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Effect of Biochar and FYM and its Interaction on Soil Health Indicator under the Salt Affected Soil

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ABSTRACT

The exploration of using biochar in saline soils has garnered increasing interest in research. In the Kharif season of 2018, an experiment was conducted in the net house of the Department of Agricultural Chemistry and Soil Science at Anand Agricultural University, Anand. The aim was to study the impact of biochar and farmyard manure (FYM) on crop yield and the physical and chemical aspects of saline soil. The soil used in the experiment was loamy sand with good drainage and a pH of 8.0 at a depth of 0-15 cm. The experiment followed a completely randomized design factorial. The treatments involved four levels of biochar (B1: 0 t ha^{-1}, B2: 2.5 t ha^{-1}, B3: 5 t ha^{-1}, B4: 7.5 t ha^{-1}) and three levels of FYM (F1: 0 t ha^{-1}, F2: 5 t ha^{-1}, F3: 10 t ha^{-1}). The results revealed that the presence of biochar significantly affected the availability of nitrogen and phosphorus in the soil post-harvest. Notably, there was a notable decrease in soil pH, electrical conductivity (EC), and exchangeable sodium percentage (ESP) with the application of biochar at 7.5 t ha^{-1} (B4). Additionally, at this level (7.5 t ha^{-1}), biochar enhanced the soil's physical properties by reducing bulk density and improving water retention, comparable to the effects observed at 5 t ha^{-1}. Moreover, a substantial increase was observed in organic carbon, cation exchange capacity (CEC), and available NPK under the treatment F3 (FYM @ 10 t ha^{-1}), which was on par with treatment F2 (FYM @ 5 t ha^{-1}). Although there was a significant change in bacterial populations, no significant variation was observed in fungi and actinomycetes. In conclusion, the emerging body of knowledge supports the effectiveness of biochar addition in enhancing the physical, chemical, and biological properties of salt-affected soils.

Key words: *Biochar, FYM, Salt affects Soil, Water Holding Capacity*

Introduction

India, the world's second most populous country with over 1.38 billion people, relies significantly on agriculture, contributing about 19.9% to its Gross Domestic Product (GDP). The nation's economy heavily depends on agricultural outputs such as food, fibers, fuels, and raw materials. Hence, it's imperative to boost crop productivity to meet nutritional demands. However, the increased use of inorganic fertilizers, while enhancing yield, adversely impacts soil fertility, leading to land degradation. Approximately 187.8 million hectares of cultivable land in India suffer from degradation, notably 67 lakh hectares affected by salinity, with Gujarat alone reporting 22 lakh hectares (Kumar and Sharma, 2020). Soil amendments, both organic (compost, biochar) and inorganic (gypsum, lime), can improve soil quality, a focus of this study employing FYM and biochar as amendments.

Maintaining balanced fertilization stands as the key to sustainable crop productivity (Lester *et al*., 2007). Recent years have seen a surge in organic inputs, notably in newly reclaimed lands. Escalating energy costs and a heightened awareness of environmental issues, such as excessive use of fertilizers, herbicides, and pesticides, highlight the urgency to enhance fertilizer and chemical efficiency. This has spurred interest in organic manures, innovative approaches like biochar, and biofertilizers as alternatives to mineral fertilizers. These alternatives offer diverse essential nutrients, ease of soil integration, eco-friendliness, and cost-effectiveness. Organic manures play a pivotal role in rejuvenating depleted lands, aiding nutrient retention, enhancing soil properties, and fostering microbial activity (Schnitzer, 1991). They release organic acids that aid nutrient dissolution, ensuring better plant growth, balanced nutrient levels, improved yields, and fruit quality compared to mineral fertilizers. Efforts to replace costlier organic manures with more accessible sources aim to maximize benefits. Biochar, derived from biomass via pyrolysis, emerges as an agricultural asset, boosting crop yields and curbing fertilizer runoff and pollution. Its stability fosters soil fertility and augments crop productivity (Laird *et al*., 2010; Elsayed *et al*., 2008). Overall, biochar stands out as a cost-effective nutrient source, fostering sustainable crop production and enriching soil properties. The paper's primary aim was to explore the influence of biochar and FYM on productivity and soil health in salt-affected soils, emphasizing the potential positive effects on soil properties, particularly physicochemical aspects.

