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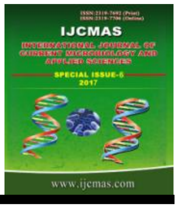

Original Research Article

Performance of Nano-Gypsum on Reclamation of Sodic Soil

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ABSTRACT

Keywords

Nano-gypsum, Reclamation, Sodic soil

Sodic soil collected from Anbil Dharmalingam Agricultural College and Research Institute (ADAC &RI), Navalur Kuttapattu, Tiruchirappalli district was remediated by nano-gypsum in comparison with conventional gypsum in the Department of Soil Science and Agricultural Chemistry, TNAU, Coimbatore. Nano-gypsum was synthesized and characterized in the Department of Nano Science and Technology, TNAU, Coimbatore. The green house experiment was laid out in a factorial completely randomized block design (FCRD) with two amendments *viz.*, nano-gypsum (NG) and conventional gypsum (CG) at four levels of Gypsum Requirement (GR) @ 25, 50, 75 and 100 % and control, replicated thrice. In the pot experiment, the experimental sodic soil was analysed for pH, EC, ESP, exchangeable Na^+, Ca^{2+}, Mg^{2+} and K^+ on reclamation, the pH of the soil reduced to 7.43 and ESP to 10.37 by 100 % GR as nano-gypsum from the unamended control soil and was significant and very effective over 100% GR as conventional gypsum.

Introduction

In India, out of 329 million hectares of total geographical area, the arid and semi-arid occupy more than one third of the area (127.4 m ha). The salt affected soils occurring in these zones occupy 12 m ha spread over 15 states of the country. These salt affected soil zones comprise of 4.12 m ha of alkali soil, 3.26 m ha of saline soil and 4.62 m ha of saline alkali soils. Among these salt affected soils, alkali soils are found to be highly problematic for crop production because of very poor physical and chemical environment particularly in irrigated areas. Sodicity problem in irrigated agriculture is becoming more and more serious because of poor quality water, lack of adequate knowledge about soils and poor management practices. The amelioration of these alkali soils is not only expensive but also time consuming and laborious (Gupta *et al.,* 1995). Traditionally, gypsum is recommended for the reclamation of sodic soils but ability to reclaim the soil depends on the quality (fineness and solubility) and quantity of gypsum used. With an idea to explore the possibilities of nanotechnology in soil reclamation and to improve the efficiency and economise the gypsum requirement, a maiden attempt was made to design nano-gypsum for soil reclamation.

Materials and Methods

Pot culture experiment

A pot culture experiment was conducted in the greenhouse of Department of Soil Science and Agricultural Chemistry, TNAU, Coimbatore during 2011-2012. The sodic soil of the experiment (Panjappur series (Typic Ustropept) was collected from AC&RI, Navalurkuttapattu, Trichy to evaluate the efficacy of the synthesised nano-gypsum and to study the relative performance with conventional gypsum with rice (Co 43 Variety) as test crop. The initial soil was analysed for the physico chemical properties and the GR was calculated. The two sources viz., nano-gypsum and conventional gypsum were evaluated at four levels and one control. The experiment was laid out in a Factorial Completely Randomised Design (FCRD) replicated thrice.

Reclamation of the experimental sodic soil

The experimental soil was collected from ADAC & RI, Tiruchirappalli and analysed for the initial physico chemical properties. The Gypsum requirement of the soil was found to be 12.66 tons ha^{-1} based on the ESP method (Das, 1996).

The sodic soil was processed, sieved with a 2mm sieve and uniformly and gently filled in pots of 5kg capacity. The amendments, nano-gypsum and conventional gypsum were added to the soil according to the GR to the respective treatments. The conventional gypsum used was the agricultural gypsum of 85% purity.

