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Proceeding Paper

Changes in Soil Physico-Chemical Properties and Seedling Growth of Green Gram (*Vigna radiata* L.) under Sodic Soil as Affected by Soil Amendments: An Incubation Study †

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Abstract: The salinization and sodification of agricultural lands in arid and semi-arid regions of the world are two limiting factors in crop production. In India, an area of about 6.72 million ha is salt-affected, of which 3.77 million ha is sodic soil. To evaluate the reclamation potential of soil amendment, a laboratory incubation study was conducted at the Agricultural College and Research Institute, Tiruchirappalli (2022). Different soil amendments, viz., T_1-Pongamia GLM @ 6.25 t ha^{-1}, T_2-Pressmud @ 10 t ha^{-1}, T_3-CSR GROMOR 25 kg ha^{-1}, T_4-Marine gypsum 50% GR, T_5-Marine gypsum @ 50% GR + Pongamia GLM 6.25 t ha^{-1}, T_6-Marine gypsum 50% GR + Pressmud 10 t ha^{-1}, T_7-Marine gypsum 50% GR + CSR GROMOR 25 kg ha^{-1} and T_8-Control (no amendments), were used for incubation. After 90 days of incubation, a pot culture using post-incubated soil was raised to study the seedling parameters of green gram, which was laid out in a randomized block design with three replications. The analysis of post-incubated soil using ICP-MS shows higher levels of cations, viz., Ca (+67%), Mg (+65%) and K (+66%), were found in marine gypsum @ 50% GR + CSR GROMOR @ 25 kg ha^{-1} with lower values of pH (−15%), EC (−63%), ESP (−39%) and Na (−58%) compared to the control. The same treatment recorded higher chlorophyll, relative water content and seedling vigor index I and II in green gram. The results indicated that marine gypsum + CSR GROMOR had a positive impact on reducing soil sodicity and improving soil fertility.

Keywords: laboratory incubation; soil amendments; soluble cations; seedling parameters

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1. Introduction

Increases in soil salinity and alkalinity are due to poor management and intensified land use, both of which contribute to the loss of soil fertility. In India, about 6.72 million ha, which is around 2.1% of the country's geographical area, is affected by salt, of which 2.95 million ha is saline and 3.77 million ha is sodic. In the study area, the sodic soil of the Manikandam block of Trichy district accounts for around 18,115 ha which is 29% of the district's total area [1]. Salt stress causes a significant reduction in green gram development. Sodicity, also called alkali soil and solonetz, is characterized by high pH (>8.2) and high ESP (>15) with EC typically measuring 4 dS m^{-1}, leading to low biological activity, poor physical characteristics and nutrient deficiencies. Soil dispersion and clay platelet and aggregate swelling are the key physical processes linked to high sodium concentrations. When there are too many large sodium ions between clay particles, the forces that bind them together are disrupted. When clay particles separate, they expand, creating swelling and soil dispersion. Clay particles fill soil pores as a result of soil dispersion, reducing soil permeability. When clay dispersion develops as a result of repeated wetting and drying, the soil recovers and solidifies into an almost cement-like soil with little or no structure.

Gypsum is the most often-used amendment for sodic soil reclamation. Due to its limited solubility, increasing the efficacy of applied gypsum in the absence of adequate moisture, whether from irrigation or rainfall, is a difficult task. The addition of organic sources performs a dual role in these situations, enhancing gypsum solubility and thereby helping to improve the soil's physico-chemical characteristics. Also, organic amendments provide a good substrate for microorganisms and help to maintain a healthy nutritional balance in the soil ecosystem [2]. It is a good source of organic manure, and it can be used as an alternate source of plant nutrients and act as a soil ameliorate. The appropriate inoculation of beneficial microorganisms increased nutrient mineralization, decomposition, residue nutrient cycling and the generation of bioactive components, all of which stimulate plant development, boosting nutrient intake and crop yield. A microbial culture of CSR CROMOR coupled with gypsum as a soil application and foliar spray improved water absorption, nutritional uptake and crop yield [3]. Under laboratory incubation conditions, organic amendments were mixed with sodic soil and a number of chemical parameters were analyzed to understand the processes that occur throughout time.

