<0.1	<0.1	**<0.1**	<0.1	<0.2
Acenaphthene	<0.1	<0.1	<0.1	<0.1	**<0.1**	<0.1	<0.2
Fluorene	<0.1	<0.1	<0.1	<0.1	**<0.1**	<0.1	0.2
Phenanthrene	1.4	0.6	0.6	<0.1	**<0.1**	<0.1	0.4
Anthracene	<0.1	<0.1	<0.1	<0.1	**<0.1**	<0.1	<0.2
Fluoranthene	0.2	0.1	0.2	<0.1	**<0.1**	<0.1	<0.2
Pyrene	0.2	0.2	0.2	<0.1	**<0.1**	<0.1	<0.2
Benzo(a)anthracene	0.1	<0.1	<0.1	<0.1	**<0.1**	<0.1	<0.2
Chrysene	0.2	<0.1	<0.1	<0.1	**<0.1**	<0.1	<0.2
Benzo(b)fluoranthene	<0.1	<0.1	<0.1	<0.1	**<0.1**	<0.1	<0.2
Benzo(k)fluoranthene	<0.1	<0.1	<0.1	<0.1	**<0.1**	<0.2	<0.1
Benzo(a)pyrene	<0.1	<0.1	<0.1	<0.1	**<0.1**	<0.1	<0.2
Indeno(1,2,3-cd)pyrene	<0.1	<0.1	<0.1	<0.1	**<0.1**	<0.1	<0.2
Dibenzo(a,h)anthracene	<0.1	<0.1	<0.1	<0.1	**<0.1**	<0.1	<0.2
Benzo(g,hi)perylene	<0.1	<0.1	<0.1	<0.1	**<0.1**	<0.1	<0.2
sum of 16 EFSA-PAK	**<7.6**	**<6.4**	**<6.3**	**<3**	**<2.2**	**<2.3**	**<6.6**

Biochar produced at a **550°C with 2 hour RT** has the **lowest PAHs**.

Biochar based fertilizer production



3:1:1 ratio (by volume) and composted

Conventional Compost

Biochar 20% of the total mixture mixed and co-composted

Biochar based fertilizer

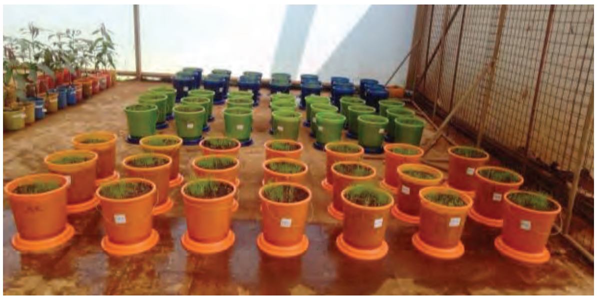
Biochar 20% and bone char mixed and co-composted

Biochar based fertilizer + bone char

No	Treatments
1	Conventional Compost **(C1)**
	60% NP
2	Biochar + Compost (co-composted) **(C2)**
	60% NP
3	Conventional Compost (C1) + biochar (20% of the biochar directly applied)
	60% NP
4	Biochar + Compost + Bone char (co-composted) **(C3)**
	60% NP
5	Biochar + Compost (co-composted) **(C2)** + **Bone char (directly applied)**
	60% NP
6	Recommended mineral fertilizer

No.	Fertilizer sources	Amount in Kg/ha
1	NPS	200 kg at planting
2	UREA	100 kg top dressing

Pot experiment



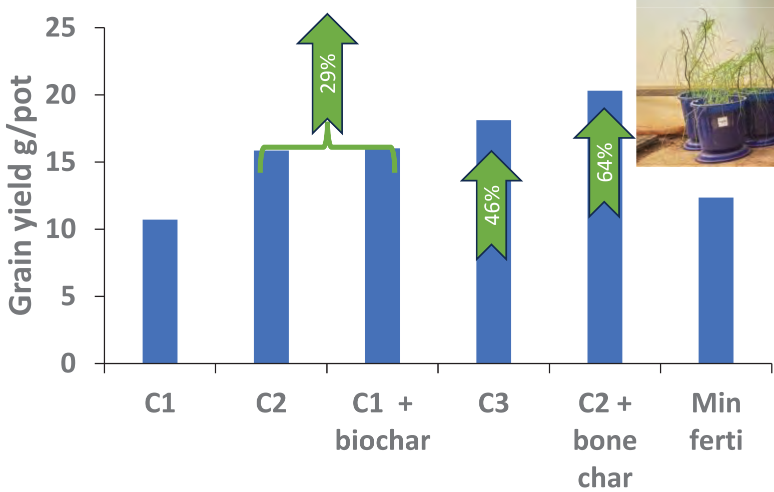
Field experiment

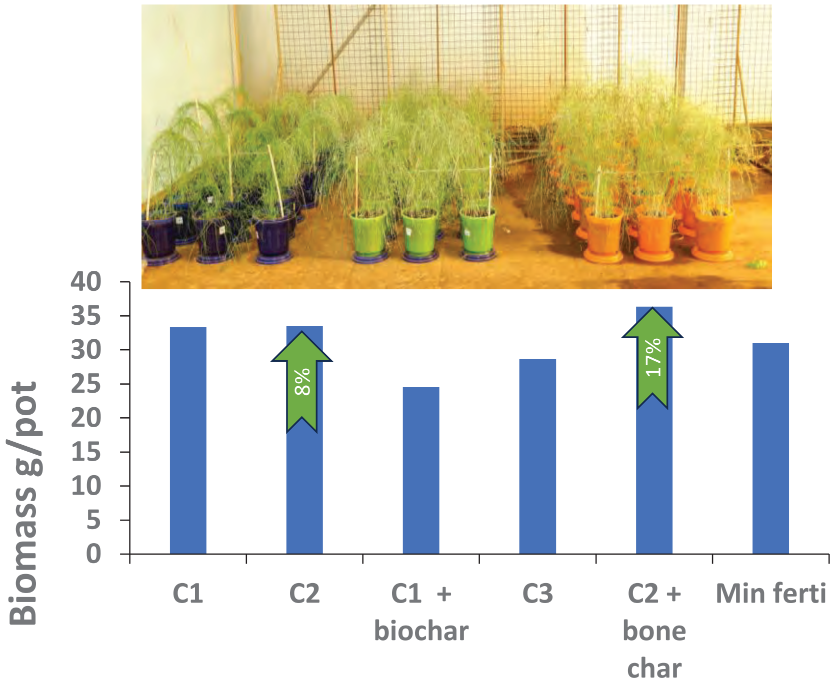
- Biochar based fertilizers was applied in row, below the root zone at the rate of 10 t/he

- On the top 60% of inorganic fertilizer were drilled, then covered by soil.

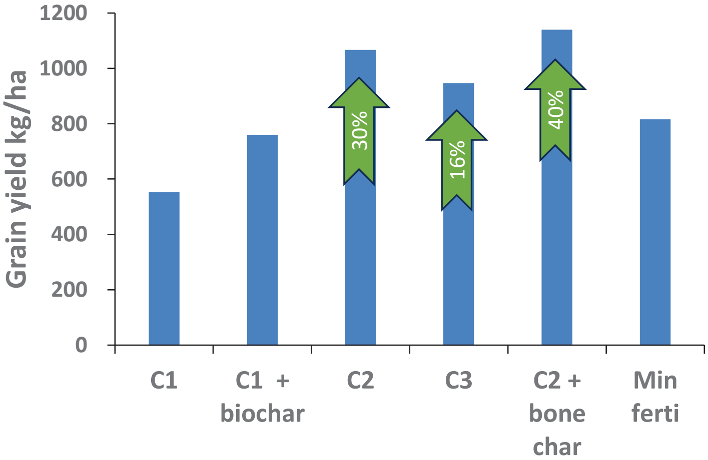
- Teff variety Qunco was used as a test crop and sowed at the rate of 12Kg/ha.

Results

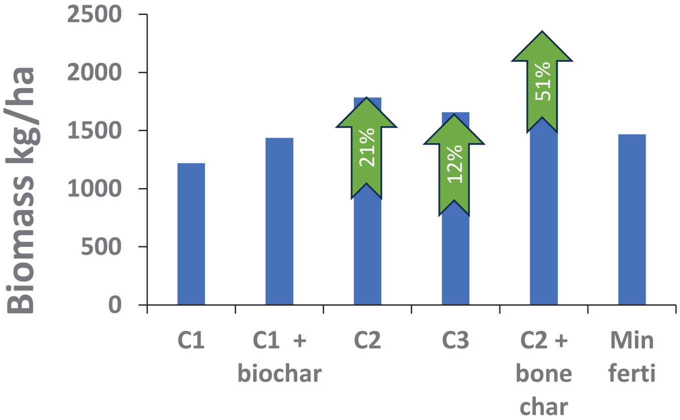




Biomass g/pot
40
35
30
25
20
15
10
5
0
8%
17%
C1
C2
C1 + biochar
C3
C2 + bone char
Min ferti



Grain yield kg/ha
1200
1000
800
600
400
200
0
30%
16%
40%
C1
C1 + biochar
C2
C3
C2 + bone char
Min ferti


Biomass kg/ha
2500
2000
1500
1000
500
0
21%
12%
51%
C1
C1 + biochar
C2
C3
C2 + bone char
Min ferti


Thank You
Gracias
Спасибо
Tak
Danke
Merci
Obrigado
Kiitos
Grazie
Takk
Köszönöm
Efharisto
Xièxie
Toda
Hvala
Sagolun
Dankjewel
Matondo
Mauruuru
Rahmat
Faleminderit
Misaotra
Terima Kasih
Mahalo
Mèsi
Dankon
Dankie
Gratias Tibi
Mercé
ありがとう
شكرا
תודה

Evaluation of biochar-treated amendments for their agronomic effectiveness in acidic soils: (Part I) Assessing the production process and product quality

Researchers:

Yackob Alemayehu[1] | Temesgen Kebede[1] | Habtamu Berihun[1] | Negussie Zeray[1]
Dereje Andualem[1] | Abebe Nigussie[2] | Milkyas Ahmed[2] | Zeleke Wondimu[2]

2nd Soil Symposium
Soil amelioration with biochar
13th February 2024, Addis Ababa

[1] Dilla University

ETH-SOIL

Contents:

Introduction

Objectives

Methodology

Results

Conclusion

***Pot-trials: current status**

Introduction:

- Coffee production in Gedeo is the main component of its mixed-crop-livestock system,
  - coffee processing practices generate a huge amount of coffee processing waste (CPW) posing a threat to the environment due to unsafe disposal.
- Thus, converting such agricultural wastes into potentially valuable soil conditioners/fertilizers appears to be an opportunity to solve this double challenge.
- However, traditional composting of CPW –
  - poor efficiency and
  - long composting period due to the high lignocellulosic content of CPW
- To solve this:

  we used the vermicomposting technique with process-enhancing additives to
  - modify the vermicomposting process and
  - improve the fertilizing value of the final product

Introduction:

- The project involved in integrating biochar with enriched organic preparations:
  - vermicompost (VC), and manure-based liquid formulation (MLF), and
  - testing their various quality during preparation process and
  - after soil addition (agronomic value and the behavior of nutrients in soils).
- Therefore, the VC study involving the conversion of coffee wastes into efficient bio-fertilizers was conducted in two stages of vermicomposting:
  a) lab-scale study (experiment I)
  b) enrichment study (experiment II) involving different proportions of CPW and N-rich substrate (poultry manure, PM) mixtures each without/with initially screened biochar level, under vermibed condition.
- In both experiments, the growth and reproduction of earthworms (Eisenia fetida) as a bio-indicator parameter for vermicomposting process, and various quality parameters were monitored.

Goals and objectives of the project:

5

The overall goal of project.

- to develop effective biochar-based nutrient-rich fertilizers from locally-available biowastes that improve soil health and maize/barley productivity while reducing production costs and environmental impacts

Objectives:

a) to evaluate the effect of biochar addition on the activity of earthworms and the obtained vermicompost.

b) to investigate whether enrichment agent (with biochar) during the process has added value to the quality of vermicompost product of coffee processing waste.

c) to evaluate the effect biochar on the fertilizer properties of MLF

d) to investigate the effects of biochar-assisted enriched preparations (VC and MLF) on growth, and nutrient use of maize and barley crops and nutrient availability in acidic soil

Biochar preparation

Biochar: coffee pulp collected from a local wet-dry coffee processing units….air-dried …

- Jimma: produced under a slow-pyrolysis process in O_2-limited furnace after cooling the produced biochar
- Dilla: using a locally-made pyrolysis unit.
- appropriate for farmers to produce biochar at a small-scale level.
  - the impurities removed, crushed into a fine powder.
- samples characterized for pH, fixed C, bulk density, ash yield, total N

Experiment I: testing biochar dose on the activity of earthworms…

7

Preparation of mixtures for bin vermicomposting (CPW: CM 3:1)

Trt	Biochar%	Biochar wt (g)	Biowaste dry(g)	Total wt (g)
1	0	0	1200	1200
2	3	36	1164	1200
3	6	72	1128	1200
4	9	108	1092	1200
5	12	144	1056	1200
6	15	180	1020	1200
7	20	240	960	1200
8	25	300	900	1200

Coffee processing waste (CPW)

Poultry litter (PL), & CM

Biochar (CHB)

Experiment I: testing biochar dose on the activity of earthworms…

Measurements *Eisenia fetida* activities

- Growth, reproduction, and biomass production at 0, 20, 35, 55, 75-d…):

Counting – washing/blotting with filter paper – weighing

- **reproduction** (in terms of number of cocoons, juveniles, and adult)
- **biomass** (weight gain)
- **growth rate(mg/worm/day**
- conversion rate of waste to vermicompost

Lab-level vermicomposting: testing biochar effect on the activity of earthworms

Experiment II: Enrichment study: vermibed level vermicomposting

- CPW as the main component (>50) is mixed with cow dung and/or poultry litter in different proportions in the absence and presence of biochar
- earthworms (Eisenia fetida) - 1.6 kg/m² stocking density

Table 2: Combinations of composting substrates

Code	% Proportion of mixtures (w/w, dry weight)			Biochar (9%)	Ratio
	CPW	Cow dung	Poultry litter		
CPW single	100	0	0	Without	-
CPW:CD	75	25	0	Without	3:1:0
CPW:CD:PL	62.5	25	12.5	Without	2.5:1:0.5
CPW:PL	50	25	25	Without	2:1:1
CP:CD +B	75	25	0	With	3:1:0 + 9%B
CPW:CD:PL +B	62.5	25	12.5	With	2.5:1:0.5 + 9%B
CPW:PL +B	50	25	25	With	2:1:1 + 9%B

Experiment II: Enrichment study: vermibed level vermicomposting….

composting mixtures, preparation and vermicomposting process on vermibeds

Earthworm related studies

Total population and biomass of earthworms at 35, 70d

- **Method**: hand-sorting method (Gong et al.2021)
- **Sample size**: 4 samples per vermibed
- Counting the earthworm population groups: juvenile and adults separately
- values converted into **total population per m²** for each vermibed
- **Biomass of earthworm**: each hand-sorted – washed (DW) - weighed - placed back to vermibed

Sampling core size= 20 × 20 cm

Experiment II: Enrichment study: vermibed level vermicomposting…. 12

Sampling and measurements: changes during the period of vermicomposting

- physico-chemical analysis of final vermicompost

- **Physico-chemical analysis**: raw material, initial mixtures, 35, final (70d) vermicompost

Parameter	Method	Instrument used
pH-H2O	1:2.5	
EC	1:5	
TOC	Walkley and Black	
TN	Kjeldahl Method	
Total P	Metavanadate (Colorimetric)	Spectrophotometer
Copper	DTPA-Extraction	ICP-OES
Iron	DTPA-Extraction	ICP-OES
Manganese	DTPA-Extraction	ICP-OES
Boron	DTPA-Extraction	ICP-OES
Zinc	DTPA-Extraction	ICP-OES
Potassium	Mehlich-3	ICP-OES

Calculations: using various indices:

- N loss during vermicomposting
- OM loss
- Relative efficiency of nutrient recovery.

13

Seed germination bioassays for phytotoxicity test:

- determined to assess the quality of vermicompost
- Aqueous extracts of each was prepared (w/v) using standard preparation protocol (Tiquia, et al. 1996),
- 10-ml of filtered extracts was transferred into petri-dish having a filter paper, 20 seeds placed in 4 replication.
- After 7-days, data on germination rate, root length and shoot length will be collected.
- Relative germination of seed (RSG), relative growth of root (RRG) and germination index (GI)

$$\mathrm{RSG\%} = \frac{\text{No. of seeds germinate in trt}}{\text{No. of seeds germinate in control}} \text{x100}$$

$$\mathrm{RRG\%} = \frac{\text{Average root elongation for trt}}{\text{Average root elongation for control}} \text{x100}$$

$$\mathrm{GI\%} = \frac{\mathrm{RSG}}{\mathrm{RRG}} \text{x100}$$

Results

14

Summarized findings of experiment I

biochar effect on worm activity and property of VC

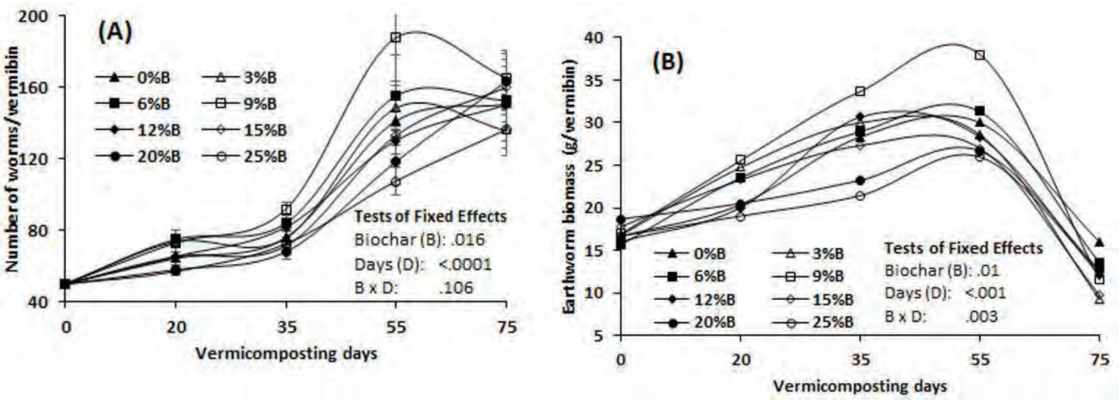


Fig.1. Temporal changes in the (a) population of adult earthworms *Eisenia fetida*, (b) biomass weight under different biochar doses in coffee waste-based vermicomposting.

Results…

Summarized findings of experiment I…

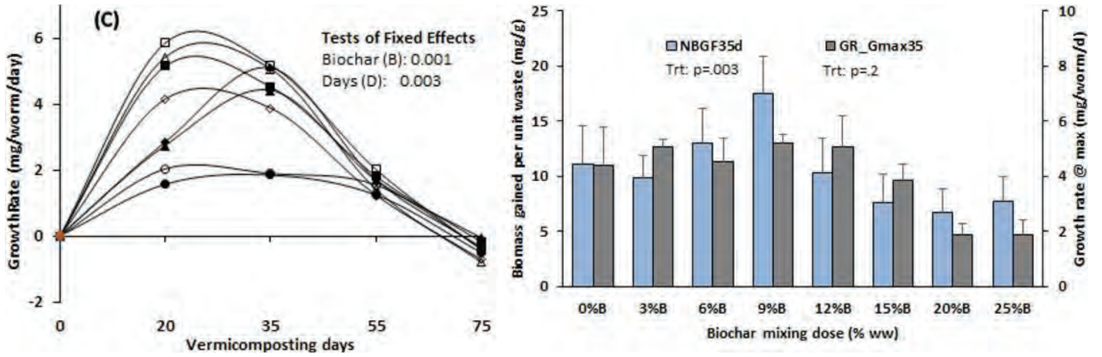


Fig.1. Temporal change in the (a) growth rate, and (b) net biomass gain per unit feed under different biochar doses in coffee waste vermicomposting over the period of 70d. Error bars re[resent standard error (n=4).

9% better biochar level promoted to the subsequent enrichment studies

Results….

Summarized findings of experiment I…

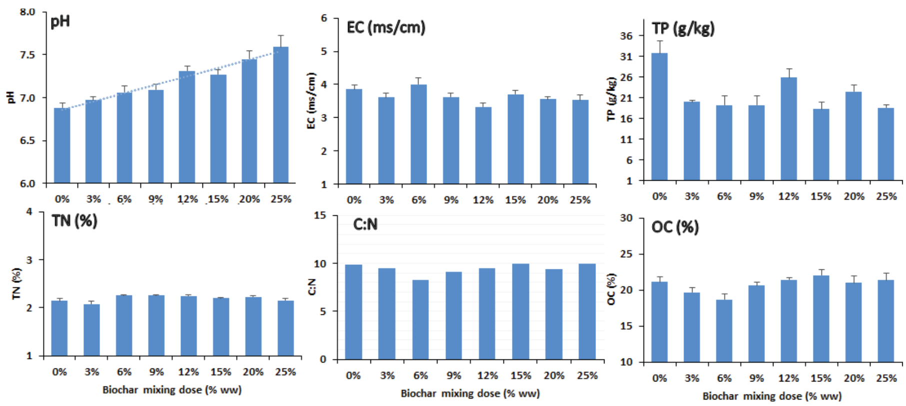


Fig.1. Chemical of final vermicompost products under different biochar doses in coffee waste-based vermicomposting over the period of 70d.

Results….

Summarized findings of experiment I...

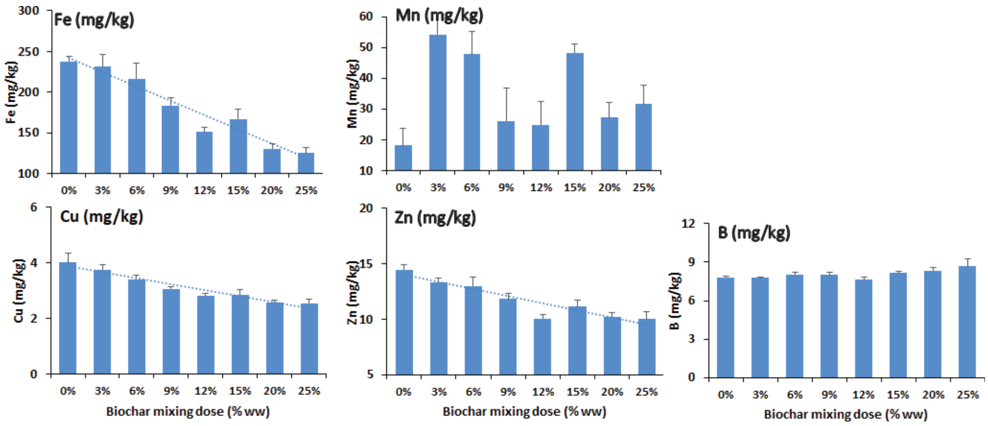
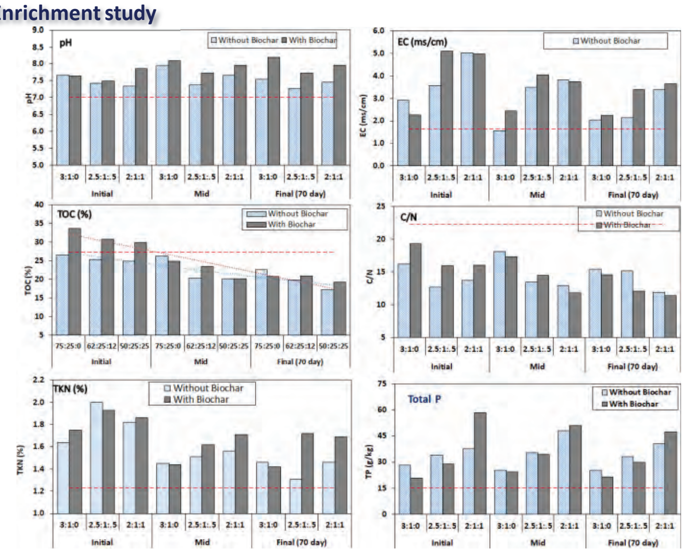


Fig.1. Chemical properties of final vermicompost products under different biochar doses in coffee waste-based vermicomposting over the period of 70d.

