

Effect of Biochar on Yield and Yield Components of Wheat and Post-harvest Soil Properties in Tigray, Ethiopia

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Abstract

Biochar is a solid material obtained from the carbonization of any biomass including weeds, crop residues and other wastes of plant origin. A greenhouse pot experiment was conducted on biochar, obtained from carbonization of *Prosopis juliflora*, to evaluate effects on wheat productivity and post-harvest soil properties. This experiment has used four different combinations of biochar and compost besides the chemical fertilizers. Biochar was significantly increased grain and straw yields of wheat by 15.7% and 16.5% respectively, over the NP application (control). Moreover, the root biomass was significantly increased by 20%. This shows that biochar retains nutrients and water to improve wheat productivity. Hence, the biochar produced from *Prosopis juliflora* could be used for wheat productivity improvement.

Keywords: Biochar; Compost; Ethiopia; *Prosopis juliflora*; Tigray; Wheat

Introduction

Prosopis juliflora is an introduced invasive weed to the Afar region, Ethiopia [1]. It is becoming a widespread weed in the region. Currently no effective control measures are in place. It is also a threat to the indigenous biodiversity. Hand weeding is impractical because of its harmful side-effects. Although its biomass is utilized as wood charcoal and sold at different markets, there are no notable efforts to use the *Prosopis juliflora* weed in compost and biochar making. Biochar is a solid material obtained from the carbonization of any biomass including weeds, crop residues and other wastes of plant origin [2,3]. It is also defined as a fine-grained, highly porous charcoal substance that can be used as a soil amendment [4]. Biochar may be added to soils with the intention to improve soil functions and to reduce emissions from biomass that would otherwise naturally degrade to greenhouse gases [5]. Biochar also has appreciable carbon sequestration value [5-7]. Moreover, Lai et al. (2013) [7] reported a 5% application of biochar increase carbon sequestration on rice. These properties are measurable and verifiable in a characterization scheme, or in a carbon emission offset protocol. Biochar enhances soils by converting agricultural waste into a powerful soil enhancer that holds carbon and makes soils more fertile. As a result, it can boost livelihood, discourage deforestation and preserve cropland diversity. Biochar can improve almost any soil [4,8,9]. Areas with low rainfall or nutrient-poor soils will most likely appreciate the largest impact from addition of biochar. Overall, biochar is reviewed to be economically important technology to wards food security improvement [10]. This technology would be suitable to Tigray region where the rainfall is low and nutrients in the soil are poor. Hence, the aim of this experiment is to evaluate the effect biochar made from *Prosopis juliflora* for soil fertility amendment thereby enhances wheat productivity under greenhouse in Tigray region, Ethiopia.

Materials and Methods

Description of the study area

A pilot pot experiment was conducted in greenhouse at Mekelle Agricultural Research Centre, Tigray region, north Ethiopia. It is located at 39° 30'E and 13° 30' N at an altitude of 1970 m.a.s.l. The average annual maximum and minimum temperatures are 26.5°C and 11.9°C with mean annual humidity 51.98%. Moreover, the annual rainfall is 530

mm and the soil type is dominated by clay [11]. The physicochemical property of the experimental soil is presented in Tables 1-3.

Treatments	NP fertilization	Amendment 1	Amendment 2
1	Standard NP		
2	Standard NP	4 t/ha biochar	
3	Standard NP	7 t/ha compost	
4	Standard NP	2 t/ha biochar	3.5 t/ha compost

Table 1: Treatments considered under ton per hectare (t/ha) basis.

Treatments	NP fertilization/pot	Amendment 1/pot	Amendment 2/pot
1	0.5g DAP and 0.5 g urea		
2	0.5g DAP and 0.5 g urea	19.6 g biochar	
3	0.5g DAP and 0.5 g urea	34.3 g compost	
4	0.5g DAP and 0.5 g urea	9.8 g biochar	17.2 g compost

Where; NP stands for the fertilizers of nitrogen and phosphorus.

Table 2: Treatments considered under gram per area of pot basis.

Soil parameters	Values
pH _{water} (1:2.5)	8.07
EC _{water} (1:2.5)	0.16
Organic carbon (%)	1.59
Total N (%)	0.20
P-Olsen (mg kg ⁻¹)	5.5
CEC (meq/100 soil)	27.6
Clay (%)	42
Silt (%)	21
Sand (%)	37

Table 3: Physicochemical properties of experimental soil.

