IMPACT OF BIOCHAR ON WATER QUALITY IN COTTON PRODUCTION SYSTEM IN THE MISSISSIPPI DELTA

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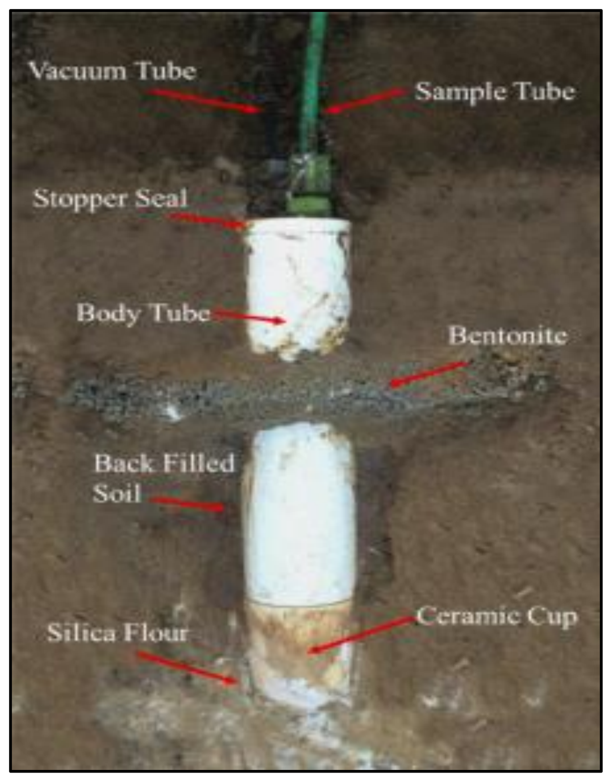
INTRODUCTION

- Mississippi Delta has about **1.6 million acres** under intensive tillage[(1)].
- Conventional tillage practices compact, destroy soil structure, reduce soil organic matter reserves, and consequently increase nutrient losses to the groundwater[(2)].
- Nitrogen (N) is lost from soil through nitrate leaching and cause surface and sub-surface water contamination[(3)].
- Soil amendments such as biochar have a potential to reduce the nutrient losses[(3)].
- Biochar is made using a pyrolysis process which involves thermal degradation of the organic waste biomass in the absence of oxygen.

OBJECTIVE

- To evaluate the effects of sugarcane biochar on nutrient leaching in dryland cotton production systems on a Sharkey clay soil in the Mississippi Delta.



Picture 1. Suction cup lysimeter installed in the field[(4)].

Picture 2. Collection of soil solution samples from research field.

MATERIALS AND METHODS

- The research was conducted at the USDA-ARS crop production system Research Unit's farm (33º44′ N, 90.88′ W) in Stoneville, MS.
- Experiment was set up as a completely randomized design with four replications.
- Sugarcane biochar was applied before planting cotton at rates of **0, 10, 20, and 40 Mg ha^{-1}**.
- Suction cup lysimeters installed at **46 and 81 cm** depth, were used to collect soil solution samples (Pictures 1 and 2).
- Soil solution samples were collected after every significant precipitation event (>12.7 mm). A total of **42 events** of soil solution were collected in this study **(Dec 2019 – May 2022).**
- Fallow season had **28 soil solution** collection events and **14 soil solution** events were from the cotton growing season.
- The collected soil solution samples were analyzed for pH using Fisherbrand pH Combination Electrodes (Chelmsford, MA), electrical conductivity (EC) using Fisherbrand Four Cell conductivity probe (Chelmsford, MA), anions [Chloride (Cl^-), Nitrite-N (NO_2-N), Bromide (Br^-), Nitrate-N (NO_3-N), Phosphate-P (PO_4-P), and Sulphate-S (SO_4-S)] using the Dionex Integrion High Pressure Ion Chromatograph (Sunnyvale, CA), cations [calcium (Ca^{2+}), sodium (Na^+), iron (Fe^+), magnesium (Mg^{2+}) and potassium (K^+), using atomic absorption spectrometry (AAS)] and ammonia (NH_4-N) using Lachat 8400 series II ion analyzer (Hach Corp., Loveland, CO).
- The soil solution data were analyzed separately for each season (fallow & cotton) using GLIMMIX procedure in SAS software (9.4v) (Table 1).

Table 1. P-values associated with sources of variation for soil solution pH, EC, Cl^-, NO_2-N, Br^-, NO_3-N, PO_4-P, SO_4-S, NH_4-N, Ca^{2+}, Na^+, Fe^{2+}, Mg^{2+}, and K^+ for fallow and cotton season. P-values showing significant differences have been underlined and where interaction is significant, only interaction p-values have been underlined.