Analysis of quality parameters of final vermicompost products:

Results

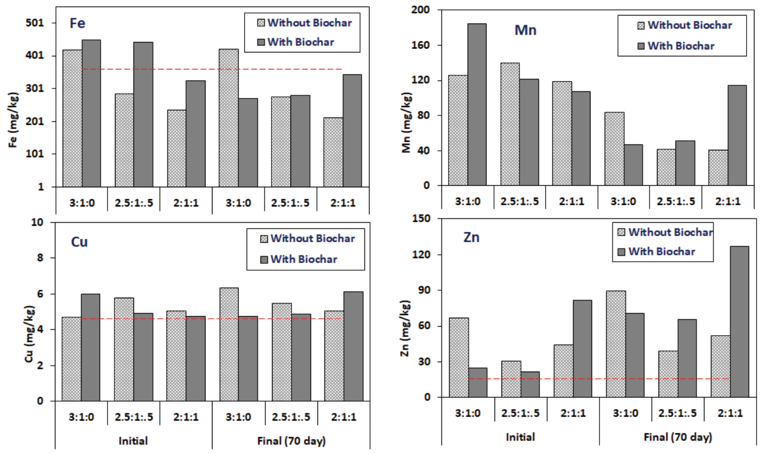
Experiment II... Enrichment study



Chemical properties during the period of vermicomposting

Results

Experiment II… Enrichment study



Initial and final available micronutrients levels of vermicomposts different N-rich level with and without biochar

Results

Experiment II… Enrichment study

Table: Earthworm population under different N-rich level with and without biochar during the period of vermicomposting

CP:CD:PL +B	35-d Juvenile	35-d Adult	35-d Total	70-d Juvenile	70-d Adult	70-d Total
3:1:0	39.0 ± 2.3	137.8 ± 9.5	176.8 ± 10.5	351.8 ± 39.1	265.5 ± 15.4	617.3 ± 46.9
2.5:1:.5	48.3 ± 6.8	130.5 ± 44.2	178.8 ± 49.5	31.0 ± 9.9	150.3 ± 34.8	181.3 ± 42.8
2:1:1	74.0 ± 4.3	212.5 ± 47.8	286.5 ± 50.8	111.5 ± 12.9	221.8 ± 62.7	333.3 ± 74.1
3:1:0 +9%	59.0 ± 4.4	160.5 ± 30.5	219.5 ± 34.3	234.3 ± 62.6	261.8 ± 33.3	496.0 ± 63.6
2.5:1:.5+9%	26.3 ± 3.0	135.0 ± 27.4	161.3 ± 29.7	92.5 ± 3.9	153.0 ± 29.0	245.5 ± 32.8
2:1:1+9%	80.5 ± 14.1	167.5 ± 42.2	248.0 ± 55.9	257.3 ± 17.7	203.3 ± 18.2	460.5 ± 22.4

Earthworm biomass

CP:CD:PL +B	35-d Total biomass (g)	35-d Total biomass (kg/m²)	70-d Total biomass (g)	70-d Total biomass (kg/m²)
3:1:0	59.3 ± 4.4	29.6 ± 2.2	76.5 ± 5.6	38.3 ± 2.8
2.5:1:.5	45.5 ± 13.8	22.8 ± 6.9	51.0 ± 6.5	25.5 ± 3.3
2:1:1	84.01 ± 4.2	42.07.1	73.5 ± 20.7	36.8 ± 10.4
3:1:0 +9%	58.3 ± 8.6	29.1 ± 4.3	71.0 ± 6.8	35.5 ± 3.4
2.5:1:.5+9%	45.8 ± 9.0	22.9 ± 4.5	46.5 ± 8.1	23.3 ± 4.1
2:1:1+9%	69.0 ± 16.1	34.5 ± 8.1	68.3 ± 7.1	34.1 ± 3.5

Results

Experiment II… Enrichment study

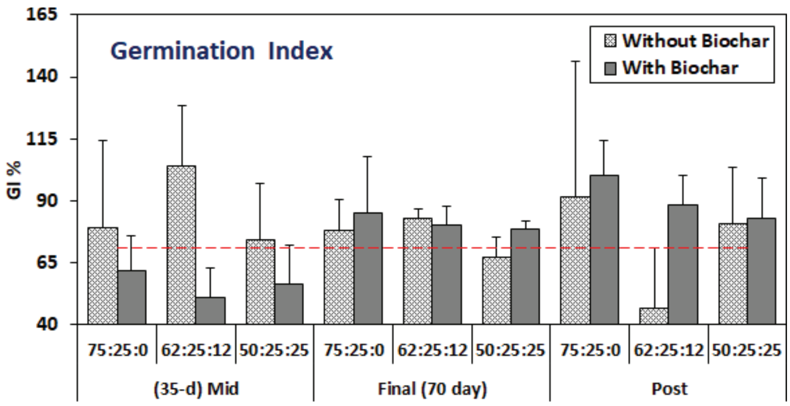


Fig: Germination index (GI) of different N-rich substrate with and without biochar during the period of vermicomposting and 2-weeks after harvesting

Conclusion

Overall, the results indicated

1. The resulting vermicomposts (CPW+PL) with biochar generally exhibited more fine particles, decrease in C/N ratio, TOC, and mass reduction, indicating the faster progression of vermicompost maturity as also evidenced by worm population decline towards the end.
2. Vermicomposting technique with process-enhancing additives (biochar, N-rich substrate) could be a good strategy for the effective transformation of CPW into a valuable resource
   - management of coffee processing waste in the region.
3. increase over the LOF group (the least GI, relative seed germination, and root elongation also observed) suggesting
   - biochar successfully reduced addition phytotoxicity o these manure

23

Pot-trials: current status

- under the greenhouse experiment: to evaluate the crop response to the above-mentioned BBF products. Pot trials with maize and barley crops grown using each VC and LOF treatment (with/without biochar) at two application rates, including NPK-mineral fertilizer and pure biochar groups.
- 20 treatments

24

Pot-trials: current status…

25

Pot-trials: current status…

Pot-trials: current status…

29 d: maize and barley trial crops

Thank you

ETH-SOIL

Smallholder farmers involved preparation and evaluation of biochar-based fertilizers

Project team members:

Wondimu Tamara
Ermias Alayu
Mekdes Lulu and
Girma W/Michael

2nd Soil Symposium: Soil amelioration – the circular way!
13th February 2024

Outline

- **Introduction**
- **Materials and methods**
- **Results and discussion**
- **Conclusion**

Introduction

- Agriculture serves as the cornerstone of economies worldwide.
- However, its sustainability is affected globally with several factors ice erosion, acidification, nutrient imbalances, and etc.
- In many parts of Ethiopia including the study area, intensive cultivation of agricultural soils coupled with inappropriate and prolonged use of chemical fertilizers resulted in serious environmental issues which greatly affects the productivity of soil and crops (Montanarella et al., 2016; Erango et al., 2017).

Cont…

- In the Hadiya zone, central Ethiopia, the sustainability of major cereal crops production has also become a major concern because of severe soil erosion, continuous cultivation, and others, which causes depletion of soil nutrients. E.g., our initial soil survey in Table 1.
- Among others, food barley is one of the multi-purpose crop for many smallholder farmers in the region, providing food, feed, malt, home made drinks, and other revenues.
- However, its productivity remains low due to several constraints like depletion of soil fertility, which is caused by intensive cropping, imbalanced fertilization, limited application of organic manures, and soil erosion (Gebre et al., 2016).

Table 1. Initial soil properties of the experimental soil

Soil parameters	Mean ±SD value
Soil Texture	24±2% Sand
	36±3% Clay
	40±2.2% Silt
Soil pH (1:2.5)	4.9±0.51
Organic carbon (%)	2.7±0.25
Nitrate-Nitrogen (mg/kg)	8.8±0.85
Ammonium – Nitrogen (mg/kg)	10.5±0.5
Total Nitrogen (%)	0.2±0.01
Avail. Phosphorus (mg/kg)	12.8±0.92
Total Phosphorus (mg/kg)	679.5±2.1

Cont…

- Although efforts have been made and continue to be made to stop the soil fertility problem through the application of chemical fertilizers, but the ability of inorganic fertilizers to maintain soil fertility is limited.
- In such scenario, it becomes crucial to adapt and innovate a research-based sustainable soil fertility management approach.
- Fortunately, the use biochar based fertilizers (BBFs) have emerged as a promising solution to improve soil fertility, crop productivity and promoting sustainable agriculture.
- Previous research works conducted in Ethiopia also suggested that use of BBFs can improve the yield of a variety of crops and soil attributes.
- So far, no research work has been conducted on the application of biochar-based fertilizers to improve soil fertility and crop yield at field levels in the study areathrough farmers' participatory approach.

5

Objective of the Study

- Therefore, it needs further study investigation to understand the effects of applying BBFs on soil infertility and crop productivity (Agegnehu et al., 2016 ; Das et al., 2021; Demissie et al., 2023).

- **General objective**
  - To prepare and evaluate the effect of biochar based fertilizers on food barely productivity and soil fertility management through the involvement smallholder farmers' in Anlemo Woreda of Hadiya Zone, Central Ethiopia.
- **Specific objectives**
  - To evaluate the response of food Barley to the application of bio-char based fertilizers at the study area.
  - To evaluate the effect of bio-char based fertilizers application on degraded soil fertility improvement.
  - To determine the appropriate type of bio-char based fertilizers that improve sustainable soil fertility for crop productivity.

6

Materials and Methods

Study area description

- The study was conducted on farmers' fields at sanfe wasala Kebele, Analemo district, Hadiya Zone southern Ethiopia.
- The district is purposively selected as it represent quite well the farming systems, where intensive crop cultivation and accelerated rain-induced soil erosion is at an alarming rate.

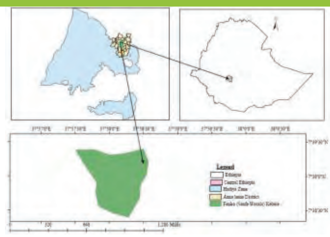


Figure 1. Map the study

Cont…

❑ Preparation of BBFs, treatments and experimental design

❑ Preparation of BBFs and characterization

▶ Biochar production and analysis method

- *Cordia africana* saw dust was collected, washed with distilled water, and kept for sun dry before making biochar.
- The biochar was produced following Huang et al. (2016) method with slightly modification using furnaces with a pyrolysis temperature range of 300 - 500 °C at 2 hours.

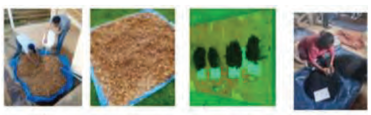


Figure 2. Photo of (a) raw *Cordia africana* saw dust washing, (b) sund drying of washed *Cordia africana*, (c) activated *Cordia africana* carbon at different temperatures, and (C) powdered activated *Cordia africana* carbon

8

Cont…

Biochar analysis methods

Table 2. Biochar analysis method

Biochar properties	Measurement method used
pH (1:5)	Digital Electrode method (Chopra and Kanwar, 1976).
Electrical conductivity (mS/cm)	
Moisture content (%)	ASTM D2867-91 method (Heavner et al., 1996).
Ash content (%)	
Bulk density (g/mL)	
Pore volume (mL/g)	Gravimetric method (Verla et al., 2012).
Organic carbon (%)	Loss ignition method (Sadaka et al., 2014).
Total Nitrogen (%)	Kjeldahl Method (Jackson, 1958).
Total Potassium (mg/kg)	Weight digestion method (i.e., Aquarejia+ICP OES) (Bai et al., 2018).
Total Phosphorus (mg/kg)	
Total Sulphur (mg/kg)	

9

Cont…

❑ Production of conventional compost

- Agricultural wastes (green leaves, maize stalks, animal dung, peel of fruit and vegetables, horse dung, grass cuttings, and wood ash) were gathered from surrounding area.
- A 2m length x 1m width x 0.5m depth size composting pit reactor was used (Figure 3).
- The preparation was done for 3 months following Chinweuba et al. (2017) approach, with a few minor changes to the feedstock organic materials and other things.

Figure 3. Conventional compost preparation process from locally available feed stocks using pit method under shaded conditions.

10

Cont…

❑ Production of vermicompost

- Similarly, same feed stock materials and method except with addition of red earthworms was used for vermicompost preparation.
- The production was done in a two vermicomposting reactors (size: 1.5m length x 1.1m width x 0.6m depth) (Figure 3).
- Vermicompost was produced within 60 days, and harvested and stored under shade using plastic materials.

Figure 4. Vermi-compost production process using red earthworms in woody reactor under shaded conditions.

Cont…

❑ BBFs co-composting

- BBFs were formulated on the basis of 5% and 10% of 5 t ha^{-1} biochar with 5 t ha^{-1} organic fertilizers for co-composting process.
- The co-composting process was done two weeks.

Figure 5. Co-composting of biochar and organic fertilizers

Cont…

DBFZ

Table 3. BBFs analyses methods

Type of parameters	**Measurement method**
pH (1:5)	Digital Electrode method (Chopra and Kanwar, 1976).
Electrical conductivity (mS/cm)	
Nitrate – Nitrogen (mg/kg)	Devarda's Method (Siegel, 1980).
Ammonium – Nitrogen (mg/kg)	
Total nitrogen (%)	Kjeldahl Method (Jackson, 1958).
Organic carbon (%)	Walkely And Black (Walkley and Black, 1934).
Available phosphorous (mg/kg)	Olsen method (Olsen et al., 1954).
Total phosphorous (mg/kg)	Weight digestion method (i.e., Aquarejia+ICP OES) (Bai et al., 2018).
Total Potassium (mg/kg)	
Total Sulphur (mg/kg)	
Boron (mg/kg)	DTPA-Sorbital Extraction (FAO, 2022).
Iron (mg/kg)	
Manganese (mg/kg)	
Zinc (mg/kg)	
Copper (mg/kg)	

13

Cont…

DBFZ

Treatments and experimental design

- A field experiment was conducted in a RCBD with 12x1x3 treatments, with three replications in plot size of 2m wide by 1m long with total area of 2 m^2.
- Distance between plots and blocks were kept 0.5 m and 1 m, respectively.

Figure 6. The treatment details:

- Control (negative control)
- NPS (positive control)
- Compost
- Vermicompost
- Compost + Vermicompost
- Compost + 5% biochar
- Compost +10% biochar
- Vermi-compost + 5% biochar
- Vermicompost + 10% biochar
- NPS +5% biochar
- NPS +10% biochar
- Compost +vermicompost +5% biochar (integrated 1)
- Compost +vermicompost +10% biochar (integrated 2)

14

Cont…

Pre- soil sampling, field layout and treatment application

- Before applied BBFs into the experimental site, soil sample was collected.
- After two weeks of co-composting, all OFs, BBFs, and Biochar were incorporated into the soil for two weeks before sowing.
- Food barley variety (HB 1307) was used as a planting material.
- Then, barely seeds were sown as rate of 90 kg ha^{-1} in rows of 25 cm spacing having a depth of 5 cm manually in the first week of August, 2023 main cropping season at field condition.
- Recommended amount of NPSB (100 kg ha^{-1}) was applied at planting. All management practices such as seed bed preparation, cultivation, weeding was done uniformly for all treatments.
- During each activity, 16 farmers were participated.

Figure 7. organic, biochar and biochar based organic fertilizers incorporation with the soil.

15

Cont…

Data Collection and Measurements

- Plant growth and yield-related traits was recorded from five sample plants randomly selected from the central rows in each plot.
- **Days to flowering** was determined as the number of days from emergence to the period when 50% of the plants in each plot produce their first flower. **Days to 90% maturity** was taken as the number of days from emergence to the period when the plants in a plot became yellow.
- **Plant height (cm)** was measured from the soil level to the apex of the main stem using a measuring tape at the maturity stage.
- **The effective and non-effective tillers per plants** were counted from each plot randomly and averaged for each plot.
- **Spike length(cm)** excluding the awns, was measured and averaged for each plot at the maturity stage.

16

Cont…

- **The number grains per spike** of was determined and filled and unfilled grains spike was counted and averaged for each plot at the maturity stage.
- **Total biomass** was calculated after sun drying from the total weight of harvest at each plot.
- **Grain yield (kg ha^{-1})** was measured for each plot after air drying and then was weighed and the straw yield obtained by the difference between total biomass and grain yield.

Data analysis

- All collected data were subjected to analysis of variance (ANOVA) using SAS version 9.20 statistical computer software (SAS, 2008).

17

Results and Discussion

❑ **Physicochemical properties of biochar**

Table 4. Physicochemical characteristics of biochar

Biochar properties	**Mean ±SD value at different pyrolysis temperature**			
	350°C	400°C	450 °C	500 °C
Soil pH (1:5)	6.4±0.99	5.5±0.49	9.02+0.21	8.8±0.91
Electrical conductivity (mS/cm)	0.39±0.09	0.78±0.1	1.1±0.13	0.92±0.06
Moisture content (%)	10.2±1.65	12.2±0.4	13±0.85	15±2.2
Ash content (%)	6.9±0.95	9.4±0.8	12.3±0.9	14.6±1.8
Bulk density (g/mL)	0.33±0.09	0.67±0.11	0.84±0.08	0.73±0.18
Pore volume (mL/g)	0.02±0.01	0.05±0.02	0.1±0.01	0.08±0.02
Organic carbon (%)	63.4±4.1	56.2±1.9	48.7+2.9	34.8±1.95
Total Nitrogen (%)	0.52±0.04	0.46±0.08	0.37±0.03	0.29±0.1
Total Potassium (mg/kg)	9938.7±5.2	9868.5±7.99	9768.4±9.6	9696.4±7.8 9
Total Phosphorus (mg/kg)	1870.3±4.82	1792.3±6.1	1789.6±5.11	1776.4±5.2
Total Sulphur (mg/kg)	192.8±4.05	187.5±3.9	172.2±3.8	154.8±5.99
PAHs (mg/kg)	-	-	5.5	-

18

Cont…

- The alkaline nature of this study biochar might be due to the increment of **ash content** (i.e., alkaline elements and available phosphorous) and **removal of acid functional groups** (Gaffar et al., 2021).
- This higher pH can be used as a potential alternative for acidic soil amendment agent, and maintain the best acceptable pH range (Dzihora, 2021).
- Biochar pH value can vary in between the range of 3.1-12.0 (Singh et al., 2017), and the present biochar pH values produced at higher are **in agreement with the recorded alkaline pH value of biochar varied from 8.84 – 9.84** (Mary et al., 2016).

Cont…

- The pore volume was increased from 0.02 to 1.0 mL/g as the pyrolysis temperature increased from 350 to 500°C.
- This increase in pore volume might be associated with the increase in morphology and surface structural changes of biochar (Amin et al., 2016). Similar study reports also indicated that biochar pore volume tending to increase with increasing pyrolysis temperature (Mary et al., 2016).
- Furthermore, in this study, a decrease in organic carbon content from 63.4 to 34.8% was observed as the operating temperature increases from 350 to 500°C. This might be due to the promotion of carbon burn-of and tar volatilization.
- In agreement to the present study finding, other similar result was reported for wheat-straw (32.40–22.8 %) biochar as the pyrolysis temperature increased from 400 to 700 °C at 1.5 hour (Gai et al. 2014).

Cont…

❑ Physicochemical properties of different organic amendments

Table 5. Characteristics of different types organic amendments

Parameters	Mean ±SD value								
	Compost	Vermicompost	Compost + Vermicompost	Compost + 5% Biochar	Compost + 10% Biochar	Vermicompost + 5% Biochar	Vermicompost + 10% Biochar	Compost + Vermicompost + 5% Biochar	Compost + Vermicompost + 10% Biochar
Soil pH (1:2.5)	7.25±0.07	7.94±0.19	7.46±0.22	8±0.11	8.27±0.01	7.61±0.2	7.73±0.21	7.78±0.11	7.96±0.02
Electrical conductivity (mS/cm)	1.67±0.01	2.64±0.05	2±0.02	2.4±0.2	1.8±0.28	1.62±0.15	1.49±0.2	1.94±0.07	1.72±0.03
Organic carbon (%)	14.8±0.92	17.5±1.1	14.2±0.34	21.2±0.47	24.7±0.38	26.9±0.67	29.9±1.89	32.3±0.61	34.4±0.93
Nitrate-Nitrogen (mg/kg)	23.8±0.98	30.6±1.75	28.6±0.73	25.4±1.8	26.7±0.9	31.1±0.99	32.2±0.52	29.8±2.05	30.2±1.09
Ammonium – Nitrogen (mg/kg)	22.4±1.2	35.7±0.99	28.3±0.66	27.4±1.5	34±0.88	36.3±1.84	38±0.93	35.1±0.79	37.2±1.12
Total Nitrogen (%)	1.2±0.11	1.64±0.05	1.4±0.15	1.8 ±0.05	1.94±0.1	2.3±0.07	2.5±0.23	2.4±0.14	2.8±0.01
Avail. Phosphorus (mg/kg)	462±6	798±3.0	648±10	392.4±6.8	384±3.4	574.8±4.92	536.4±3.0	436.8±3.9	412.4±4.04
Total Phosphorus (mg/kg)	2066±7.5	4988.1±24.0	3427.7±9.1	3474.6±8.5	3668.3±3.1	3973.3±8.91	4118.1±5.0	3642.3±9.2	3531±4.99
Total Potassium (mg/kg)	8542±6.0	11671.5±28.0	10,843±13.4	10662.1±2	9806.3±3.2	9097.6±7.0	9046.3±11.68	10427.5±5.75	9924.8±16.15
Total Sulfur (mg/kg)	2046.3±4.4	2068.3±9.95	1,866.9±10.0	1541±4.03	997.5±3.48	1691.1±6.01	1186.9±7.98	1523.1±8.1	1301.3±5.06
Boron (mg/kg)	4.49±0.49	5.5±0.49	4.8±0.17	4.7±0.17	4.1±0.14	4.2±0.22	5.36±0.69	4.85±0.34	4.48±0.39
Iron (mg/kg)	77±1.99	315.2±17.0	185.9±5.5	66.6±4.14	44.6±2.99	156.7±6.91	204.13±4.87	146.4±3.89	114±2.01
Manganese (mg/kg)	86.9±4.46	98.8±9.1	91±4.0	67.9±5.1	40.3±3.8	53.7±2.91	54.34±2.66	61.9±3.01	50.6±2.89
Zinc (mg/kg)	29±2	7.94±0.19	37.1±2.0	23.6±0.81	17.3±1.79	27.7±2.16	34.1±3.95	29.1±3.89	24.54±4.08
Copper (mg/kg)	3.9±0.21	2.64±0.05	4.5±0.37	2.3±0.16	1.6±1.56	2.5±0.21	2.9±0.2	2.72±0.19	2.31±0.29
C:N	12.3	10.8±1.1	10.1	11.8	12.7	11.7	12.0	13.9	13.4

Cont…

- The pH value of BBFs was increased due to the alkaline nature of biochar that can quickly release base cations (Wu et al., 2017).
- Similarly, the higher EC of BBFs could be due to the production of inorganic ions and dissolved substances such as phosphate, ammonium, and nitrate could have contributed to the increase in EC (Lazcano et al., 2008; Negi and Suthar, 2018).
- The increment of percentage of total organic also could be due to the large amounts of recalcitrant carbon in biochar with organic fertilizers would have resulted in lower rate of decomposition (Leckie et al, 2004).

