

Original Research Article

Effect of Invasive Weed Biochar Mixed With Inorganic Fertilizer on Soil Physical and Chemical Properties in Semi-Arid Region of India

ABSTRACT

The application of different forms of organic material is a traditional strategy used to sustain soil fertility by replenishing soil organic matter (SOM) and enhancing nutrient profile for crops. This study focuses on the comparative efficacy of biochar prepared from locally available invasive weed biomass (*Parthenium hysterophorus* L. and *Lantana camara* L.) with or without inorganic fertilization on soil properties and nutrient availability in post harvested soils. Results revealed that soil bulk density (BD) and particle density (PD) were significantly decreased with application of biochar @ 5 t ha⁻¹ and 10 t ha⁻¹ along with 75% RDF (Recommended dose of fertilizers) as compared to control while water holding capacity (WHC) significantly increased in the range of 18.40-32.78% as compared to RDF by the application of *Parthenium hysterophorus* L. and *Lantana camara* L. biochar @ 2.5t ha⁻¹, 5.0 t ha⁻¹ and 10.0 t ha⁻¹ along with 75% RDF. It was also observed that *Parthenium hysterophorus* L. and *Lantana camara* L. biochar along with 75% RDF addition to soil increased SOC (5.17 g kg⁻¹ to 7.99 g kg⁻¹) and cation exchange capacity (CEC) by 3.36-37.14% as compared with control, depending on the quantity of biochar application. Similar trends were also reported in case of available macro and micro nutrients in the post harvest soil. Therefore, application of invasive weed biochar with inorganic fertilization is considered as promising strategy for improve physical and chemical properties of soils and soil health in semi-arid ecosystem.

Keywords: Biochar; inorganic fertilization; available nutrients; micronutrients; semi-arid region.

1. INTRODUCTION

Application of biochar in agricultural soils is one promising strategy that can enhanced carbon sequestration in the soil, improve soil physico-chemical properties and soil

quality [1]. Biochar is a porous, low-density, carbon-rich material prepared by the pyrolysis of vegetative biomass in an oxygen-limited or absent environment [2], having potential option to be used for enhancement of soil health and soil organic carbon(SOC) stock [3]. Due to the presence of condensed aromatic structure which make its stable form of carbon resistant against decomposition and store carbon in soils for long time. Application of biochar influences water holding capacity and soil bulk density [4]. Biochar is also effective in improving the microbial population in a degraded land [5] and improving the nutrient content of the soil [6]. The benefits of biochar application on SOC build-up, soil properties and crop yields in different studies varied greatly with the composition of biochars, soil types and environmental conditions. Looking at the beneficial effect of biochar application on soil quality and crop productivity, there is a need to evaluate the appropriateness of locally available biomass materials, which is not economically important for preparation of biochar. *Parthenium hysterophorus* L. and *Lantana camara* L. are harmful and hazardous invasive weeds in the world [7,8]. Direct addition of residues of these weeds to soil may show allelopathic effects, affecting adversely the germination and growth of crops [9]. Utilization of these weed biomass materials as valuable resource is a big challenge before the environmentalists, agriculturists and ecologists. Thus, using them as feedstock for preparing biochar would be an effective weed management approach. Research work on preparation of biochar from different perennial weed biomass and its characterizations and benefits of its application to fodder crops and soil health indicators are limited. Keeping these points in view, the present study was undertaken to find out the comparative efficacy of biochar prepared from locally available weed biomass (*Parthenium hysterophorus* L. and *Lantana camara* L.) with or without inorganic fertilization on soil properties and nutrient availability. The overall objective of this study was to sustainable use of locally available

weed biomass, as useful amendment material for improving soil quality and crop productivity in semi-arid regions.