Source	df	pH	EC	Cl^-	NO_2-N	Br^-	NO_3-N	PO_4-P	SO_4-S	NH_4-N	Ca^{2+}	Na^+	Fe^{2+}	Mg^{2+}	K^+
Fallow season															
Biochar rates (BR)	3	0.381	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.109	<0.001	0.838	0.304	0.070	0.091
Depth	1	0.026	<0.001	0.013	0.637	0.112	0.624	0.065	0.951	0.004	0.428	0.001	0.203	0.587	0.030
BR × Depth	3	0.191	<0.001	0.042	0.114	0.052	0.045	0.150	<0.001	0.068	0.140	<0.001	0.168	0.143	0.151
Cotton season															
Biochar rates (BR)	3	0.193	0.460	0.289	0.786	0.083	0.142	0.449	0.005	0.137	0.565	0.699	0.392	0.106	0.091
Depth	1	0.002	0.023	0.746	0.454	0.756	0.583	0.076	0.994	0.469	0.066	0.002	0.481	0.343	0.001
BR × Depth	3	0.460	0.625	0.704	0.961	0.051	0.310	0.359	0.559	0.956	0.301	0.087	0.406	0.415	0.295

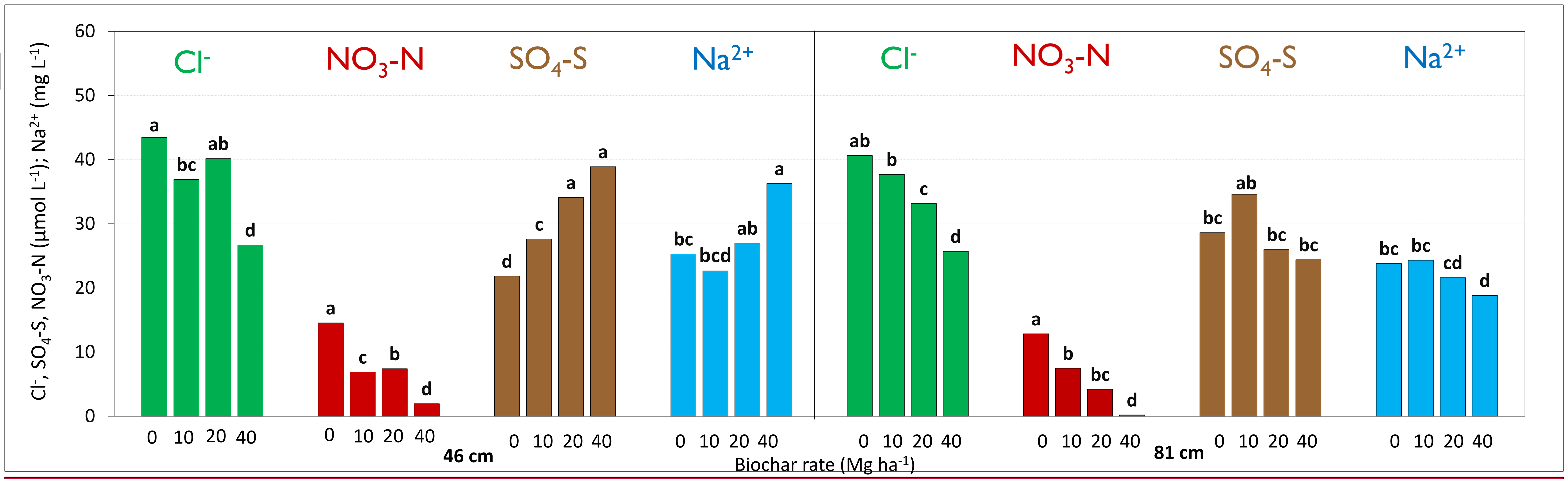


Figure 1. Concentrations of Cl^-, SO_4-S, Na^+, and NO_3-N in soil solution as affected by biochar application for fallow season at two soil depths (46 and 81 cm). Similar letters on bars indicate no significant difference between means at α≤0.05.

