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Effect of Amendments on Physicochemical and Biological Properties of Sodic Soil and Yield of Rice CO 52 (*Oryza sativa L.*) Grown in a Subtropical Region

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Sodic soils are low in available nutrients, organic carbon, microbial population and enzyme activities. Amendments application not only used to improve soil physico-chemical properties and also increase soil organic carbon and biological activity of sodic soil. Field experiment was conducted in sodic soil using rice (CO 52) as a test crop with various amendments viz., gypsum+ green manure (G+GM), green leaf manure (GLM) and press mud (PM). The influence of amendments on reclamation as well as availability of plant nutrients and biological activity were

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studied. The microbial population viz., bacteria, fungi and actinomycetes and enzyme activity viz dehydrogenase, phosphatase and urease were increased on reclamation over control. Higher microbial population and greatest enzyme activities were observed in the gypsum+ green manure (G+GM) applied treatments followed by green leaf manure (GLM) and press mud (PM) applied plots. Sodic soil reclamation using various amendments resulted in enhanced crop yield, physicochemical and biological properties of soil.

Keywords: Gypsum + green manure; green leaf manure; press mud; microbial population; enzyme activity.

1. INTRODUCTION

“Salt affected refers to soils that are saline or sodic. Many countries of arid and semi-arid climates having salt affected soils. In India nearly 6.73 million hectare area is salt affected and out of that 3.77 million hectare of land is affected by sodic soil. Sodicity not only affect the chemical and physical properties of soils, but also inhibit several soil enzyme activity, such as alkaline phosphatase, β-glucosidase and microbial respiration” [1]. “Sodic soil are normally poor in biological properties with low organic carbon content and low microorganism activity” [2]. “Microbial activity plays an important role in organic matter decomposition and nutrient mineralization” [3]. “Sodic soils reclamation not only increased nutrients content, but also increased microbial activity” [4]. Hence this study was undertaken to investigate the influence of amendments on microbial and enzyme activity of a sodic soil and the impact on rice yield.

2. MATERIALS AND METHODS

The experimental site geographically located at 10^0 55” 29.34 North latitude and 78^0 49 “ 35.61 East longitude and at an altitude of 70 meters above the mean sea level. The soil of the experimental site belongs to Madukhur series, clay loam in texture, highly sodic (pH 9.98), low in EC (0.35 dS m^{-1}), low in organic carbon (0.46%), low in available nitrogen (221 kg ha^{-1}), medium in available phosphorus (11.2 kg ha^{-1}) and potassium (126 kg ha^{-1}) having exchangeable sodium percentage (ESP) of 29.6%. The microbial population viz., bacteria, fungi, actinomycetes of initial soil was 12.05 × 10^7 CFU g^{-1} soil), 2.56 × 10^2 CFU g^{-1} soil), 1.28 × 10^3 CFU g^{-1} soil and the enzyme activity viz., Actinomycetes (× 10^3 CFU g^{-1} soil), Dehydrogenase (µg TPF g^{-1} hr^{-1}), Urease (µg NH_4-N g^{-1} hr^{-1}) and Phosphatase (µg nitrophenol g^{-1} hr^{-1}) were 1.28, 1.06, 1.37, 2.91 respectively. The experiment was laid out in a split plot design with four main plots and seven sub plot treatments. The amendments gypsum @ 50% GR+ Green manure @ 6.25 t ha^{-1}, Green leaf manure @ 12.5 t ha^{-1} and press mud @ 10 t ha^{-1} were used as amendments for the reclamation of sodic soil by adopting standard reclamation procedure and the treatments without amendment was maintained as control. Different levels of $ZnSO_4$ application were imposed as sub-plot treatments. The treatments were replicated thrice. Each treatment was super imposed with recommended levels of NPK fertilizers (150:50:50 N, P_2O_5 and K_2O kg ha^{-1}). CO 52 rice variety was medium duration (135 days) fine grained high yielding variety and it was transplanted with 20x10 cm spacing. The growth and yield attributes of transplanted rice were recorded. The soil and plant samples were collected at post harvest stages from each plot. Post-harvest soil samples were analyzed for pH, EC, microbial and enzyme activity using potentiometric, conductometric, Waksman. [5] method, spectroscopic method (casida et al. [6]), steam distillation (Tabatabai and Bremner. [7]) method. Post-harvest soil exchangeable sodium percentage (ESP) was analysed by Ammonium acetate and flame photometry method.