Cont…

- Similarly, the total N increased in the combined biochar with compost and vermi-compost. Higher total N content could be explained by the abundance of surface functional groups and highly porous structure of biochar, leading to biochar pores, which enhance biological processes such as mineralization, nitrification and other mineral solubilization activities (Hagemann etal.,2017).

- However, TON in the composted biochar treatments was higher than in the sole treatments.
- The decreased C/N ratio in sole compost and vermi-compost may be due to the rate of organic N mineralization being lower than that of organic C (Wu et al., 2019).

23

Cont…

- The value of available P increased in the combined compost and vermi-compost with 10% BC .
- The higher available P upon biochar amendment with the combination of compost and vermi-compost could be due to reduced leaching losses, higher P retention, which enhance the P biogeochemical cycles (total P, available P) (Ebrahimi et al.,2021;Li etal.,2019).
- More over, the organic matter with biochar to reduce soil P fixation and increase P availability because organic matter and its decomposition products (e.g., organic acids) occupy the surfaces of phosphate adsorbents in soils and prevent the formation of P precipitation (Du et al., 2013).
- The total Potassium (K) increased in the combined compost and vermi-compost amended with 10% BC could be due to the higher surface area of biochar, which adsorbs K strongly (Martinsen et al.,2015).

23

Cont…

DBFZ

- **Effect of different fertilizer amendments on phonological and growth parameters of food barley**

Table 6. Effect of different fertilizer amendments on barley phonological and growth parameters

Treatments	Days to 50% flowering	Days of 90% maturity	Plant Height (cm)
Control	52.66^{h}	89^{g}	53.88^{g}
NPSB	54.33^{h}	97.33^{f}	75.98^{f}
Compost	57.66^{g}	100.33^{def}	77.66^{ef}
Vermicompost	60.33^{ef}	103.66^{bcde}	80.44^{de}
Compost + Vermicompost	58.33^{fg}	102.33^{cde}	81.55^{cde}
Compost + 5% biochar	60.66^{def}	105.33^{abc}	84.1^{bcd}
Compost + 10% biochar	63.00^{bcd}	106.33^{abc}	85.62^{ab}
Vermicompost + 5% biochar	64.00^{abc}	107^{abc}	86.33^{ab}
Vermicompost + 10% biochar	66.00^{a}	108.33^{ab}	87.1^{ab}
NPSB + 5% biochar	58.66^{fg}	99.33^{ef}	83.99^{bcd}
NPSB + 10% biochar	61.66^{cde}	105^{bcd}	88.88^{a}
Compost + Vermicompost + 5% biochar	63.33^{bc}	107.33^{ab}	84.88^{bc}
Compost + Vermicompost + 10% biochar	64.66^{ab}	110^{a}	86.66^{ab}
CV%	2.52	2.71	2.88
LSD(0.05)	2.57	4.71	3.95

Cont…

DBFZ

- As indicated in the table, the longest flowering days recorded in Vermicompost+10% biochar (66) followed by Compost + Vermicompost + 10% biochar 64.66. Whereas, the control (52.66) showed the shortest days to flowering and maturity.
- On the other hand, the longest days to maturity (110) was observed for treatment ‘Vermicompost+10% biochar’ while the shortest days to maturity (89) was recorded for treatment ‘control’.
- Generally, this result revealed that fertilizers treated with biochar matured lately while those treatments not treated with biochar matured earlier.
- The delayed days to flowering and maturity in biochar based fertilizers might be explained due to the positive effect of biochar's nutrient carrier effect (Bair *et al*., 2020).

Cont…

- The tallest plant height was recorded for 'NPSB +10% biochar' (88.88 cm) followed by other biochar-based organic fertilizers. Whereas, the shortest plant height (53.88 cm) was recorded from control treatment.
- This result revealed that fertilizers treated with biochar showed higher plant height than not treated with biochar.
- Additionally, Yin *et al*. (2019) reported a positive effects of biochar-based fertilizers fertilization on maize growth.
- The tallest plant height of biochar-based inorganic fertilizer might be due to the availability of nutrients, good porosity, and moisture retention capacity of biochar contributed to an increase in the plant height compared to other treatments.

Cont…

Table 7. Effect of different fertilizer amendments on yield components of food barley

Treatments	**Number of total tillers per plant**	**Number of effective tillers per plant**	**Spike length per plant (cm)**	**Number of seeds per spick**
Control	1.96^{g}	1.28^{f}	3.66^{f}	32.5^{h}
NPSB	3.85^{f}	2.75^{e}	6.44^{de}	45.61^{f}
Compost	3.88^{f}	3.1^{de}	6.05^{e}	38.66^{g}
Vermicompost	4.22^{ef}	3.33^{cde}	6.44^{de}	45.83^{f}
Compost + Vermicompost	4.66^{de}	3.39^{cde}	6.55^{cde}	46.83^{ef}
Compost + 5% biochar	5.07^{cd}	3.55^{cde}	7.21^{bc}	48.66^{de}
Compost + 10% biochar	5.55^{bc}	3.77^{bcd}	7.55^{ab}	50.5^{cd}
Vermicompost + 5% biochar	5.99^{ab}	4.44^{ab}	7.99^{a}	53^{bc}
Vermicompost + 10% biochar	6.55^{a}	4.99^{a}	8.22^{a}	56.83^{a}
NPSB + 5% biochar	4.93^{cd}	$3.18d^{e}$	7.09^{bcd}	48.83^{de}
NPSB + 10% biochar	5.1^{cd}	3.55^{cde}	7.6^{ab}	51^{cd}
Compost + Vermicompost + 5% biochar	5.36^{bcd}	4.1^{bc}	7.99^{a}	52.5^{bc}
Compost + Vermicompost + 10% biochar	5.88^{ab}	4.55^{ab}	8.1^{a}	54.83^{ab}
CV%	8.62	14.62	6.09	3.13
LSD(0.05)	0.704	0.872	0.71	2.54

Cont…

- The highest number of **total tillers and effective tillers** per plant were recorded under Vermicompost+10% biochar followed by Vermicompost+5% biochar (5.99) and Compost + Vermicompost +10% biochar (5.88) while the minimum number of total tillers per plant was recorded under the control.
- This result is in agreement with previous reports in rice (Wang et al., 2012) and oats (Schulz and Glaser, 2012), in which biochar had a beneficial effect on plant growth and tillers (Wang et al., 2014).
- In this result, biochar-based organic fertilizers significantly increased tiller bearing capacity of food barely compared to untreated once.
- The increase in number of tillers under biochar amended plots might be due to the nutritive nature of biochar that enriches the soil with essential nutrients for the long run (Major *et al*., 2010), reduce nutrients leaching (Schulz *et al*., 2013), and ultimately activates nutrient use efficiency to enhance plant growth.

Cont…

- The attainment of the higher **number of effective tillers** might be due to the positive effects of biochar in improving soil health and fertility to enhance water-holding capacity and nutrient availability which in turn promotes crop growth at different stages such as germination, seedling, flowering and yield (An *et al*., 2020).
- This result was consistent with previous reports in rice (Wang *et al*., 2012) and oats (Schulz and Glaser, 2012), in which biochar had a beneficial effect on plant growth (Wang *et al*., 2014).
- The possible reason for the increase in **spike length and number of grains per spike** with biochar based fertilizers might be related to the synergistic interaction effect of biochar and organic fertilizers which improves the root system development, enhanced the absorption of essential nutrients by plants, and promoted the growth and grains spike^{-1} of crops (Khan *et al*., 2021).

Cont…

- **Farmers' preference criteria evaluation of biochar based fertilizers impact on barley agronomic data**

Table 8. Farmers' preference criteria evaluation result

Treatments	PES	OAP	STS	NOT	NET	KH	KW	SN	PH	DR	MD	GY	SY	Total	Mean	Rank
Control	2	2	2	2	2	2	2	2	2	2	2	2	2	26	2	11
NPSB	3	3	3	3	3	3	3	3	3	3	3	3	3	39	3	10
Compost	3	3	3	3	3	4	3	3	3	3	3	3	3	40	3.07	9
Vermicompost	3	3	4	3	3	3	3	3	3	3	3	3	3	40	3.07	9
Compost + Vermicompost	3	4	3	3	3	4	3	4	3	3	3	3	3	42	3.23	7
Compost + 5% biochar	3	4	3	4	3	3	3	4	3	3	3	4	3	43	3.30	6
Compost + 10% biochar	3	4	3	4	4	3	3	4	5	5	3	4	4	45	3.46	5
Vermicompost + 5% biochar	3	4	4	4	5	4	4	3	4	4	3	4	4	50	3.84	4
Vermicompost + 10% biochar	4	4	4	4	5	5	5	5	4	4	4	5	4	57	4.38	1
NPSB + 5% biochar	3	3	4	3	3	3	3	3	3	3	4	3	3	41	3.15	8
NPSB + 10% biochar	4	4	4	3	3	3	3	4	3	3	3	3	3	43	3.30	6
Compost + Vermicompost + 5% biochar	4	4	4	4	4	4	4	4	4	4	4	4	3	51	3.92	3
Compost + Vermicompost + 10% biochar	4	4	4	5	5	4	4	4	4	3	4	5	5	55	4.23	2

Cont…

- The evaluations mean score value for each treatment ranged from 2 to 4.38.
- Among the treatments, treatment Vermicompost + 10% biochar scored the highest mean followed by Compost + Vermicompost + 10% biochar. Whereas, the control got the lowest mean score.
- The farmers preference criteria evaluation results and researchers' collected data had better performance and found to be promising.
- It seems plausible that the biochar additions increased the farmers' attentiveness towards plots with biochar. Biochar improved early plant growth and this visible difference might have enhanced the attention of the farmers.

Conclusion

- Characterization of the BBFs results revealed that the presence of important nutrients that can be a potential source of nutrients to improve soil fertility and crop productivity.
- The application of biochar significantly affected the phenological, growth and yield components of food barely.
- The results of the farmers' preference evaluation bear biochar based fertilizers performed better than other treatments in all measured parameters the productivity of barley crops.
- However, it is challenging to draw general conclusions in the absence of comprehensive agronomic, post soil and plant tissue experimental data strengthened by statistical analysis.

33

Acknowledgements

Dr. Kristin, Dr. Annet, Dr. Getachew, Betelehem, Mrs. Bellmann Virginie, Wachemo University Administrators

Thank you!

Discussions and reactions on questions raised by participatory farmers

128

Integrated use of coffee husk biochar and vermicompost on smallholder farms in Sidama Region, Southern Ethiopia

Shimelis Gizachew (PhD), School of Plant and Horticultural Sciences, College of Agriculture, Hawassa University

Background

- Continuous decline in agricultural productivity, particularly in the highland regions of Ethiopia
- Contributing factors:
  - Soil acidity,
  - Soil erosion,
  - Soil organic carbon and nutrient depletion,
  - rapidly increasing human and livestock population,
  - low agricultural input use and
  - climate change

Background…

- Organic amendments prepared from:
  - ✓ locally available and underutilized biomass can be used as a soil amendment and
  - ✓ potentially an important alternative/supplement to inorganic fertilization
- Biochar can be used in combination with other organic fertilizers including:
  - Biofertilizers,
  - compost,
  - vermicompost and others

Coffee husk?

Sidama region

- One of the major coffee producing regions
  - More than 73k ha of land covered by coffee with annual production of >50k tones of coffee in 2016 (Tesfaye et al., 2020)
- Large amount of coffee husk/pulp generated
- Coffee husk has no alternative uses and damped in the environment
- Pollution threats to soils and surface/ground water

Objectives

✓ To study the effects of different rates of biochar, vermicompost, mineral fertilizers and their integrated use on selected soil properties and yield of **Wheat** in Sidama region

Experimental site and participant farmers selections

- Hula district in Sidama region
    - Altitude: mostly highland
    - Soil acidity, soil erosion and nutrient depletion ➔ common
    - **Wheat**, barley, faba bean commonly grown
- Farmers selected based on:
    - Willingness
    - Ownership of suitable plots
- 10 farmers (**4 treatments**)
- One FTC was selected to undertake full set

of **treatments (12)** with replicates

(Tesfaye, 2005)

Treatments

#	Treatments (FTC)	# of Replication	Treatments (On-farm)	Replications
1	W-F	**3**	**W+F**	-
2	**W+F**	**3**	**W+BC1+F**	-
3	W+BC1	**3**	**W+VC**	-
4	**W+BC1+F**	**3**	**W+BC1+VC**	-
5	W+BC2	**3**	BC1 = 4 t/h BC2 = 8 t/ha VC used at 4.5 t/ha Mineral fertilizer used at recommended rate (64 kg N and 20 kg P/ha)	
6	W+BC2+F	**3**		
7	**W+VC**	**3**		
8	W+F+VC	**3**		
9	**W+BC1+VC**	**3**		
10	W+F+BC1+VC	**3**		
11	W+BC2+VC	**3**		
12	W+F+BC2+VC	**3**		

Biochar preparation

Pyrolysis

- The double barrel method was used for pyrolyzin the feedstock (coffee husk)
- A small barrel (diameter of about 43cm) was fille with coffee husk and sealed to limit oxygen entry
- The small barrel was then inserted into a bigger barrel (diameter 65-70 cm)
- Firewood was inserted into the space between the bigger and smaller barrels

Vermicompost preparation

- Vermicompost was prepared from coffee husk and avocado waste at College of Agriculture
- Equal proportions of the avocado waste and coffee husk were used as feedstock
- Manure was also added to the mix
- A sample of the vermicompost was analyzed for pH, EC, TN, OC and moisture content

Vermicompost used for the experiments

#	Total N (%)	Organic carbon (%)	C:N	pH-H_2O	EC (ds/cm)
1	1.61	17.35	10.77	7.66	0.6
2	1.64	17.96	10.97	-	

Biochar Quality?

				Probennummer		123036912	
Parameter	Lab.	Akkr.	Methode	BG	Einheit	anl	wf
Eigenschaften der Pflanzenkohle							
Gesamtwassergehalt	FR	F5	DIN 51718: 2002-06	0,1	Ma.-%	7,6	-
Organ. Schadstoffe a. d. Toluolextrakt n. DIN EN 16181:2019-08(Extrakt.-verf. 2)							
Naphthalin	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	1,0
Acenaphthylen	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	< 0,1
Acenaphthen	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	< 0,1
Fluoren	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	0,1
Phenanthren	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	0,5
Anthracen	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	0,1
Fluoranthen	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	0,2
Pyren	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	0,2
Benzo[a]anthracen	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	< 0,1
Chrysen	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	< 0,1
Benzo[b]fluoranthen	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	< 0,1
Benzo[k]fluoranthen	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	< 0,1
Benzo[a]pyren	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	< 0,1
Indeno[1,2,3-cd]pyren	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	< 0,1
Dibenzo[a,h]anthracen	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	< 0,1
Benzo[ghi]perylen	FR	F5	DIN EN 16181:2019-08	0,1	mg/kg	-	< 0,1
Summe 8 EFSA-PAK exkl. BG	FR	F5	DIN EN 16181:2019-08		mg/kg	-	n. b.) [1]
Summe 16 EPA-PAK exkl. BG	FR	F5	DIN EN 16181:2019-08		mg/kg	-	2,1

Baseline Soil properties

On-farm	Farm1	Farm2	Farm3	Farm4	Farm5	Farm 6	Farm7	Farm8	Farm9	Farm10
%Sand	58.96	60.96	56.96	50.96	42.96	42.96	48.96	54.96	58.96	58.96
%Silt	18	22	22	30	28	22	24	20	16	20
%Clay	23.04	17.04	21.04	19.04	29.04	35.04	27.04	25.04	25.04	21.04
OC(%)	1.56	2.73	2.14	2.73	2.53	2.73	2.65	2.73	2.53	2.53
Av.P (ppm)	5.34	5.31	7.19	11.13	15.82	6.36	5.96	6.07	10.02	17.53
CEC	30	32	37	37	31	36	38	39	37	36
pH-H_2O	4.4	4.5	4.5	4.7	5.1	4.6	4.7	4.6	4.8	5.1

FTC

%Sand	%Silt	%Clay	%OC	Av.P (ppm)	CEC (cmol/kg)	pH-H_2O
44.96	26	29.04	2.73±0.1	11.46±2.5	31.5±2.5	6.1±0.3

Planting

- ✓ Wheat (Variety Kekeba) was planted using a spacing of 20cm between rows
- ✓ $12m^2$ plots, replicated 3 times at FTC
- ✓ No replicates at on-farm

Activities to popularize biochar benefits….

- **Farmers' training** to raise awareness on benefits and preparation of biochar and vermicompost

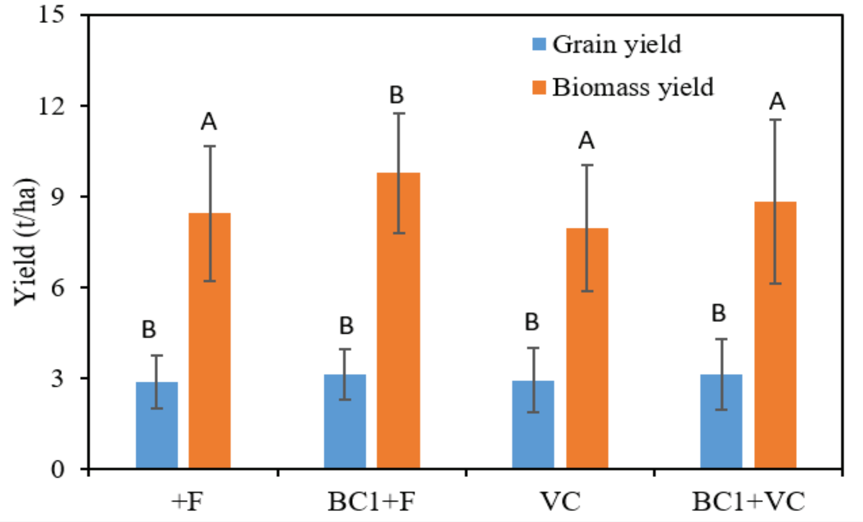
Preliminary Results

✓ Effect of biochar based fertilizers on Wheat Biomass and grain yield?

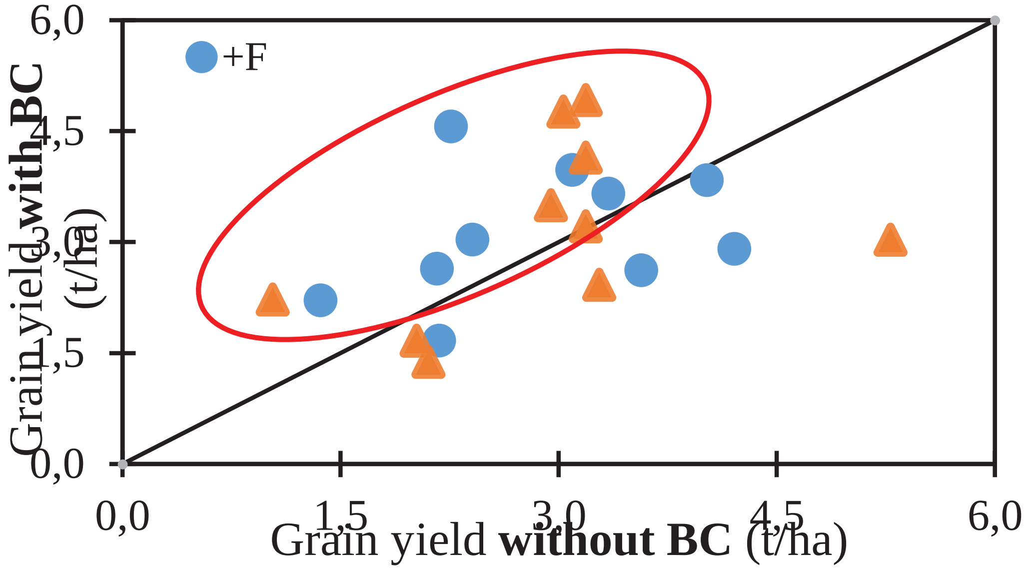
✓ Effect on nutrient uptake?

✓ Effect on soil properties?

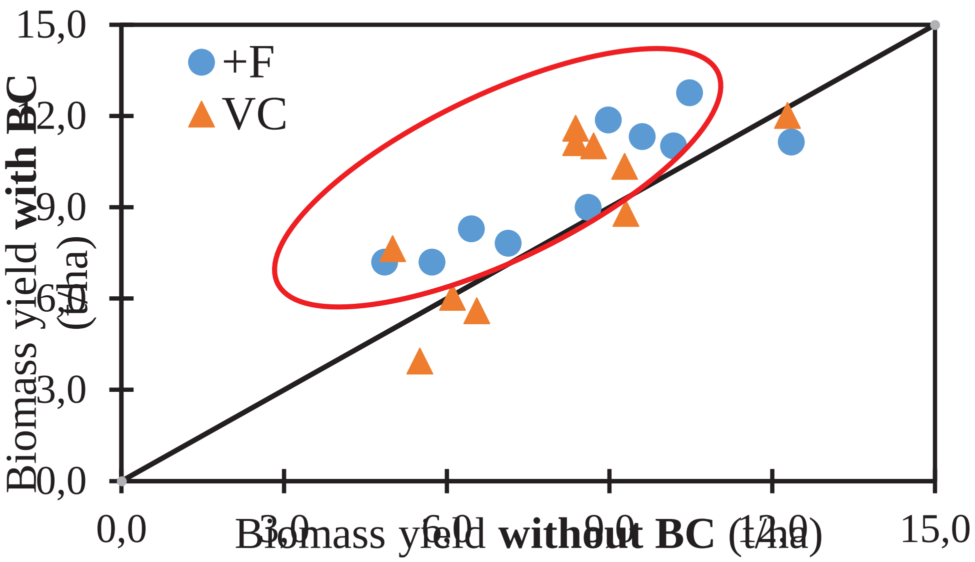
Effect of Biochar based fertilizers on yield of wheat (On-farm)



Yield benefits of biochar? (Grain yield, on-farm)

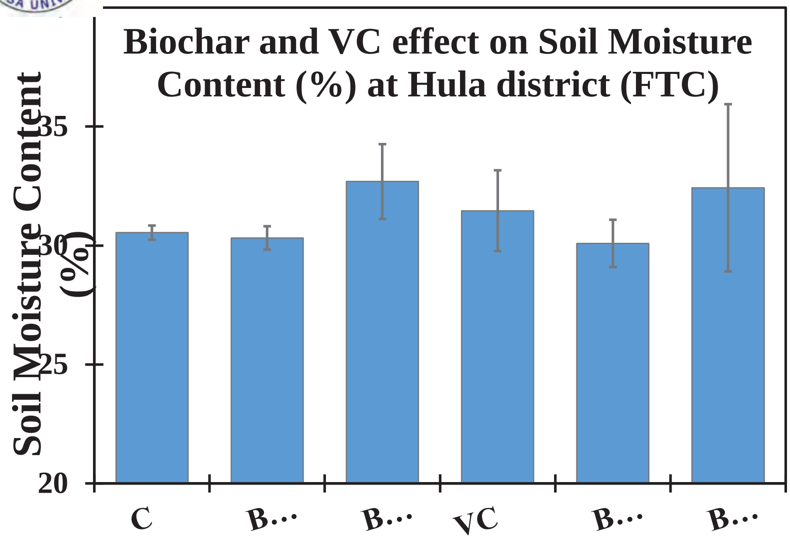


Yield benefits of biochar? (Biomass yield, on-farm)



Treatment	BY (t/ha)	GY (t/ha)
C	6.63^E	1.78^C
+F	9.07^DEC	2.79^BAC
BC1	7.33 ^E	1.97^BC
BC1+F	12.13 ^BDAC	2.54^BC
BC2	7.77 ^DE	1.69^C
BC2+F	10.53^BDEC	2.41^BC
VC	10.53^BDEC	2.69^BAC
VC+F	13.13^BAC	2.84^BAC
BC1+VC	9.87 ^BDEC	2.30^BC
BC1+VC+F	15.47 ^A	4.31^A
BC2+VC	9.50 ^BDEC	2.33^BC
BC2+VC+F	13.67 ^BA	3.52^BA
LSD,5%	4.45	1.67
CV (%)	25.13	38.08

Effect on Soil Properties?



