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Effect of rice husk biochar in physicochemical properties of laterite soil in Bajra Napier hybrid

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Abstract

This study investigates the efficacy of rice husk biochar as a soil amendment to enhance the physicochemical properties of laterite soil, with implications for sustainable fodder production. A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani, Kerala, from September 2024 to July 2025. The experiment was laid out in Randomized Block Design (RBD) with seven treatments and three replications. The treatments were, T₁- Biochar at 2.5 t ha⁻¹+ RDN+ ½ FYM, T₂- Biochar at 5 t ha⁻¹+RDN+ ½ FYM, T₃- Biochar at 7.5 t ha⁻¹+RDN+ ½ FYM, T₄- Biochar at 10 t ha⁻¹+ RDN+ ½ FYM, T₅-RDN (KAU POP), T₆- ½ FYM alone and T₇- Absolute control. Results demonstrated that biochar application significantly improved key soil parameters. The treatment with 10 t ha⁻¹ biochar (T₄) yielded the highest water holding capacity (46.33%) and increased soil pH from 5.53 to 6.95, mitigating soil acidity. Soil available potassium (100.72 kg ha⁻¹) was higher with 7.5 t ha⁻¹ biochar treatment (T₃), attributed to enhanced nutrient retention. However, bulk density and electrical conductivity were not significantly affected. The findings concluded that the integrated application of rice husk biochar at 7.5-10 t ha⁻¹ with organic and inorganic fertilizers is a promising strategy for ameliorating acidic laterite soils by improving water retention, reducing acidity, and boosting nutrient availability, thereby supporting sustainable agricultural productivity.

Keywords: Biochar, laterite soil, soil amendment, water holding capacity, soil pH, nutrient availability

1. Introduction

India is the world's largest milk producing country in the world contributing 209.96 million tonnes of milk in the year 2020 - 2021. Livestock being a key source of supplementary income contribute to 4.90 per cent to India's total Gross Value Added (GVA) and plays a crucial role in rural economy (DAHD, 2022) [3]. Despite an increase in cattle production, milk productivity remains low. Hence, ensuring an adequate supply of quality feed and fodder is one of the important challenges faced by Indian farmers. Fertile soil ensures quality fodder production. Soil fertility and pH are critical factors which govern a fodder crop's ability to absorb nutrients, and in turn determines key quality metrics like protein, fibre, and overall digestibility (Reddy *et al.*, 2023) [11]. The use of inorganic fertilizers is linked to several adverse environmental effects, such as soil degradation, eutrophication, reduced population of soil microbes and rise in plant diseases (Khushali *et al.*, 2015) [6]. Combined application of reduced chemical fertilizers with organic amendments like biochar and farm yard manure (FYM) significantly enhanced fodder yield, nutrient use efficiency, and profitability compared to 100 per cent chemical fertilization (Kumar *et al.*, 2023) [7]. Biochar, a carbon-rich product derived from biomass pyrolysis, represents a promising organic soil amendment with multiple benefits for sustainable agriculture (Pillai *et al.*, 2022) [9].

Biochar application as a soil amendment shows promising results for improving fodder crop productivity and soil health. It modifies soil properties and impacts crop productivity. Biochar reduces soil bulk density, increases water holding capacity, soil porosity, infiltration rate, microbial activity, soil nutrient retention and pH levels, though effects vary with soil texture (Murtaza *et al.*, 2021) [8]. Biochar properties like high surface area, cation exchange capacity, and nutrient content enhance soil fertility in acidic soils compared to alkaline soils (Premalatha *et al.*, 2023) [10].

In laterite soils, biochar application is more effective than farmyard manure

2. Materials and Methods

2.1 Description of Study Area

The research was conducted in Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during the period from September 2024 to May 2025. The field is located at latitude 8.5 ° 25' 46'' North and longitude 76.9 ° 59' 24'' East and 30 m above MSL altitude. The mean maximum temperature ranged between 29.84 °C and 33.67 °C and mean minimum temperature ranged between 19.81 °C and 24.17 °C. The relative humidity ranged from 65.57 to 95.86 per cent. The mean bright sunshine hours recorded was 5.60. A total rainfall of 1662.9 mm was received during the experimental period.