2. MATERIAL AND METHODS

Weed biomass of *Parthenium hysterophorus* L. and *Lantana camara* L. were collected from Central Research Farm, ICAR-Indian Grassland and Fodder Research Institute, Jhansi- 248 003 (U.P.), India. The biomass of both weeds was cut into small pieces (30-50 mm) and used for preparation of biochar. All biomass was heated at a temperature of ~ 400 °C for 2 hours in a cylindrical low cost portable biochar kiln, using the methodology as described by [10]. After cooling, the biochar was crush manually and ground to pass through a 2 mm sieve in order to have the uniform particle size as that of the soil. A pot experiment was conducted during two consecutive *rabi* season of 2020-21 and 2021-22 in net house at technology demonstration block (TD Block), ICAR- Indian Grassland and Fodder Research Institute (ICAR-IGFRI), Jhansi (U.P.) using oat (*Avena sativa* L.) as test crop in completely randomized design (CRD) with ten treatments and replicated trice. The site is situated in a semi-arid region that located at (25° 27' of Northern latitude, 78° 35' of Eastern longitude) in the Bundelkhand region of Uttar Pradesh, India which covered about 7.16 million ha area [11, 12]. The average precipitation of this region is 887.4 mm. The long-term average maximum and minimum temperatures were 32.95°C and 19.08°C, respectively. The soil for the pot experiment was collected from Institute's TD block field. The soil used in the pot experiment was sandy clay loam (sand:50%; silt:22% and clay: 28%), with a pH 7.3, electrical conductivity 0.026 dSm⁻¹, available N, P, K and S were 201, 6, 226, and 13 kg ha⁻¹, respectively and 26% water holding capacity. The sieved biochar were applied before 15 days of oat (variety: JHO-822) sowing and mixed with the soil as per treatments.

The treatments were T₁: Control, T₂: Recommended dose of fertilizers (RDF 80 kg N+40 kg P+ 40 kg K ha⁻¹), T₃: 75% RDF+ 2.5 t ha⁻¹ *Parthenium hysterophorus* biochar, T₄: 75% RDF+ 5.0 t ha⁻¹ *Parthenium hysterophorus* biochar, T₅: 75% RDF+ 10.0 t ha⁻¹ *Parthenium hysterophorus* biochar, T₆: 75% RDF+ 2.5 t ha⁻¹ *Lantana camera* biochar, T₇: 75% RDF+ 5.0 t ha⁻¹ *Lantana camera* biochar, T₈: 75% RDF+ 10.0 t ha⁻¹ *Lantana camera* biochar, T₉: 10.0 t ha⁻¹ *Parthenium hysterophorus* biochar and T₁₀: 10.0 t ha⁻¹ *Lantana camera* biochar. Soil sampling was carried out in March, 2021 and 2022 after harvest of oat crop for fodder (at 50% flowering). Different observations on soil physical and chemical properties were taken in post harvest soils. The soil bulk density (BD), particle density (PD) (pycnometer bottle) and WHC (Keen-Rackzowski box) were determined using in laboratory in disturbed soil sample [13]. Soil chemical properties like pH and EC (electrical conductivity)[14]soil organic carbon (SOC) [15], available macro nutrients; Nitrogen (N, alkaline permanganate method), phosphorous (P, Olsen's method), potassium (K, Flame photometer method), sulphur (S), DTPA extractable micro nutrients; zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) were determined using standard procedures given by [16]. The data of the both year were pooled together. Statistical analysis of all the experimental data was performed by the analysis of variance (ANOVA) and the significance of treatment differences were tested by Duncan's Multiple Range Test (at p=0.05) using SAS v9.3 [17].

3. RESULTS AND DISCUSSION

3.1 Soil physical properties

The results revealed that soil BD and PD decreased with the application of biochar @ 5.0 t ha⁻¹ and 10.0 t ha⁻¹ along with 75% RDF. Lower dose of biochar (2.5 t ha⁻¹ with 75% RDF) have no significant effect on BD and PD (Table1).