- ✓ 8 t/ha Biochar seems to improve soil moisture content

Preliminary Conclusions

- ✓ Yield benefits of biochar amendment when used integrated with mineral fertilizer and/or vermicompost
- ✓ Marginal improvements in soil moisture content with biochar amendment at 8 t/ha
- ✓ Wheat to be planted for 2024/25 season to confirm effects on yield and soil
- ✓ Post harvest soil analysis underway to investigate more effects on soil properties like OC and soil pH
- ✓ There is significant interest from farmers in the study area to adopt wider use of biochar and organic fertilizers

Challenges encountered

- ✓ Late planting
- ✓ Wheat seed availability
- ✓ Pests and diseases

Thank you!

Co-application of biochar and digestate in highly degraded acidic soils: Effect on crop production and soil quality

Feb 13, 2024

Our Team

Dr. Abebe Nigussie

Dr. Milkiyas Ahmed

Dr. Solomon Tulu

Dr. Bayu Dume

Dr. Amsalu Nebiyu

Bezabih Addisu
(PhD student)

Beiftu Umer
(PhD student)

Outline

Digestate

Outline

Question

Outline

Methodology

Outline

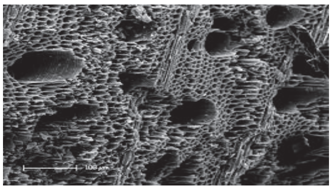
Preliminary Results

Outline

Demonstration

Solid digestate

- The use of solid digestate as an alternative fertilizer has been increased
- Solid digestate often stored under shade to dry and/or composted
  - ↑ N loss through volatilization
  - ↑ Nutrient loss through leaching



Biochar

Porous and surface area

Pre-decomposed solid digestate

Nutrient-rich substrate

Biochar-based fertilizer (BBF)

Research questions

01

To what extent the biochar rate influence the effectiveness of BBF (Biochar-based fertilizer)?

Research questions

01

Does the biochar rate influence the effectiveness of BBF (Biochar-based fertilizer) on crop yield and soil quality?

02

Does the effectiveness of BBF on crop yield and soil quality vary along the soil fertility gradient?

Methodology

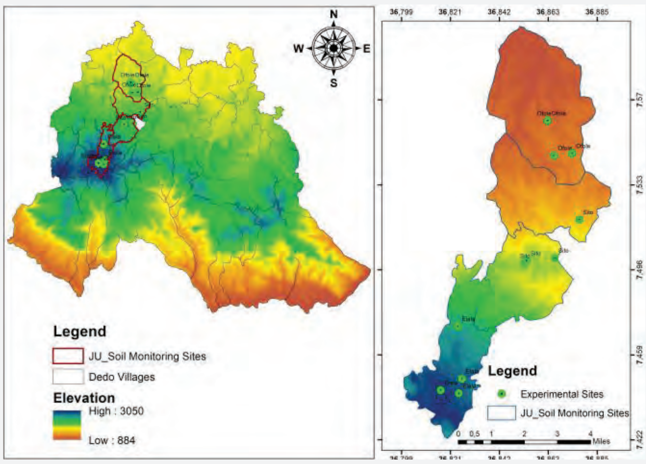
Two sites:

- Sito: 2000 – 2300 m
- Elala: 2700 – 3000m

Five farmers from each site, a total of 10 farmers

Crop type: Wheat (variety: King bird)

Plot size: 3m * 3 m



Production of Biochar-based biofertilizers (BBF)

Coffee husk biochar
@ 500 ^{o}C
1 hr resident time

50 L pyrolysis unit

Mixture (w/w)

- 12.5 % biochar
- 25 % biochar

Application rate

5 t/ha and **20 t/ha**

Manure digestate
Pre-decomposed for
six months

ETH-SOIL

ETH-SOIL

Four treatments included in addition to the BBFs:

(i) Digestate alone (5 t/ha)
(ii) Digestate alone (20 t/ha)
(iii) Recommended mineral fertilizer (**positive control**)
(iv) Control – without any soil amendment (**negative control**)

Excluded treatments – despite scientific importance

(i) Coffee husk without char (Control)
(ii) Coffee husk char alone

Eight treatments

1. Control (CON)
2. Mineral fertilizer (MIN)
3. Digestate at 5 t/ha
4. 5 t/ha digestate + 12.5% biochar
5. 5 t/ha digestate + 25% biochar
6. Digestate at 20 t/ha
7. 20 t/ha digestate + 12.5% biochar
8. 20 t/ha digestate + 25% biochar

* 40% Recommended fertilizer was applied for the treatments 4 - 8

15 cm application depth

Mixed thoroughly

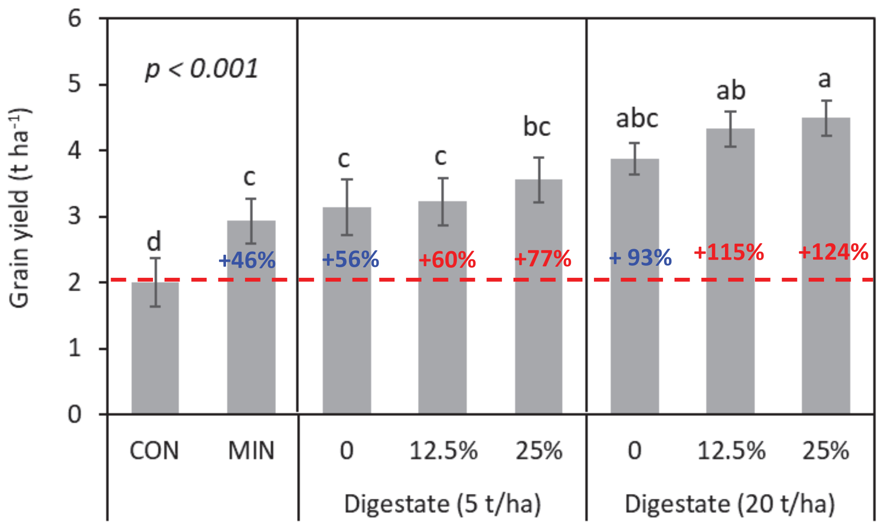
Seed applied

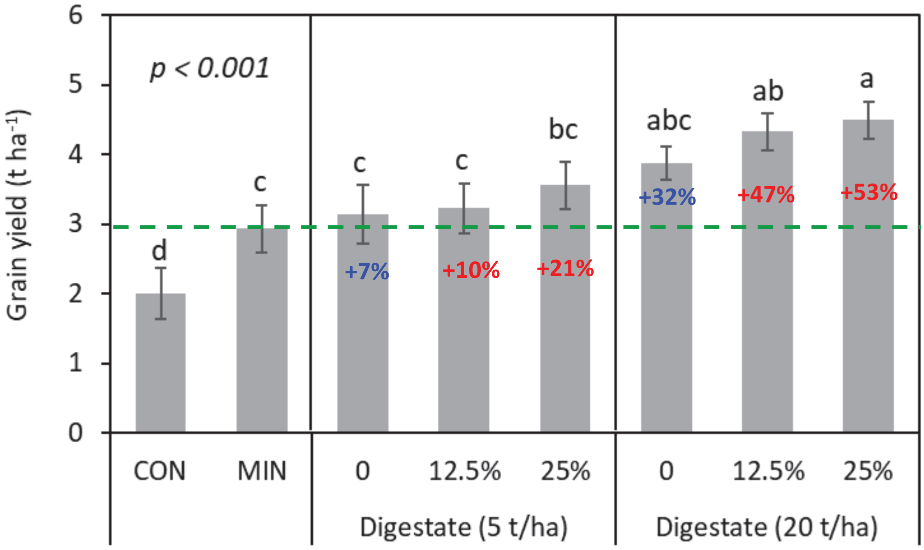
Recommended agronomic practices

Follow ups

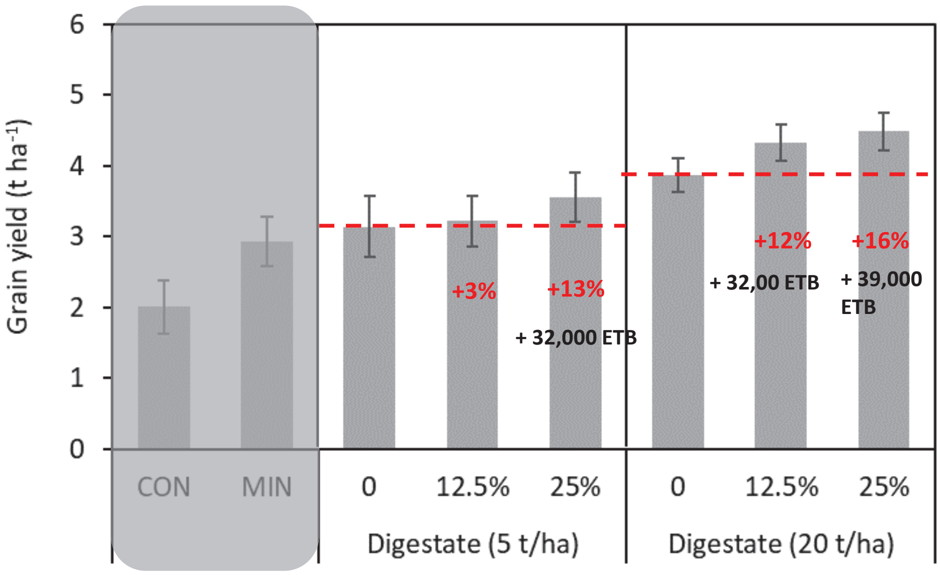
Soil sampling

Preliminary results



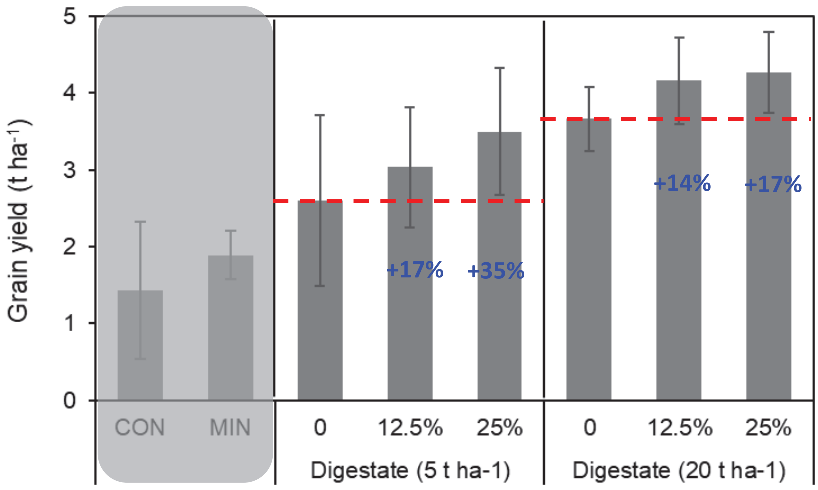


Grain yield (t ha-1)
p < 0.001
d
c
c
c
bc
abc
ab
a
+7%
+10%
+21%
+32%
+47%
+53%
CON
MIN
0
12.5%
25%
0
12.5%
25%
Digestate (5 t/ha)
Digestate (20 t/ha)

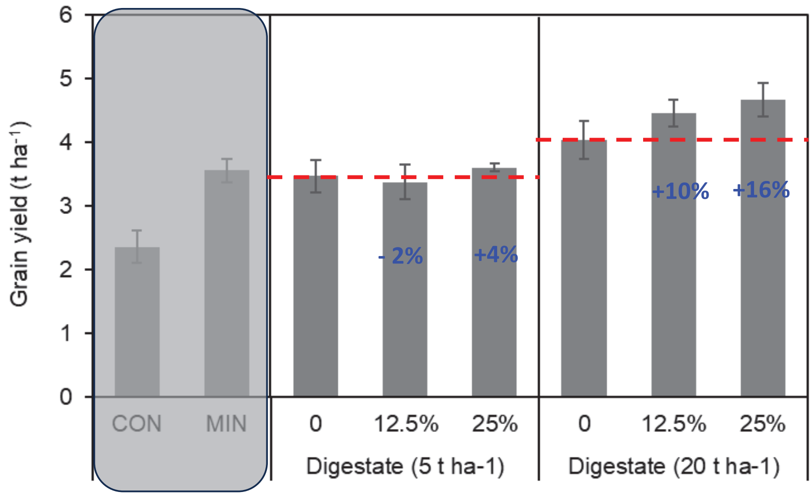


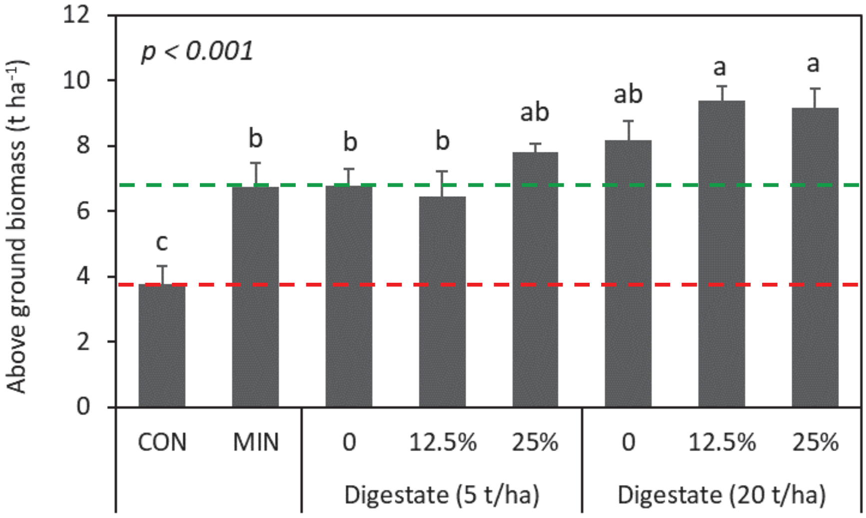
Grain yield (t ha-1)
+3%
+13%
+ 32,000 ETB
+12%
+16%
+ 32,00 ETB
+ 39,000 ETB
CON
MIN
0
12.5%
25%
0
12.5%
25%
Digestate (5 t/ha)
Digestate (20 t/ha)

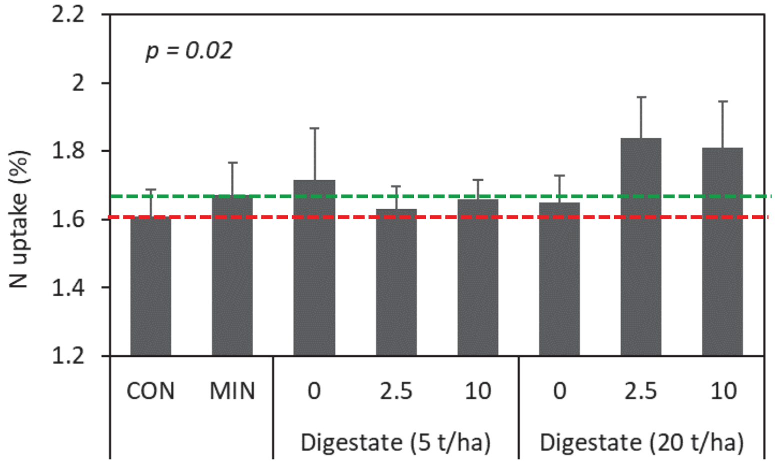
A higher altitude (2800 – 2900 m) – *Elala site*

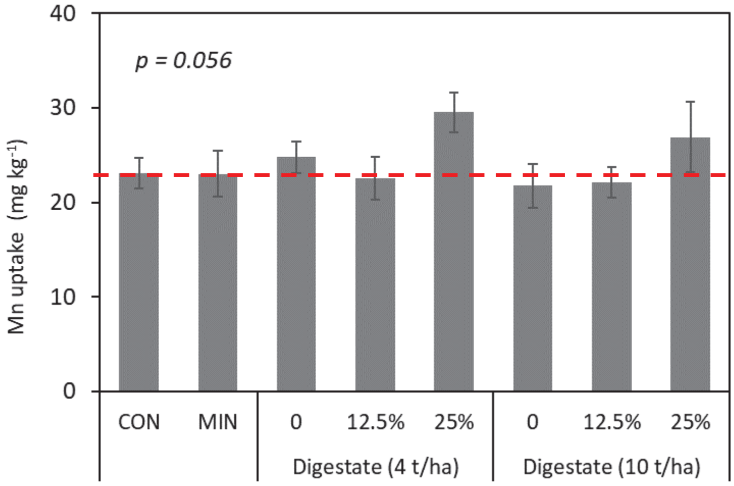


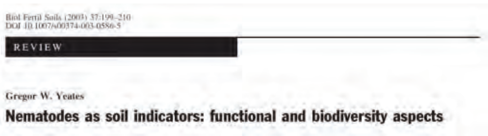
A lower altitude (2000 – 2100 m) – *Sito site*




p < 0.001
Above ground biomass (t ha-1)
12
10
8
6
4
2
0
c
b
b
b
ab
ab
a
a
CON
MIN
0
12.5%
25%
0
12.5%
25%
Digestate (5 t/ha)
Digestate (20 t/ha)


p = 0.02
N uptake (%)
2.2
2
1.8
1.6
1.4
1.2
CON
MIN
0
2.5
10
0
2.5
10
Digestate (5 t/ha)
Digestate (20 t/ha)

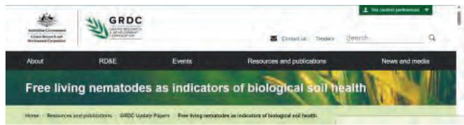


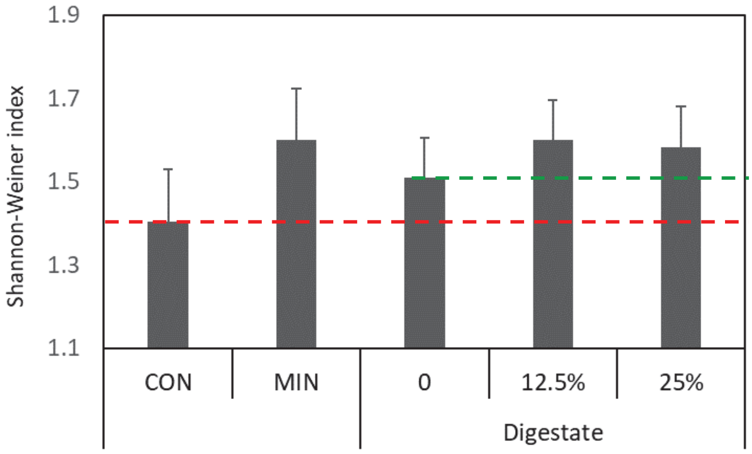

Biol Fertil Soils (2003) 37:199–210
DOI 10.1007/s00374-003-0586-5

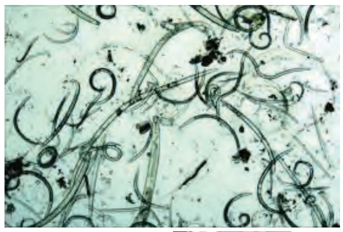
REVIEW

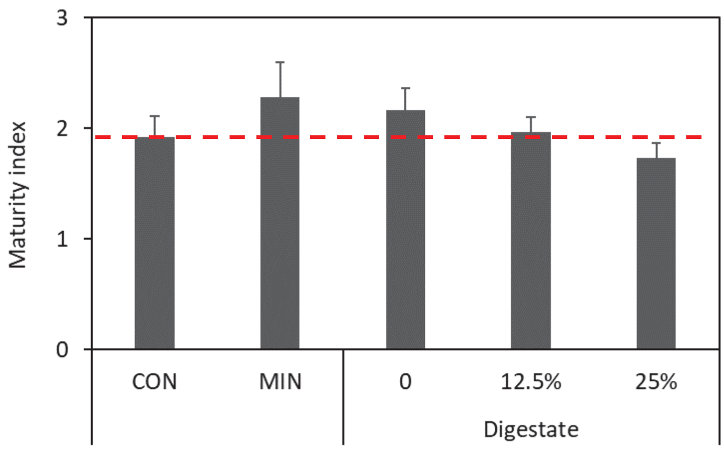
Gregor W. Yeates

Nematodes as soil indicators: functional and biodiversity aspects









- Low Maturity index → more disturbed and/or enriched environment
- High Maturity index → a stable environment

Demonstration

- Demonstration for 120 farmers
- 40 female farmers
- Four-round demonstration

On-going activities

- Soil chemical analysis
- Soil microbial biomass C and N
- Plant nutrient uptake
- PAHC content

Thank you !!

Danke !!

አመሰግናለው !!





Oromia Agricultural Research Institute

Batu Soil Research Center

2nd Soil Symposium

Soil amelioration with biochar

Tilahun Abera

13th February, 2024

Addis Ababa

1

Presentation outline

- ❖ Introduction
- ❖ Materials and Methods
- ❖ Results and Discussion
- ❖ key findings and Conclusion

2

Activity Title

Integrated effect of Biochar and Bio-slurry compost with NP Fertilizers on soil physic-chemical properties, climate change mitigation, yield components and yield of Sorghum

3

INTRODUCTION

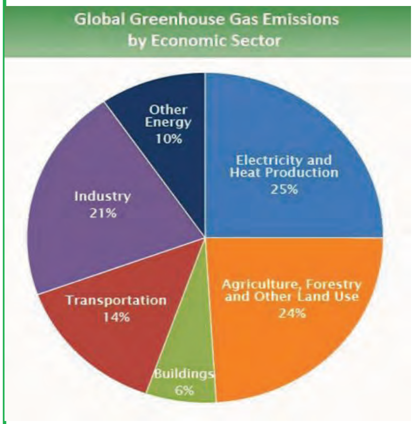
Challenges:

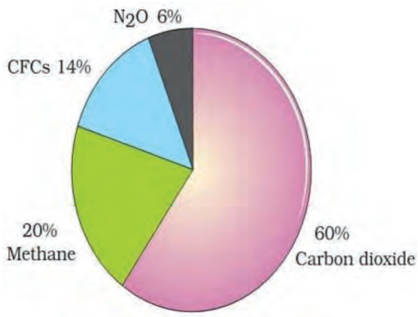
Declining soil fertility:

- ❖ Negative nutrient balance due to :-
  - ✓ intensive cropping,
  - ✓ low organic matter, and
  - ✓ firewood scarcity.
- ❖ This leads to reduced crop yields and food insecurity for millions (Agegnehu *et al*., 2015; Heluf *et al*., 2006; FAO, 2006).

