

Original Research Article

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Effects of Different Amendments and Nitrogen Application on Physico-Chemical and Biological Properties of Sodic Soil

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ABSTRACT

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Currently more than 20 per cent of the world's irrigated land is salt affected. Of that about 60 per cent are sodic soils, warranting attention for efficient, inexpensive and environmentally feasible amelioration. An incubation study was performed to study the influence of amendments on physico-chemical and biological properties of sodic soil. Gypsum + Green manure @ 6.5 t ha⁻¹, Distillery spentwash (DSW)@ 5 lakhs liter⁻¹, Green leaf manure (GLM) @ 12.5 t ha⁻¹ were used as amendments for the reclamation of sodic soil by adopting standardized reclamation procedure. The results of the incubation study revealed that application of amendments decreased the pH of the soil. The pH declined from the initial level of 10.2 to 8.37, 8.42 and 9.21 due to application of DSW, Gypsum + GM, and GLM respectively. Maximum reduction in soil pH was recorded in DSW applied treatments. The soluble salt concentration was found to be slightly increased in the DSW applied treatments, but the extent of increase was within the permissible limit (<4 dS m⁻¹). Soil ESP was significantly reduced on reclamation to the level of 13.1, 13.5 and 24.2 per cent on account of application of DSW, Gypsum + GM, and Green leaf manure respectively from the initial level of 31.8 per cent with increased exchangeable Ca, Mg and K and reduced exchangeable Na content of the soil. The application of amendments significantly improved microbial population and soil enzyme activity of the soil in the order of DSW>Gypsum + GM>GLM>control.

Introduction

Sodic soils are exhibiting poor physical and chemical properties, which impede water infiltration, water availability and ultimately plant growth. 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. Tamil Nadu alone has 3.5 lakh hectares of sodic soil. Large extent of land in India is affected by sodicity due to major degradation processes like sodification, water logging, chemical impairment and desertification (Dagar and Singh, 1994). In

order to overcome sodicity different amendments were used based on its availability and cost which favourably improved the physico-chemical and biological properties of sodic soil.

Reclamation of sodic soils are normally achieved by supplementing readily available calcium (Ca^{2+}) sources to replace the excess Na^+ on the exchange complex and leaching the displaced Na^+ from the root zone through excess irrigation water with better drainage facilities. Amelioration of these soils has been predominantly achieved through the application of chemical amendments. However increasing cost of chemical amendments and recurrent sodicity issues necessitated the identification of alternative low cost approaches to sustain the productivity of these soils.

Gypsum, distillery spent wash, green manures and green leaf manures are widely used for reclamation (Davies *et al.*, 2011). Hence effective utilization of distillery spent wash, gypsum, green manure and Green leaf manure on reclamation of sodicity was assessed to improve the soil physico-chemical and biological properties. Sustainable farming in sodic soil and increased food production.

Materials and Methods

The soil used for incubation experiment was clay loam in texture belongs to Madukhur series. The incubation experiment having eight treatments with three replications. The experiment was laid out in CRD with the treatments includes control (T_1), gypsum + green manure @ 6.25 t ha^{-1} (T_2), green leaf manure @ 12.5 t ha^{-1} (T_3), Distillery spent wash @ $5 \text{ lakh liters ha}^{-1}$ (T_4), Nitrogen alone @ 75 kg ha^{-1} (T_5), Gypsum + Green manure @ 6.25 t ha^{-1} + Nitrogen @ 75 kg ha^{-1} (T_6), Green leaf manure @ 12.5 t ha^{-1} + Nitrogen @

75 kg ha^{-1} (T_7), DSW @ $5 \text{ lakh liters ha}^{-1}$ + Nitrogen @ 75 kg ha^{-1} (T_8).

The soils were incubated at saturated condition for 60 days and were analysed for physico-chemical properties viz, Exchangeable Ca, Mg, Na, and K, ESP and biological properties viz., Bacteria, Fungai, Actinomycetes, Dehydrogenase activity, Urease activity, and Phosphatase activity.