3. RESULTS AND DISCUSSION

3.1 Soil pH

The soil pH directly influencing soil physical, chemical and biological properties. Application of amendments resulted in highly significant decrease in soil pH (Table 1). “pH of the soil ranged from 9.95 to 8.34. Maximum reduction in soil pH was recorded in gypsum+ Green manure applied plots (8.45). The reduction in soil pH on application of gypsum+ Green manure was attributed to the displacement of exchangeable Na by the calcium ions of gypsum which get leached out due to drainage provided” [8]. The addition of Green manure after gypsum leads to further reduction in pH by producing organic acids during decomposition which solubilizes the native Ca. The Green leaf manure (GLM) proved its superiority over press mud (PM) in reducing the soil pH. The fresh organic materials present in the Green leaf manure (GLM) might have readily decomposed and released higher amount of organic acids.

3.2 Soil EC

In spite of higher amount of gypsum application, only small increase in EC was observed which might be due to very low solubility of gypsum (2.8 g L^{-1}). Decomposition of organic materials released organic acids or acid forming compounds that reacted with the sparingly soluble salts already present in the soil and either converted them in to soluble salts or at least increased their solubility resulting in slight increase in EC.

3.3 Exchangeable Sodium Percentage

Amendments application decreased the exchangeable sodium percentage (ESP) with desirable reduction being noticed in gypsum+ green manure (G+GM) treated plots followed by green leaf manure (GLM) and press mud (PM). A decrease in exchangeable sodium percentage (ESP) of 14.8, 4.4 and 3.5% was noted due to gypsum+ green manure (G+ GM), green leaf manure (GLM) and press mud (PM) application respectively over the control. "In case of gypsum, the reduction in exchangeable sodium percentage (ESP) was attributed to replacement of exchangeable Na by Ca of the gypsum" [9]. "The application of organic amendments also reduced the soil exchangeable sodium percentage (ESP) from initial level which may be due to increase in exchangeable Ca and Mg ions due to solubilization during decomposition of organic matter and also due to supply of beneficial cations like K, Ca and Mg from the GLM and press mud" [10].

3.4 Soil Microbial Population

The bacterial, fungal, actinomycetes population of post harvest soil was markedly influenced due to application of treatments. The bacterial population ranged from 12.39 to 16.83 × 10^7 CFU g^{-1} of soil. The minimum (2.84 × 10^2 CFU g^{-1}) and maximum (4.66 × 10^2 CFU g^{-1}) fungal population being observed in control and gypsum+ green manure (G+GM) applied treatments. The actinomycetes population ranged between 1.34 to 3.26 × 10^3 CFU g^{-1} of soil.

Microbial activity had a direct impact on the plant nutrient availability as well as other properties related to soil productivity [11]. The microbial population viz., bacteria, fungi and actinomycetes were also increased on reclamation over control (Table 2). This may be due reduced adverse nature of sodic soil in terms of reduced pH, exchangeable sodium percentage (ESP) and exchangeable Na and increased favorable conditions for microbes [12]. Higher Bacterial, Fungal, Actinomycetes population was observed in the gypsum+ green manure (G+GM) applied treatments followed by green leaf manure (GLM) and press mud (PM) applied plots. The application of zinc sulphate does not possess significant changes in microbial population.

3.5 Soil Enzyme Activities

Significant increase in the soil enzyme activity was observed on application of amendments. The Table 2 represents the dehydrogenase activity of post harvest soil which was varied from 1.15 to 1.64 µg TPF g^{-1} hr $^{-1}$. The urease activity and phosphatase activity in the post harvest soil ranged between 1.45 to 2.22 µg NH_4-N g^{-1} hr^{-1} and 3.84 to 5.63 µg nitrophenol g^{-1} hr $^{-1}$.

"Enzyme activity in soil is directly correlated with soil microbial population [13]. Dehydrogenases is considered to play an essential role in initial stages of the oxidation of soil organic matter by transferring hydrogen and electrons from substrates to acceptors" [14]. "The phosphatases hydrolyze organic P to inorganic P, catalyze the rate limiting steps of P nutrient cycling and therefore, phosphatase activity plays a significant role in P availability to plants from native organic P compounds" [15]. "The enzyme urease was associated with N mineralization. These three enzymes play a significant role in the bio-transformation of nutrients in soil, and thus influence the nutrients availability in soil and uptake by crops. There is always a positive correlation exists between N mineralization and urease as well as P mineralization and phosphatase activity" [15].