Material and Methods

An experimental setup took place in Anand, situated at 22.035°N, 72.055°E, about 37 meters above sea level and 45 meters from the Arabian Sea. The region experiences a sub-tropical climate with a rainy season from mid-June to mid-September, receiving 920mm of rainfall in 2018, close to the 32-year average of 865mm. Soil from the plow layer was collected, air-dried, sieved, and homogenized. Corn stover was turned into biochar using a two-barrel method. The soil's characteristics included loamy-sand texture, pH 8.1, EC 1.39 dS m^$^{-1}$, organic carbon 0.48%, and various nutrient contents. The experiment followed a factorial completely randomized design with varying biochar and farmyard manure levels.

Results and Discussion

Physical properties

Application of biochar and FYM resulted in the significant improvement in the physical properties of soil *i.e.*, decrease in bulk density and increase in water holding capacity in table 2. The bulk density of soil was reduced 10.07% and 10.79 % due to application of biochar @ 7.5 t ha^{-1} and 5.0 t ha^{-1} over no application of biochar. The significantly higher value of water holding capacity of soil was recorded in soil when biochar@ 7.5 t ha^{-1} applied but it was at par with application of biochar @ 5.0 t ha^{-1} as compared to control and application of biochar @ 2.5 t ha^{-1}. In case of application of FYMon soil physical properties is concerned, the significantly lower value of bulk density was recorded in soil when FYM @ 10.0 t ha^{-1} applied but it was at par with application of FYM @ 5.0 t ha^{-1} as compared to control. The significantly higher value of water holding capacity of soil was recorded in soil when FYM @ 10.0 t ha^{-1} applied but it was at par with application of FYM @ 5.0 t ha^{-1} as compared to control. Interaction effect of different levels of biochar and FYM on on bulk density and water holding capacity of soil was found non-significant after harvest off odder sorghum. The reduction in bulk density can be attributed due to low specific gravity of organic material and enhancing soil aggregation which has ultimately increased apparent soil volume and resulted in decline of bulk density of soil. The decrease in bulk density of the biochar-amended soils appears to have also been the result of modification of soil aggregate sizes, as shown by (Timilsina *et al*., 2020). Compost application improves soil physio-chemical characteristics, soil salinity and increases beneficial microbes (Munir *et al*., 2020). Biochar particles are fine grained with low density and they will decrease the fraction of macro-pores but increased meso and micro pores which contributed to overall increase in porosity. Thus increase in capillary porosity lead to increase in water holding capacity. Laird *et al*. (2020) who found that water holding capacity was improved with the application of biochar.

Chemical properties

The data regarding chemical properties *i.e.* EC, pH, CEC, ESP, OC and available nutrient status (available N, P_2O_5, K_2O and DTPA extractable Fe, Cu, Mn and Zn) of soil after harvest of fodder sorghum are conveyed. Significantly the lowest values of EC, pH and ESP was recorded of soil after harvest of fodder sorghum were recorded when biochar @ 7.5 t ha^{-1} applied as compared to no biochar application. The significantly lower value of EC was recorded in soil when biochar applied @ 7.5 t ha^{-1} applied followed by treatment received biochar @ 5.0 t ha^{-1}. The application of biochar @ 7.5 t ha^{-1} was recorded significantly lower pH as compared to control and application of biochar @ 5.0 t ha^{-1} but it was at par with application of biochar @ 2.5 t ha^{-1}. The values of ESP of soil was reduced 13.39%, 7.95% and 6.82 % due to application of biochar @7.5 t ha^{-1} , 5.0 t ha^{-1} and 2.5 t ha^{-1} over no application of biochar. In case of FYM application, the significantly lower value of EC and

Table 1. Initial Physio-Chemical properties of experimental soil, biochar and FYM.

Properties	Soil	Properties	**Biochar**	**FYM**
Bulk density(Mg m^{-3})	1.38	Bulk density (Mg m^{-3})	1.28	0.86
Water holding capacity (%)	28.05	Water holding capacity (%)	58.0	34.67
pH	8.1	pH (Soil : water, 1: 2.5)	8.30	6.40
EC (dS m^{-1})	1.39	EC (d Sm^{-1})(Soil : water,1:2.5)	1.80	0.89
Organic carbon(%)	0.48	Carbon (%)	70.90	38.70
Cation exchange capacity	12.80	Cation exchange capacity	33.8	-
Exchangeable sodium percentage	11.48	Nitrogen (%)	5.30	0.42
Available nitrogen (kg ha^{-1})	188.2	Phosphorus (%)	2.11	0.18
Available P_2O_5 (kg ha^{-1})	39.08	Potassium (%)	10.70	0.67
Available K_2O (kg ha^{-1})	267.3	Ash Content (%)	15.89	—
Available micronutrient (ppm)				
Available micronutrient (ppm)				
Fe	5.23	Fe		—
Zn	1.20	Zn		—
Mn	1.89	Mn		—
Cu	0.20	Cu		—

