biology and life sciences forum

MDPI

Proceedings

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†

Mohanapriya R [1]*, Kalpana R [2] and Vijay Aravinth K [3]

[1] School of Agricultural Sciences, Karunya Institute of Technology and Sciences, Coimbatore, India- 641 114
[2] SRS Institute of Technology & Sciences, Dindigul, India – 624 710
[3] Tamil Nadu Agricultural University, Coimbatore, India- 641 003
* Correspondence e-mail ID: vjpriya1995@gmail.com.
† Place: Coimbatore; Date: 24.09.2023.

Abstract: Salinization and sodification of agricultural lands in arid and semi-arid regions of the world are two limiting factors in the crop production. In India, about 6.72 million ha area is salt affected of which 3.77 million ha is sodic soil. To evaluate the reclamation potential of soil amendments, laboratory incubation study was conducted at 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, pot culture using post-incubated soil was raised to study the seedling parameters of green gram which was laid out in randomized block design with three replications. Analysis of post-incubated soil using ICP-MS shows, higher cations *viz.*, Ca (+67%), Mg (+65%) and K (+66%) was 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 control. The same treatment recorded higher chlorophyll, relative water content and seedling vigour index I & II of 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 and Seedling parameters

1. Introduction

The increase in soil salinity and alkalinity is 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 as alkali soils and solonetz is characterized by high pH (>8.2) and high ESP (>15) with EC typically 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

Citation:

Academic Editor(s): Name

Published: date

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. Addition of organic sources performs a dual role in these situations, enhancing gypsum solubility there by helping to improve the soil physico-chemical characteristics. Also, organic amendments provide a good substrate for microorganism 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 nutrient and act as a soil ameliorates. Appropriate inoculation of beneficial microorganisms increased nutrient mineralization, decomposition, residue nutrient cycling and generation of bioactive components, all of which stimulate plant development, boost nutrient intake and crop yield. 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 condition organic amendments are mixed with sodic soil and a number of chemical parameters were analysed to understand the processes that occur throughout time.

2. Materials and Methods

Soil sample for incubation were collected from Poongudi village, Tiruchirapalli. The experimental sites are situated at 10º74′ N latitude and 78º61′ E longitude, 85 m above MSL and is a part of 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, pot culture using post-incubated soil was raised to study the seedling parameters of green gram VBN (Gg) 5 which was laid out in randomized block design with three replications.

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 2 mm sieve. Initial elemental analysis of soil and amendments were analysed in Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Soil samples was 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).

Exchangeable sodium percentage (ESP)

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

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

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.

Seedling Vigor Indices

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

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

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

Relative water content

The relative water content was estimated by the method suggested by [5]. The relative water content (RWC) of seedling was calculated by the following formula and expressed in %.

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

The data were collected from three replications are statistically analyzed by using of 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 control (T_8) (9.28) which was presented in Figure 1. With regard to EC and ESP, higher reduction of 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 control (T_8) which recorded highest EC and ESP of 4.67 dS m^{-1} and 37.73%.

Figure 2 shows effect of soil amendments on soluble cations. With respect to soluble cations, higher Ca, Mg and K content of 42.98, 9.11 & 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 & 1.01 meq 100 g^{-1}) with lower values of Na content (3.29 & 3.45 meq 100 g^{-1}) compared to control (T8) recorded lower values of Ca, Mg & K (13.35, 2.93 & 0.34 meq 100 g^{-1}) with higher Na content of 8.31 meq 100 g^{-1}.

With regards to seedling parameters in Figure 3, the mean performance of SPAD value (45.21 & 4.37), RWC (93.75 & 91.25%) and seedling vigour index I (3369 & 3224) and seedling vigour index II (52.70 and 52.57) was maximum 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 control (T_8) which recorded lower SPAD value (28.52), RWC (80.12%) and seedling vigor index I & II (1777 & 26.94).