Greatest activities of dehydrogenase, phosphatase and urease were observed with the gypsum+ green manure (G+GM) followed by green leaf manure (GLM) and press mud (PM) treatments. Generally, organic manure addition found to enhance the microbial activities which in turn favoured the synthesis of various enzymes in soil [16]. The application of zinc sulphate had no significant changes on enzyme activities.

Table 1. Effect of amendments and *zinc sulphate on pH, EC and exchangeable sodium percentage (ESP) of post harvest soil

	pH	EC (dS m^{-1})	ESP (%)
Control	9.95	0.35	29.7
Gypsum + GM	8.45	0.41	14.8
GLM	8.95	0.37	25.2
Press mud	9.13	0.37	26.2
S Ed	0.1	0.006	0.36
CD(0.05)	0.25	0.01	0.91

Table 2. Effect of amendments and * zinc sulphate application on microbial population and enzymes activity of post harvest soil

Treatments	Bacterial (× 10^7 CFU g^{-1} of soil)	Fungal (× 10^2 CFU g^{-1} of soil)	Actinomycetes (× 10^3 CFU g^{-1} of soil)	Dehydrogenase (µg TPF g^{-1} hr^{-1})	Urease (µg NH_4-N g^{-1} hr^{-1})	Phosphatase (µg nitrophenol g^{-1} hr^{-1})
Control	12.39	2.84	1.34	1.15	1.45	3.84
Gypsum+GM	16.83	4.66	3.26	1.64	2.22	5.63
GLM	16.05	4.24	2.85	1.59	2.04	5.23
Press mud	15.64	4.10	2.75	1.55	2.02	4.93
S Ed	0.23	0.06	0.04	0.02	0.3	0.07
CD(0.05)	0.57	0.15	0.1	0.05	0.07	0.19

Table 3. Effect of amendments on yield (kg ha^{-1}) parameters of rice

Treatments		Mean	
Grain yield			
Control		2846	
Gypsum+ GM		5511	
GLM		4972	
Press mud		4904	
Mean		4558	
Straw yield			
Control		3382	
Gypsum+ GM		6563	
GLM		5930	
Press mud		5818	
Mean		5423	
	S Ed		CD (0.05)
Grain yield	74.1		182
Straw yield	88.2		217

3.6 Grain and Straw Yield

The results of the field experiment revealed that application of amendments to sodic soil along with $ZnSO_4$ application significantly increased all the yield components of rice viz., grain yield and straw yield (Table 3). The yield of crop is a function of many factors, which includes soil, crop and climatic factors, and the effective management of monetary and non-monetary inputs. In other words, the final economic yield of a crop is determined by various growth parameters. There are so many factors which may have to be manipulated to increase the above said favorable environment and providing a better soil condition with respect to its physical, physicochemical, chemical and biological properties.

Among the amendments, highest yield (5511 kg ha^{-1}) was recorded in the gypsum+ green manure (G+GM) applied treatments owing to creation of favourable micro climate, increased availability of essential nutrients which in turn increased the yield. Next to gypsum+ green manure (G+GM), higher yield was noted in green leaf manure (GLM) and press mud (PM) applied treatment over the control. The organic amendments not only reclaimed the sodic soil but also enhanced soil organic carbon content and biological properties [17].

In gypsum+ green manure (G+GM) and organic materials applied plots dry matter production (DMP) was increased due to the combined action of amelioration and increased availability of nutrients which in turn increased the growth and yield attributes of the crop. The increase in dry matter production (DMP) was mainly attributed to nitrogen assimilation which was supplied by organic materials and increased N mineralization. Increased dry matter production enhanced the grain yield because there is always a positive relationship between dry matter production (DMP) and the grain yield, as it forms the basis for translocation [18-21].

4. CONCLUSION

The results of field experiment concluded that application of amendments enhanced physicochemical properties, microbial population and enzyme activities of soil. Greatest biological activities were observed with the gypsum+ green manure (G+GM) followed by green leaf manure (GLM) and press mud (PM) treatments. Application of amendments to sodic soil significantly increased the yield parameters (DMP and grain and straw yield) of rice.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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