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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(7): 2233-2237

www.thepharmajournal.com
Received: 21-04-2023
Accepted: 26-05-2023

Elucidating potential application of organic manure in conjunction with gypsum for effective reclamation of salt affected soils

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Abstract
Abiotic constraints such as soil salinity are significant because they have a direct impact on crop yields, soil productivity, and soil quality. It is crucial to ensure that saline soils are used sustainably while keeping environmental integrity. Exploring and putting into practice strategies that can increase productivity without harming the ecology are crucial if we want to achieve this. In the present study, the effects of gypsum, vermicompost and simultaneous inoculation of two biomes (*Pseudomonas fluorescence* and *Trichoderma harzianum*) on soil parameters were examined. The combination of 65 percent GR + vermicompost @5t/ha and biome @2 kg/ha reduced pH (9.32 to 7.52), EC (3.65 to 1.76 dSm^{-1}), and SAR (24.22 to 6.45 Cmolc (+) kg^{-1}) the most of all the treatments.

Keywords: Biomes, gypsum, PGPR_plant growth promoting rhizobacteria, soil salinity, vermicompost

Introduction

The global salinity problem is spreading at an alarming rate. According to reports, high salt concentration affects around 7% of the planet's land and 20% of its arable land (Munns 2008) [21]. An estimate indicates that salinity and associated issues have varied degrees of impact on more than 1100 million hectares (M ha) of worldwide land area. Irrigated agriculture cannot endure indefinitely without sufficient drainage and salt balance, according to agricultural history. Salinity is to blame for the annual loss of billions of dollars' worth of crop yield. According to Rashid *et al.*, (2004) [32] and Ashraf *et al.*, (2002) [2], the soil solution of salty soils is made up of a variety of dissolved salts, each of which contributes to salinity stress. These salts include NaCl, Na_2SO_4, $MgSO_4$, $CaSO_4$, $MgCl_2$, KCl, and Na_2CO_3. Both salinization (high salt content) and alkalinization (high pH) lead to sodification (high ESP) of the soil because of the high solubility of Na+ salts in nature and the precipitation of calcium carbonate at high pH values, according to Porcel *et al.*, (2012) [22]. Crop yields are immediately impacted when an excessive amount of soluble salt is deposited on arable land. High salt intake prevents several physiological and metabolic functions of plants, even affecting their survival. Na^+ buildup in the soil reduces soil aeration, porosity, and water conductivity. Tsai and others (2012) [27].

Traditional techniques for reclaiming salty soil, such as scraping, flushing, leaching, or applying an amendment (such gypsum, $CaCl_2$, etc.), have a poor track record and negatively impact agro-ecosystems. Gypsum works well, but because of its poor solubility (0.2%), it takes a long time to recover sodic soils, and it must be applied repeatedly to keep the sodium content below a desirable level. These soils require expensive, time-consuming, and arduous amelioration. In this setting, establishing sustainable strategies for increasing saline soil production while minimising environmental impact is critical.

Chemical amendments can be substituted with and supplemented with organic additions like manure. When organic amendments are added to sodic soils, they bind small water-stable particles into big aggregates, increasing porosity and enhancing the soil's physical attributes (Srivastava *et al.*, 2016) [26]. By reducing the exchangeable Na^+ level and enhancing aggregate stability, fertilisation with organic matter is predicted to improve salt-affected soils' chemical and physicochemical features and their physical qualities (Lax *et al.*, 1994) [16]. Additionally, using organic amendments to remediate saline-sodic soils is more affordable and environmentally friendly than using inorganic ones.

Additionally, according to Mahmoodabadi *et al.* (2013) [18], applying gypsum along with organic amendments may, depending on their chemical makeup, promote some synergistic effects on soluble Na^+ and K^+ concentrations and improve the characteristics of calcareous saline-sodic soils. Additionally, Diacono and Montemurro (2015) [6] came to the conclusion that the majority of the well-known impacts of organic materials on the chemical, biological, and physical characteristics of salt-affected soils are relevant in terms of effectiveness.

Incubating helpful bacteria in agriculture and using organic materials are two examples of such sustainable strategies. Many scientists have concentrated on the biotic approach of "plant-microbe interaction" to address salt and salinity issues. Some microorganisms have been shown to be able to recover plants' salt tolerance with incredibly favourable outcomes (Ilanghumaran *et al.*, 2017) [8]. *Trichoderma harzianum* and *Pseudomonas fluorescence* species are widely utilised in the experiment to lessen the harmful effects of SAS due to their high success rates. According to Shoresh *et al.*, (2010) [25], trichoderma strains can make plants more resilient to biotic and abiotic challenges like salt and drought.