Cont…..

Climate change



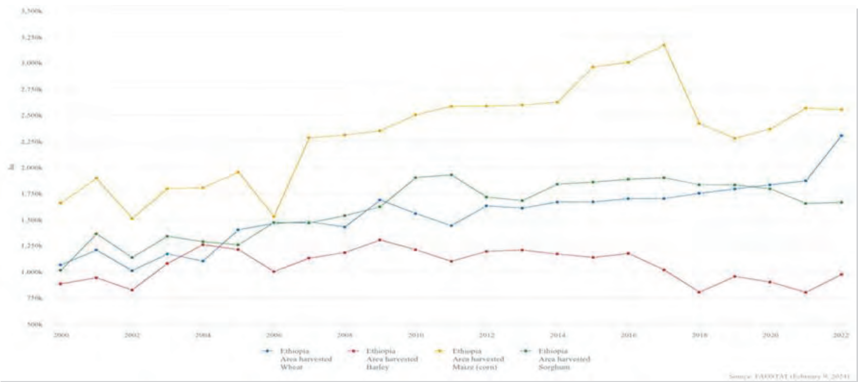


Relative contribution of various greenhouse gases to total global warming

Cont…..

Sorghum Yield:

❖ A valuable and resilient crop for Ethiopia's climate and food security, known as the "King of Millets" (FAO, 2021; Hossain *et al*., 2016).



Cont…..

Solutions:

❖ Combined application of biochar, bio-slurry compost, and NP fertilizers:

➢ This approach has been shown to improve :-

✓ soil health

✓ nutrient availability, and

✓ crop yields while

✓ reducing climate impact

(Lehmann & Rondon, 2006; Glaser *et al*., 2002; Bonten *et al*., 2014; Lehmann *et al*., 2003; Smith *et al*., 2014).

Cont…..

Research Objectives:

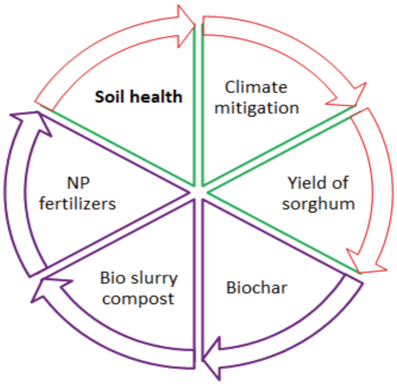
❖ To evaluate the combined effect of biochar, bio-slurry compost, and NP fertilizers on:

✓ Climate change (emission reduction)

✓ Soil health (physicochemical properties

✓ Sorghum yield and yield components

✓ Determine the optimal application rate



MATERIALS AND METHODS

Description of the Experimental Site

- The experiment have been conducting at Batu Soil Research Center on station

- ❖ Far 165 km from Adis Ababa
- ❖ Longitude:- 0468586E;
- ❖ Latitude:- 0877118N
- ❖ Altitude 1631 masl

9

MATERIALS USED

Biochar = Coffe husk (550°C/1hr)

Bioslurry compost = formulated with 75% liquid bio-slurry and 25% wheat straw

Crop:- Crop type: Sorghum (Melkam variety)

Pot:- a diameter of 30 cm at the top, 26 cm at the bottom, and a height of 30 cm.

10

Treatments and experimental design

- **0 tone biochar**
  - 0% bsc
  - 50% bsc
  - 100% bsc
- **2 tone biochar**
  - 0% bsc
  - 50% bsc
  - 100% bsc
- **4 tone biochar**
  - 0% bsc
  - 50% bsc
  - 100% bsc
- **6 tone biochar**
  - 0% bsc
  - 50% bsc
  - 100% bsc

✓ Design= CRD
✓ Replication= 3 times
✓ Recommended NP fertilizers applied

12

IQQO
Oromia Agricultural Research Institute

BSRC
ETH-SOIL

RESULTS AND DISCUSSION

Table 1. Pre soil Test Results

Lab. No.	pH	EC (dS/cm)	Av. K (mg/kg)	Av. P (ppm)	OC (%)	OM (%)	TN (%)
BSRC-027/16	7.45	0.16	734	12.27	1.12	1.93	0.12

Table 2. Nutrient Contents of Bio-Slurry compost

Lab. No.	pH	EC (dS/cm)	Av. K (mg/kg)	Av. P (ppm)	OC (%)	OM (%)	TN (%)	C:N
BSRC-026/16	6.96	1.05	1542	188.06	9.36	16.14	0.58	16.14:1

13

IQQO
Oromia Agricultural Research Institute

ETH-SOIL

Cont…

Table 3: Plant height(cm) as influenced by interaction effect of biochar and bio-slurry compost

Urea equivalent Bio-slurry compost	Biochar rate tone /ha			
	0	2	4	6
0%	58e	73cd	91.5b	81bc
50%	59e	87.5b	107.7a	85b
100%	72.7cd	87.7b	65de	89b
LSD(0.05)	10.87			
CV (%)	8.1			

14

Cont…

Table 4: Head length(cm) as influenced by interaction effect of biochar and bio-slurry compost

Urea equivalent Bio-slurry compost	Biochar rate tone /ha			
	0	2	4	6
0%	12f	20bcd	22ab	20bcd
50%	19cde	21.50abc	19.67bcde	23a
100%	17.67de	20.67abc	17e	20.50abc
LSD(0.05)	2.687			
CV (%)	8.2			

CONCLUSION AND KEY FINDINGS

Key finding

- Plant height peaked at 107.7 cm recorded with 50% bio-slurry compost and 4-ton/ha biochar.
- Head length reached 23 cm recorded with 50% bio-slurry compost and 6-ton/ha biochar.
- Therefore, it is concluded that early findings showed that combined application of biochar and bio-slurry compost with NP fertilizers significantly impacts sorghum growth and development, especially in terms of plant height, head length, grain filling duration, head fertility, and overall crop stand. Although data collection remains ongoing, the initial analysis reveals promising results.

Treatment effect on grain filling period and fertility

18

THANK YOU !

19

202

AGGREGATE SIZE DISTRIBUTION, LABILE CARBON FRACTIONS AND LITTER DECOMPOSITION AFTER LONG-TERM APPLICATION OF BIOCHAR-BASED SOIL AMENDMENTS IN LOW-INPUT ACIDIC SOILS

Getachew Mulatu,
Ethiopian Institute of Agricultural Research (EIAR, JARC)
February, 2024
Addis Ababa, Ethiopia

Doc ID

Introduction

- Soil quality is defined as the ability of soil to deliver multiple ecological functions, such as
  - biomass production,
  - nutrient recycling,
  - climate change mitigation,
  - maintain water and air quality
  - habitat provision for biodiversity (Zwetsloot *et al.*, 2021).

- Thus, multi-criteria indices have been used to evaluate the long and short-term effects of agricultural management practices on soil quality (Bongiorno *et al.*, 2019).

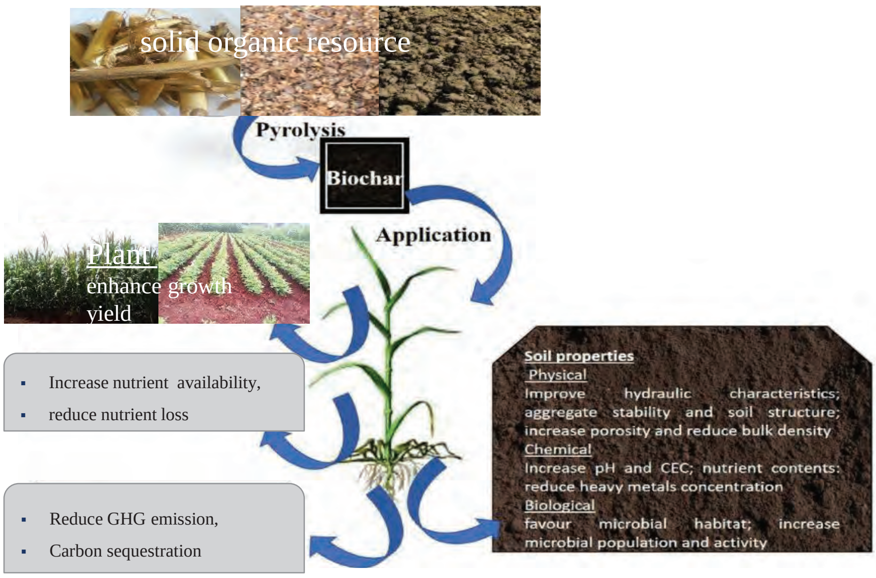
204

Cont…

- Soil quality assessment often includes proxies that are more responsive to changes in agricultural management practices.

- The most commonly used soil quality proxies are:
  - soil aggregate formation and stability (Řezáčová *et al.*, 2021),
  - labile carbon fractions (Bongiorno *et al.*, 2019) and
  - litter decomposition (Barel *et al.*, 2018).

Cont…



Cont…

- Recently, attempts have been made to investigate the effect biochar application on soil quality indicators, including soil aggregate formation and labile carbon fractions (Huang *et al.*, 2022).

- Despite a few studies, the existing literature is inconclusive about the reported effects of biochar on soil aggregation and labile carbon fractions.

- For instance, Ma *et al.* (2016) and Sun *et al.* (2022) found an increase in soil aggregation in intensively cultivated fields owing to biochar application.

- In contrast, Fungo *et al.* (2017) found a limited effect of *Eucalyptus* wood biochar after two years of application in minimum tillage system.

207

Cont…

- The observed variation between the studies could be attributed to different factors, including the duration of the experiment.

- Overall, long-term biochar experiments are generally scarce to better understand the long-lasting effect of biochar (Jeffery *et al.*, 2017; 2011; Wakweya *et al.*, 2021). Therefore,

- The main objective of this study was to determine the long-term effect of biochar-based soil amendments on:
  - ✓ soil aggregate formation,
  - ✓ labile carbon fractions and
  - ✓ litter decomposition rate

208

Material and method

Description of the study area

- Located geographically at
  - ✓ altitude of 1814 m
  - ✓ latitude 7^0 42" 098' N and
  - ✓ longitude 36^0 48" 633' E
  - ✓ maximum temperature = 26.8^0C and minimum temperature = 11.4^0C
  - ✓ mean annual rainfall of 1745 mm

- The soil is characterized as Nitisol (World Reference Base, 2006)
  - ✓ with a pH value of 5.08, TC=3.13%, a TN=0.28% and a CEC=41.26 Cmolec kg^{-1} soil.
  - ✓ The soil texture is 50% clay, 48% silt and 2% sand (Melaku *et al.*, 2020)

209

Treatments and Experimental Design

- Two long-term field experiment were used for this study, namely
  - Maize (*Zea mays*) field – where maize was cultivated continuously for nine years
  - Soybean (*Glycine max*) field – where soybean was cultivated continuously for nine years

- The long-term field experiments contains seven treatments:

1. Control (CON)(-ve)
2. Mineral fertilizer (MIN)(+ve)
3. Biochar (BIO)
4. Compost (COM)
5. Bone char (BC)
6. Combination of biochar and compost (BCOM)
7. Combination of biochar, bone char and compost (MIX).

210

Cont…

- ❑ The experiment was conducted in RCBD with three replications.
- ❑ Each plot had a size of 4 m x 3 m (12 m^2).
- ❑ Plowing was undertaken with a hand-hoe (fixed plot).

211

Cont…

❑ Preparation of biochar, bonechar and compost

❑ The lignocellulose biochar was produced from coffee husk at 350°C,

Coffee husk

No oxygen

Pyrolysis

The resident time 3 hrs

coffee husk biochar

❑ Bone char was produced from cattle bone at 400°C.

Animal bone

No oxygen

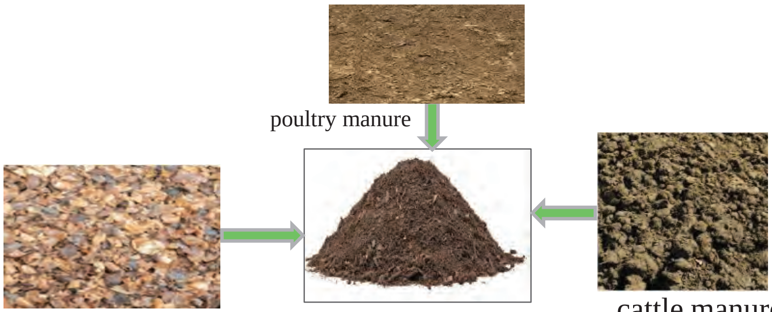
Pyrolysis

Bone char

❖ Prior to bone char production, cattle bone was collected, oven-dried at 70°C for 72 hrs, grounded, and passed through a 2- mm sieve (Wakweya *et al.*, 2021).

212

Cont…



at a ratio of 1:1:1 (dry weight basis)

- Accordingly, the biochar, bonechar and compost were applied at the rate of 4 t ha^{-1} $year^{-1}$ and were applied one month before planting every year.
- Fertilizer: TSP was applied at the rate of 12 kg P ha^{-1} $year^{-1}$.

213

Soil Sampling and laboratory analyses

- In this study, the treatment effect is expected to be at shallow soil depths because the soil amendments were applied on the surface soil, and the treatments were mixed using a hand-hoe.
- Accordingly, soil samples were collected from each treatment at a depth of 10 cm.
- Ten core samples were collected from each plot, composited, and transported immediately for laboratory analyses.

214

Cont…

- The visible stones and fine roots were removed in the laboratory, and each soil sample was divided into two portions.
  - The first part (i.e., 300 g) was air-dried and sieved through 8 mm mesh to determine soil aggregate size distribution.
  - The second part (i.e., 200 g) was air-dried and sieved through 2 mm sieve for permanganate oxidizable carbon (POX-C) and particulate organic carbon (POC) measurements.

- Soil aggregate size distribution was determined using the wet sieving method as described by (Torres-Sallan *et al.* 2017).

215

Cont…

- Briefly, 80 g soil that passed through an 8 mm sieve was placed on top of a 2 mm sieve and submerged in distilled water for five minutes.

- The mean weight diameter (MWD, mm) was calculated as follows:

$$MWD = \sum_{i=1}^{n} Wi * x$$

Where:- x is the average diameter of the openings of the two consecutive sieves, and wi is the weight ratio of aggregates remained on the i^{th} sieve.

216

Doc ID

Cont…

❑ Permanganate oxidizable Carbon (POXC) also commonly referred to as "active carbon" was determined following the procedure described by (Bongiorno *et al.*, 2019).



217

Doc ID

Cont…

❑ Particulate organic carbon (POMC) was determined using a method described by (Wyngaard *et al.*, 2016).



218

Cont…

❑ Litter decomposition experiment

➢ Four crop residues (litter) with different C:N ratios and lignin content were used to determine the long-term effects of biochar based soil amendment on litter decomposition.

Maize stover (C = 46.2 %, N = 0.4 %, C:N ration of 115.6, Acid extractable lignin content = 21.65 %),

Wheat straw (C = 39.7 %, N = 0.52 %, C:N ratio of 76.3, Acid extractable lignin content = 19.98 %)

Coffee husk (C = 41 %, N = 1.2 %, C:N ratio of 34.2, Acid extractable lignin content of 29.99 %),

Faba bean stalk (C = 38.7 %, N = 1.6 %, C:N ratio of 24.2, Acid extractable lignin content = 14.89 %).

219

Cont…

- ✓ Each litter was oven-dried at 70 ^{0}C and cut to 4 cm length. Five grams of each litter was then place in 10 cm × 10 cm nylon litterbag (0.02 mm mesh size).
- ✓ Six litter bags from each litter were buried randomly in each plot at 10 cm soil depth
- ✓ accordingly, a total of 1,008 litter bags were used
- ✓ Two litterbags from each litter were then retrieved after 30, 60 and 90 days gently rinsed to remove adherent soil and/or roots (Martinez-García *et al.*, 2021).

- ✓ The litter bags were dried at 80 ^{0}C until constant weight and the remaining litter was weighted.
- ✓ Litter decomposition rate k (day^{-1}) was then calculated as:

$$\boxed{f_r = e^{-kt}}$$

220

Data analyses

- All statistical analyses were carried using R software version 3.6.1 (R Studio Team, 2019).

- Mixed effects model ("*nlme*" package; Pinheiro *et al.*, 2019) was used to assess the effects of biochar-based soil amendments

221

Result and discussion

Table 1. Long-term effects of biochar-based soil amendments on soil aggregate distributions at maize field (mean + standard error)

Treatments	…………………. Maize field …………………….			
	>2 mm	2mm-250µm	250 – 53 µm	< 53 µm
	………………..……..… % ………………………..			
CON	4.1+0.38[f]	26.7+0.98[e]	58.1+1.83[a]	11.1+0.59[a]
MIN	6.7+0.42[ef]	40.1+1.91[d]	43.6+0.82[b]	9.7+0.71[a]
BC	9.2+0.75[de]	46.6+0.93[c]	38.0+0.64[c]	6.1+0.22[b]
BIO	15.4+0.91[ab]	61.3+1.43[a]	18.0+1.08[f]	5.4+1.13[b]
COM	13.7+0.96[bc]	51.9+2.58[b]	27.1+1.73[de]	7.2+1.24[b]
BCOM	17.1+0.56[a]	53.0+0.61[b]	24.7+1.55[e]	5.2+1.01[b]
MIX	12.0+1.74[cd]	52.5+1.22[b]	30.4+2.90[d]	5.2+0.36[b]
p - value	***	***	***	***

222

Cont…

Table 2. Long-term effects of biochar-based soil amendments on soil aggregate distributions at soybean field (mean + standard error)

Treatments	Soybean field			
	>2 mm	2mm-250µm	250 – 53 µm	< 53 µm
	%			
CON	7.7+1.11[d]	30.0+3.74[e]	55.6+4.30[a]	6.6+0.25[a]
MIN	9.6+0.79[cd]	39.7+0.68[d]	44.6+0.81[b]	6.2+0.72[ab]
BC	10.9+0.84[bc]	48.4+0.97[c]	34.4+0.63[c]	6.3+0.82[ab]
BIO	12.7+0.95[ab]	54.1+1.06[b]	28.2+1.85[c]	5.0+0.21[bc]
COM	11.7+1.14[abc]	52.6+2.28[bc]	30.1+3.29[c]	5.6+0.45[abc]
BCOM	14.6+0.17[a]	61.9+1.24[a]	19.2+1.52[d]	4.3+0.45[c]
MIX	13.3+0.59[ab]	54.2+2.06[b]	27.1+2.35[c]	5.4+0.22[abc]
p - value	***	***	***	***

223

Cont…

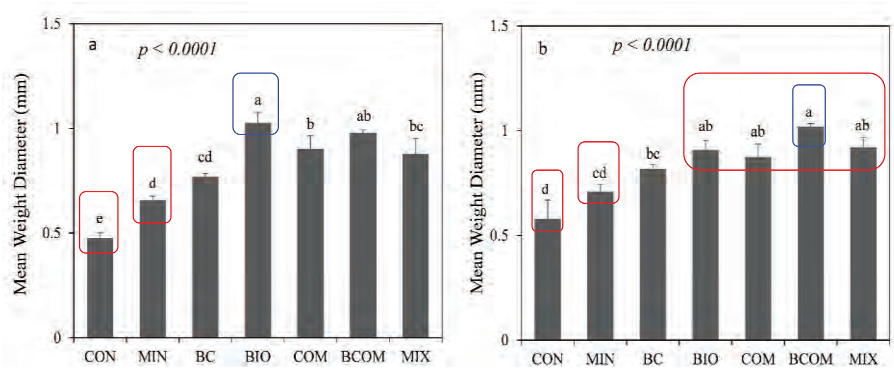


Figure 3. Long-term effect of soil amendment on soil mean weight diameter (MWD) at maize (a) and soybean field (b)

224

Cont…

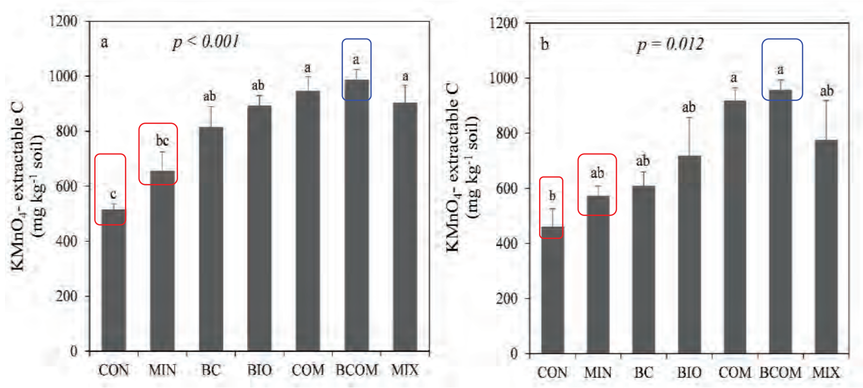


Figure 1. Long-term effects of biochar-based soil amendments on permanganate-oxidized carbon (a) maize cultivation field, and (b) soybean cultivation field.

225

Cont…

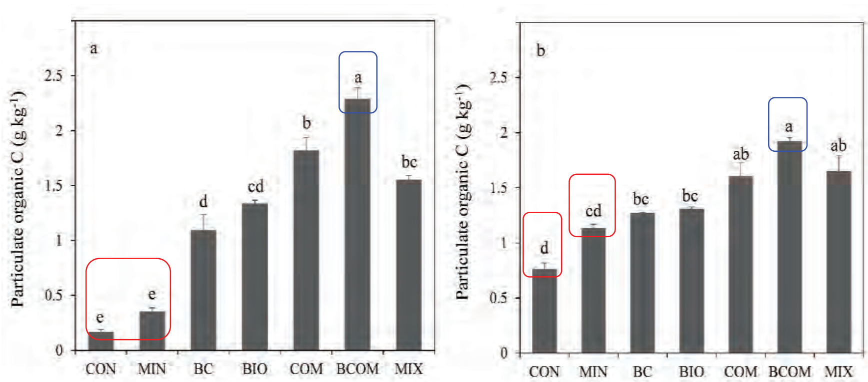


Figure 2. Long-term effects of biochar-based soil amendments on particulate organic carbon (a) maize cultivation field, and (b) soybean cultivation field.

226

Cont…

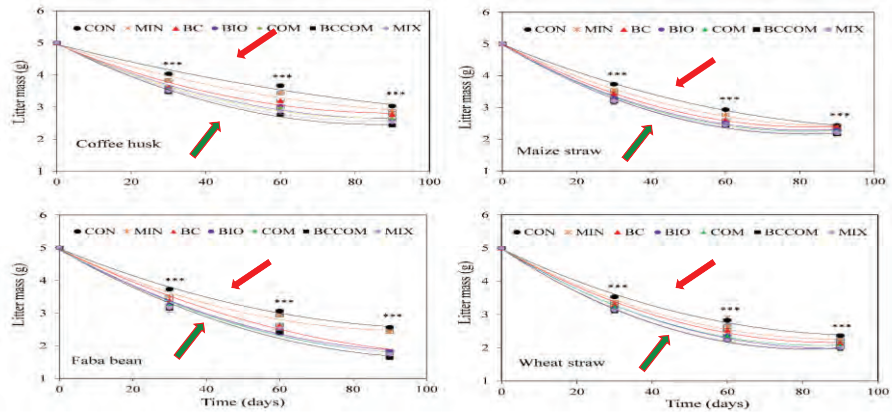


Figure 4. The long-term effect of biochar-based amendments on litter decomposition – coffee husk, maize straw, fababean, and wheat straw – in maize cultivation field.

