Original Research Article

Effect of amendments on physicochemical and biological properties of sodic soil and yield of rice (Oryza sativa. Cv.?) grown in a tropical (?) subtropical (?) temperate (?) environment

ABSTRACT

Sodicsoils are low inavailable nutrients, organic carbon, microbial population and enzyme activities. Amendments application not only used to improve~~the~~soilphysico-chemical properties and alsoincrease soil organic carbon and biological activity. 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 studied.The microbial population viz., bacteria, fungi and actinomycetes and enzyme activity vizdehydrogenase, phosphatase and ureasewere increased on reclamation over control. Higher microbial population and greatest enzyme activities were observed in the G+GM ~~Gypsum+ GM~~ applied treatments followed by GLM and PM~~press mud~~ applied plots. Sodic soil reclamation using various amendments resulted in enhanced crop yield, physicochemical and biological properties of soil.

Keywords: Gypsum +GM, GLM, 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. 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 soils are normally poor in biological properties with low organic carbon content and low~~er~~ microorganismactivity (or content) [2].Microbial activity plays an important role in organic matter decomposition, and nutrient mineralization[3].Sodic soils reclamation not only increased ~~the~~ nutrients content, but ~~and~~ also increased ~~the~~ microbial activity[4].Hence this study was undertaken to investigate the influence of amendmentson microbial and enzyme activity of a sodic soi, and the impact on rice yield.~~l.~~

2. MATERIALS AND METHODS

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 ESPof 29.6%. The microbial polulation 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} soiland the enzyme activity viz., Actinomycetes ($\times 10^{3}$ 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 amendments gypsum @ 50% GR+GM @ 6.25 t ha^{-1}, GLM @ 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$ZnSO_4$

Comment [DC1]: If this statement: #Amend...activity" is coming from the literature, please delete.

Comment [DC2]: Authors need to be consistent about how to quote the treatments, either you mention them completely or by acronomys, but consistently, please.

Comment [DC3]: Authors need to make a reference to the country, location, weather and growing period of the crop. Also, year or years of the experiment...some of this information should be mention in the Intro and some in M&M

Comment [DC4]: Besides indication requested in the Introduction, when referring to the crop is necessary to indicate: how the crop was manage, if it was sown directly or transplanted, etc. etc.

Comment [DC5]: Need to explain ESP

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}). The growth and yield attributes of rice were recorded. Post harvest soil samples were analyzed for pH, EC, ESP, microbial and enzymeactivity.

Comment [DC6]: Need to present size of the plots, and how the amendments were applied; standard reclamation procedures is not enough for a practice that is core for this paper

Comment [DC7]: Which and how were these attributes assessed? Which was the rice variety?

Comment [DC8]: There is no reference about how the pH, EC, etc were asseseed. All these protocols must be mentioned.

Comment [DC9]: There is also not reference to when and how the soil samples were taken. There is also no reference to when and how the crop samples were taken

Comment [DC10]: In the M&M section is made reference to dose...In this section there is no mention about different rates for the same amendment and is also not mentioned how many days before implanting the crops they were applied.

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+ GM applied plots (8.45). The reduction in soil pH on application of gypsum+ GM was attributed to the displacement of exchangeable Na by the calcium ions of gypsum which get leached out due to drainage provided[5]. The addition of GM after gypsum leads to further reduction in pH by producing organic acids during decomposition which solubilizes the native Ca. The GLM proved its superiority over press mud in reducing the soil pH. The fresh organic materials present in the GLM might have readily decomposed and released higher amount of organic acids.

Comment [DC11]: It is more clear if you refer to the treatmens as Gypsum+Green Manure, etc....

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 gL^{-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 ESP with desirable reduction being noticed in gypsum+ GM treated plots followed by GLM and press mud. A decrease in ESP of 14.8, 4.4 and 3.5% was noted due to gypsum+ GM, GLM and press mud application respectively over the control. In case of gypsum, the reduction in ESP was attributed to replacement of exchangeable Naby Ca of the gypsum[6]. The application of organic amendments also reduced the soil 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.

3.4 Soil microbial population

The bacterial, fungal, actinomycetes population of post harvestsoil 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+ GM applied treatments. The actinomycetes population ranged between 1.34 to 3.26 × 10^3 CFU g^{-1} of soil.

Comment [DC12]: Again, reference should be made in M&M to when the soil samples were taken. Then, you only refer to soil analysis...

Microbial activity had a direct impact on the plant nutrient availability as well as other properties related to soil productivity[7]. 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, ESP and exchangeable Na and increased favorable conditions for microbes[8]. Higher Bacterial, Fungal, Actinomycetes population was observed in the Gypsum+ GM applied treatments followed by GLM and press mud applied plots. The application of zinc sulphate does not possess significant changes in microbial population.

3.4 Soil enzyme activities

Significant increase in the soil enzyme activity was observed on application of amendments. Thetable 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 activitry 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$g^{-1}hr^{-1}$.

Comment [DC13]: As already mentioned, in the M&M section it is necessary to explain how these activities were measured

Enzyme activity in soil is directly correlated with soil microbial population[9]. 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[10]. 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[11]. 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[11].

Greatest activities of dehydrogenase, phosphatase and urease were observed with the gypsum+ GM followed by GLM and press mud treatments. Generally, organic manure addition found to enhance the microbial activities which in turn favoured the synthesis of various enzymes in soil [12]. The application of zinc sulphate had no significant changes on enzyme activities.

3.5 Grain and straw yield

The results of the field experiment revealed that sodic soil on reclamation with amendments, increased the yield significantly (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.

Comment [DC14]: This sentence needs to be re-elaborated, please

Comment [DC15]: All the general considerations about yield are already known, the authors need to focus on the effect of the treatments on yield and straw

Among the amendments, highest yield (5511 kg ha^{-1}) was recorded in the Gypsum+ GM applied treatments owing to creation of favourable micro climate, increased availability of essential nutrients which in turn increased the yield. Next to Gypsum+ GM, higher yield was noted in GLM and press mud applied treatment and over the control. The organic amendments not only reclaimed the sodic soil but also enhanced soil organic carbon content and biological properties[13].

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+ GM followed by GLM and press mud treatments. Application of amendments to sodic soil significantly increased the yield parameters(DMP and grain and straw yield) of rice.

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Table 1. Effect of amendments and *zinc sulphate on pH, EC and 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

* Effect of zinc sulphate was non-significant.

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

*Effect of zinc sulphate was non-significant.

Comment [DC16]: Need to indicate when the soil sample to make all these analysis was taken, At harvest of the crop and if it was post-harvest, how many days, etc?

Comment [DC17]: Will be much more easy for the reader i the authors indicate with letters (as normally done) which treatments differ from the control, etc.

Comment [DC18]: Zn sulphate was not mentioned in the M&M section, plese, explain this!!!

Table 3. Effect of amendments on grain and straw yield (kg ha^{-1}) in 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

Comment [DC19]: This table can be a Two column table, please. One for grain yield and the other for straw yield.