2. Materials and Methods

Soil samples for incubation were collected from Poongudi village, Tiruchirapalli. The experimental sites are situated at 10°74′ N latitude and 78°61′ E longitude, 85 m above MSL, and are a part of the Cauvery delta zone of Tamil Nadu. Different soil amendments, viz., T_1-Pongamia GLM @ 6.25 t ha^{-1}, T_2-Pressmud @ 10 t ha^{-1}, T_3-CSR GROMOR 25 kg ha^{-1}, T_4-Marine gypsum 50% GR, T_5-Marine gypsum @ 50 % GR + Pongamia GLM 6.25 t ha^{-1}, T_6-Marine gypsum 50% GR + Pressmud 10 t ha^{-1}, T_7-Marine gypsum 50% GR + CSR GROMOR 25 kg ha^{-1} and T_8-Control (No amendments) were used for incubation. After 90 days of incubation, a pot culture using post-incubated soil was raised to study the seedling parameters of green gram VBN (Gg), 5 of which were laid out in a randomized block design with three replications.

2.1. Soil Sampling and Preparation

A representative composite surface soil sample (0–15 cm) was collected from the experimental site before the commencement of the experiment for initial soil properties. Collected soil samples were brought to the laboratory and spread on a polythene sheet and kept for one day for air drying. In order to minimize soil heterogeneity, the samples were mixed thoroughly and sieved through a 2 mm sieve. The initial elemental analysis of soil and amendments were carried out via Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Soil samples were taken in a plastic air-tight container. Soil amendments were oven-dried at 70 °C, crushed and passed through a 2 mm sieve. The amendments were separately added to six soil samples and then thoroughly mixed. One control soil sample (with no amendment) and seven treated soil samples were placed in polyethylene containers in duplicate as initial samples (i.e., 16 samples) and incubated for 90 days at the field capacity moisture and room temperature (25 ± 1 °C).

2.2. Exchangeable Sodium Percentage (ESP)

ESP is the amount of adsorbed Na^+ on the soil exchange complex to the CEC of soil. ESP was computed from the derived parameters in the equation suggested by [4]:

$$\text{ESP } (\%) = \frac{\text{Exchangeable sodium}}{\text{Cation exchange capacity}} \times 100$$

where CEC is considered as the sum of exchangeable K^+, Ca^{2+}, Mg^{2+} and Na^+, as they were dominant at the exchangeable sites and expressed in meq 100^{-1} g of soil.

2.3. Seedling Vigor Indices

The vigor indices were calculated using the following procedure suggested by [5] and expressed in whole numbers.

Seedling Vigor I = Total seedling length (cm) × Germination (%)

Seedling Vigor II = Dry matter production (gram/10 seedlings) × Germination (%)

2.4. Relative Water Content

The relative water content was estimated using the method suggested by [6]. The relative water content (RWC) of seedlings was calculated using the following formula and expressed in %.

$$\text{RWC }(\%) = \frac{\text{Seedling fresh weight } - \text{ Seedling dry weight}}{\text{Seedling turgid weight } - \text{ Seedling dry weight}} \times 100$$

The data were collected from three replications and were statistically analyzed using an analysis of variance (ANOVA). For substantial treatment differences, a critical difference was calculated at a five-per-cent probability level and values were provided.

3. Results

Among different soil amendments, marine gypsum @ 50% GR + CSR GROMOR @ 25 kg ha^{-1} (T_7) and marine gypsum @ 50% GR + pressmud @ 10 t ha^{-1} (T_6) comparably reduced the pH value (7.59 and 7.82) in incubated soil over the control (T_8) (9.28), which is presented in Figure 1. With regard to EC and ESP, a higher reduction in EC (0.29 and 0.31 dS m^{-1}) and ESP (6.96 and 7.65%) was observed in marine gypsum @ 50% GR + CSR GROMOR @ 25 kg ha^{-1} (T_7), followed by marine gypsum @ 50% GR + pressmud @ 10 t ha^{-1} (T_6) over the control (T_8), which recorded the highest EC and ESP of 4.67 dS m^{-1} and 37.73%.