Table 2. Effect of biochar and FYM on bulk density and water holding capacity

Treatments		Bulk Density (Mg m^{-3})	Water Holding Capacity (%)
Levels of Biochar(B)			
B0	Control	1.39	28.72
B1	Biochar@2.5 t ha-1	1.37	29.96
B2	Biochar@5.0 t ha-1	1.24	30.88
B3	Biochar@7.5 t ha-1	1.25	32.52
S Em±	0.03	0.72	
C.D. @ 0.05	0.08	2.11	
Levels of FYM(F)			
F0	Control	1.37	28.28
F1	FYM@ 5.0 t ha-1	1.30	31.02
F2	FYM@10.0 t ha-1	1.27	32.26
S. Em±	0.02	0.62	
C.D. @ 0.05	0.07	1.82	
Interaction effect of B x F	NS	NS	

pH was recorded in soil when FYM applied @ 10.0 t ha^{-1} applied but it was at par with application of FYM @ 5.0 t ha^{-1} as compared to control. However, the ESP in soil decreased due to application of FYM but it has not reached at significant levels. The interaction effect of different levels of biochar and FYM was found significant only in case of EC of soil after harvest of fodder sorghum. The application of 7.5 t ha^{-1} biochar + 10.0 t ha^{-1} FYM (B_3F_2) recorded significantly lowest EC but it was at par with application of biochar alone @ 7.5 t ha^{-1} (B_3F_0) or combination with 5.0 t ha^{-1} FYM (B_3F_1).

The improvement in CEC of soil was found due to application of different levels of biochar and FYM after harvest of fodder sorghum. Application of biochar @7.5 t ha^{-1} recorded significantly higher CEC (12.98 cmol kg^{-1}) of soil after harvest of fodder sorghum crop as compared to rest of the treatments. The CEC was recorded under the application of biochar @ 7.5 t ha^{-1} and 5.0 t ha^{-1} was 14.77 % and 9.11%, respectively higher to the control. Application of FYM @ 5.0 t ha^{-1} recorded significantly higher CEC of soil after harvest of fodder sorghum crop as compared to control but it was at par with application of FYM @ 10.0 t ha^{-1} treatment. The interaction effect of different levels of biochar and FYM was found significant on CEC of soil after harvest of fodder sorghum. The result revealed that application of B_3F_1 (7.5 t ha^{-1} biochar + 5.0 t ha^{-1} FYM) has recorded significantly highest CEC as compared to rest of the treatments except biochar application alone @ 5.0 and 7.5 t ha^{-1} and treatment combination B_3F_2 (7.5 t ha^{-1} biochar + 10.0 t ha^{-1} FYM). Lowest soil CEC was observed under no application of biochar and FYM (B_0F_0), but it was at par with B_1F_0 (2.5 t ha^{-1} biochar alone)

The availability of macronutrient in soil was increased due to due to application of different levels of biochar and FYM after harvest of fodder sorghum. The application of biochar @ 7.5 t ha^{-1} recorded significantly highest available nitrogen, phosphorus, potassium and organic carbon as compared to control. The available nitrogen, phosphorus, potassium and organic carbon was 42.43%, 68.31%, 22.11% and 48.84% increased due to application of biochar @ 7.5 t ha^{-1} over control. In case of FYM application, the significantly higher available nitrogen, phosphorus and organic carbon content was recorded under the application of FYM @ 10.0 t ha^{-1}, however it was at par with treatment F_1 (FYM @ 5.0 t ha^{-1}) as compared to control treatment. The available potassium content was found high in the treatment received FYM @ 10 t ha^{-1} but the variation among the data of different treatments was recorded non-significant. The interaction effect of different levels of biochar and FYM was found significant with respect to available nitrogen and potassium after harvest of fodder sorghum only. Application of 7.5 t ha^{-1} biochar + 10 t ha^{-1} FYM has significantly highest soil available nitrogen as compared to all other treatment combinations. Application of B_3F_2 (7.5 t ha^{-1} biochar + 10.0 t ha^{-1} FYM) has significantly highest soil available potash as compared to rest of the treatment combinations except treatment combi-

Table 3. Effect of biochar and FYM on EC, pH, CEC, ESP, OC and available nitrogen phosphorus and potassium