The soil in the pots were mixed well and impounded with water and incubated for 24 hrs and later the water was drained and the leachate was collected. This was repeated twice. To assess the efficacy of the reclamation properties if any, of nano-gypsum and to compare its efficiency with conventional gypsum, the leachate was collected and analysed for the exchangeable ions. To accomplish this, a known quantity of water (4L) was added every time and mixed thoroughly. Bulk soil samples were collected before and after with a stainless steel kurpi and shade dried, gently powdered with a wooden mallet, sieved through 2mm stainless steel sieve and stored in polythene bags to analyse the physical, chemical, and electrochemical properties as per the standard procedures.

Results and Discussion

Soil chemical analysis

Soil pH (Table 2)

The pH of the soil was analysed after reclamation with nano-gypsum (NG) and conventional gypsum (CG). There was a profound change in the soil pH with addition of nano-gypsum and conventional gypsum at varying levels of application based on gypsum requirement (GR). The pH values ranged from 9.38 in control to 7.43 in the 100% GR as nano-gypsum applied treatments. Among the two sources, nano-gypsum recorded a pH of 8.41 and was significant over that recorded in conventional gypsum (8.78) irrespective of the levels. Among the different levels tried, application of 100% GR reduced the pH to 7.80 followed by 75% (8.20) and then 50% (8.60) and the effect of different levels was significant. However the interaction between the levels and sources was non-significant. A significant reduction in pH by the application of 100% GR as nano-gypsum (7.43) was recorded over the other levels and conventional gypsum.

Soil EC (Table 1)

The EC of the soil was significantly reduced by the application of the amendments. The least value of EC was recorded in 100% GR as nano-gypsum (1.06 dSm^{-1}) followed by 100% GR as conventional gypsum (1.18 dSm^{-1}). The application of 75% GR as nano-gypsum (1.28 dSm^{-1}) was on par with 100 % conventional gypsum (1.18 dSm^{-1}) and 75% GR as conventional gypsum (1.39 dSm^{-1}) in reducing the EC. The significant effect of amendments and levels were observed.

Exchangeable sodium and Exchangeable Sodium Percentage (ESP) (Table 2)

Exchangeable sodium and exchangeable sodium percentage was significantly affected by the amendments. The exchangeable sodium was 9.32 C mol (p^{+}) kg^{-1} in control and ESP was 43.15. The exchangeable sodium levels declined to 2.24 C mol (p^{+}) kg^{-1} in 100 % GR as nano-gypsum followed by 3.18 C mol (p^{+}) kg^{-1} in 100% GR as conventional gypsum and 3.14 C mol (p^{+}) kg^{-1} in 75% GR as nano-gypsum.

The decline was significant over the control and other treatments. The application of 75 and 50% GR as conventional gypsum recorded exchangeable sodium of 4.63 and 6.20 C mol (p^{+}) kg^{-1} respectively. Among the two sources, nano-gypsum recorded the least exchangeable sodium of 5.43 C mol (p^{+}) kg^{-1} which was significant over the application of conventional gypsum [6.22 C mol (p^{+}) kg^{-1}]. Among the levels 100% nano-gypsum significantly reduced the exchangeable sodium to 2.71 C mol (p^{+}) kg^{-1} followed by 75 % [3.89 C mol (p^{+}) kg^{-1}].

The exchangeable sodium percentage being a measure of exchangeable sodium and CEC of the soil, a trend similar to that of exchangeable sodium was observed. The ESP significantly reduced to 12.55 in 100% GR irrespective of the sources compared to the initial ESP of 44.07. The significant role of nano-gypsum in reducing the ESP to 25.15 was also recorded, while ESP reduced to 28.80 in the conventional gypsum treatments. The interaction among the amendments and levels was significant in both exchangeable sodium and ESP. The least value of 10.37 of ESP was recorded in 100 % nano-gypsum. Application of 75% GR as nano-gypsum (14.54%) was on par with 100 % GR conventional gypsum (14.72%).

Exchangeable cations in the soil (Table 3)

The exchangeable Ca^{2+}, Mg^{2+} and K^{+} were analysed in the exchange complex to evaluate the extent of exchange of ions that has occurred during the reclamation process.