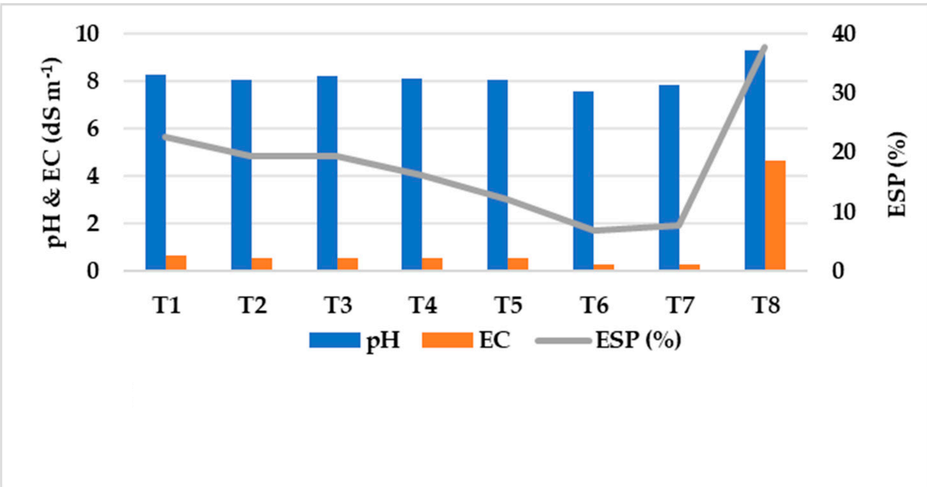

Figure 1. Effect of soil amendments on physico-chemical properties of incubated soil.

Figure 2 shows the effect of soil amendments on soluble cations. With respect to soluble cations, higher Ca, Mg and K content of 42.98, 9.11 and 1.05 meq 100 g^{-1} was found in marine gypsum @ 50% GR + CSR GROMOR @ 25 kg ha^{-1} (T_7), followed by marine gypsum @ 50% GR + pressmud @ 10 t ha^{-1} (T_6) (40.78, 8.48 and 1.01 meq 100 g^{-1}) with lower values of Na content (3.29 and 3.45 meq 100 g^{-1}) compared to the control (T8), which recorded lower values of Ca, Mg and K (13.35, 2.93 and 0.34 meq 100 g^{-1}) with a higher Na content of 8.31 meq 100 g^{-1}.

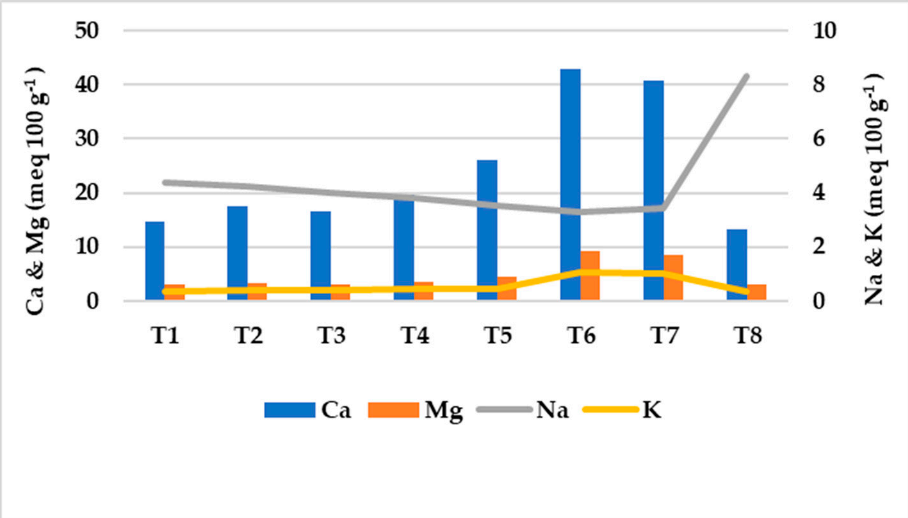

Figure 2. Effect of soil amendments on soluble cations of incubated soil.

With regard to the seedling parameters in Figure 3, the mean performance of the SPAD value (45.21 and 4.37), RWC (93.75 and 91.25%) and seedling vigor index I (3369 and 3224) and seedling vigor index II (52.70 and 52.57) was maximized in marine gypsum @ 50% GR + CSR GROMOR @ 25 kg ha^{-1} (T_7) and marine gypsum @ 50% GR + pressmud @ 10 t ha^{-1} (T_6) over the control (T_8), which recorded a lower SPAD value (28.52), RWC (80.12%) and seedling vigor index I and II (1777 and 26.94).