Treatments		EC (dS m^{-1})	pH	ESP	OC (%)	CEC (cmol kg^{-1})	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
Levels of Biochar (B)									
B_0	Control	1.46	7.90	11.57	0.43	11.31	172.5	29.67	265.4
B1	Biochar @ 2.5 t ha-1	1.38	7.78	10.78	0.53	11.49	210.8	39.80	267.1
B2	Biochar @ 5.0 t ha-1	1.34	7.89	10.65	0.62	12.34	209.1	49.21	299.0
B3	Biochar @ 7.5 t ha-1	1.26	7.62	10.02	0.64	12.98	245.7	49.94	324.1
S. Em±		0.02	0.06	0.24	0.02	0.15	5.7	1.74	9.2
C.D. @ 0.05		0.05	0.19	0.71	0.06	0.44	16.5	5.07	26.9
Levels of FYM (F)									
F0	Control	1.40	7.95	11.10	0.51	11.72	199.9	39.07	281.4
F1	FYM @ 5.0 t ha-1	1.35	7.81	10.60	0.56	12.36	210.4	42.34	284.8
F2	FYM @10.0 t ha-1	1.33	7.63	10.57	0.60	12.02	218.2	45.05	300.6
S. Em±		0.01	0.06	0.21	0.02	0.13	4.9	1.50	8.0
C.D. @ 0.05		0.04	0.17	NS	0.05	0.38	14.3	4.39	NS
Interaction effect B x F		Sig	NS	NS	NS	Sig	Sig	NS	Sig

nations B_2F_1, B_2F_2, B_3F_0 and B_3F_1.

Micronutrients

With regard to micronutrients, the availability of micronutrient in soil was increased due to application of different levels of biochar and FYM after harvest of fodder sorghum. Application of biochar @ 7.5 t ha^{-1} recorded significantly higher DTPA extractable Fe, Mn and Zn after harvest of fodder sorghum crop as compared to control. But there is non-significant influence on available copper (Cu) concentration in soil by the application of biochar. The DTPA extractable Fe, Cu, Mn and Zinc was 15.61%, 2.43%, 13.33% and 26.96% increased due to application of biochar @ 7.5 t ha^{-1} over control. In case of FYM application, the significantly lowest DTPA extractable Mn and Zinc after harvest of fodder sorghum crop was recorded under the no application of FYM but it was at par with treatment F_2 (FYM @ 5.0 t ha^{-1}) as compared to application of FYM @ 10.0 t ha^{-1} treatment. However, the application of FYM @5.0 t ha^{-1} recorded higher available Fe and Cu after harvest of fodder sorghum as compared to control but has not reached at significant level. The DTPA extractable Fe, Cu, Mn and Zinc was 6.38%,5.00%,15.00% and 12.59%, respectively increased due to application of FYM @ 10.0 t ha^{-1} over control. The interaction effect of different levels of biochar and FYM was found non-significant on available Fe, Cu andMn concentration in soil after harvest of fodder sorghum except in case of available Zn. Application of B_3F_2 (7.5 t ha^{-1} biochar + 10.0 t ha^{-1} FYM) has significantly highest soil available Zn as compared to rest of the treatments except treatment combination B_3F_1 (7.5 t ha^{-1} biochar+5.0 t ha^{-1} FYM). The significant reduction electrical conductivity through biochar might be due to biochar can adsorb salt on it's surface and hence lead to reduction in EC of soil. The results are in line with those reported by Mousa, (2017). The decrease in EC due to FYM could be due to improvement in soil structure similar to others in literature (AbdElrahman *et al*., 2012).

The slow oxidization of biochar in soils can produce carboxylic functional groups. The formation of the acidic functional groups can neutralize alkalinity and eventually decrease soil pH (Wu *et al*., 2014). The results of soil pH (1:2.5) as influenced by application of FYM due to release of organic matter and this could help in the reduction of alkalinity of soils also proved by Chaudhary *et al*. (2015). Potential to increase soil CEC may be due to biochar is variably charged organic material with high surface area and rich in functional groups into soil. Compost amendment resulted in an increase of CEC due to input of stabilized organic matter being rich in functional groups into soil. The exchangeable sodium percentage of soil decreased significantly due to application of biochar facilitates leaching of Na from surface and increased Ca^{2+} content of soil through biochar which has helped to ameliorated the chemical properties of degraded salt-affected soil and thus induced better leaching of salt from soil surface similar to Atkinson *et al*. (2010). The high carbon content in biochar might be responsible for OC build-up and it is also attributed to the very low level of degradation and recalcitrant nature of biochar in soil the re-