Results and Discussion

Characteristics of the initial soil

The incubation experiment was carried out on Madukhur soil series at AEC &RI, Kumulur. The soil was clay loam in texture with a bulk density, particle density and porosity of 1.2 Mg m^{-3} , 2.22 Mg m^{-3} and 58.60 per cent respectively. The experimental soil was highly sodic (pH 10.2), low in EC (0.72 dS m^{-1}). The soil organic carbon was 0.48 %. The Exchangeable Ca, Mg, Na, K and ESP were $6.21 \text{ cmol(p+)kg}^{-1}$, $4.81 \text{ cmol(p+)kg}^{-1}$, $5.12 \text{ cmol(p+)kg}^{-1}$, $0.08 \text{ cmol(p+)kg}^{-1}$ and 31.8 respectively.

Effect of Soil pH and EC:

Soil physical, chemical and biological properties are directly related with pH. The soils without amendment registered highest pH of 10.2. In sodic soils, reaction of exchangeable sodium and CaCO_3 under low CO_2 conditions lead to higher concentration of sodium carbonate and consequently increased the soil pH (Cruz-Romero and Coleman, 1975). The application of amendments significantly reduced the pH. The maximum reduction in pH was recorded in the DSW applied treatments followed by Gypsum + GM and GLM.

This reduction in pH on application of DSW was due to several reasons. The acidic nature

(pH 4.3) of DSW which directly contributes to the pH reduction. Because of the acidic nature of DSW, the free lime may be solubilized in soil and releasing Ca ions. The Ca ions replaces Na ions and forms soluble sodium salts which get leached out during leaching. The reduction in pH might also be due to Ca supplied directly by the DSW. Similar reduction in pH was reported by Mohamed Harron and Subash Chandra Bose (2004) for calcareous sodic soils of Tiruchirapalli,

The reduction in soil pH on application of Gypsum + GM was attributed to the displacement of exchangeable Na by the calcium ions of gypsum and subsequent formation of sodium sulphate which get leached out due to drainage provided. The addition of GM after gypsum leads to further reduction in pH by producing organic acids during decomposition which solubilizes the native Ca. Application of GLM had ameliorative effect and reduced the soil pH due to liberation of CO₂ and organic acids during decomposition process and produces hydrogen ions which solubilize the CaCO₃ and neutralize the sodicity. Similar results were observed by Pattanayak *et al.*, (2001), Yaduvanshi (2001) and Smiciklas *et al.*, (2002) where they observed a decrease in soil pH after the use of organic materials.

The application of distillery spent wash (DSW) had slightly increased the electrical conductivity of soils. This was due to high salt content in raw spent wash added to soils during reclamation process, resulting in slight salt build-up even though drainage was provided to these treatments. There was no reduction in EC in Gypsum + GM applied treatments which might be due to very low solubility of gypsum (2.8 g L⁻¹) but there was a slight increase in EC in the GLM applied treatments and Gypsum + GM treatments due to increase in amount of soluble salts.

Effect on soil exchangeable cations

Application of amendments had a significant influence on the exchangeable cations of incubated soil especially the beneficial cations viz., Ca, Mg and K. The changes in the concentration of exchangeable cations on application of DSW were significant.

Exchangeable calcium

The exchangeable calcium content of soil was found in the range of 6.24 to 8.86 cmol (p+) kg⁻¹ (Table 1). The exchangeable calcium content of the incubated soil after 60th day was significantly increased due to application of amendments. The acidic nature of distillery spent wash might have solubilized some native free lime as well as small quantity of dolomitic lime which have released Ca + Mg in free ionic forms that might have also contributed for increased Ca on exchange sites by replacing exchangeable Na. Similar observations were reported by Mahimaraja and Bolan (2000). The application of raw spent wash increased the Ca contents was also reported by Baskar *et al.*, (2003).

The increase in calcium in the Gypsum + GM applied treatments was mainly due to calcium ions from gypsum (CaSO₄.2H₂O). In addition, the solubilization of native calcium on decomposition of green manure incorporated in the fields also contributed Ca. The exchangeable Ca content was on par with DSW applied treatments due to high amounts of Ca present in gypsum. Application GLM also considerably increased the exchangeable calcium content. This might be due to the positive effect of organic substance on improving sodic soil. The release of CO₂ during the degradation process decreased the precipitation of Ca²⁺ and CO₃²⁻ ions in the CaCO₃ form (Sekhonand Bejawa, 1993). On the other hand, the organic acids released the Ca from CaCO₃.