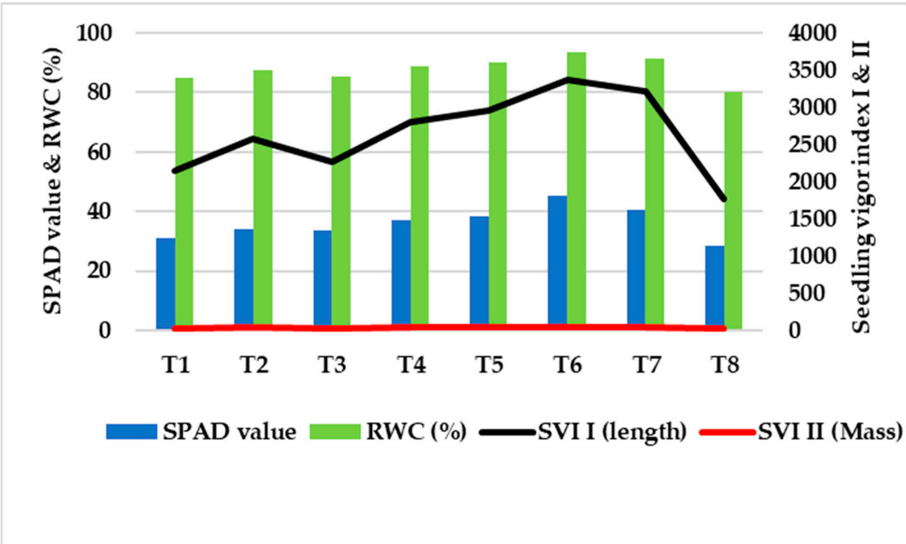

Figure 3. Effect of soil amendments on seeding growth of green gram.

4. Discussion

High pH denotes the dominance of sodium among the cations and carbonates/ bicarbonates among the anions. Among different soil amendments, marine gypsum @ 50% GR + CSR GROMOR @ 25 kg ha^{-1} significantly reduced the pH value over the control. The application of marine gypsum decreased soil pH, increased ionic activity in the soil solution and decreased the uptake of Na by plants. These findings were also reported by [7,8]. It was followed by marine gypsum @ 50% GR + pressmud @ 10 t ha^{-1}. The results were in agreement with the experiment conducted by [9] in saline soil and in calcareous saline–sodic soil by [10], which might be explained by the acidic nature of the amendments and to the acidifying effect of organic acids and H+ produced from the decomposition of the amendment.

The electrical conductivity of the soil extract indicates the concentration of soluble salts in the soil solution. A significant effect was found on soil electrical conductivity due to various soil amendments. Marine gypsum @ 50% GR + CSR GROMOR @ 25 kg ha^{-1} followed by marine gypsum @ 50% GR + pressmud @ 10 t ha^{-1} markedly reduced the soil electrical conductivity. The EC values of post-harvest soil samples were decreased with the application of bio compost [11].

The application of different soil amendments shows variations in ESP in all the treatments. Marine gypsum @ 50% GR + CSR GROMOR @ 25 kg ha^{-1} significantly registered the lowest soil ESP, followed by marine gypsum @ 50% GR + pressmud @ 10 t ha^{-1}. Organic amendments led to the production of organic acids that help in dissolving native $CaCO_3$, resulting in the faster removal of exchangeable sodium and the acceleration of the reclamation of calcareous sodic soil [12,13]. The maximum soil ESP was recorded in the control. Apart from gypsum, all the amendments had appreciable quantities of Ca, Mg and K. During mineralization, amendments may release cations to the soil. An increase in exchangeable cations through the application of pressmud was reported by [14].

Among the application of different soil amendments, the seedling characters, viz., SPAD value, RWC and seedling vigour index, were maximized in marine gypsum @ 50% GR + CSR GROMOR @ 25 kg ha^{-1}, which was on par with marine gypsum @ 50% GR + pressmud @ 10 t ha^{-1}. Such an enhancement might be due to the ability of bacteria to fix nitrogen, solubilize phosphate and produce growth regulators [15]. It is suggested that a decrease in seed germination and a depression in seedling vigor under saline stress is attributed to decreased water uptake, followed by the limited hydrolysis of food reserves from storage tissues as well as the impaired translocation of food reserves from storage tissue to the developing embryo axis [16].

5. Conclusions

From the above study, it is concluded that the application of marine gypsum @ 50% GR + CSR GROMOR @ 25 kg ha^{-1} had a positive impact on reducing soil sodicity and improving soil fertility and the productivity of green gram.

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