227

Cont…

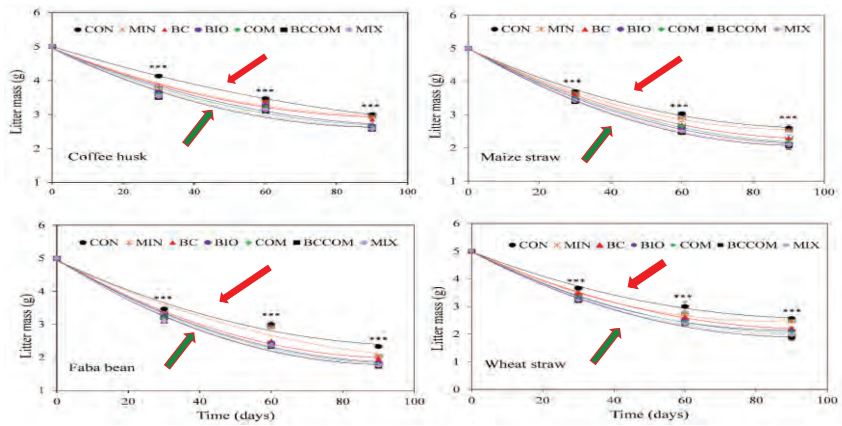


Figure 5. The long-term effect of biochar-based soil amendments on litter decomposition(mass loss) – coffee husk, maize straw, faba bean, and wheat straw – in soybean cultivation practices.

228

Cont…

Table3. Long-term effects of biochar-based soil amendments on decomposition rate (k) of different crop residues

Treatments	Faba bean	Coffee husk	Wheat straw	Maize stalk
	k ($year^{-1}$)	k ($year^{-1}$)	k ($year^{-1}$)	k ($year^{-1}$)
CON	2.67 ± 0.07^{c}	1.94 ± 0.05^{d}	2.99 ± 0.04^{e}	2.92 ± 0.05^{e}
MIN	2.84 ± 0.04^{c}	2.11 ± 0.05^{c}	3.29 ± 0.06^{d}	2.98 ± 0.03^{de}
BC	3.93 ± 0.08^{b}	2.32 ± 0.05^{c}	3.43 ± 0.07^{c}	3.02 ± 0.07^{cde}
BIO	3.98 ± 0.05^{b}	2.59 ± 0.08^{b}	3.77 ± 0.04^{ab}	3.16 ± 0.04^{bcd}
COM	4.15 ± 0.06^{b}	2.56 ± 0.06^{b}	3.61 ± 0.07^{b}	2.92 ± 0.07^{abc}
BCOM	4.41 ± 0.06^{a}	2.91 ± 0.06^{a}	3.81 ± 0.03^{ab}	3.39 ± 0.03^{a}
MIX	4.14 ± 0.13^{b}	2.73 ± 0.02^{ab}	3.76 ± 0.03^{a}	3.32 ± 0.03^{ab}
p- value	***	***	**	**

229

Conclusions and Recommendation

- ❑ The findings demonstrated that:
  - ✓ increased soil aggregate formation,
  - ✓ permanganate extractable carbon,
  - ✓ particulate organic carbon and
  - ✓ litter decomposition compared to the control and/or mineral fertilizer treatment.

❑ Similarly, this study confirmed the convincing effect of mixing biochar and compost on the above stated soil quality attributes.

230

Cont…

- ❑ Unlike the expectation, permanganate-oxidizable carbon was less responsive for the biochar-based soil amendments than particulate organic matter, indicating the need for further studies to identify soil carbon fractions sensitive to the long-term addition of biochar-based soil amendments.
- ❑ Quantitative evidence from long-term trials is crucial to robust our understanding on the long-lasting effect of biochar based amendments on soil quality indicators.
- ❑ Thus, long-term experiments are recommended across a broad spectrum of soil-crop combinations before large-scale applications, particularly in low-input acidic soil.

231

Acknowledgements

- ✓ EIAR
- ✓ Jimma university (JUCAVM)
- ✓ Dr. Abebe Nigussie

232

Doc ID

Thank You

233

Co-composting of organic wastes with biochar: a new path in improving soil quality and sustainable crop production

13 February 2024

Daniela Castro-Herrera[1], Katharina Prost[1], Yonas Schäfer[1], Dong-Gill Kim[3], Fantaw Yimer[3], Menfese Tadesse[3], Mersha Gebrehiwot[3], Zeleke Asaye[3], Katharina A. Werner[2], Elisabeth Grohmann[2], Nicolas Brüggemann[1]

[1]Institute of Bio- and Geosciences—Agrosphere (IBG-3), Forschungszentrum Jülich, 52425 Jülich, Germany;[2] Faculty of Life Sciences and Technology, Department of Microbiology, Berliner Hochschule für Technik, 13347 Berlin, Germany; [3]Wondo Genet College of Forestry and Natural Resources, Hawassa University, Shashemene P.O. Box 128, Ethiopia

Outline of presentation

Rationale/Background

Problem and aims

Approaches/Methods followed

Results

Conclusion

Future plan

Acknowledgement

References

Rationale/Background

- In sub-Saharan Africa, little or no organic residues are returned to the farmland, leading to a decline in soil fertility, a subsequent decline in crop yield, and eventually to soil degradation.

- In low-input crop production systems, such as in smallholder farming in Ethiopia, mineral fertilizers are neither available nor affordable in sufficient quantities.

Rationale/Background

- There is, thus, a need for soil fertility management strategies that are environmentally sound, sustainable and economically affordable.

- Application of biochar-compost to soil can be part of such strategies.

- This combination has proven to act synergistically in improving crop productivity and soil quality in addition to lowering the need for chemical fertilizers.

- *Using neglected waste resources, like human excreta can therefore be one possible option of filling this gap.*

Problem and aims

To our knowledge, no studies combining thermophilic composting of **human excreta** (HM) from ecological sanitation and **biochar (BC)** exist to date.

- To undertake a **thermophilic composting experiment** of HM together with other organic waste and BC to produce a pathogen-free and nutrient-rich organic fertilizer.

- Evaluate the effect of BC addition and the type of manure (HM and cattle manure) on the composts' **key nutrients, its chemical and physical characteristics, its ammonia and greenhouse gas** (GHG) **emissions** and Maize yield.

Approaches/Methods

We conducted a 185-d thermophilic composting experiment with HM, and with CM, mixed with kitchen scraps, teff straw, sawdust, and BC in composting boxes.

The treatments were:
1) HM-Compost (HM);
2) Biochar-Compost from HM (HM-BC);
3) cattle manure compost (CM);
4) Biochar-compost from CM (CM-BC).

- These were tested in field trials and compared to mineral fertilizer (MF) and a control without fertilizer (C) on basis of N contents of the compost.

A micro-gasifier cook stove

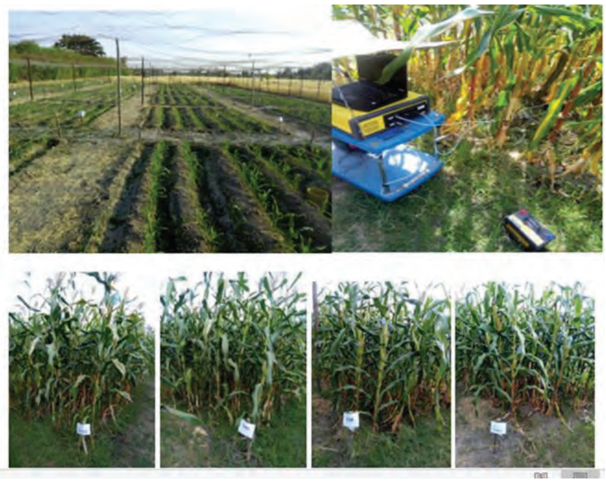
BC was produced from *Eucalyptus camaldulensis* with a top-lit up-draft micro-gasifier (NOAH Stove) at a pyrolysis temperature between 500 and 600 ˚C and residence time of 40−50 min.

The NOAH stove was invented and patented by the German
company PRO LEHM and built from local materials (soil, sand and straw and used tin cans).

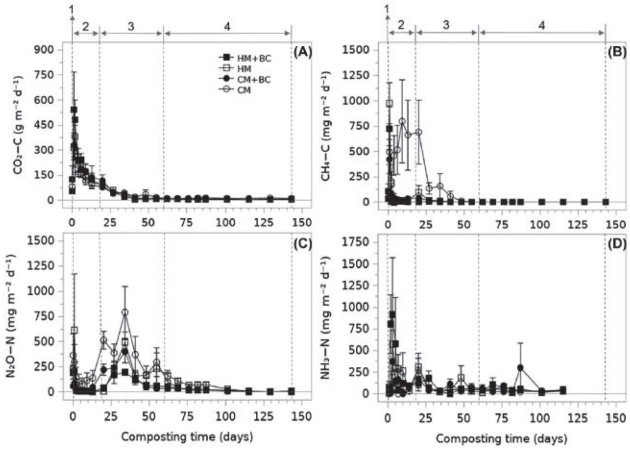
Ecological toilet

Compost generation

Field trials



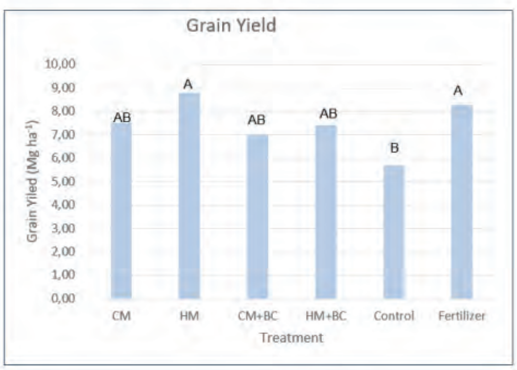
Results (1)



- BC significantly reduced non-CO_2 GHG-emissions (51-71%).
- The P and K were preserved during composting, whereas Ca and Mg losses were low (< 18%),
- Addition of BC led to a relative reduction of TOM losses by 18–23% and of TOC by 33–42%, and N (49–100%), and decreased the amount of extractable NO_3 (32–36%) in the final compost, attributed to the higher amount of remaining TOM and TOC in the BC-amended composts mainly due to the BC's stability against microbial degradation during composting.

Results (2)

- For the field trials all organic amendments significantly increased total biomass and yield with 18–35 % (35 % in HM treatment and 18 % in the CM-BC treatment), compared to the control, attributed to increased nutrient availability and soil moisture.
- No yield difference was observed between mineral fertilizer and the compost treatments.
- Agronomic nitrogen use efficiency (ANUE) was significantly (< 0.049) different with treatments,



CM = Cattle Manure Compost,
HM = Humanure Compost
CM+BC = Cattle Manure + Biochar Compost
HM+BC = Humanure + Biochar Compost
Fertilizer = Mineral NPS Fertilizer
Control = Without Fertilization

Results (3)

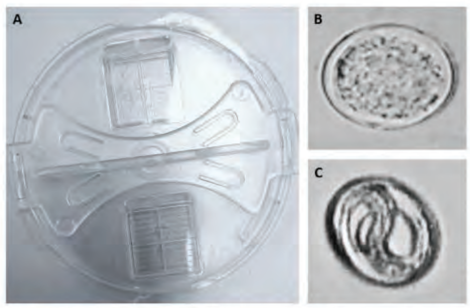


Figure 2. Mini-FLOTAC counting chamber (**A**); light microscopy of *Ascaris suum* egg before larvation, isolated from female worms (**B**); larvated *A. suum* egg after development in 0.1 M H_2SO_4 at room temperature for 28 days (**C**) (Photos: Khaliel El-Said).

- The amount of detected *Escherichia coli* (*E. coli)* was below the thresholds of German and European regulations for organic fertilizer. *Salmonella* and *Ascaris* eggs were not detected.

- Thus, the matured compost was free of pathogens at the end of a 6-month composting period.

Conclusion

Composting human excreta is a safe way to produce nutrient-rich compost, with BC reducing non-CO_2 GHG emissions during composting.

- Composting of human and cattle manure with biochar reduced N_2O emission up to 57%;
- Composting of cattle manure with biochar reduced CH_4 emission up to 91%; Biochar addition to compost did not significantly affect CO_2 and NH_3 emissions;
- overall, non-CO_2 -GHG emissions were reduced by 51%−71% by biochar addition.

Application of biochar-compost is furthermore a sustainable and cost-effective technique for increasing crop productivity and improving soil quality.

The mature compost fulfilled the legal regulations on organic fertilizer regarding potential human pathogens.

Future plan: to scale-up and translate it to a business, create job for women and youths.

Acknowledgement: The research was conducted in the frame of the ClimEtSan project and funded by the Federal Ministry of Education and Research (BMBF, FKZ 01DG17010) and the German Academic Exchange Service (DAAD, project ID 57354010).

References: Asaye et al., 2022. Land, 11: 784; Daniela et al., 2021. J. Environ. Qual. 51:19–32; Werner et al., 2023. Sustainability, 15: 4624.

Thank you for your attention

Sustainable Soil Health and Agricultural Productivity with Biochar based Indigenous Organic Fertilizers in Acidic Soils: Insights from Northwestern Highlands of Ethiopia

2nd Soil Symposium

Ewunetu Tazebew[ae*], Solomon Addisu[b], Eshetu Bekele[c], Asmamaw Alemu[a], Berhanu Belay [d], Shinjiro Sato[e],

[a]college of agriculture and environmental science, university of Gondar, Gondar, Ethiopia;

[b]college of Agriculture and environmental science, Bahir Dar University, Bahir Dar, Ethiopia;

[c]School of Applied Natural Sciences, Adama Science and Technology University, Ethiopia.

[d]College of Agriculture, Food and Climate Sciences, Injibara University, Injibara, Ethiopia.

[e]Faculty of Science and Engineering, Soka University, Tokyo, Japan

February, 2024

Addis Abeba , Ethiopia

Out line of the presentation

- Introduction
- Objectives
- Material and methods
- Result and discussion
- Conclusion and recommendations

Introduction

Charcoal production from smallholder plantations

Photos: © Ewunetu T 2022.

Charcoal production from smallholder plantations

Photos: © Ewunetu T 2022.

Charcoal production from smallholder plantations

Objectives of the study

- To produce and characterize BIF from *Acacia decurrens* biochar co-composted with chicken litter, and cow dung manure
- To investigate the effects of BIF on soil physicochemical properties
- To evaluate the effects of BIF on crop yield and yield component

Materials and Methods

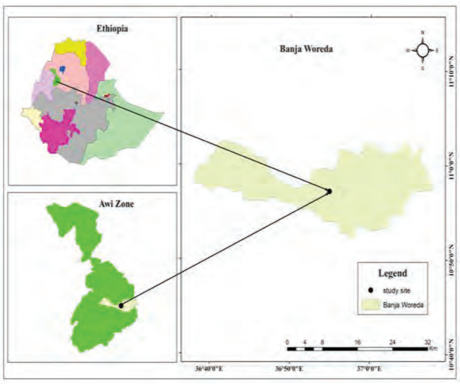
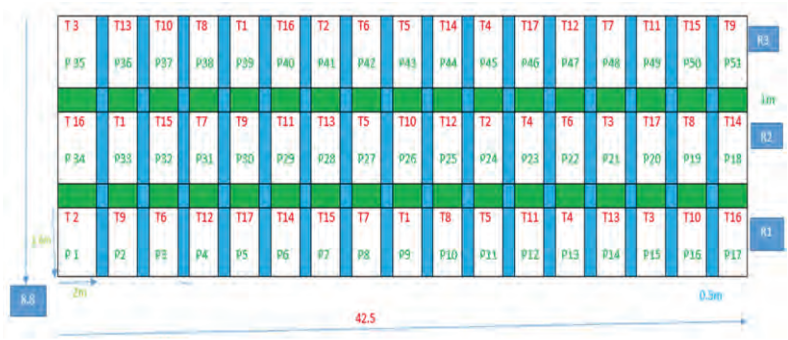


Figure 1: map of the study area

- **Study area description**
- **Injibara University** (latitude 10° 50’N, longitude 37° 00’ E)
- Altitudinal range :
- 700 to 2900 meters above sea level
- Temperature : 9.4°C - 26°C
- Rainfall distribution: 800 to 2700 mm
- Farming system: mixed farming
- Soil-Acrisoil (Gebreselassie, 2002).

biochar based indigenous fertilizer application measurement and field trial

- Four distinct biochar based indigenous fertilizer (BIF) were established, with weight ratios of biochar: litter: manure setted at 100:0:0, 25:75:0, 15:85:0, and 25:0:75.



biochar based indigenous fertilizer application measurement and field trial cont….

biochar based indigenous fertilizer application measurement and field trial cont….

Photos: © Ewunetu T 2022.

Soil and agronomic data collection

- Soil physical and chemical properties were collected before and after BIF amendments
- Teff yield and yield component were evaluated after BIF amendments
- To assess the economic aspects of different BIF, economic data was calculated using the approach outlined by CIMMYT, (1988).

Statistical analysis

- As part of the statistical analysis, the collected data were subjected to an analysis of variance (ANOVA) to ascertain the presence of any notable variances.
- In instances where significant differences were detected at $p < 0.05$, mean comparisons were performed using Tukey's honestly significant difference (HSD) tests, with the aid of SAS version 9.4.

Results and discussion

Sustainable Soil Health and Agricultural Productivity with Biochar based Indigenous Organic Fertilizers in Acidic Soils: Insights from Northwestern Highlands of Ethiopia

Ewunetu Tazebew[a, e*], Solomon Addisu[b], Eshetu Bekele[c], Asmamaw Alemu[a], Berhanu Belay [d], Shinjiro Sato[e],

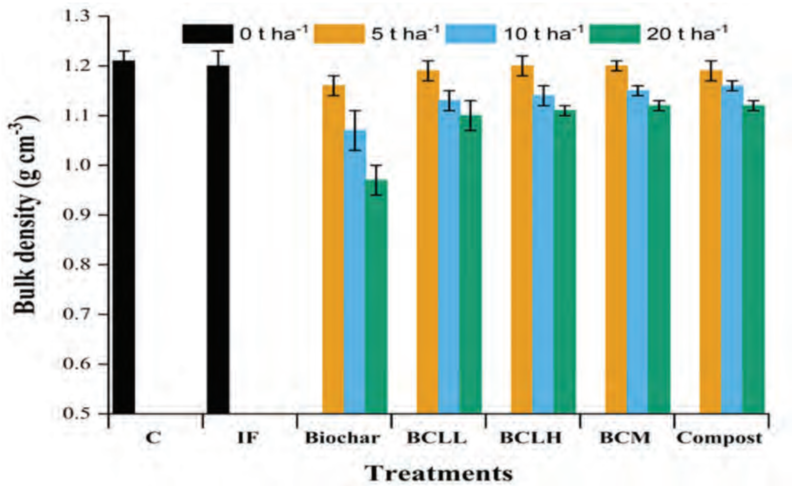
[a]college of agriculture and environmental science, university of Gondar, Gondar, Ethiopia;
[b]college of Agriculture and environmental science, Bahir Dar University, Bahir Dar, Ethiopia;
[c]School of Applied Natural Sciences, Adama Science and Technology University, Ethiopia.
[d]College of Agriculture, Food and Climate Sciences, Injibara University, Injibara, Ethiopia.
[e]Faculty of Science and Engineering, Soka University, Tokyo, Japan
*Corresponding Author; Ewunetu Tazebew, email address; jackmanof23@gmail.com

Characteristics of BIF before application

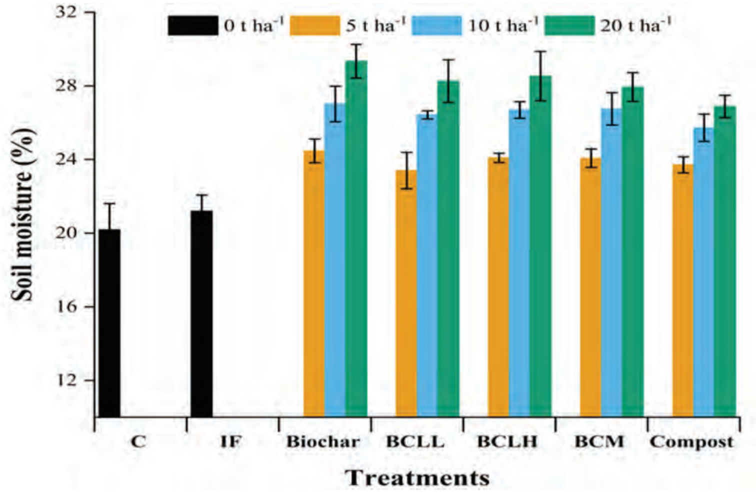
Parameters	Soil	Biochar	Compost	BCLL	BCLH	BCM
Sand %	52	Nd	Nd	Nd	Nd	Nd
Clay %	31	Nd	Nd	Nd	Nd	Nd
Silt %	19	Nd	Nd	Nd	Nd	Nd
Bulk density (g cm^{-3})	1.22	Nd	Nd	Nd	Nd	Nd
pH	4.61	8.56	6.67	6.73	7.07	6.74
Organic carbon %	1.5	65	10.35	10.59	13.61	11.8
Total nitrogen %	0.18	0.66	1.18	1.24	1.23	1.03
C: N	8.3	98.5	8.35	8.61	11.53	11.46
Available phosphorus (mg kg^{-1})	10.77	250.25	311.72	625.75	533.56	531.89
CEC (cmol kg^{-1})	25	30	55.94	58.02	54.07	49.76

Nd = Not determined, BCLL= 15% biochar + 85 % chicken litter+ other locally available green wastes, BCLH= 25 % biochar + 75 % chicken litter+ other locally available green wastes, BCM= 25 % biochar + 75 % cow manure + other locally available green wastes.