Table 1. Effect of different levels of biochars along with inorganic fertilizer on soil bulk density (BD), particle density (PD) and water holding capacity (WHC)

Treatments	BD (Mg m ⁻³)	(Mg m ⁻³)	WHC (%)
T ₁	7.37 ^e	0.030 ^d	5.17 ^e
T ₂	7.48 ^{de}	0.055 ^c	6.48 ^{cd}
T ₃	8.01 ^{abc}	0.065 ^{bc}	6.51 ^{cd}
T ₄	8.02 ^{abc}	0.067 ^{bc}	7.33 ^{abcd}
T ₅	8.17 ^{ab}	0.081 ^{ab}	7.85 ^{ab}
T ₆	8.04 ^{ab}	0.066 ^{bc}	6.85 ^{bcd}
T ₇	8.03 ^{abc}	0.074 ^{abc}	7.56 ^{abc}
T ₈	8.21 ^a	0.090 ^a	7.99 ^a
T ₉	7.67 ^{cde}	0.056 ^c	6.21 ^{de}
T ₁₀	7.81 ^{bcd}	0.063 ^{bc}	6.23 ^{de}
S.Em ±	0.13	0.007	0.38
C.D. (0.05)	0.37	0.021	1.13

Values in each column followed by different lowercase letters are significant according to Duncan's Multiple Range Test at p=0.05.

T₁: Control, T₂: Recommended dose of fertilizers (RDF i.e. 80:40:40 N, P and K kg ha⁻¹, respectively), T₃: 75% RDF+ 2.5 t ha⁻¹ *Parthenium hysterophorus* biochar, T₄: 75% RDF+ 5.0 t ha⁻¹ *Parthenium hysterophorus* biochar, T₅: 75% RDF+ 10.0 t ha⁻¹ *Parthenium hysterophorus* biochar, T₆: 75% RDF+ 2.5 t ha⁻¹ *Lantana camera* biochar, T₇: 75% RDF+ 5.0 t ha⁻¹ *Lantana camera* biochar, T₈: 75% RDF+ 10.0 t ha⁻¹ *Lantana camera* biochar, T₉: 10.0 t ha⁻¹ *Parthenium hysterophorus* biochar and T₁₀: 10.0 t ha⁻¹ *Lantana camera* biochar

The soil BD and PD were decreased 9.65% and 10.08%, respectively in T₈ followed by T₅ and T₇ treatment as compared to T₁ treatment. Soil BD and PD observed in both biochar treatments along with 75% RDF were almost statistically at par with similar application rates. The significant decreased in BD and PD with the application of biochar might be caused by physical dilution effects and increased total carbon content in soils. Blanco-Canqui [18] also reported similar findings that changes in BD and PD after biochar application, which is directly influence soil porosity. The WHC increased in the range of 18.40-32.78%, with the highest increased being observed in T₅ (32.78%) and T₈ (31.77%) treatments as compared to T₂ by the application of biochars @ 2.5 t ha⁻¹, 5.0 t ha⁻¹ and 10.0 t ha⁻¹ along with 75% RDF. Das and Ghosh [19] also reported that application of maize stalk biochar @ 5 t ha⁻¹, 7.5 t ha⁻¹ and 10.0 t ha⁻¹ significantly increased (11.37 to 19.8 g cm⁻³) the WHC of sandy loam.

3.2 Soil Chemical properties

The results showed that biochar application significantly increased in soil pH and EC (Table 2). The highest increase in soil pH was recorded in T₈ treatment (8.20) followed by T₅ treatment (8.17). Similar trend was also observed in case of EC. *Lantana camera* biochar addition recorded higher pH and EC over *Parthenium hysterophorus* biochar. The increased in soil EC and pH with biochar applications could be due to the presence of salts in biochar and its alkaline nature, respectively. Similar results were also reported by [20] in green house pot experiment on sandy soil. There was a significant increase on SOC in T₈ (7.99 g kg⁻¹) and T₅ (7.85 g kg⁻¹) treatments followed by T₇ (7.56 g kg⁻¹) and T₄ (7.33 g kg⁻¹) treatments. Primary reason for these observations could be due to presence of stable carbon in the biochar that is difficult to decompose in soil environments, thus contributing to the soil carbon pool [21]. Almost similar results were also observed in case of CEC. CEC were significantly increased (3.36-37.14%) following the amendment of both biochars compared to control.