Exchangeable calcium (Ca^{2+})

The exchangeable Ca^{2+} was 4.93 C mol (p^{+}) kg^{-1} in control, while the exchangeable Ca^{2+} in the reclaimed soil increased up to 13.2 C mol (p^{+}) kg^{-1}. The highest was recorded in soil amendment with 100% GR as nano-gypsum [13.2 C mol (p^{+}) kg^{-1}]. This was significantly higher than 100% GR as conventional gypsum [11.1 C mol (p^{+}) kg^{-1}]. Application of nano-gypsum significantly increased the exchangeable Ca^{2+} [9.08 C mol (p^{+}) kg^{-1}] in the soil as against conventional gypsum [8.06 C mol (p^{+}) kg^{-1}]. Lower levels of exchange of Ca^{2+} were observed with reduction in the levels of amendments. The significant effect of amendments on the exchangeable Ca^{2+} was observed in the reclaimed soil.

Exchangeable magnesium (Mg^{2+})

There was no marked variation in the exchangeable Mg^{2+} of the soil due to amendments. However a significant decrease in Mg^{2+} from the control soil [2.48 C mol (p^{+}) kg^{-1}] was recorded. Among the amendments, conventional gypsum recorded significantly higher exchangeable Mg^{2+} of 2.38 C mol (p^{+}) kg^{-1} over nano-gypsum. Among the levels, 100%, 75% and 50% GR were on par.

Exchangeable potassium

The effect of amendments and their levels was non-significant with respect to exchangeable potassium of the reclaimed soil

Soil reaction

The pH of the initial soil was 9.40 and on reclamation with conventional gypsum (CG) and nano- gypsum (NG), the pH significantly reduced up to 7.43. The impact of amendments in decreasing soil pH significantly from the control could be observed at all levels of application. The role of $CaSO_4$ $2H_2O$ in submerged soil is well projected in this study, as there was replacement of Na^+ from the soil exchange complex by Ca^{2+} supplied by the amendments.

The significant reduction in pH due to nano-gypsum could be accounted to the finer particle size and larger surface area of nano-gypsum, which would have enhanced the dissolution of $CaSO_4$ $2H_2O$ in the submerged condition. Similar findings highlighting the reduction of soil pH due to application of conventional gypsum was also reported by Duraisamy *et al.,*(1986), Chauhan (1992), Patel and Suthar (1993) and Ilyas *et al.,* (1997). When the size of the substrate or the carrier gets reduced, surface area increased correspondingly, thereby nano-gypsum could have helped to exchange greater amounts of Na^+ in comparison to conventional gypsum. These processes may have resulted in significant reduction in pH.

Electrical conductivity

Decrease in EC from the initial value was registered by the application of conventional gypsum and nano-gypsum at all levels. The increased reduction in EC with increasing levels was clearly attributed to the removal of soluble salts during the reclamation process especially ponding and surface leaching. Sharma *et al.,* (1991) and Ilyas *et al.,* (1997) reported a similar change in EC. The marked effect of nano-gypsum in reducing the EC could also be observed in the present study. The reason similar to that of reduction of soil pH could be thought of for the reduction in EC.

Exchangeable sodium and Exchangeable Sodium Percentage (ESP)

The amelioration of sodic soil with gypsum and nano-gypsum reduced the Na^+ ion concentration in the exchange complex and thereby reduced the ESP significantly. The leachate contained higher concentration of Na^+ ions indicating the effective role of gypsum in replacing the Na^+ ions from the exchange complex. Irrespective of the sources, whether conventional gypsum or nanogypsum, the reclamative effect with the increasing levels of amendments was registered. This indicated that higher the quantity of Ca^{2+} supplied through the amendments, higher the replacement of Na^+ ions from the soil complex and resulting in reduction of exchangeable Na^+ and ESP. The decrease in sodium saturation of the soil clay micelle by the amendments could be mainly due to the increase in dissolution of gypsum and increasing the partial pressure of CO_2 in the soil (Chhabra and Abrol, 1977). The findings of Kumar and Singh (2003) corroborate the results of this study. They reported ESP below 15 in all the treatments with gypsum at different levels of GR and fly ash and the values were considerably less compared to initial ESP of the soil.