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Biochar production

A biochar produced from *Prosopis juliflora* was collected from existing charcoal markets in Mekelle. This biochar was produced by traditional method of charcoal making. The detail of traditional method of biochar making is found in (Miguel) [12]. The produced biochar was in charcoal form that is similar in size with the particle size of the soil used in this experiment.

Experimental procedure

The plastic pots which represent the treatments were arranged in Randomized Complete Block Design (RCBD) and replicated three times. In each pot 15 wheat seeds were planted that was thinned to ten plants per pot after emergence. 5 plants/pot were sampled for biomass estimation after one month from emergence. The remaining 5 plants were used for grain and straw yield estimation. Urea and DAP (di ammonium phosphate) was applied in charcoal form with surface incorporation at the time of planting. The standard NP (Nitrogen and Phosphorus) used in the greenhouse experiment was 100 kg urea /ha and 100 kg DAP/ha. This was done due to; there was no deficit of water under the greenhouse experiment. Normal growth conditions under greenhouse were ensured and pots were irrigated whenever needed to keep the soil moisture to field capacity. Biochar and compost was applied and watered simultaneously three days before planting. The diameter of the plastic pots applied for this experiment was 25 cm in diameter at top and 30 cm in height. These pots were filled with soil as per the allocation of treatments of the experiment. The treatments applied for this experiment and their rates of application in ton per hectare basis and as if converted in to the size of the plastic pots are mentioned below in Tables 1 and 2 respectively.

Laboratory analysis

Experimental pot soil was taken and analysed for soil texture, organic carbon, total nitrogen, P Olsen, pH, CEC and EC before the trial has been conducted. Post experimental soil which was amended with biochar and compost were also analysed for organic carbon, total nitrogen, total P, pH and EC. These soil parameters were analysed by using standard soil laboratory procedures and equipments [13]. Hence, Soil texture was determined by hydrometer and pH was measured by using a pH meter in a 1:2.5 soil: water ratio. Electrical conductivity (EC) was also measured in water at a soil to water ratio of 1:2.5. The soil organic carbon and total nitrogen (N) was determined by the

Parameters	Biochar	Compost
pH _{water} (1:2.5)	6.8	8.3
EC _{water} (1:2.5)	1.86	0.32
Organic carbon (%)	3.46	2.17
Total N (%)	0.44	0.33
Total P (%)	0.07	0.026

Table 4: Physicochemical properties of Biochar and compost.

Treatments (on ha basis)	pH _{water} (1:2.5)	EC _{water} (1:2.5)	Organic carbon (%)	Total N (%)	P-Olsen (mg kg ⁻¹)	CEC (meq/100 soil)
100 kg urea+100 kg DAP	7.9	0.55	2.0	0.19	15.0	28
100 kg urea+100 kg DAP+4 ton biochar	7.9	0.68	2.0	0.19	15.4	29
100 kg urea+100 kg DAP+7 ton compost	8.0	0.57	2.1	0.19	15.6	28
100 kg urea+100 kg DAP+2 ton biochar+3.5 ton compost	8.0	0.64	2.1	0.21	15.3	28
P-value	0.06	0.37	0.78	0.16	0.89	0.5
LSD	0.11	0.18	0.26	0.02	3.8	1.9
CV	0.7	14.9	6.4	6.0	13.1	3.4

Table 5: Effect of biochar application on postharvest chemical properties of the soil.

Walkley-Black method and the Kjeldahl method respectively. Available phosphorous (P) was determined using Olsen method and the cation exchange capacity was determined at soil pH 7 after displacement by using 1N ammonium acetate method after it has been displaced by sodium by distillation of ammonium.

Statistical analysis

One way analysis of variance (ANOVA) was performed to assess the significance differences among different treatments. Hence, in this experiment the soil parameters, yield and yield components of wheat were analysed using Genstat statistical software [14]. Means separation was also done using least significant difference (LSD) after the treatments were found significant at P<0.05.

Results and Discussion

Physical and chemical properties of experimental soil, biochar and compost

Tables 3 and 4 shows the physical and chemical characteristics of experimental soil, biochar and compost. These data were taken before the experiment was undertaken. This data were used to know the physical and chemical properties of biochar, compost and the experimental soil. The pH of the experimental soil was slightly basic (8.07) and the electrical conductivity was 0.16 dSm⁻¹ with the Cation Exchange Capacity (CEC) of 27 (meq/100 soil). Carbon content was very small with a value of 1.59. Total nitrogen content of the soil was 0.20% and the available phosphorus was found to be 5.5%. The soil is clay dominated with clay (42%), silt (21%) and sand (37%). The pH of the biochar was neutral (6.8) and the electrical conductivity of biochar was 1.86 dSm⁻¹. In addition, the organic carbon of biochar was 3.46%. The total nitrogen of biochar is 0.44% with total phosphorus 0.07%. However, the physiochemical properties of compost was expressed by pH value 8.3 which was slightly basic with EC 0.32%. The content of carbon, total nitrogen, and total phosphorus was 2.17%, 0.33% and 0.026% respectively.