Table 2. Effect of different levels of biochars along with inorganic fertilizer on soil reaction, electrical conductivity, organic carbon, cation exchange capacity and macro nutrient availability

Treatments	pH	EC (dSm-1)	OC (g kg ⁻¹)	CEC (cmol (p+) kg ⁻¹)	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)	Available S (kg ha ⁻¹)	DTPA extractable micronutrients			
									Fe (mg kg ⁻¹)	Cu (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Mn (mg kg ⁻¹)
T ₁	7.37 ^e	0.030 ^d	5.17 ^e	18.44 ^e	206.67 ^d	6.86 ^c	227.56 ^c	14.95 ^b	6.08 ^d	1.98 ^a	0.86 ^d	13.99 ^d
T ₂	7.48 ^{de}	0.055 ^c	6.48 ^{cd}	20.65 ^d	215.47 ^{cd}	10.33 ^{ab}	234.25 ^c	16.95 ^b	8.10 ^{bc}	2.12 ^a	1.48 ^{bc}	15.64 ^{cd}
T ₃	8.01 ^{abc}	0.065 ^{bc}	6.51 ^{cd}	20.87 ^d	225.10 ^{bcd}	10.52 ^{ab}	240.14 ^{bc}	18.88 ^b	8.13 ^{bc}	2.21 ^a	1.49 ^{bc}	15.75 ^c
T ₄	8.02 ^{abc}	0.067 ^{bc}	7.33 ^{abcd}	23.19 ^{bc}	228.63 ^{bc}	10.95 ^{ab}	290.57 ^{ab}	20.57 ^{ab}	8.36 ^{ab}	2.24 ^a	1.64 ^{ab}	17.48 ^b
T ₅	8.17 ^{ab}	0.081 ^{ab}	7.85 ^{ab}	25.00 ^{ab}	244.77 ^{ab}	12.00 ^a	294.78 ^a	28.84 ^a	8.89 ^{ab}	2.28 ^a	2.06 ^a	22.48 ^a
T ₆	8.04 ^{ab}	0.066 ^{bc}	6.85 ^{bcd}	22.97 ^c	225.27 ^{bcd}	10.58 ^{ab}	247.54 ^{abc}	18.94 ^b	8.18 ^{bc}	2.17 ^a	1.59 ^{ab}	16.34 ^{bc}
T ₇	8.03 ^{abc}	0.074 ^{abc}	7.56 ^{abc}	23.26 ^{bc}	229.63 ^{bc}	11.89 ^a	291.89 ^{ab}	23.20 ^{ab}	8.43 ^{ab}	2.24 ^a	1.65 ^{ab}	17.76 ^b
T ₈	8.21 ^a	0.090 ^a	7.99 ^a	25.29 ^a	253.23 ^a	12.16 ^a	297.24 ^a	29.12 ^a	9.31 ^a	2.30 ^a	2.06 ^a	22.48 ^a
T ₉	7.67 ^{cde}	0.056 ^c	6.21 ^{de}	19.06 ^{de}	212.93 ^{cd}	8.39 ^{bc}	232.37 ^c	15.95 ^b	7.31 ^c	2.10 ^a	1.00 ^{cd}	15.10 ^{cd}
T ₁₀	7.81 ^{bcd}	0.063 ^{bc}	6.23 ^{de}	19.13 ^{de}	223.67 ^{bcd}	9.50 ^{abc}	234.20 ^c	16.92 ^b	8.05 ^{bc}	2.12 ^a	1.46 ^{bc}	15.72 ^{cd}
S.Em ±	0.13	0.007	0.38	0.64	21.83	1.05	18.50	3.19	0.34	0.06	0.12	0.56
C.D. (0.05)	0.37	0.021	1.13	1.91	7.35	3.12	54.97	9.46	1.02	NS	0.36	1.68

Values in each column followed by different lowercase letters are significant according to Duncan's Multiple Range Test at p=0.05.