The prominent impact of nano-gypsum in reducing ESP could be attributed mainly to its greater surface area and high CEC. Ghafoor *et al.,* (2001) have reported the significant effect of fineness of gypsum. The higher the surface area, greater the dissolution and can reclaim soils effectively.

There was a reduction in ESP to the level of 75 per cent in 100 % GR as nano- gypsum applied soil to 16 per cent in 25% GR as conventional gypsum owing to the incorporation of amendments. Plethora of evidences is available in the literatures with respect to the effect of amendments in reclaiming sodic soil (Channal, 1992). However, application of 75% GR as nano-gypsum in the present study reduced the ESP to 66.30 per cent which was almost equal to the reduction caused by the application of 100% GR as conventional gyspum (65.88 %).

Nano-gypsum synthesized during the study is found to have a surface area of 900 m^2 g^{-1}, while the conventional montmorillionite clay has only 700-800 m^2 g^{-1} (Das, 1996), which makes nano-gypsum very unique with extensive adsorptive sites to retain Ca^{2+} and exchange Na^+ ions into the soil solution. Nano-gypsum is fairly recent and no published data are available to judge the mechanism associated with the ameliorative properties. Our data clearly suggest that the nano-gypsum possess extensive surface area to exchange adsorbed ions, thereby it improves the ameliorative properties of gypsum.

Exchangeable cations in the soil

The exchangeable cations *viz*., Ca^{2+}, Mg^{2+} and K^+ were estimated in the soil after reclamation. The results on the exchangeable cations in the soil after reclamation revealed the significant effect of both conventional gypsum and nano-gypsum in reclaiming the sodic soil.

The higher concentration of Ca^{2+} ions in the exchange complex proved the positive effect of nano-gypsum and conventional gypsum in the reclamation of sodic soil. However nano-gypsum treated soil has accumulated more Ca^{2+} in the exchange complex than conventional gypsum. The significant effect of nano-gypsum in replacing Na^+ from the complex over that of conventional gypsum could be attributed to the finer particle size, higher CEC and solubility of nano-gypsum. The exchangeable Ca^{2+} increased with increasing levels of gypsum irrespective of sources confirming its ameliorating property. Similar findings were also reported by Patel and Suthar (1993) and Ilyas *et al.*, (1997). The increase in the concentration of Ca^{2+} in the exchange sites with the increasing levels of amendments applied indicated that, higher the quantity of Ca^{2+} supplied as $CaSO_4.2H_2O$, higher the replacing power and reclamation.

With respect to Mg^{2+} ions, though there was no distinct variation among the treatments, a significant increase over the control was registered, which might be due to replacement of Mg^{2+} from the exchange sites. In general, a drastic change could not be recorded as no magnesium source was added.

A marginal but non-significant decrease in exchangeable K^+ was recorded which might be due to the reason that Ca^{2+} would have occupied the exchange sites of K^+ in the soil during the reclamation process.

Soil pH was reduced by both the sources of amendments *viz.*, conventional gypsum (CG) and nano-gypsum (NG). Nano-gypsum applied @ 100% GR reduced the pH from 9.38 in the unamended soil to 7.43 and was significant over 100% GR as conventional gypsum (8.16). Progressive reduction in pH was recorded with the gradation in levels of