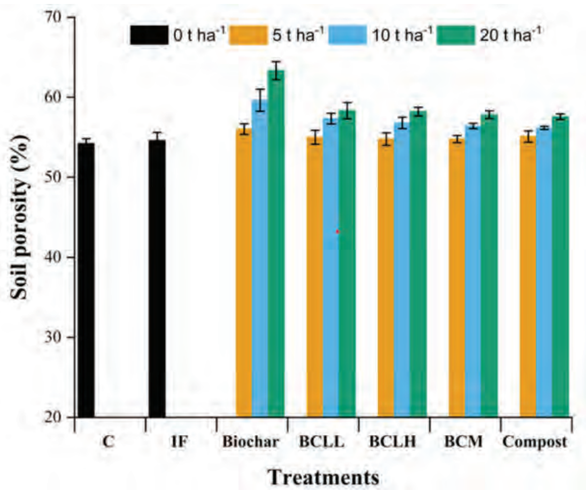
Effects of biochar based indigenous fertilizer (BIF) on soil physicochemical properties



BIF effect on soil moisture

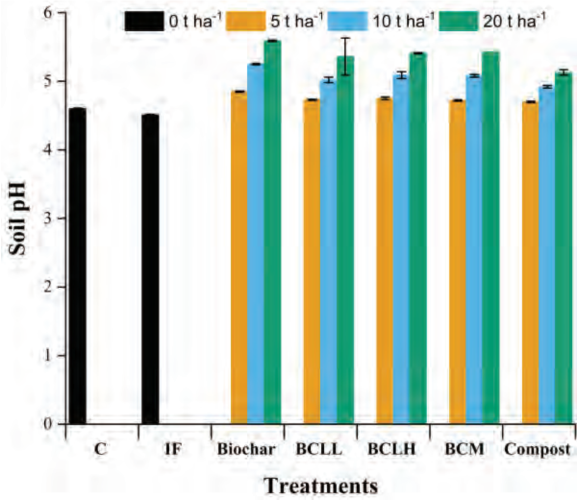


BIF effect on soil porosity



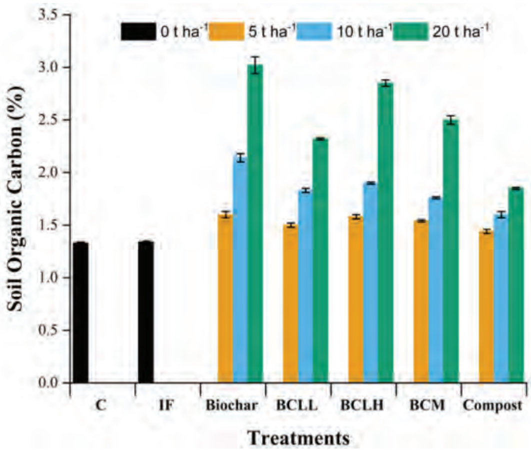
BIF effect on soil chemical properties

- soil pH



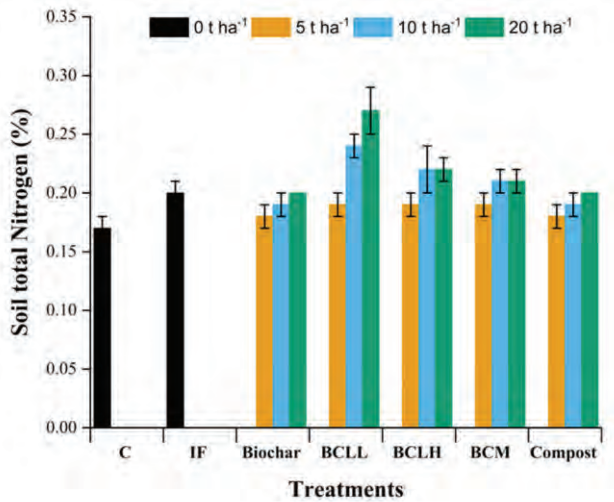
BIF effect on soil chemical properties cont…

- Soil Organic Carbon



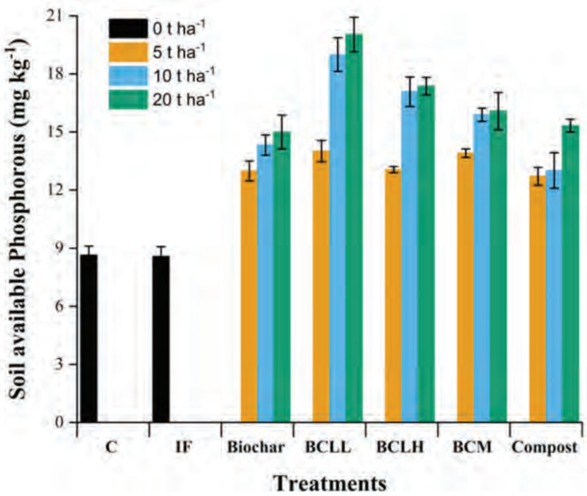
BIF effect on soil chemical properties cont…

- Total Nitrogen



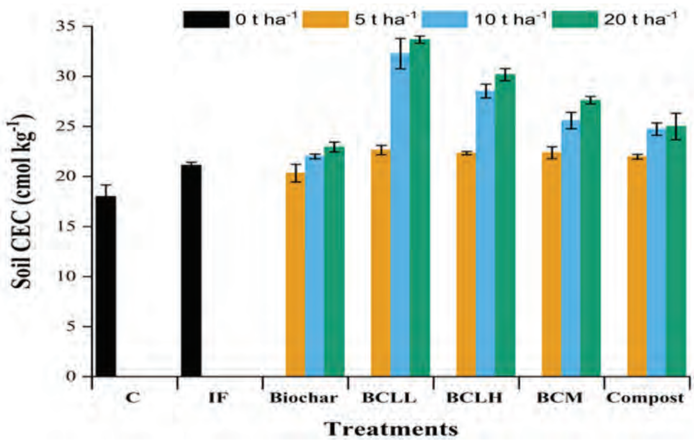
BIF effect on soil chemical properties cont…

Available phosphorus



BIF effect on soil chemical properties cont…

Cation Exchange Capacity



BIF effect on plant height, panicle length, and tiller number

Amendments	Plant height (cm)	Panicle length (cm)	Number of tillers
Control	41.80 ± 0.67^{i}	21.43 ± 0.29^{h}	10.57 ± 0.44^{h}
IF	87.23 ± 1.04^{cd}	38.10 ± 0.35^{c}	19.67 ± 0.29^{cdef}
5 t ha^{-1} biochar	58.73 ± 1.15^{h}	25.63 ± 0.29^{g}	14.23 ± 0.44^{gh}
10 t ha^{-1} biochar	75.83 ± 1.23^{f}	33.10 ± 0.35^{e}	17.03 ± 0.03^{efg}
20 t ha^{-1} biochar	87.10 ± 1.17^{cd}	37.97 ± 0.30^{c}	19.10 ± 0.31^{def}
5 t ha^{-1} (BCLL)	86.60 ± 1.17^{d}	37.80 ± 0.29^{c}	19.03 ± 0.29^{def}
10 t ha^{-1} (BCLL)	95.43 ± 1.46^{ab}	44.43 ± 0.32^{a}	24.67 ± 0.33^{ab}
20 t ha^{-1} (BCLL)	96.53 ± 1.40^{a}	45.80 ± 0.35^{a}	25.57 ± 0.30^{a}
5 t ha^{-1} (BCLH)	85.50 ± 1.17^{de}	35.97 ± 0.33^{d}	17.93 ± 0.48^{efg}
10 t ha^{-1} (BCLH)	93.33 ± 1.23^{abc}	42.40 ± 0.31^{b}	23.73 ± 0.29^{abc}
20 t ha^{-1} (BCLH)	94.90 ± 1.25^{ab}	42.50 ± 0.35^{b}	24.13 ± 2.99^{ab}
5 t ha^{-1} (BCM)	80.13 ± 1.19^{ef}	34.53 ± 0.44^{de}	17.57 ± 0.30^{efg}
10 t ha^{-1} (BCM)	91.23 ± 1.40^{abcd}	40.93 ± 0.30^{b}	22.83 ± 0.55^{abcd}
20 t ha^{-1} (BCM)	93.13 ± 1.34^{abc}	42.23 ± 0.29^{b}	23.20 ± 0.31^{abcd}
5 t ha^{-1} compost	68.60 ± 1.41^{h}	28.50 ± 0.31^{f}	16.40 ± 0.31^{fg}
10 t ha^{-1} compost	75.23 ± 0.32^{f}	33.70 ± 0.30^{e}	17.33 ± 0.33^{efg}
20 t ha^{-1} compost	89.17 ± 1.13^{bcd}	39.13 ± 0.37^{c}	20.73 ± 0.29^{bcde}
P-value	***	***	***
CV (%)	2.5	1.5	7

BIF effect on crop yield

Effects of different biochar based fertilizers on Tef yield components

Amendments	Grain yield t ha^{-1}	Dry biomass yield t ha^{-1}	Straw yield t ha^{-1}
Control	0.68 ± 0.04^{i}	7.50 ± 0.48^{j}	6.82 ± 0.44^{e}
IF	1.90 ± 0.07^{d}	12.92 ± 0.42^{d}	11.02 ± 0.47^{abc}
5 t ha^{-1} biochar	0.90 ± 0.06^{hi}	8.05 ± 0.50^{hi}	7.15 ± 0.44^{e}
10 t ha^{-1} biochar	1.17 ± 0.05^{fgh}	8.33 ± 0.24^{fgh}	7.17 ± 0.27^{e}
20 t ha^{-1} biochar	1.53 ± 0.01^{e}	12.50 ± 0.48^{e}	10.97 ± 0.47^{abc}
5 t ha^{-1} (BCLL)	1.47 ± 0.01^{e}	12.08 ± 0.24^{e}	10.61 ± 0.24^{bcd}
10 t ha^{-1} (BCLL)	2.71 ± 0.12^{ab}	15.83 ± 0.48^{ab}	13.13 ± 0.60^{ab}
20 t ha^{-1} (BCLL)	2.82 ± 0.03^{a}	16.67 ± 0.48^{a}	13.85 ± 0.46^{a}
5 t ha^{-1} (BCLH)	1.38 ± 0.07^{ef}	9.58 ± 0.72^{ef}	8.21 ± 0.65^{cde}
10 t ha^{-1} (BCLH)	2.57 ± 0.07^{ab}	14.17 ± 0.42^{ab}	11.60 ± 0.44^{ab}
20 t ha^{-1} (BCLH)	2.71 ± 0.06^{ab}	15.42 ± 0.7^{2ab}	12.71 ± 0.74^{ab}
5 t ha^{-1} (BCM)	1.38 ± 0.03^{ef}	9.17 ± 0.48^{ef}	$7.79\pm0.51d^{e}$
10 t ha^{-1} (BCM)	2.21 ± 0.07^{c}	13.75 ± 0.72^{c}	11.54 ± 0.65^{ab}
20 t ha^{-1} (BCM)	2.50 ± 0.02^{bc}	14.03 ± 0.97^{bc}	11.53 ± 0.98^{ab}
5 t ha^{-1} compost	1.00 ± 0.05^{hg}	$8.05\pm0.28g^{h}$	7.05 ± 0.24^{e}
10 t ha^{-1} compost	1.29 ± 0.05^{efg}	$8.61\pm0.74ef^{g}$	7.32 ± 0.75^{e}
20 t ha^{-1} compost	1.90 ± 0.04^{d}	13.06 ± 0.37^{d}	11.15 ± 0.33^{ab}
P-value	***	***	***
CV (%)	5.6	8.1	9.2

Economic profitability of the different BIF

Partial budget analysis of the different biochar-based indigenous fertilizers.

Amendments	Total variable cost (ETB ha-1)	Net benefit (ETB ha-1)	Marginal rate of return (%)
Control	-	73909.72	-
IF	5800	163776.40	dominance
5 t ha^{-1} biochar	1000	87576.39	13.70
10 t ha^{-1} biochar	2000	113229.20	dominance
20 t ha^{-1} biochar	4000	160298.60	52.00
5 t ha^{-1} (BCLL)	1237.5	140915.30	224.60
10 t ha^{-1} (BCLL)	2475	221587.50	358.40
20 t ha^{-1} (BCLL)	4950	229223.60	148.70
5 t ha^{-1} (BCLH)	1268.75	125411.80	dominance
10 t ha^{-1} (BCLH)	2537.5	199962.50	dominance
20 t ha^{-1} (BCLH)	5075	216904.20	dominance
5 t ha^{-1} (BCM)	2031.25	106218.80	dominance
10 t ha^{-1} (BCM)	2937.5	137000.00	dominance
20 t ha^{-1} (BCM)	4281.25	203322.90	152.97
5 t ha^{-1} compost	2112.5	91665.28	dominance
10 t ha^{-1} compost	3100	113518.10	dominance
20 t ha^{-1} compost	4606.25	178122.90	dominance

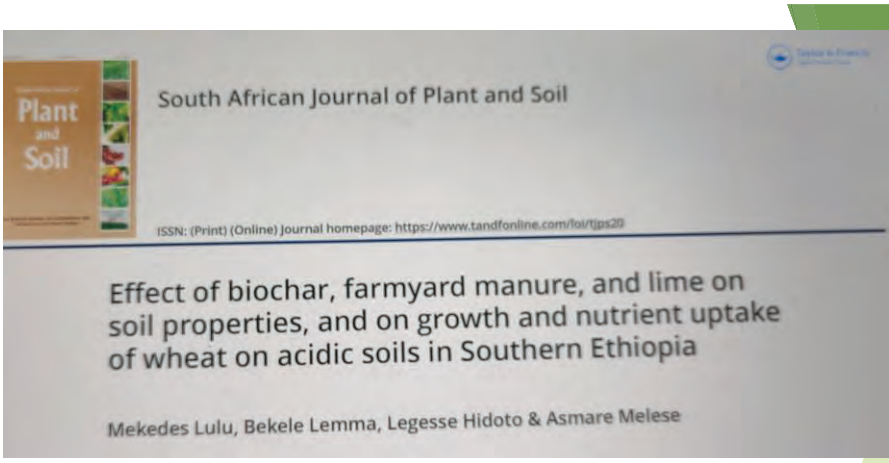
conclusion and recommendation

- **Conclusion**
  - **BIF improved**
    - soil properties
    - crop yield and yield component
    - The effects of biochar were significant when it is co-composted with other organic amendment (CL and CM)
- **recommendation**
  - Species-Specific Approaches-co-composting materials and mixing ratio
  - Research and Education: soil microbial community, nutrient cycling and carbon sequestration

Effect of biochar, farmyard manure, and lime on soil properties, and on growth and nutrient uptake of wheat on acidic soils in Southern Ethiopia

Mekedes Lulu, **Bekele Lemma**, Legesse Hidoto & Asmare Melese

February 13, 2024
Addis Ababa, Ethiopia



South African Journal of Plant and Soil

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tjps20

Effect of biochar, farmyard manure, and lime on soil properties, and on growth and nutrient uptake of wheat on acidic soils in Southern Ethiopia

Mekedes Lulu, Bekele Lemma, Legesse Hidoto & Asmare Melese

South African Journal of Plant and Soil 2022, 39(2): 112–122

Introduction

Agricultural land productivity is low in sub-Sahara Africa (World Bank, 2019), which includes Ethiopia.

The low soil fertility in agricultural soils resulted from

- unsustainable soil management.

- and also from soil acidity (toxicity, fixation, ….)

Acid soils are predominant in the humid and sub-humid highlands of Ethiopia (Beukes *et al*. 2012).

intensive cropping systems,

reduced manure (organic) inputs, and

low rates of chemical fertilizer input (Haile and Boke 2009).

Soil amendments - Address agricultural soil degradation and crop yield decline.

- Sole mineral fertilizer – improves crop yield, but not sustainable due to cost and effect in long term (Agegnehu et al., 2014).
- Liming materials: improves crop yield (Chimdi et al. 2012; da Costa and Crusciol, 2016).
- Organic amendments- improves soil properties and crop production
  - Compost
  - Vermicompost
  - Biochar – but most studies are in temperate regions (Lehmann and Rondon 2006, Vaccari *et al*. 2011).
  - Crop residue
- Combination of organic and mineral fertilizer= can be a viable approach (Waseem et al., 2013; Agegnehu et al., 2016; Agegnehu et al., 2017).
- More studies are required to understand effect of biochar and combined effect in the tropics on different soils and agroecology.

- Ethiopia - the largest wheat producers (area cultivated and production) in SSA (Minot et al. 2015). Ethiopia's wheat lower than domestic needs, forcing the import of wheat.

- Objectives: to evaluate the effects of acacia BC, FYM, lime amendments, and combinations thereof, on:
  - *i. soil chemical properties, and*
  - *ii. growth components and nutrient contents in the straw and grain of bread wheat (Triticum aestivum L.) under two P-fixing acidic soils in Wolaita Zone, Southern Ethiopia.*

3. Materials and methods

Study area

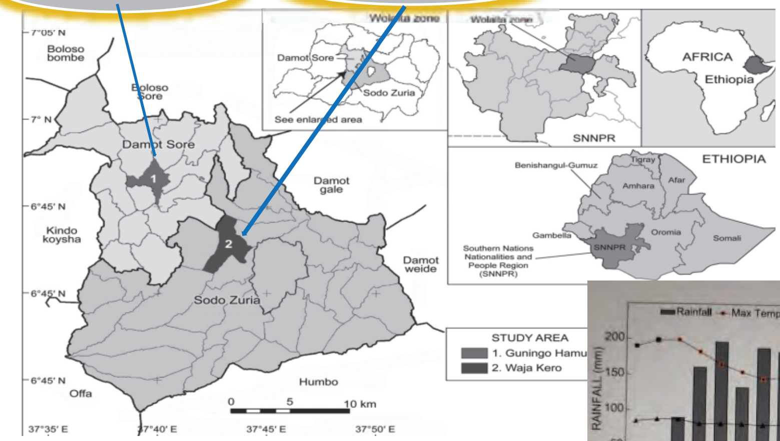
Ochric Andosol

Altitude
1 900 to 2 100 m asl

Eutric Nitisols

Gununo Hamus

Waja Kero



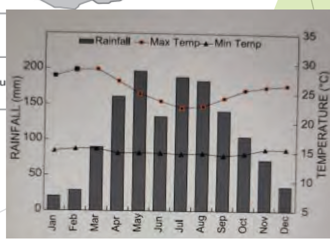


Figure 1: Location map of the study areas

Treatments and experimental design

- **Test Crop**: Wheat variety (Kakaba) was obtained from agricultural offices.

Farmyard manure (FYM)
- collected from farmer households
- cattle manure; bedding materials, household waste.
- Incorporated into the soil 10 days before sowing.

→ 0, 5 and 10 tha[-1]

Biochar(BC)
- finer residue (< 2 mm sieve) of charcoal (*Acacia albida*).
- incorporated into the soil 13 days before sowing

→ 0, 2 and, 5 tha[-1]

Lime = CCE of 98.6%.
- Lime was applied into the soil two months before sowing.
- The lime requirement (Shoemaker et al. 1961).

→ **Gununo Hamus** 0, 0.29 and 5.7 tha[-1]

→ **Waja Kero** 0, 3.75 and 7.5 tha[-1]

Their factorial combinations → Three replicates

↓ Randomized complete block design (RCBD)

Table 1: Soil properties before amendments

Soil properties	Sites: Gununo Hamus	Sites: Waja Kero
Sand (%)	36	32
Silt (%)	20	30
Clay (%)	44	38
Textural class	**Clay**	**Clay loam**
Bulk density (g cm^{-3})	**1.03**	**1.03**
pH (H_2O)	**5.6**	**5.4**
CEC (cmol$_c$ kg^{-1})	**29**	**2 7**
OC (%)	**1.6**	**1.5**
N (%)	**0.19**	**0.18**
AP (mg kg^{-1})	**2**	**2**
Ex. Acidity (cmol$_c$ kg^{-1})	**1.16**	**2.8**
Ex. Ca (cmol$_c$ kg^{-1})	**11.35**	**10.30**
Ex. Mg (cmol$_c$ kg^{-1})	**5.03**	**5.32**
Ex. K (cmol$_c$ kg^{-1})	**1.88 `**	**1.67**
Ex. Na (cmol$_c$ kg^{-1})	**0.33**	**0.58**

Soil sampling and analysis

- ❖ Composite soil samples **(0-20 cm)** following harvest from all treatment plots.
- ❖ five random soil samples bulked to form composite samples.
- ❖ **162** composite soil samples (**27 treatments × 3 replications × 2 sites**)
- ❖ soil samples were air dried, ground (mesh size 2 mm) for chemical analysis.

Analysis: using standard procedure at collage of agriculture in Hawassa and Hawassa agriculture research center.

Soil pH (H_2O) a pH meter (Okalebo et al. 2002).

SOC & **TN** by the Walkley and Black method (Walkley and Black 1934) and Kjeldahl methods (Okalebo et al. 2002), respectively.

Available P (Olsen et al. 1954).

Base cations and CEC Okalebo et al. (2002).
Exchangeable acidity

The land was cultivated by oxen and plough

the seeds were sown => hand drilling in rows spaced 20 cm apart at a rate of 100 kg ha^{-1}

Agronomic practices

Recommended rates
N fertilizer 120 kg N ha^{-1},
P fertilizer 30 kg P ha^{-1} and
K fertilizer 52 kg K ha^{-1}

Weeding was carried out by hand-pulling and then by hoeing.

Agronomic data Measured by standard procedure

Growth parameters
- Plant height (cm)
- Total and productive tillers per plant
- Number of grains per spike and spike length/m^2

Yield and Yield Components
- Total biomass(kg ha^{-1})
- Number of hundred seeds weights
- Grain yield(kg ha^{-1})
- Straw yield (kg ha^{-1})
- Harvest index (%)

Plant analysis
N, P, Ca, Mg, Na and K

Statistical analysis

Data were analyzed with SAS software version 9.4 (SAS Institute 2017).

⇩

Soil chemical properties and agronomic data were evaluated by analysis of variance (ANOVA) following the general linear model procedure at $p < 0.05$.

⇩

Mean separation for significant results soil properties and wheat growth components was made by using the **least significant difference** (LSD) test.