Table.1 Influence of different amendments and nitrogen on physico-chemical properties of Sodic soil

	pH	EC (dSm ⁻¹)	Ca	Mg	K	Na	ESP (%)
			cmol(p ⁺)kg ⁻¹				
T1	10.2	0.74	6.24	4.83	0.08	5.12	31.8
T2	8.45	0.76	8.86	5.12	0.12	2.16	13.5
T3	9.25	0.75	7.1	5.24	0.12	4.01	24.2
T4	8.38	1.18	8.2	5.1	0.92	2.14	13.2
T5	10.1	0.76	6.45	4.84	0.09	5.21	30.8
T6	8.42	0.65	8.81	5.08	0.1	2.17	13.9
T7	9.21	0.78	7.12	5.21	0.12	4.15	24.5
T8	8.37	1.20	7.84	5.35	0.96	2.17	13.1
SE(d)	0.20	0.01	0.12	0.10	0.008	0.08	0.36
CD 5%	0.44	0.02	0.26	0.21	0.018	0.17	0.77

Table.2 Correlation between different physico-chemical properties of sodic soil

	pH	Exch. Na	Exch. Ca	Exch. Mg	ESP (%)
		cmol(p ⁺)kg ⁻¹			
pH	1				
Exchangeable Na	0.96*	1			
Exchangeable Ca	-0.92*	-0.94*	1		
Exchangeable Mg	-0.75	-0.61	0.47	1	
ESP	0.96*	1.00	-0.94*	-0.62	1

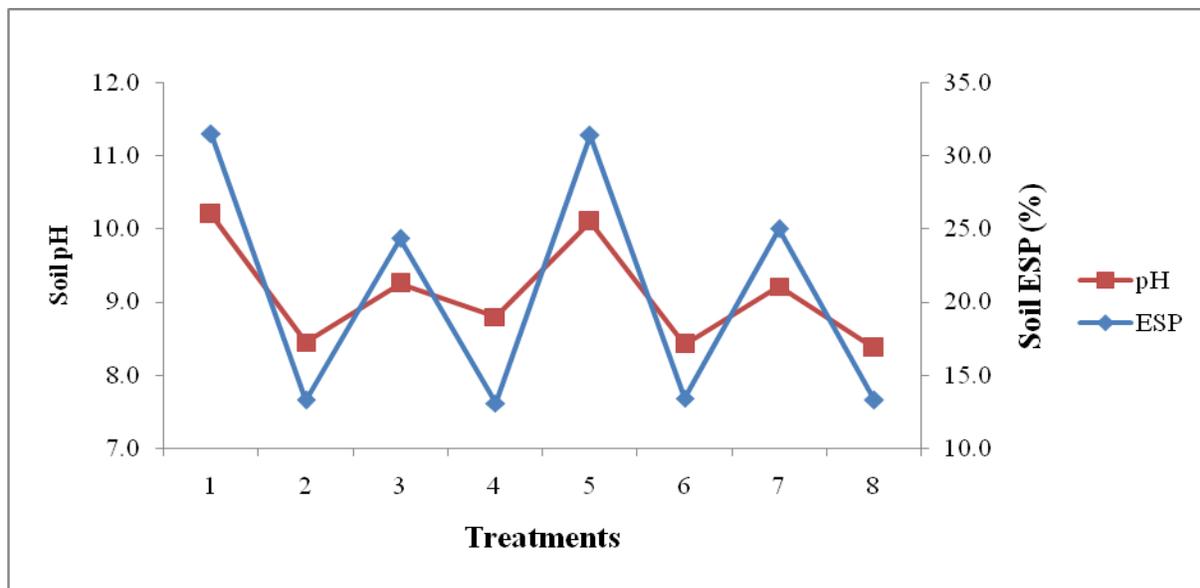
Table.3 Influence of different amendments and nitrogen on microbial population of sodic soil