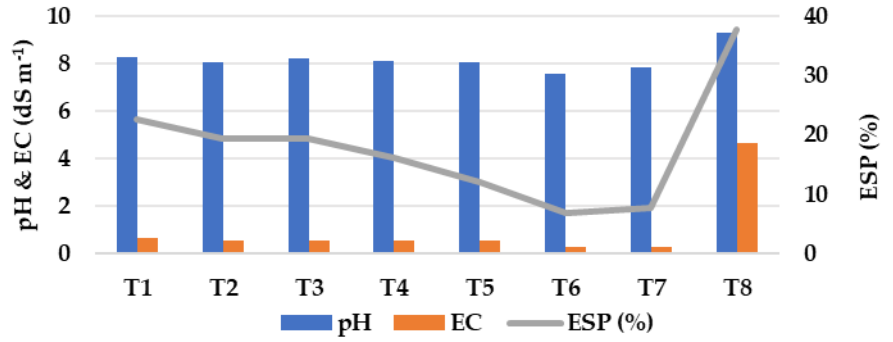

Figure 1. Effect of soil amendments on physico-chemical properties of incubated soil

.

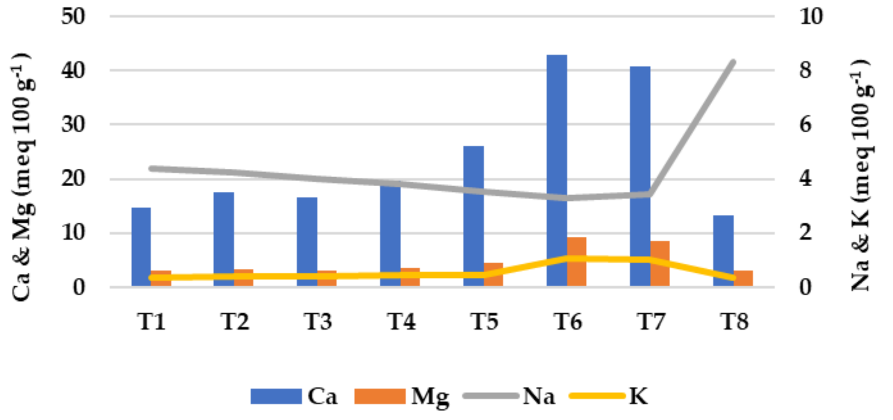

Figure 2. Effect of soil amendments on soluble cations of incubated soil

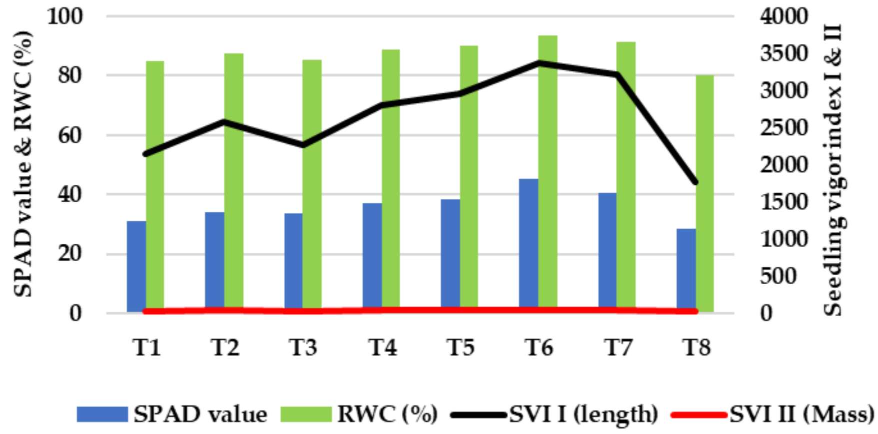

Figure 3. Effect of soil amendments on seedling growth of green gram

4. Discussion

High pH denotes the dominance of sodium among the cations and carbonates/ bicarbonates from anions. Among different soil amendments, marine gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} significantly reduced the pH value over control. 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] and [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.

Electrical conductivity of the soil extract indicates concentration of soluble salts in the soil solution. 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. Decrease in the EC values of post harvest soil samples with the application of bio compost [11].

The application of different soil amendments noticed variations in ESP in all the treatments. Marine gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} significantly registered lowest soil ESP followed by marine gypsum @ 50 % GR + pressmud @ 10 t ha^{-1}. Organic amendments led to production of organic acids that helps in dissolving native $CaCO_3$, resulting in the faster removal of exchangeable sodium and acceleration of the reclamation of calcareous sodic soil [12] and [13]. The higher soil ESP was recorded in control. Apart from gypsum all the amendments had appreciable quantities of the Ca, Mg and K. During the mineralization, amendments may release the cations to the soil. Increase in exchangeable cations by 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 was maximum 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 the phosphate and produce growth regulators [15]. It is suggested that decrease in seed germination and depression in seedling vigour under saline stress is attributed to decreased water uptake followed by limited hydrolysis of food reserves from storage tissues as well as due to impaired translocation of food reserves from storage tissue to developing embryo axis [16].