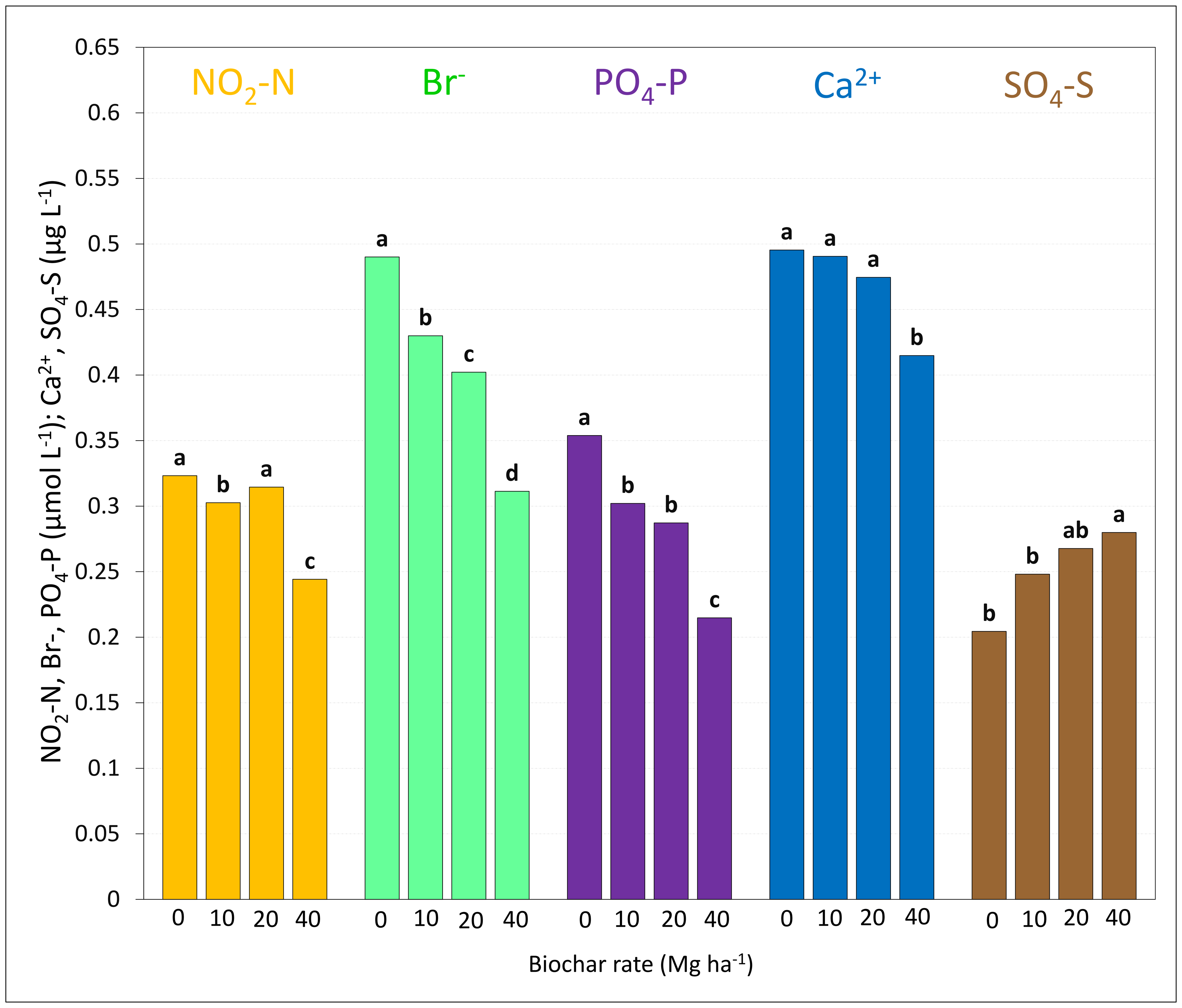


Figure 2. Mean values of NO_2-N, Br^-, PO_4-P, and Ca^{2+} for fallow season and SO_4-S for cotton season in soil solution as affected by different biochar application rates. Means followed by the same letter on bars and line graph indicate no significant differences between means at α≤0.05.

RESULTS AND DISCUSSION

- Biochar application reduced **chloride losses** at 10 (15%) and 40 Mg ha^{-1} (39%) for 46 cm soil depth while, 18 and 37% at 20 and 40 Mg ha^{-1} for 81 cm soil depth, respectively, compared to the control (Figure 1).
- Similarly, **EC** was reduced by 14% and 27% with biochar application at 20 and 40 Mg ha^{-1}, respectively, at 81 cm soil depth compared to control (Figure 1).
- Biochar application resulted in greater **SO_4-S concentration** (26-78%) at 46 cm soil depth in the fallow season (Figure 1). In cotton season, SO_4-S leaching was increased by 37% at 40 Mg ha^{-1} compared to the control (Figure 2).
- Higher concentration of **Na^+** was recorded at 40 Mg ha^{-1} (43%) at 46 cm soil depth compared to the control, however, it reduced by 21% at 81 cm soil depth with the same rate of biochar (Figure 1).
- Relative to the control, **bromide** losses were reduced by 12, 18, and 37% at 10, 20, and 40 Mg ha^{-1} biochar application, respectively (Figure 2).
- Biochar application at 40 Mg ha^{-1} reduced **Ca^{2+}** concentration by 16%compared to the control (Figure 2).
- **Phosphate** losses dropped by 14-40% from the control (Figure 2).
- **Nitrite-N** concentration was reduced with biochar application at the rate of 10 (6%) and 40 Mg ha^{-1} (25%) compared to the control (Figure 2).
- **Nitrate-N** concentrations were reduced by 54 to 86% at 46 cm depth and by 42 to 99% at 81 cm with biochar application (Figure 1).
- **Ammonium-N, pH, and phosphate decreased** with depth in the fallow season, similarly during cotton season pH, EC, Na^+, and K^+ decreased with depth (data not presented).
- Biochar reduced the leaching losses by increasing the cation exchange capacity of the soils[(5)].

CONCLUSION AND FUTURE STUDIES

- Biochar application reduced leaching losses of **NO_3-N, NO_2-N, PO_4-P, Cl^-, Br^-, and Ca^{2+}.**
- Considering the harmful effects of nitrate and phosphate leaching, more research should be focused on different types of biochar that could help minimizing nutrient leaching.
- Further research is needed to understand the impact of biochar on nutrient leaching in different soils in the Mississippi.

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