(FYM) in mitigating carbon dioxide (CO₂) emissions and promoting nitrogen mineralization. This is evidenced by higher concentrations of ammonium-nitrogen (NH₄-N) and nitrate-nitrogen (NO₃-N) in biochar-treated soils, particularly in the later phases of incubation (Jabin *et al.*, 2020) ^[5].

2.2 Treatments, design and experimental procedure

The experiment was laid out in RBD design with seven treatments and three replications. The treatments were, T₁- Biochar at 2.5 t ha⁻¹+ RDN+ ½ FYM, T₂- Biochar at 5 t ha⁻¹+RDN+ ½ FYM, T₃- Biochar at 7.5 t ha⁻¹+RDN+ ½ FYM, T₄- Biochar at 10 t ha⁻¹+ RDN+ ½ FYM, T₅- RDN (KAU POP), T₆- ½ FYM (12.5 t ha⁻¹) alone and T₇- Absolute control. The recommended dose of nutrients was NPK @ 200:50:50 kg ha⁻¹. The variety Suguna released by Kerala Agricultural University was used for the research work. The spacing followed was 60 cm × 60 cm. The first harvest was taken at 75 DAP and subsequent harvests were done at an interval of 45 days

Table 1: Initial soil parameters before the experiment

Parmeter	Unit	Values
Bulk density	Mg m-3	1.35
Water holding capacity	%	22
pH	-	5.53
Electrical conductivity	dS m-1	0.091
Available N	Kg ha ⁻¹	551
Available P	Kg ha ⁻¹	30.24
Available K	Kg ha ⁻¹	207.08

Table 2: Physical and chemical characters of rice husk biochar

Parameter	Unit	Value
Bulk density	Mg m-3	0.34
Water holding capacity	%	277.33
pH	-	7.16
Electrical Conductivity	-	3.2
Total N	%	1.16
Total p2O5	%	1.3
Total K2O	%	0.96

3. Results and Discussion

Biochar application had significantly resulted in improved soil physical and chemical properties. Soil bulk density did not show any significant change on biochar addition as in table 3. On the other hand, water holding capacity exhibited significant effect on different rates of biochar. The treatment, T₄(biochar at 10 t ha⁻¹+½ FYM+ RDN) resulted in the highest water holding capacity of 46.33 per cent among other treatments. The lowest water holding capacity of 24 per cent was exhibited by the treatment T₇ (Absolute control).

By increasing soil porosity and specific surface area, biochar application diminishes barriers to water permeability, enhances the soil water-holding capacity (WHC), which led to improved water retention and promoted soil aggregate formation (Abukari *et al.*, 2022) ^[1]. The result is in agreement with Vikram *et al.* (2022) ^[13] establishing a higher water holding capacity by biochar addition in sandy soils.

Table 3: Effect of biochar in BD, WHC in soil after the experiment

Treatments	BD (Mg m-3)	WHC (%)
T ₁ : T ₁ - biochar at 2.5 t ha ⁻¹ + ½ FYM+ RDF	1.26±0.03	34.00±2.29c
T ₂ - biochar at 5 t ha- 1+½ FYM+ RDF	1.23±0.04	36.83±1.60c
T ₃ -biochar at 7.5 t ha- 1+½ FYM+ RDF	1.20±0.02	42.16±1.75b
T ₄ - biochar at 10 t ha- 1+½ FYM+ RDF	1.81±0.01	46.33±1.52a
T ₅ -RDF alone	1.25±0.04	28.66±1.60d
T ₆ -½ FYM alone	1.41±0.42	29.66±1.52d
T ₇ - Absolute control	1.32±0.02	24.00±2.00e
SE(m) ±	0.097	1.105
C D(0.05)	NS	3.405

Soil pH was significantly increased with increased dose of biochar addition owing to the alkaline pH of biochar. The treatment, T₄ (Biochar at 10 t ha⁻¹+½ FYM+ RDN) resulted in higher soil pH which was on par with the treatment T₃ (Biochar at 7.5 observed in absolute control (5.22) exhibiting high acidity as in table 4.