Effect of biochar application on postharvest chemical properties of soil

The result of this experiment reveals that there was no significant difference (p<0.05) among the treatments across all physical and chemical soil parameters measured (Table 5). The reason for this could be due to the quality of biochar used for the greenhouse pot experiment. Since, it was not prepared through proper pyrolysis process under high temperature.

Effect of biochar application on plant height, spike length and numbers of total tillers of wheat

As revealed in Table 6, the yield components of wheat parameters such as plant height, spike length and total number of tillers per 15 plants shows statistically non-significant(p<0.05). But, the treatment

Treatments (on ha basis)	Plant height at maturity (cm)	Spike length at maturity (cm)	Total number of tillers per 15 plants
100 kg urea+100 kg DAP	64.53	10.07	27.7
100 kg urea+100 kg DAP+4 ton biochar	66.8	10.30	36.7
100 kg urea+100 kg DAP+7 ton compost	69.02	10.17	30.0
100 kg urea+100 kg DAP+2 ton biochar+3.5 ton compost	67.27	10.13	31.7
P-value	0.089	0.848	0.416
LSD	3.4	0.659	12.54
CV	2.5	3.2	19.9

Table 6: Effect of biochar application on plant height, spike length and numbers of total tillers of wheat.

Treatments (on ha basis)	Grain yield (g/15 plants)	Straw yield (g/15 plants)	Root yield (g/15 plants)	100 seed weight (g)
100 kg urea+100 kg DAP	20.97	30.30	5.07	6.43
100 kg urea+100 kg DAP+4 ton biochar	24.87	36.30	6.07	6.83
100 kg urea+100 kg DAP+7 ton compost	20.70	28.03	4.69	6.47
100 kg urea+100 kg DAP+2 ton biochar+3.5 ton compost	20.40	27.53	5.05	6.37
P-value	0.003	0.046	0.027	0.33
LSD	1.8	6.26	0.813	0.6
CV	4.2	10.3	7.8	4.7

Table 7: Effect of biochar on grain, straw and root yields and 100 seed weight of wheat.

(100 kg urea+100 kg DAP+7 ton compost) shows relatively higher in average. The spike length and total number of tillers per 15 plants were observed higher in (100 kg urea+100 kg DAP+4 ton biochar) which contains biochar as an amendment for soil. Therefore, even if statistically non-significant ($p < 0.05$) the treatment which used biochar as an amendment of soils shows definite increment over the other treatments. This non-significance is due to the treatments set up in this experiment as there were non-fertilized with no biochar plot for comparison. Carter et al. [15] indicated that a total increments were stated in biomass, root biomass, plant height and number of leaves in all the cropping cycles in comparison to no biochar treatments for lettuce and cabbage.

Effect of biochar application on grain, straw and root yields and 100 seed weight of wheat

The most important thing observed in this trial is that the grain, straw and root yields shows significant difference ($p < 0.05$) as explained in Table 7. The treatment which contains biochar as a soil amendment beats the other treatments which show higher values. So, grain and straw yields of wheat in the biochar treatment (100 kg urea+100 kg DAP+4 ton biochar/ha) were significantly increased by 15.7% and 16.5%, respectively over the NP applications alone. This is in-line with [15,16] as crop productivity was increased by an average of 10%. Similarly, the root biomass was significantly increased by 20% over the control. Similar results were also found in (Abebe et al.) [9]. This shows that biochar retain nutrients and water to improve wheat productivity. However, the biochar treatment had no significant effect on 100 seed weight of wheat.

Conclusions

The results of this experiment revealed that biochar amended soils increases grain and straw yield and root biomass of wheat significantly. Hence, the presence of plant nutrients and charcoal in the biochar could have increased wheat production at biochar treated soils. Therefore, application of biochar is authoritative in order to increase soil fertility status, water retention and wheat productivity. Hence, we recommend field experiments on the use of the *Prosopis juliflora* for soil fertility amendments through biochar making. However, proper application of pyrolysis equipment should be used for optimum biochar production and effective soil fertility amendments.

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