Coffee husk biochar application improved soil chemical properties and yield of soybean grown in a tropical nitisol, Ethiopia

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1. Introduction

- Low soil fertility and soil acidity are among the major bottlenecks that limit agricultural productivity in the humid tropics.
- Soil management systems that enhance soil fertility and biological cycling of nutrients is crucial to sustain soil productivity.
- Biochar is one of the most important and easily available soil amendment resources that can improve soil properties and yield of tropical crops such as soybean.
- However, there are still many uncertainties about biochar, particularly whether it has positive effects with a particular soil and crop type.
- The study was, therefore, conducted to determine the effects of coffee husk biochar, rhizobium inoculation and P fertilizer application on Arbuscular mycorhyzal fungi (AMF) root colonization, biomass yield, P accumulation and BNF of soybean grown on tropical Nitisol of Jimma, southwest Ethiopia

2. Materials and methods

The coffee husk biochar was produced using an electrically heated pilot scale pyrolysis reactor (500° C with 3-hours retention time) in an oxygen limited atmosphere.
The experiment consisted of two levels of *rhizobium* inoculation (with and without), phosphorous (P) application (0 and 20 kg ha^{-1}) and four levels of biochar (0, 6, 12 and 36 t ha^{-1}) in a 2 × 2 × 4 factorial design with 3 replications.
The experiment was conducted under lath house conditions in 2015/16 crop season

A strongly acidic (pH = 4.59) soil was used for the experiment

3. Results

3.1. Soil physicochemical properties

Soil physicochemical properties measured after harvesting of the soybean differed substantially among the 16 treatment combinations. Soil pH, EC and CEC, were significantly increased compared to the soil chemical properties obtained at the control (Table 1).

Table 1. Mean after harvest soil pH$_{(H2O)}$ obtained from the 4 levels of Biochar(t ha^{-1}),electrical conductivity (EC; mS cm^{-1}) and cation exchange capacity (CEC; me/100 g) obtained from the 8 combinations of P(kg ha^{-1}) and Biochar, and CEC obtained from the 2 levels of Inoculation.

Biochar	pH$_{(H2O)}$	P	Biochar	EC (mS cm^{-1})	CEC (cmolc kg^{-1})	Inoculation	CEC (cmolc kg^{-1})
0	5.25 c	0	0	0.05 d	14.4 f	**With**	**20.9a**
6	5.42 bc	0	6	0.07 cd	18.2 e	Without	20.4 b
12	5.56 b	0	12	0.13 b	22.6 c		
36	**6.08 a**	0	36	0.14 b	24.7 b		
		20	0	0.05 d	14.6 f		
		20	6	0.09 c	19.0 d		
		20	12	0.13 b	24.4 b		
		20	**36**	**0.17 a**	**27.5 a**		

Within each response variable, means sharing the same letter are not significantly different.

3.2. Root and shoot biomass and P accumulation

Table 2: Mean root dry biomass, shoot dry biomass and P accumulation obtained from the 8 combinations of P, and Biochar.

P	Biochar	Root dry biomass (g plant^{-1})	Shoot dry biomass (g plant^{-1})	P accumulation (g plant^{-1})
0	0	2.11 e	17.17 d	0.854 e
0	6	2.82 cd	24.83 c	2.546 d
0	12	3.16 bc	26.17 bc	2.681 d
0	36	3.57 b	27.50 bc	2.951 c
20	0	2.40 de	19.50 d	0.879 e
20	6	3.63 b	27.83 b	3.025 c
20	12	4.23 a	34.17 a	3.619 b
20	36	4.73 a	36.17 a	4.533 a

within each response variable, means sharing the same letter are not significantly different.

The highest P accumulation (4.5 g plant^{-1}) was attained when 20 kg P ha^{-1} was combined with the highest rate of biochar (36 t ha^{-1}) (Fig 1). This was followed by the application of 20 P kg ha^{-1} and 12 t biochar ha^{-1}.