	Bacteria (× 10 ⁵ CFU g ⁻¹ of soil)	Fungi (× 10 ² CFU g ⁻¹ of soil)	Actinomycetes (× 10 ³ CFU g ⁻¹ of soil)
T1	12.4	2.8	1.2
T2	13.8	3.4	1.8
T3	15.2	3.9	2.4
T4	16.3	4.4	2.9
T5	12.9	2.9	1.4
T6	14.2	3.7	2.3
T7	15.6	4.2	2.9
T8	16.8	4.7	3.2
SE(d)	0.27	0.07	0.05
CD 5%	0.57	0.16	0.11

Table.4 Influence of different amendments and nitrogen on soil enzyme activities of sodic soil

	Dehydrogenase ($\mu\text{g TPF g}^{-1}\text{hr}^{-1}$)	Urease ($\mu\text{g NH}_4\text{-N g}^{-1}\text{hr}^{-1}$)	Phosphates ($\mu\text{g nitrophenol g}^{-1}\text{hr}^{-1}$)
T1	1.12	1.36	4.14
T2	1.46	1.59	5.1
T3	1.54	1.95	6.21
T4	1.59	2.01	6.75
T5	1.16	1.39	4.31
T6	1.51	1.65	5.48
T7	1.58	1.98	6.35
T8	1.61	2.18	6.81
SE(d)	0.03	0.03	0.13
CD 5%	0.07	0.07	0.28

Fig.1 Interaction between soil pH and ESP as influenced by different amendments and levels of N application



Exchangeable Magnesium

A significant increase in the exchangeable Mg content of the incubated soil after 60th day was enrolled on application of amendments. Increase in exchangeable Mg content ($5.35 \text{ cmol (p+) kg}^{-1}$) after application of distillery spent wash (Table 1) was attributed to direct contribution and also due to the solubilization of small quantity of dolomitic lime which have released Ca + Mg in free ionic forms

that might have also contributed for increased Mg on exchange sites. This was in line with Mahimaraja and Bolan (2000) and Baskar *et al.*, (2003). The increase in Ca and Mg in the Gypsum + GM applied treatments was mainly due to reduction in pH of soil and solubilization of native calcium and magnesium ions on decomposition of green manure incorporated in the fields. The tendency of the DSW to increase the exchangeable Ca and Mg was also reported

by Cepro and Machado (1987) and Thitakamol and Kaewpinthong (2007).

Exchangable potassium

The exchangeable potassium (K) content of the incubated soil at 60th day ranged from 0.08 to 0.96 cmol (p+)kg⁻¹ (Table 1). The influence of amendments significantly maximized the exchangeable K content of the soil. Among the different amendments, DSW @5 lakh liters ha⁻¹+ Nitrogen @ 75 kg ha⁻¹ showed highest exchangeable K content of 0.96cmol (p+)kg⁻¹ followed by 0.92 cmol(p+)kg⁻¹ (Table 1) in DSW@ 5lakh liters ha⁻¹, 0.12 cmol(p+)kg⁻¹ in gypsum + green manure @ 6.25 t ha⁻¹ and green leaf manure @ 12.5 t ha⁻¹ application and lowest value of 0.08cmol(p+)kg⁻¹ was registered in the control. In DSW applied treatments, the quantity of increase in exchangeable K was higher due to enormous supply of K from DSW. In Gypsum and GM incubated soil exchangeable K increased due to replacement of Na (Abdel Fattah, 2012). The GM and GLM also contributes considerable amount of K to the soil since it contains a good amount of K (1.8%).

Exchangable Sodium

The data on the exchangeable sodium (Na) content showed that the values ranged between 2.14 and 5.21cmol (p+)kg⁻¹ (Table 1). The application of amendments showed a highly significant decline in the exchangeable Na content of soil. The lowest exchangeable Na content of 2.14cmol (p+)kg⁻¹ and highest exchangeable Na content of 5.21cmol (p+) kg⁻¹ (Table 1) was observed in DSW and the N application without amendments respectively

The greatest decrease in exchangeable Na in DSW applied treatments was because of greater solubilization of free lime by the

acidic nature of raw spent wash that released adequate Ca which is sufficient enough to replace exchangeable Na. Similar observation was also reported by Mohammed Harron and Subash Chandra Bose (2004) for calcareous soils in Tamil Nadu.