Table 4. Effect of biochar and FYM on DTPA extractable micronutrients

Treatments		Available Fe(mg kg^{-1})	Available Cu (mg kg^{-1})	Available Mn(mg kg^{-1})	Available Zn (mg kg^{-1})
Levels of Biochar (B)					
B0	Control	5.51	0.164	1.82	1.15
B1	Biochar @ 2.5 t ha-1	5.98	0.163	1.84	1.15
B2	Biochar @ 5.0 t ha-1	6.34	0.159	1.88	1.27
B3	Biochar @ 7.5 t ha-1	6.37	0.168	2.10	1.46
S. Em±		0.19	0.006	0.05	0.05
C.D. @ 0.05		0.57	NS	0.14	0.13
Levels of FYM (F)					
F0	Control	5.80	0.160	1.80	1.18
F1	FYM @ 5.0 t ha-1	6.18	0.164	1.87	1.24
F2	FYM @10.0 t ha-1	6.17	0.168	2.07	1.35
S. Em±		0.17	0.005	0.04	0.04
C.D. @ 0.05		NS	NS	0.12	0.13
Interaction effect of B x F		NS	NS	NS	Sig

sult is supported by Sara and Shah (2018).

The perusal of data revealed that application of biochar significantly increased available N this type of effect has been observed might be due to reduction in leaching loss of nitrogen and better retention of fertiliser on surface of biochar similar results given by Palviainen *et al*. (2018). The increase in $KMnO_4$-N in FYM amended plots is attributed to the increase in total SOC and might have been partially due to a slow release of N from manure, as suggested by Yadav *et al*. (2000). Kumar *et al*. (2018) reported that the increase in available P_2O_5 status of the soil with addition of organic sources may be due to greater mobilization of native soil P. Increased in soil available K might be attributed to the presence of K rich ash in the biochar the results are in line with Zhang *et al*. (2017). The higher content of available micronutrient might be due to reduction in pH and appreciable amount of micronutrient present in biochar and FYM. The obtained results are in agreement with those reported by Shankar and Evelin, (2019); Gao and DeLuca, (2016) and Moharana *et al*. (2017).

Biological properties

Data generated from the different treatment combinations clearly showed in Table 4 and that there was a significant ($p < .05$) difference among treatments regarding bacterial population (10^{-6} CFU g^{-1} soil) but in case in Fungal population (10-4cfu g^{-1} soil), Actinomycetes population (10-5cfu g^{-1} in soil), soil microbial biomass carbon and Actinomycetes population (10-5cfu g-1 in soil). This is because biochar and FYM e is rich source of carbon which has provided the source of energy for microorganisms and the substrate for growth and activities. Hence, significant increase in bacterial population was recorded in the treatments with the application of sewage sludge.

Conclusion

From the present study it can be concluded that amending salt affected loamy sand soil with biochar and FYM have beneficial influence on soil chemical properties. Biochar and FYM has raise soil fertility by enhancing nutrient status, boosting soil organic carbon status and CEC of soil. Biochar and FYM have ameliorated poor soil condition by reducing pH, EC and ESP of salt affected soil. In this investigation biochar and FYM have been proved an ideal amendment for improving soil physical properties because it has reduced the bulk density and boosted water holding capacity of salt affected loamy sand soil. The application of biochar @ 7.5 t ha^{-1} and FYM @ 10.0 t ha^{-1} has found to be better for a majority of parameters in comparison with other treatments. Further, the high cost associated with production of biochar, transport and high application rates remains a significant challenge to its widespread use in areas affected by salinity and sodicity especially in India. In this context some more studies need to be carried out in future.

Table 4. Effect of biochar and FYM on biological properties

Treatments		Bacteria (10^{-6} CFU g^{-1} soil)	Fungi (10^{-4}cfu g^{-1} soil)	Actinomyceties (10-5cfu g^{-1} in soil)	SMC	DHA (µg TPF released g^{-1} soil day^{-1})
Levels of Biochar (B)						
B0	Control	80.0	50.00	71.0	98.20	25.00
B1	Biochar @ 2.5 t ha-1	81.5	52.20	74.5	102.30	25.30
B2	Biochar @ 5.0 t ha-1	82.3	53.00	76.8	105.40	26.60
B3	Biochar @ 7.5 t ha-1	86.9	53.80	79.4	110.60	28.90
S. Em±		0.83	0.466	1.011	1.715	0.295
C.D. @ 0.05		2.59	1.646	3.566	4.278	1.040
Levels of FYM (F)						
F0	Control	80.8	50.60	71.8	99.80	24.60
F1	FYM @ 5.0 t ha-1	84.7	54.90	73.3	106.70	25.10
F2	FYM @10.0 t ha-1	88.1	56.40	76.9	111.40	27.30
S. Em±		0.068	0.466	1.011	1.715	0.295
C.D. @ 0.05		2.11	0.660	1.430	4.278	1.040
Interaction effect of B x F		0.933	NS	NS	NS	NS

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