The increased pH of biochar can be due to release of acidic compounds and the polymerization or condensation of aliphatic t ha⁻¹+½ FYM+ RDF). The lowest pH was substances (Sohi *et al.*, 2009) ^[12] Similar results were observed by Banu *et al.* (2023) ^[2]. Electrical Conductivity (EC) did not exhibit any significant increase by biochar addition.

Table 4: Effect of biochar in pH, and EC in soil after the experiment

Treatments	pH	EC (dS m-1)
T ₁ : T ₁ - biochar at 2.5 t ha ⁻¹ + ½ FYM+ RDF	6.15±0.65b	0.114±0.014
T ₂ - biochar at 5 t ha- 1+½ FYM+ RDF	6.61±0.34ab	0.120±0.020
T ₃ -biochar at 7.5 t ha- 1+½ FYM+ RDF	6.86±0.43a	0.130±0.010
T ₄ - biochar at 10 t ha- 1+½ FYM+ RDF	6.95±0.44a	0.127±0.012
T ₅ -RDF alone	5.42±0.19c	0.100±0.01
T ₆ - ½ FYM alone	6.18±0.35b	0.094±0.015
T ₇ - Absolute control	5.22±0.18c	0.100±0.010
SE(m) ±	0.186	0.008
C D(0.05)	0.574	NS

Table 5: Effect of biochar in Soil N, P and K after the experiment (Kg ha⁻¹)

Treatments	N (Kg ha ⁻¹)	P (Kg ha ⁻¹)	K (Kg ha ⁻¹)
T ₁ : T ₁ - biochar at 2.5 t ha ⁻¹ + ½ FYM+ RDF	230.98±20.08	12.10±1.58	78.21±13.25bc
T ₂ - biochar at 5 t ha- 1+½ FYM+ RDF	237.42±25.13	13.43±4.70	91.47±6.82ab
T ₃ -biochar at 7.5 t ha- 1+½ FYM+ RDF	255.72±37.23	13.20±3.10	100.72±4.28a
T ₄ - biochar at 10 t ha- 1+½ FYM+ RDF	225.73±23.90	11.90±1.64	80.77±3.43bc
T ₅ -RDF alone	232.45±44.45	8.65±1.19	79.29±8.21bc
T ₆ - ½ FYM alone	215.84±37.90	10.24±2.66	75.46±5.09cd
T ₇ - Absolute control	186.63±16.29	7.46±0.66	61.52±8.35d
SE(m) ±	19.243	1.355	4.776
C D(0.05)	NS	NS	14.716

Soil nutrients were significantly influenced by varying rates of biochar. Soil nitrogen and phosphorous did not exhibited any significant effect on biochar addition.

Soil potassium had exhibited significant influence on different doses of biochar. Soil available potassium of 100.72 kg ha⁻¹ was the highest in the treatment T₃(Biochar at 7.5 t ha⁻¹+½ FYM+ RDF) and the lowest was in the absolute control kg ha⁻¹). Biochar promotes potassium availability by altering clay mineral composition and enhancing potassium-dissolving activity of bacteria (Zhang *et al.*, 2020) ^[14]. This was in agreement with Gandahi, *et al.* (2015) ^[4], who observed a significant change in soil potassium in fodder maize.

4. Conclusion

With respect to soil characters, it can be concluded that application of rice husk biochar at rates 7.5 to 10 t ha⁻¹ in combination with RDN, and FYM resulted in better soil physico-chemical properties.

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