In Gypsum + GM applied treatments, the reduction in exchangeable Na was attributed to replacement of exchangeable Na by Ca present in gypsum and dissolution of free lime on decomposition of GM applied along with gypsum. The present findings are in agreement with the findings of Moustafa (2005). In GLM applied treatments also exchangeable Na was reduced to considerable amount due to replacement by Ca released to the soil solution by the action of organic acids and also the direct contribution of Ca from organics. The exchangeable sodium and pH was highly correlated with the R² value of 0.96 (Table 2).

Exchangable sodium percentage

The relative amounts of exchangeable sodium in comparison with the total cations in the soil exchange complex are dependent on factors, such as type of minerals, concentration of electrolytes and status of soluble cations (Sehgal *et al.*, 1968). The exchangeable sodium percent of the incubated soils after 60th day were greatly reduced due to DSW application. The exchangeable sodium percentage decreased from the initial level of 31.8 to 13.2, 13.5 and 24.2 due to application of DSW, Gypsum + GM and GLM respectively. The highest ESP was observed in control and the lowest ESP percentage was observed in treatment DSW @5 lakh liters ha⁻¹ + Nitrogen @ 75 kg ha⁻¹ (T₈) (Fig. 1; Table 1). The decreased trends follows for the application of different amendments were DSW, Gypsum + Greenmanure and Greenleaf manure respectively. This might be due to increase in beneficial cations *viz.*, Ca, Mg and

K in exchangeable complex. The ESP and pH was positively correlated with the R^2 value of 0.96 (Table 2).

Effect on biological properties

Soil microbial population

Microbial activity had a direct impact on the plant nutrient availability as well as other properties related to soil productivity. The soil microbial population viz, bacteria, fungi, and actinomycetes were significantly improved due to application of different amendments. The bacterial population ranged between 12.4 and 16.8×10^5 CFU g^{-1} (Table 3) of soil. The highest bacterial population was observed in DSW @5 lakh liters ha^{-1} + Nitrogen @ 75 kg ha^{-1} (T_8). The lowest fungi population was observed in control (2.8×10^2 CFU g^{-1} of soil) and highest population of fungi was observed in the treatment which received DSW @5 lakh liters ha^{-1} + Nitrogen @ 75 kg ha^{-1} (T_8). The population of actinomycetes ranged from 1.2, to 3.2×10^3 CFU g^{-1} (Table 3) in control and DSW @5 lakh liters ha^{-1} + Nitrogen @ 75 kg ha^{-1} (T_8) respectively. Being rich in nutrients and organic material, particularly easily oxidizable and soluble organic carbon, the DSW might have favoured the proliferation of microbial population throughout the crop growth by the steady supply of nutrients and buildup of organic matter in soils. This was in line with the findings of Maheswari (2011).

Soil enzyme activities

Enzyme activity in soil is an indirect indication of the microbial activity, which is directly correlated with soil microbial population. Dehydrogenases are 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. Remarkable

improvement in the dehydrogenase activity was observed due to application of amendments. The activities of dehydrogenase enzyme varied between 1.12 and 1.61 μg TPF $g^{-1} hr^{-1}$, minimum (1.12 μg TPF $g^{-1} hr^{-1}$) (Table 4) being observed in control (T_1) and the maximum (1.61 μg TPF $g^{-1} hr^{-1}$) in soil with the application of DSW @5 lakh liters ha^{-1} + Nitrogen @ 75 kg ha^{-1} (T_8). Ramana *et al.*, (2002) also reported that the enzyme activities were increased due to the application of distillery effluent.

The enzyme urease was associated with N mineralization. Urease activity in the incubated soil ranged from 1.36 to 2.18 μg $NH_4-N g^{-1} hr^{-1}$ (Table 4). The treatment which received of DSW @5 lakh liters ha^{-1} + Nitrogen @ 75 kg ha^{-1} (T_8) recorded highest urease activity (2.18 μg $NH_4-N g^{-1} hr^{-1}$) (Table 4) followed by DSW@ 5lakh liters ha^{-1} (T_4). 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. The phosphatase activity ranged between 4.14 to 6.81 μg nitrophenol $g^{-1} hr^{-1}$. An increase in phosphatase activity was observed due to application of DSW @5 lakh liters ha^{-1} + Nitrogen @ 75 kg ha^{-1} (T_8).

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