However, it has been economically unviable and challenging to implement appropriate management strategies and reclamation practises on a large scale in places affected by salt. This study aims to study the effect of application of gypsum in conjunction with organic manure to improve salt-affected soil and crop productivity.

Materials and Methodology

Experimental Information about the location: In the academic year 2021–2022, Rajmata Vijayaraje Scindia Krishi Viswa Vidyalaya, College of Agriculture in Gwalior (Madhya Pradesh), did a lab experiment.

Collection and preparation of soil samples

Soil samples were collected in the Malanpur region of Madhya Pradesh's Bhind district at depths ranging from 0 to 15 cm. The samples were combined to form a composite sample. After being allowed to air dry, the bigger aggregates were gently crushed with a wooden hammer before being placed through a 2 mm filter. For the column and pot studies, the sieved soils were incubated in a plastic bag.

Analytical process

Different physical and chemical properties of soil were examined using the procedures indicated below.

The organic carbon content of soil samples was determined using the wet digestion method (Walkley and Black 1934) [33] while the electrochemical conductivity (EC) and pH were assessed using the methods described by Jackson in 1967 [11] and 1962, respectively. Neutral ammonium acetate solution was used to calculate the CEC (Jackson, 1962) [10]. To determine the total nitrogen content of the soil, the Micro-Kjeldahl method was employed. (Piper, 1950) [34]. According to Piper and Jackson (1973) [12], Ca^{2+} and Mg^{2+} were recovered from a 1 N NH4OAc solution at a pH of 7.0. Using a sodium filter (Jackson, 1962) [10] and a flame emission spectrophotometer (Model: Jenway, PEP-7) to individually evaluate the sodium (Na+) content of soil samples. The sodium adsorption ratio is calculated using the equation SAR = [Na]/(([Ca]+Mg])/2)1/2 (Bohn *et al.* 2001) [3]. The following conventional procedures were employed in conjunction with cutting-edge technologies.

Leaching Experiment

The soil column experiment, conducted by Roy *et al.*, (2020b) [35], incubated soil samples with various combinations of amendments for 45 days. Leaching was then carried out in 10 steps (0.5–5 pv) with amounts of water of the desired pore volumes (pv). The experiment was designed to observe the deterioration of specific salt components, to evaluate the remediation of saline soils, and to monitor changes in soil characteristics for the purpose of leaching. The pore volume of a saturated soil is the volume of water that exists within its pores. Following leaching, soil samples from various columns underwent analysis.

Treatment Information

T_1 Control, T_2 100% Gypsum Requirement, T_3 65% Gypsum Requirement, T_4 Vermicompost, T_5 Biomes, T_6 65% Gypsum Requirement + Vermicompost + Biomes, *Rate of application of vermicompost- 5 t/ha and Biomes- 2.5 kg/ha (*Trichoderma harzianum* and *Pseudomonas fluorescence*).

Culture collection and inoculum preparation:

This experiment used strong isolation of the biome. ICAR's National Bureau of Agriculturally Important Microorganism (NBAIM) (NAIMCC) Kushmaur, Mau Nath Bhanjan (U.P.) provided the pure strains of *Trichoderma harzianum* (NAIMCC-F-1744) and Pseudomonas fluorescence (NAIMCC-B-762). *Trichoderma harzianum* was propagated in large quantities using PDA media that was incubated at 250 °C for 7–10 days. By simply switching the growth medium from PDA to PDB, *Pseudomonas fluorescence* was propagated via a similar mechanism of mass propagation. Harvesting the biomass from a 10–15-day old culture, an appropriate diluent was used to modify the concentration, and the spore suspension was created. The spore suspension was then extensively soaked into the soil.

Result and Analysis

Various figures illustrate the effects of changes in soil physico-chemical parameters.