GR applied. Nano-gypsum @ 75% GR (7.92) was also comparable with conventional gypsum @ 100% GR (8.16). The EC of the soil was significantly reduced by nano-gypsum and conventional gypsum. The lowest EC of 1.06 dSm^{-1} was recorded in 100% GR as nano-gypsum, while the unamended control recorded EC to the tune of 1.94 dSm^{-1}. Nano-gypsum @ 75% GR was on par with conventional gypsum @ 100% GR in reducing the EC of the sodic soil during reclamation. A promiscuous decline in exchangeable sodium to 2.24 C mol (p$^+$) kg^{-1} was achieved with the application of 100% GR as nano-gypsum and the corresponding ESP was 10.37, recording a 75% decrease in ESP. The nano-gypsum @ 75% GR was on par with 100% GR as conventional gypsum in reducing the exchangeable Na$^+$ in the clay micelle thereby the ESP of the sodic soils indicating the effectiveness of the reclamation by nano-gypsum @75% GR for this test soil.

Table.1 Nano-gypsum /Conventional gypsum on soil pH and EC (dSm^{-1})

Treatments	pH			EC (dSm^{-1})		
	NG	CG	Mean	NG	CG	Mean
Control	9.38	9.38	**9.38**	1.94	1.94	**1.94**
25% GR	8.89	9.09	**8.99**	1.72	1.74	**1.73**
50% GR	8.41	8.78	**8.60**	1.50	1.53	**1.52**
75% GR	7.92	8.47	**8.20**	1.28	1.39	**1.34**
100% GR	7.43	8.16	**7.80**	1.06	1.18	**1.12**
Mean	**8.41**	**8.78**	**8.59**	**1.50**	**1.56**	**1.53**
	A	**L**	**A×L**	**A**	**L**	**A×L**
SEd	0.06	0.10	0.13	0.02	0.03	0.04
CD (P=0.05)	0.12	0.205	NS	0.04	0.06	NS

Table.8 Nano-gypsum /conventional gypsum on exchangeable Na [C mol (p$^+$) kg^{-1}] and ESP (%)

Treatments	Na(C mol (p$^+$) kg^{-1})			ESP (%)		
	NG	CG	Mean	NG	CG	Mean
Control	9.32	9.32	**9.32**	43.15	43.15	**43.15**
25% GR	7.26	7.77	**7.52**	33.61	35.97	**34.79**
50% GR	5.20	6.20	**5.70**	24.07	28.70	**26.39**
75% GR	3.14	4.63	**3.89**	14.54	21.44	**17.99**
100% GR	2.24	3.18	**2.71**	10.37	14.72	**12.55**
Mean	**5. 43**	**6. 22**	**5. 83**	**25. 15**	**28. 80**	**26. 97**
	A	**L**	**A×L**	**A**	**L**	**A×L**
SEd	0.07	0.12	0.16	0.34	0.54	0.77
CD (P=0.05)	0.15	0.24	0.34	0.72	1.14	1.61

Table.3 Nano-gypsum /Conventional gypsum on Exchangeable Cations [C mol (p^+) kg^{-1}]

Treatments	**Ca^{2+}**			**Mg^{2+}**			**K^+**		
	NG	**CG**	**Mean**	**NG**	**CG**	**Mean**	**NG**	**CG**	**Mean**
Control	4.93	4.93	**4.93**	2.48	2.48	**2.48**	4.51	4.51	**4.51**
25% GR	7.03	6.52	**6.78**	2.40	2.42	**2.41**	4.45	4.47	**4.46**
50% GR	9.09	8.09	**8.59**	2.31	2.37	**2.34**	4.41	4.44	**4.43**
75% GR	11.2	9.66	**10.4**	2.28	2.32	**2.30**	4.38	4.42	**4.40**
100% GR	13.2	11.1	**12.2**	2.21	2.29	**2.25**	4.33	4.40	**4.37**
Mean	**9.08**	**8.06**	**8.57**	**2.34**	**2.38**	**2.36**	**4.42**	**4.45**	**4.43**
	A	**L**	**A×L**	**A**	**L**	**A×L**	**A**	**L**	**A×L**
SEd	0.09	0.14	0.19	0.02	0.04	0.05	0.05	0.07	0.10
CD (P=0.05)	0.19	0.29	0.41	NS	0.08	NS	NS	NS	NS

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