Results and Discussion

Table 2: Physiochemical properties of the biochar and farmyard manure used in the experiment

Soil properties	BC/FYM properties		
		FYM	
	BC	Gununo Hamus	Waja Kero
pH (H_2O)	8.8	8.1	8.1
CEC ($cmol_c\ kg^{-1}$)	33.8	29.5	31.5
Moisture content	9.0	62.9	63.0
OC (%)	69.4	40.6	41.2
N (%)	0.20	1.35	1.38
AP ($mg\ kg^{-1}$)	36	17	24
Ca ($g\ kg^{-1}$)	1.3	0.74	0.71
Mg ($g\ kg^{-1}$)	0.47	0.25	0.24
K ($g\ kg^{-1}$)	14.0	8.8	4.33
Na ($g\ kg^{-1}$)	1.0	0.75	3.0

BC = biochar CEC = cation exchange capacity Ex. = exchangeable
FYM = farmyard manure OC = organic carbon

Table 3. Mean values of soil chemical properties on BC, FYM and lime

Location	Treatment	$t\,ha^{-1}$	pH	TN (%)	AP (mg kg^{-1})	SOC (%)	Exc. Acidity (cmol$_c$ kg^{-1})
Gununo Hamus	BC	0	5.58^{c}	0.16^{b}	2.29	2.07^{c}	0.89^{a}
		2	6.79^{b}	0.34^{a}	3.43	3.64^{b}	0.47^{b}
		5	6.94^{a}	0.35^{a}	3.78	4.27^{a}	0.26^{c}
		$LSD_{5\%}$	0.09	0.07	ns	0.34	0.25
	FYM	0	5.68^{b}	0.18^{c}	2.17^{b}	2.25^{b}	0.67
		5	6.80^{a}	0.33^{b}	3.49^{ba}	3.71^{a}	0.50
		10	6.84^{a}	0.44^{a}	3.95^{a}	4.00^{a}	0.44
		$LSD_{5\%}$	0.09	0.07	0.51	0.34	ns
	Lime	0	5.55^{c}	0.18	2.04^{b}	2.64	1.02^{a}
		2.9	6.81^{b}	0.33	3.49^{b}	3.65	0.41^{b}
		5.7	7.0^{a}	0.34	4.08^{a}	3.68	0.18^{b}
		$LSD_{5\%}$	0.09	ns	0.51	ns	0.25
Waja kero	BC	0	5.51^{c}	0.16^{b}	2.53^{c}	2.04^{c}	1.25^{a}
		2	6.67^{b}	0.27^{b}	4.37^{b}	3.25^{b}	1.02^{b}
		5	6.78^{a}	0.31^{a}	7.05^{a}	3.80^{c}	1.02^{b}
		$LSD_{5\%}$	0.09	0.04	0.35	0.27	0.22
	FYM	0	5.55	0.17^{c}	2.72^{b}	2.14^{b}	1.21
		5	6.58	0.30^{b}	3.14^{a}	3.41^{a}	1.05
		10	6.63	0.36^{a}	3.43^{a}	3.54^{a}	1.03
		$LSD_{5\%}$	ns	0.04	0.35	0.27	ns
	Lime	0	5.57^{c}	0.16	2.88^{b}	2.37	1.52^{a}
		3.75	6.62^{b}	0.27	3.09^{ba}	3.46	1.20^{b}
		7.5	6.77^{a}	0.29	3.32^{a}	3.27	0.57^{c}
		$LSD_{5\%}$	0.10	ns	0.35	ns	0.22

Table 4 Mean values of exchangeable cations and CEC on BC, FYM and lime

Location	Treatment	$t\,ha^{-1}$	Ca^{2+} (cmol$_c$ kg^{-1})	K^{+} (cmol$_c$ kg^{-1})	Na^{+} (cmol$_c$ kg^{-1})	CEC (cmol$_c$ kg^{-1})
Gununo Hamus	BC	0	14.06^{b}	1.43^{c}	0.31	29.39^{b}
		2	15.50^{a}	2.24^{b}	0.61	29.41^{b}
		5	16.37^{a}	3.02^{a}	0.13	30.37^{a}
		$LSD_{5\%}$	1.14	0.24	ns	0.35
	FYM	0	14.87^{b}	2.16	0.36^{a}	29.50^{b}
		5	15.00^{b}	2.23	0.14^{ba}	29.74^{ba}
		10	16.26^{a}	2.29	0.10^{b}	29.93^{a}
		$LSD_{5\%}$	1.14	ns	0.23	0.35
	Lime	0	14.08^{c}	2.00^{b}	0.16	29.57
		2.9	15.34^{b}	2.41^{a}	0.29	29.7
		5.7	16.52^{a}	2.28^{a}	0.15	29.87
		$LSD_{5\%}$	1.14	0.24	ns	ns
Waja kero	BC	0	12.20^{b}	1.17^{c}	0.20^{a}	28.08^{b}
		2	12.24^{b}	2.05^{b}	0.19^{ba}	28.90^{b}
		5	12.45^{a}	3.02^{a}	0.16^{b}	29.09^{a}
		$LSD_{5\%}$	1.14	0.36	0.03	0.22
	FYM	0	12.29	2.09	0.22^{a}	28.58^{b}
		5	12.22	2.07	0.19^{a}	29.03^{a}
		10	12.38	2.08	0.13^{b}	29.25^{a}
		$LSD_{5\%}$	ns	ns	0.03	0.22
	Lime	0	11.44^{c}	2.60^{b}	0.20^{a}	28.73^{b}
		3.75	12.44^{b}	2.89^{b}	0.20^{ba}	28.96^{a}
		7.5	13.00^{a}	3.22^{a}	0.16^{b}	29.17^{a}
		$LSD_{5\%}$	0.41	0.19	0.04	0.22

Effects of amendments on chemical properties of the post-harvest soils

- The **lime and BC amendment** improved soil pH and reduced exchangeable acidity
- BC application influence => high pH and ash contents (Nigussie et al. 2012).
- **Biochar and FYM** increased SOC and TN, but lime did not have the same effect.
- The influence of BC and FYM amendment on SOC is attributable to its organic C content.
  - high C content of BC and FYM
  - BC decomposes slowly in soils => the difference between the rates of mineralization.
- The high **TN** in the soils amended with **FYM** maybe due to its high N content and N release from its mineralization (Bayu et al. 2006).
- The highest **AP** increase, due to the addition of **BC and lime** is a particularly important effect on AP and high P concentrations in the BC ash and P released from adsorption sites (Zhai et al. 2015).
- BC on **CEC and base cations** attributed to the high surface area, and porous nature of BC (Cheng et al. 2008).
- Wood-derived BC shown high contents of plant nutrients such as P, K, Ca and Mg (Mukome et al. 2013), and the **ash content of BC** (Glaser et al. 2002).

Table 5. Mean values of PH, SI, SPS and Tt of bread wheat on BC, FYM and lime.

Location	Treatment	tha^{-1}	PH (cm)	SI	SPS (m^{2})	Tt/	Pt/
Gununo Hamus	BC	0	82.94^{c}	6.17^{b}	368^{b}	549^{b}	514^{b}
		2	83.08^{b}	6.83^{b}	392^{a}	558^{ba}	558^{ba}
		5	83.60^{a}	7.44^{a}	397^{a}	626^{a}	580^{a}
		$LSD_{5\%}$	1.46	0.17	1.42	0.08	0.24
	FYM	0	82.80	7.48^{c}	382	548	527
		5	84.14	7.49^{b}	382	585	563
		10	82.69	7.81^{a}	392	586	576
		$LSD_{5\%}$	ns	0.20	ns	ns	ns
	Lime	0	82.11	7.47	380	536	535
		2.9	83.73	7.65	387	576	571
		5.7	83.79	7.66	381	588	581
		$LSD_{5\%}$	ns	ns	ns	ns	ns
Waja Kero	BC	0	66.05^{c}	6.17^{b}	284^{c}	254^{c}	249^{b}
		2	70.06^{b}	6.83^{b}	316^{b}	302^{b}	298^{b}
		5	73.90^{a}	7.44^{a}	353^{a}	377^{a}	374^{a}
		$LSD_{5\%}$	1.46	0.17	0.71	0.24	0.24
	FYM	0	66.28^{b}	6.73^{b}	317^{b}	297^{c}	294^{b}
		5	69.91^{ba}	6.80^{ba}	317^{b}	307^{b}	303^{ba}
		10	70.81^{a}	6.91^{a}	326^{a}	328^{a}	324^{a}
		$LSD_{5\%}$	1.46	0.20	0.71	0.24	0.24
	Lime	0	68.22^{c}	6.56^{c}	304^{c}	282^{b}	248^{b}
		3.75	70.09^{b}	6.82^{b}	317^{b}	306^{b}	296^{b}
		7.5	71.69^{a}	7.06^{a}	332^{a}	374^{a}	342^{a}
		$LSD_{5\%}$	1.46	0.17	0.71	0.24	0.24

Table 6. Mean values of TB, GY, SY, TSW and HI of wheat on BC, FYM and lime.

Location	Treatment tha^{-1}		TB	GY	SY	TSW	HI
			kg ha^{-1}			kg	%
Gununo Hamus	BC	0	7926^{b}	2595^{c}	4039^{c}	45.56^{c}	37.91
		2	8144^{b}	3312^{b}	5114^{b}	50.00^{b}	39.11
		5	8434^{a}	3595^{a}	5880^{a}	52.15^{a}	39.44
		$LSD_{5\%}$	0.27	0.15	0.27	0.10	ns
	FYM	0	6634^{c}	3051^{b}	4824^{b}	45.56^{b}	37.59^{b}
		5	8397^{b}	3104^{b}	5094^{ba}	50.00^{b}	38.84^{ba}
		10	9473^{a}	3346^{a}	5198^{a}	55.12^{a}	39.93^{a}
		$LSD_{5\%}$	0.23	0.15	0.27	0.10	0.16
	Lime	0	7466^{c}	2929^{c}	4399^{c}	46.67^{c}	38.03
		2.9	8286^{b}	3205^{b}	4563^{b}	50.74^{b}	38.11
		5.7	8752^{a}	3366^{a}	4788^{a}	53.33a	38.75
		$LSD_{5\%}$	0.27	0.15	0.27	0.10	ns
Waja Kero	BC	0	4442^{c}	1573^{c}	2735^{c}	44.44^{c}	34.59^{c}
		2	6145^{b}	2395^{b}	3813^{b}	51.11^{b}	35.33^{b}
		5	6633^{a}	2708^{a}	5343^{a}	57.78^{a}	38.67^{a}
		$LSD_{5\%}$	0.74	0.27	0.63	0.02	0.27
	FYM	0	5865^{c}	2106^{c}	3868^{b}	50.00	35.44
		5	6045^{b}	2233^{b}	3851^{ba}	51.48	36.52
		10	7978^{a}	2337^{a}	4356^{a}	52.85	36.00
		$LSD_{5\%}$	0.74	0.25	0.63	ns	ns
	Lime	0	5368^{b}	1955^{b}	3369^{b}	48.07^{b}	35.52
		3.75	6045^{b}	2258^{b}	3781^{b}	50.74^{b}	35.26
		7.5	7153^{a}	2463^{a}	4741^{a}	54.07^{a}	27.11
			0.74	0.25	0.63	2.71	ns

Table 7. Mean values of GN, GP, GK and GCa of bread wheat on BC, FYM and lime.

Location	Treatment tha^{-1}		GN	G P	GK	G Ca (%)
Gununo Hamus	BC	0	4.34^{b}	0.30^{c}	2.49^{b}	0.39^{b}
		2	4.51^{a}	0.34^{b}	2.73^{ba}	0.40^{ba}
		5	4.61^{a}	0.36^{a}	2.80^{a}	0.42^{a}
		$LSD_{5\%}$	0.19	0.01	0.10	0.02
	FYM	0	4.23^{c}	0.32^{b}	2.60^{b}	0.38^{b}
		5	4.44^{b}	0.33^{b}	2.68^{a}	0.41^{ba}
		10	4.87^{a}	0.34^{a}	2.78^{a}	0.42^{a}
		$LSD_{5\%}$	0.19	0.01	0.21	0.02
	Lime	0	4.38^{b}	0.32^{b}	2.60^{b}	0.36^{c}
		2.9	4.54^{ba}	0.33^{ba}	2.70^{b}	0.40^{b}
		5.7	4.60^{a}	0.34^{a}	2.72^{a}	0.46^{a}
		$LSD_{5\%}$	0.19	0.01	0.10	0.02
Waja kero	BC	0	4.28^{c}	0.32^{b}	2.37^{b}	0.35^{b}
		2	4.45^{b}	0.34^{a}	2.50^{b}	0.37^{b}
		5	4.63^{a}	0.34^{a}	2.77^{a}	0.40^{a}
		$LSD_{5\%}$	0.10	0.01	0.15	0.02
	FYM	0	4.25^{c}	0.33^{b}	2.46^{b}	0.36^{b}
		5	4.40^{b}	0.34^{ba}	2.54^{ba}	0.37^{ba}
		10	4.71^{a}	0.35^{a}	2.63^{a}	0.38^{a}
		$LSD_{5\%}$	0.09	0.01	0.16	0.02
	Lime	0	4.33^{c}	0.33^{b}	2.44^{b}	0.33^{c}
		3.75	4. 46^{b}	0.34^{ba}	2.53^{ba}	0.37^{b}
		7.5	4.57^{a}	0.34^{a}	2.66^{a}	0.41^{a}
		$LSD_{5\%}$	0.09	0.01	0.16	0.02

Table 8. Mean values of SN, SP, SK and SCa of bread wheat on BC, FYM and lime.

Location		Treatment tha^{-1}	SN	SP (%)	SK	SCa
Gununo Hamus	BC	0	2.62^{b}	0.28^{c}	2.71^{c}	0.21^{c}
		2	2.70^{b}	0.31^{b}	2.82^{b}	0.31^{b}
		5	2.82^{a}	0.34^{a}	2.96^{a}	0.33^{a}
		$LSD_{5\%}$	0.08	0.02	0.09	0.02
	FYM	0	2.54^{c}	0.30^{b}	2.78^{b}	0.29^{b}
		5	2.68^{b}	0.31^{ba}	2.84^{ba}	0.31^{a}
		10	2.91^{a}	0.32^{a}	2.88^{a}	0.32^{a}
		$LSD_{5\%}$	0.08	0.02	0.09	0.02
	Lime	0	2.65^{b}	0.29^{b}	2.78^{b}	0.25^{c}
		2.9	2.70^{ba}	0.31^{a}	2.82^{ba}	0.31^{a}
		5.7	2.77^{a}	0.32^{a}	2.90^{a}	0.36^{a}
		$LSD_{5\%}$	0.08	0.02	0.09	0.02
Waja kero	BC	0	2.67^{b}	0.26^{b}	2.53^{b}	0.32^{b}
		2	2.67^{a}	0.34^{a}	2.63^{b}	0.33^{a}
		5	2.77^{a}	0.35^{a}	2.81[illegible]	0.35^{a}
		$LSD_{5\%}$	0.06	0.04	0.14	0.03
	FYM	0	2.53^{c}	0.29^{b}	2.55^{b}	0.31^{b}
		5	2.72^{b}	0.32^{ba}	2.64^{b}	0.34^{a}
		10	2.86^{a}	0.34^{a}	2.78^{a}	0.34^{a}
		$LSD_{5\%}$	0.06	0.04	0.14	0.02
	Lime	0	2.66^{b}	0.26^{b}	2.51^{b}	0.36^{b}
		3.75	2.69^{b}	0.30^{ba}	2.68^{ba}	0.30^{ba}
		7.5	2.76^{a}	0.34^{a}	2.77^{a}	0.36^{a}
		$LSD_{5\%}$	0.06	0.04	0. 14	0.02

Effects of amendments on wheat attributes

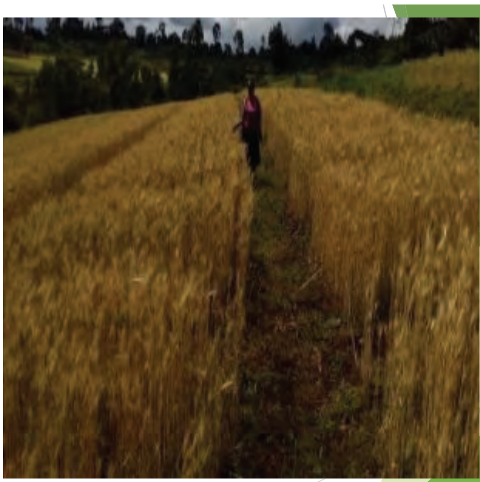
- BC increased wheat growth components more than the application of FYM or lime.

  BC has shown a positive effect on the growth and yield of annual crops (Lehmann and Rondon 2006; Uzoma et al. 2011; Kätterera et al. 2020). (different feedstocks) due to its greater infl uence on soil chemical properties

- Soil amendments influenced the straw nutrients in a similar manner to the way in which they influenced the grain nutrients of wheat.
- Farmyard manure had the greatest effect on grain and straw **N**, **BC** affected grain and straw **P** and **K**, and **lime** had the greatest effect on grain and straw **Ca** content.
- In general, it is evident that the increases in grain and straw nutrients (N, P, K, and Ca) from the cropland amendments are consistent with the improvement of the same nutrients in the soil.

An experimental field of Wheat in Waja Kero site

A field of Wheat in Gununo Hamus site



Conclusions

- BC, FYM, and lime improved soil chemical properties, wheat growth components, and nutrient contents depending on the soil types.
- Biochar had the greatest effect on SOC, exchangeable K and CEC while FYM had the greatest effect on soil TN. Lime had the most effect on soil exchangeable acidity and exchangeable Ca.
- Biochar, FYM and lime all influenced wheat growth components, as well as nutrient contents of grain and straw.
- Application of BC had the greatest effect on plant height, spike length, seed spike−1 , tiller number, grain yield, straw yield and aboveground biomass.
- Farmyard manure and BC improved the thousand seed weight as well as harvest index in Gununo Hamus and Waja Kero sites, respectively.
- Biochar amendment produced the highest P and K in wheat grain and straw while FYM and lime amendments produced the highest N and Ca increases in wheat, respectively.


THANK
YOU

Farmers Participatory Biochar Production, Nutrient Loading, Characterization, and Evaluation: Challenges and Opportunities

- **Fanuel Laekemariam (PhD) (PI)**
- **Abera Habtee (PhD) (Member)**
- **Prof. Mesfin Bibiso (Member)**

12 Feb. 2024

Outlines

1. Background
2. Objectives
3. Methodology
4. List of Activities
5. Expected Outputs
6. Work Plan, Risk Analysis and Budget
7. Dissemination Plan

Background

Challenges to Food Security

- Soil degradation
  - Low soil OC & nutrients (N,P,K,S, B, Cu).
  - Soil acidity
  - Soil erosion
- Pressure on farming land
  - Population (520.8/sq.km)
  - Small land size (0.25-0.5ha)
- Changing climatic
- Low productivity

Biochar a promising material to address triple challenges:

Soil degradation
Food Insecurity
C-sequestration

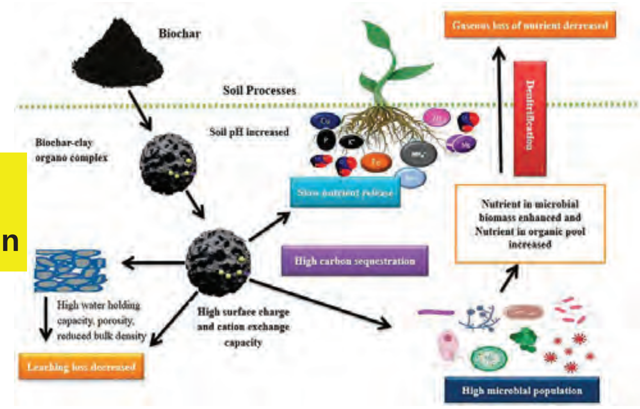


Figure (Murtaza et al. 2023)

2. Objectives

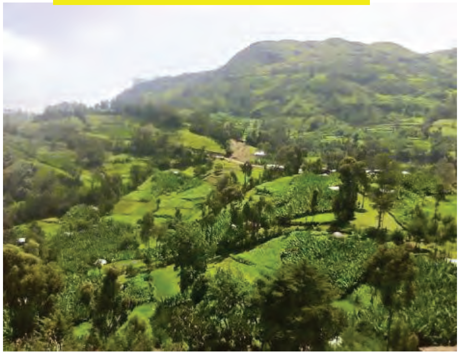
- To produce plant-based biochar, load with nutrients and test quality.

- To evaluate the effects of biochar based fertilizer (BBF) on
  - Agronomic & economic performances.
  - Soil quality.

- To document the opportunities and challenges of BBF production and utilization from the perspective of smallholder farmers.

3. Methodology

Study Area



- Wolaita Zone, Ethiopia

- Agriculturally potential districts and *Kebeles'*
  - **Sodo Zuria**
    - Kokate Marachere
  - **Boloso Bombe**
    - Farawocha
  - **Damot Sore**
    - Gununo

Participants

Researchers

- Extension workers
- Local Gov‘t Experts

Farmers (FRG)
- Male & Female

Establishing FRG (Farmers Research Group)

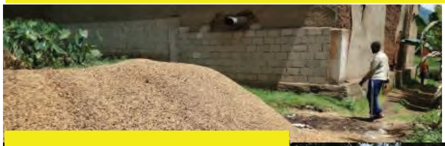
- **Criteria (Fanuel et al., 2024)**
  - Willingness.
  - Preferably model farmer.
  - Field
    - Representativeness
    - Accessibility
- **FRG per site: One**
  - **Members: 7 M &3 F**
- **Total FRG :**
  - **Three (30 Farmers)**

4. List of Activities: Based on Farmers' Participatory Approach

1	• Biochar Production, Nutrient Loading, and Characterization
2	• Effects of BBF: Agronomic and Economic Performance.
3	• Effects of BBF on Soil Quality
4	• Opportunities and Challenges from Participant Farmers Perspectives.

Activity I. Biochar Production, Nutrient Loading, and Characterization

A. Biochar Production-Materials



Coffee husk

- **Coffee husk**
- **Sawdust of *Cordia africana***
- Abundance and low trade-offs

Sawdust

B. Biochar Production: Techniques

Soil pit

1

Drum klin

2

Rounded roof iron sheet

3

C. BBF-Nutrient Loading

- **Activators @ ratio of 1:1:1**
  - Animal manure (FYM)
  - Vermicompost (VC)
  - Leaves of *Croton tree*
- **BBF (Biochar : Activator)**
  - **Weight (i.e., 2 kg):**
    - Activator: 1 kg
    - Biochar: 1 kg
  - **Incubation period:** 4 weeks

Data to be collected

- **Biochar Yield**
- **Bulk density**
- **WHC**

- **PAHs**
- **pH**
- **EC**
- **OC**
- **N,**
- **P,**
- **K**
- **C/N**
- **CEC**

NB. BBF Qulity will be judged using standard references of specific parameters.

Activity II. Evaluation of Nutrient-Loaded Biochar: Agronomic and Economic Performance

Research Design

- **Treatments**
  - **Farmers practice**
  - **BBF only**
  - **BBF+ Mineral Fertilizer**
- **Crops**: Maize, Wheat & Common bean
- **No. of Crops per FRG** (i.e., *Kebele*): two
- **Design**: RCBD
- **Data**: Relevant Agronomic Parameters
- **Analysis tool**: SAS software
- **Partial Budget Analysis**: CIMMYT (1988).

Activity III. Evaluating the effects of BBF on Soil Quality

- **Research Design**
  - **Treatment**: Activity II
  - **Sampling Time**:
    - **Before & After Treatment**.
  - **Depth**: 5-20 cm
  - **Parameters: E.g.**
    - Soil Moisture
    - Chemical Properties

Activity IV. Opportunities & Challenges of BBF: Farmers Perspectives

Appraoches:
1. **Preference Test**
2. **Survey**

- **A. Preference Test**
  - **Activity I: BBF**
    - **Production-Application**
  - **Activity II. Crop Stand**
  - **Activity II. Soil e.g.**
    - **Moisture etc**
- **Data Analysis**: Tally method

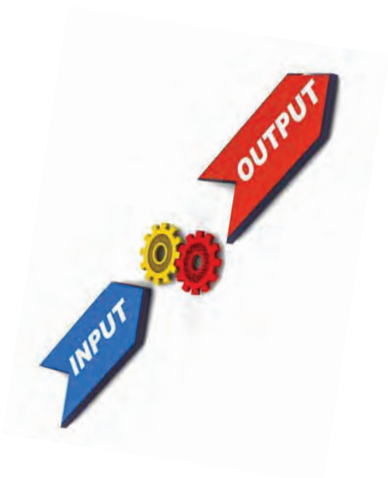
Con’t….Activity IV.

B. Survey
Opportunitie
s &
Challenges

- Exploratory visit
- Questionnaires
- FGD
- Key informant interview

Data analysis tool: SPSS

5. Expected Outputs



- Skill transfer
- Improvement:
  - Productivity
  - Soil Fertility
  - C-stock
- Information
  - Opportunities
  - Challenges
- Training manual
- One publication

6. Work Plan, Risks & Budget

- **Work Plan**
  - January-December, 2024.

- **Risk Analysis**: Low

- **Budget (Euros): 39,999.75**

7. Dissemination Plan

- **Field Days**
- **Extension material.**
- **Conferences**
- **Publication.**
- **Local media.**
- **Bringing the research findings into a lecture class.**

ETH-SOIL

eth-soil.com

DBFZ
Deutsches Biomasseforschungszentrum
gemeinnützige GmbH

Kerstin Wilde
ETH-Soil Project Manager
Phone: +49 (0)341 2434-514
E-Mail: kerstin.wilde@dbfz.de

Torgauer Str. 116
D - 04347 Leipzig
Phone: +49 (0)341 2434-112
E-Mail: info@dbfz.de
Internet: www.dbfz.de

ግብርና ሚኒስቴር
MINISTRY OF AGRICULTURE

german cooperation
DEUTSCHE ZUSAMMENARBEIT

BIIROO QONNAA OROMIYAA
OROMIA BUREAU OF AGRICULTURE

IQQO
Oromia Agricultural Research Institute

YUUNIVARSIITII JIMMAA
JIMMA UNIVERSITY
We are in the Community

Implemented by: DBFZ