Impact on soluble salt and soil reaction

Physical and chemical characteristics of the initially collected soil samples:

pH is 9.32, EC (dSm^{-1}) is 3.65, OC is 0.451, N is 180, P is 13.87, and K is kg/ha, Ca (Cmolc (+) kg^{-1}), -218.4 10, Na (Cmolc (+) kg^{-1}, 27, Mg (Cmolc (+) kg^{-1})- 247 SAR 24.22

Soil pH

The most important physico-chemical characteristic of soil is thought to be its pH, which controls the availability of nutrients and how well plants can absorb them. In the current investigation, soil pH was significantly lower in all treatments that received vermicompost either alone or in conjunction with the biomes depicted in (Figure 1) compared to the early soil pH (9.32). Lower soil pH was obtained by applying vermicompost at a rate of 5 t/ha+ and 65 percent GR. reduction of pH in salt-affected soils' surface and subsurface horizons caused by the addition of organic amendment. According to research by (Wang *et al.*, 2013) [29], the addition of charcoal decreased the pH of soil by releasing H+ ions from exchange complexes by the addition of Ca^{2+} or Mg^{2+}. Islam *et al.*, (2015) [9] found that using gypsum and manure together produced the best effects for lowering soil pH.

Soil EC

There was a substantial change in EC compared to the control when vermicompost, biome, and gypsum were utilised singly or in combination, as indicated in (Figure 2). The EC reduced when vermicompost was utilised with 65% GR and a biome (from 3.65 to 1.64 dSm^{-1}). The reduction in electrical conductivity (EC), which is then followed by the addition of organic compounds, may be caused by salt leaching. The release of organic acids during the breakdown process is what causes the leaching of salts. According to Shoresh *et al.*, (2010) [25], adding various organic additions considerably decreased the EC of saline soils. Leaching by organic matter resulted in a drop in EC and an improvement in the responsiveness of biomes by improving the physical properties of the soil.

Exchangeable Cations in Soil

The application of vermicompost, gypsum, or their combination had a substantial impact on exchangeable cations when compared to the control. The treatments 65% GR plus vermicompost @ 5 t ha^{-1} and biomes @ 2.5 kg/ha had considerably larger levels of exchangeable Ca^{2+} and Mg^{2+}, respectively. While magnesium and exchangeable Na+ in the soils decreased as a result of the gypsum application, exchangeable calcium increased (Figure 3). (Major *et al.*, 2010) [36] discovered that the availability of Ca^{2+} and Mg^{2+} was increased in a Colombian oxisol by the addition of 20 t ha-1 of organic amendment. Gypsum and cow dung both have the advantage of supplying Ca^{2+} to replace the adsorbed Na^{+}, whereas manure increases the amount of $CaCO_2$ in the soil and releases more Ca^{2+} to replace Na^{+} (Zhang *et al.*, 2018) [31]. On the other side, the addition of vermicompost and 65% GR reduced the amount of exchangeable sodium. This may be because vermicompost and gypsum produce higher exchangeable Ca^{2+} concentrations, and their sorption over vermicompost causes Na^{+} from the soil exchange complex to be replaced. It should be noted that the addition of 65% GR with 5 t ha^{-1} of vermicompost caused the greatest drop in exchangeable Na^{+}. By enhancing the soil profile exchange sites with Ca^{2+} and Mg^{2+}, increased Ca^{2+} concentrations brought on by the addition of vermicompost may have decreased the exchangeable and Mg^{2+} and Na^{+} concentrations at these locations. (Zhang *et al.*, 2018,) [31]. The combined application of gypsum and compost has been shown to increase crop yield in a saline-sodic soil by lowering EC, pH, and SAR.

Soil sodium adsorption ratio (SAR)

Vermicompost application, either alone or in combination, has a substantial effect on SAR of post-harvest soils. The treatment that received 65% GR combined with vermicompost at a rate of 5 t/ha and diverse biomes indicated in (Figure 4) produced much-reduced soil SAR. Because gypsum supplies Ca^{2+} to replace absorbed Na^{+}, which may limit dispersion and improve soil physical characteristics, the treatments may have increased aggregate stability, enabling water infiltration and movement in the soil. The increase in soil porosity generated by the addition of organic amendments may have also facilitated Na^{+} leaching from the soil profile and a decrease in SAR (Yue *et al.*, 2014) [30]. Several research have confirmed that organic amendments has a good effect on saline soils by reducing soil SAR (Amini *et al.*, 2016) [1], (Luo *et al.*, 2017) [17].