5. Conclusion

From the above study, it is concluded that 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 productivity of green gram.

Author Contributions: Conceptualization, Dr. R. Kalpana; methodology, Dr. A. Alagesan; software, writing—review and editing, Dr. K. Vijay Aravinth; validation, formal analysis, Dr. R. Mohanapriya.

Funding: This research received no external funding.

Acknowledgments: The authors are grateful to the Chairperson, Members of the advisory Committee and Tamil Nadu Agricultural University, Coimbatore for allowing them to perform the field experiment.

Conflicts of Interest: There is no conflict of interest.

References

1. Kumar, P.; Sharma, PK. Soil salinity and food security in India. *Frontiers in Sustainable Food Systems*, 2020, 4, 533-781.
2. Fujii, S.; Saka, H. Distribution of assimilates to each organ in rice plants exposed to a low temperature at the ripening stage, and the effect of brassinolide on the distribution. *Plant production science*, 2001, 4 (2),136-144.
3. Chatterjee, R.; Jana, J.; Paul, P. Enhancement of head yield and quality of cabbage (*Brassica oleracea*) by combining different sources of nutrients. *Indian Journal of Agricultural Sciences*, 2012, 82 (4), 324-328.
4. Miller, RW.; Gardiner, DT.; Miller, JU. *Soils in our environment*, 1958.
5. Abdul Baki, Aref, A.; James D Anderson. Vigor determination in soybean seed by multiple criteria. *Crop science*, 1973, 13 (6), 630-633.
6. Barrs, HD.; Weatherley, PE. A re-examination of the relative turgidity technique for estimating water deficits in leaves. *Australian journal of biological sciences*, 1962, 15 (3), 413-428.
7. Kaya, C.; Kirnak, H.; Higgs, D. Enhancement of growth and normal growth parameters by foliar application of potassium and phosphorus in tomato cultivars grown at high (NaCl) salinity. *Journal of Plant Nutrition*, 2001, 24 (2), 357-367.
8. Netwal, M.; Choudhary, M.; Jakhar, R.; Devi, S.; Choudhary, S. Exogenous application of Brassinoide and salicylic acid enhances on growth, yield and nutritional quality of Indian bean (*Lablab purpureus* L. var. *typicus*). *Journal of Pharmacognosy and Phytochemistry*, 2018, 7 (6), 2093-2096.
9. Oo, A.; Iwai, C.; Saenjan, P. Soil properties and maize growth in saline and non-saline soils using cassava-industrial waste compost and vermicompost with or without earthworms. *Land Degradation and Development*, 2015, 26 (3), 300-310.

10. Negim, O. Effect of addition pressmud and gypsum by product to reclamation of highly calcareous saline sodic soil. *American Association for Science and Technology*. 2015, 1, 76-84.
11. Sundhari, T.; Thilagavathi, T.; Baskar, M.; Thamarai Thuvasan, Eazhilkrishna, N. Effect of gypsum incubated organics used as an amendment for sodic soil in green gram. *International Journal of Chemical Studies*, 2018, 6,304-308.
12. Mubarak, A.; Nortcliff, S. Calcium carbonate solubilization through H-proton release from some legumes grown in calcareous saline-sodic soils. *Land Degradation and Development,* 2010, 21 (1), 24-31.
13. Qadir, M.; Oster, J.; Schubert, S.; Noble, A.; Sahrawat, K. Phytoremediation of sodic and saline-sodic soils. *Advances in agronomy*, 2007, 96, 197-247.
14. Soundarrajan, M.; Anandakrishnan, B.; Dawood, M.; Jebaraj, S.; Pushpavalli, R. Integrated nutrient management with organic and inorganic fertilizers on productivity of sugarcane and its impact on soil properties of Typic haplustalf. *Sugar Tech,* 2007, 9 (2), 142-146.
15. Salantur, A.; Ozturk, A.; Akten, S. Growth and yield response of spring wheat (*Triticum aestivum* L.) to inoculation with rhizobacteria. *Plant Soil and Environment,* 2006, 52 (3),111.
16. Ghoulam, C.; Foursy, A.; Fares, K. Effects of salt stress on growth, inorganic ions and proline accumulation in relation to osmotic adjustment in five sugar beet cultivars. *Environmental and experimental Botany,* 2002, 47 (1), 39-50.