3.3. BNF of soybean

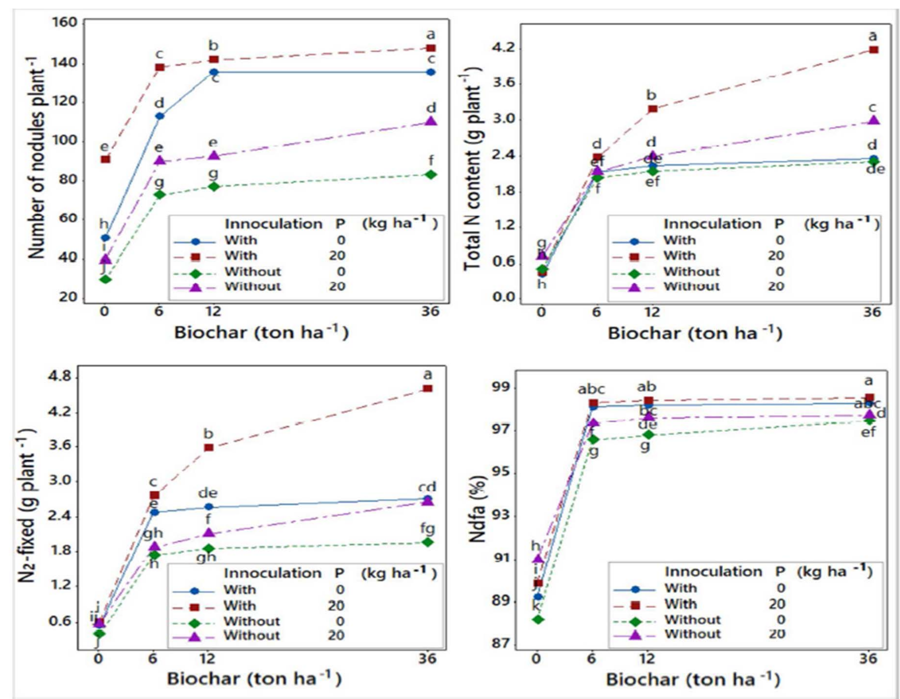

Fig 1 Interaction effect plots of Number of nodules plant^{-1}, Total N content (g plant^{-1}), N_2-fixed (g plant^{-1}), and Ndfa (%) showing the means obtained from the 16 combinations of Inoculation, P and Biochar. For each plot, means sharing the same letter are not significantly different.

- Increasing application rate of biochar increases BNF of soybean

3.4. AMF root colonization

- AMF root colonization was lower when coffee husk biochar was applied along with P regardless of rhizobium inoculation
- AMF root colonization was higher without P fertilization at the highest rate of biochar, but declined with P application

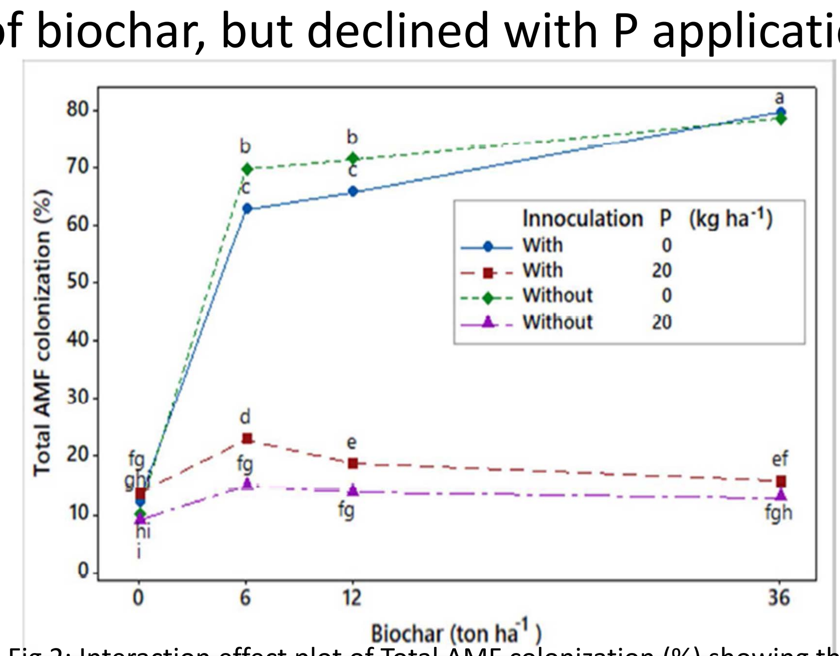

Fig 2: Interaction effect plot of Total AMF colonization (%) showing the means obtained from the 16 combinations of Inoculation, P and Biochar. Means sharing the same letter are not significantly different

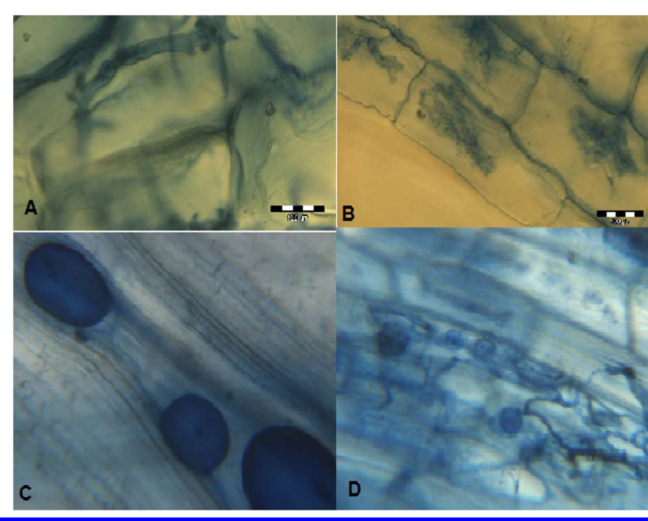

Fig **3:** A), hyphae (taken from root samples treated with 36 t BC only B) Arbuscules (taken from root samples treated with 6 t BC only); C) vesicles (taken from root samples treated with 12 t BC only); D) hyphae, vesicles and Arbuscular together (taken from root samples treated with 36 t BC +P.

4. Conclusions

- The improved soil chemical properties, biomass yield, P accumulation and BNF through combined use of biochar and P fertilizer suggests the importance of integrated use of biochar with P fertilizer to ensure that soybean crops are adequately supplied with P for nodulation and BNF in tropical acid soils for sustainable soybean production in the long term.

Acknowledgments

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