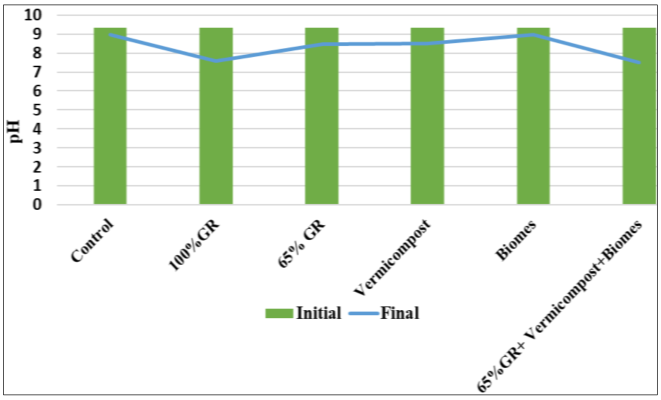

Fig 1: Soil pH for different treatments before and after leaching

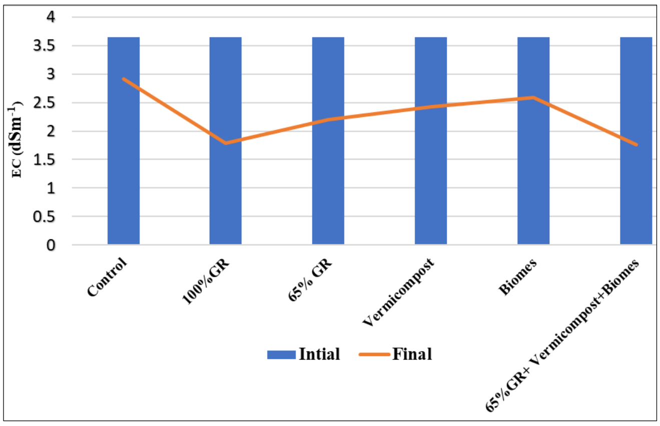

Fig 2: Electrical conductivity of saturation paste extracts of soils before and after leaching for different treatments

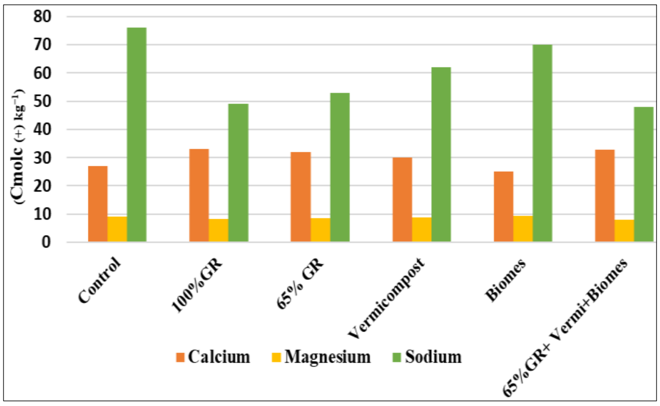

Fig 3: Soil exchangeable, Ca^{2+}, Mg^{2+} and Na^{+} concentrations (cmolc kg^{-1}) for different treatments, before and after leaching

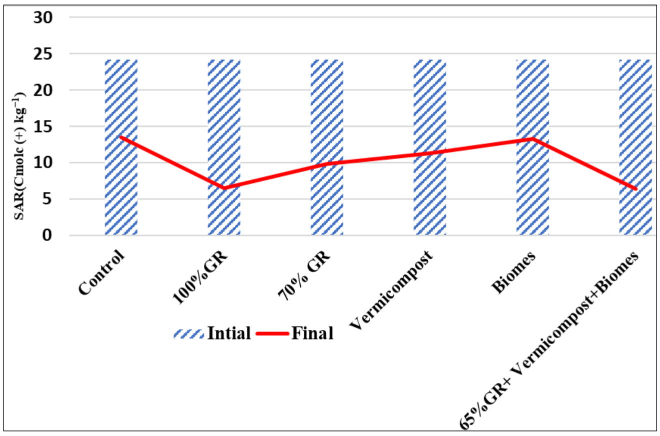

Fig 4: Sodium adsorption ratio of soils before and after leaching for different treatments

Conclusion

The results of this study indicate that a combination of 5 t/ha of vermicompost and 65% GR as a supplement to gypsum can successfully reduce soil pH, EC, and SAR when compared to utilising either gypsum or vermicompost alone. Further research, including field efficiency experiments, is required to evaluate PGPR's efficacy as a viable biofertilizer. Environmental pressures are worldwide variables that have a detrimental impact on agricultural output, prohibiting crops from being introduced into uncultivable areas and lowering yields.

Acknowledgement

The author wishes to thank their mentor, co-authors, and coworkers for their invaluable guidance, unwavering support, and encouragement during the course of their research.

Funding

This research project was not funded.

Interest Conflict

There are no conflicts of interest, according to the authors.

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