The available soil N, P, K and micronutrients (Fe, Cu, Zn and Mn) significantly influenced due to application of different types and quantity of biochar along with 75% RDF. Among the different treatments, T₈ resulted 22.52% higher available N followed by T₇ treatment as compared to T₁. The increase in available N under biochar treatment was mainly due to the enhanced the soil moisture retention and root growth and release of nitrogen from the biochar as it contains significant amount of nitrogen in its composition and biochar acts as binder for ammonia in soil [22]. The application of *Parthenium hysterophorus* and *Lantana camera* biochar @ 2.5 t ha⁻¹, 5.0 t ha⁻¹ and 10.0 t ha⁻¹ along with 75% RDF not significantly influenced P availability in the soil. The higher available P was found in T₈ (12.16 kg ha⁻¹) treatment followed by T₅ (12.00 kg ha⁻¹), which was at par with T₇, T₄, T₃ and T₂ but significantly higher than T₁ treatment. It was observed that *Parthenium hysterophorus* and *Lantana camera* biochar addition @ 2.5 t ha⁻¹, 5.0 t ha⁻¹ and 10.0 t ha⁻¹ to soil increased the available K by 2.11 to 32.62% as compared with T₁ depending on the quantity of biochar application. Biochar had significant amount of available K due to presence of the ash. Hence, application of biochar might have significant positive effect on available K in soil [23]. The higher available S was found in T₈ (29.12 kg ha⁻¹) treatment followed by T₅ (28.84 kg ha⁻¹), which was at par with T₇ and T₄. Application of *Parthenium hysterophorus* and *Lantana camera* biochar @ 10.0 t ha⁻¹ along with 75% RDF increased available S by 71.80% and 70.14% as compared to T₂ treatment. Khan *et al.* [24] also reported similar findings that application of cow dung and sewage sludge biochar @ 5.0 t ha⁻¹ increased available S content 85.36 to 99.64 ppm and 83.36 to 97.65 ppm, respectively in loamy soil. Application of *Parthenium hysterophorus* and *Lantana camera* biochar @ 2.5 t ha⁻¹, 5.0 t ha⁻¹ and 10.0 t ha⁻¹ along with 75% RDF, significantly increased availability of micronutrients in post harvest soil over T₁ and T₂ while Cu availability was not influenced by the types and quantity of biochar. Application of *Parthenium hysterophorus* and *Lantana camera* biochar @ 10.0 t ha⁻¹

along with 75% RDF increased availability of Fe, Zn and Mn by ~47% , ~139% , ~61% respectively as compared to T₁ treatment. The application of *Lantana camera* biochar showed higher micronutrient availability in soil at similar application quantity. Similar finding were also reported by [25].

4. CONCLUSIONS

From this study it may be summarized that application of invasive weed biochar along with inorganic fertilizer showed the positive effect towards the physical and chemical soil health indicators. Application of *Parthenium hysterophorus* and *Lantana camera* biochar (@ 2.5 t ha⁻¹ to 10.0 t ha⁻¹) along with 75% RDF had significant positive effect on soil bulk density, particle density, water holding capacity, soil organic carbon, cation exchange capacity and increase the availability of macro and micro nutrient in post harvest soil. At the same time it could help in reducing chemical fertilizer requirement to some extent. In general, *Lantana camera* biochar was superior over *Parthenium hysterophorus* biochar. Utilization of these weed biomass materials for preparation of biochar would be a good weed management strategy besides improvement in soil health indicators.

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