International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(6): 1552-1556

Received: 04-09-2019
Accepted: 06-10-2019

Amelioration of sodic soil with silicon and gypsum

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Abstract
A pot culture experiment was conducted in order to check the effect of silicon (Si) and gypsum in the amelioration of sodic soil. The Si sources used were rice hull ash (RHA), diatomite (DE) and calcium silicate. Gypsum was applied based on the gypsum requirement of the soil. Combined application of Si and gypsum proved to be effective in lowering the pH and ESP of soil than the sole application of Si. Application of RHA@250 kg Si ha^{-1} with 100% gypsum significantly lowered the pH of soil (7.91) at harvest of rice. The reduction in ESP occurred with the application of DE @ 250 kg Si ha^{-1} + gypsum @ 100% GR was statistically significant over the rest of the combinations at both the sampling periods. Regardless of the dosage, the combination of Si as DE and RHA performed well with gypsum than $CaSiO_3$ with gypsum which might be due to the difference in reactivity of these silica materials with gypsum and with soil.

Keywords: Gypsum requirement, DE, RHA, ESP

Introduction
Salt affected soils are of global concern as they are problematic soils characterized by poor physicochemical properties. Soil chemical properties are badly deteriorated by these salts leading to their effect on plants and hence the plant growth in salt affected soils is a major constraint. Out of 329 m ha of total geographical area of our country, 7.54 m ha land comes under the category of salt affected soils (Mandal *et al*., 2010) [10]. Based on the dominant kinds of salts present, these soils are categorized in to saline, sodic and saline sodic soils. Among them alkali soils or sodic soils are highly problematic for crop production because of their adverse physical and chemical environment. The reclamation and utilization of sodic soils are of prime importance in view of ever-increasing population demand of food grain and other related commodities.

Sodic soils are characterized by high pH and high exchangeable sodium percentage throughout the soil profile and reduced availability of some essential plant nutrients. Soil sodification induces higher swelling and water retention. Consequently, the plant available water, soil permeability and infiltrability are adversely affected. Crop grown on these soils invariably suffer from nutritional disorder (N, Ca and Zn deficiency and Na toxicity) resulting in lower yield.

The reclamation of sodic soils basically requires the removal of excess sodium from the exchange complex with calcium and the replaced sodium leached out of root zone. Various amendments are used for the reclamation of sodic soils. Use of gypsum as an amendment in reclamation of sodic soil is an established and widely adopted technology which is considered as the cheapest and most convenient method

Gypsum is an easily accessible and inexpensive source of calcium. Its usefulness depends upon the fineness of the gypsum powder, its application method and efficiency of drainage structure (Ali and Kahlown, 2001) [2].

Presently, there are some advances in the field of reclamation of salt affected soils. These include exogenous application of nutrients (silicon) (Raza *et al*., 2006) [13]. Silicon is valuable for plants in combating different biotic and abiotic stresses like diseases, pest attack and water deficiency, salts and metals toxicities (Ma, 2001) [9]. There are various means by which silicon assemble salinity tolerance in plants (Liang *et al*., 2007) [8]. Silicon boost salt tolerance in plants by rising water status of the plants. Photosynthetic activity is vital for plant survival, silicon improves photosynthesis rate and keep ultra configuration of plant organelles and provision of reactive oxygen species is reduced (Zhu *et al*., 2004) [20]. Silicon reduces the uptake of sodium and improves uptake of potassium in plants (Tahir *et al*., 2006) [18], and improve potassium to sodium selectivity (Hasegawa *et al*., 2000) [5].

The literature pertaining to amelioration of salt affected soils with silicon is very limited. Hence the present study was conducted to check the ameliorative effect of silicon sources and gypsum in sodic soil.

Material and methods

A pot culture experiment was carried out at greenhouse, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Bengaluru, Karnataka, India. Sodic soil was collected from Zonal Agricultural Research Station, V C Farm, Mandya, Karnataka. The collected bulk soil sample was air dried and used for the study. The soils were analyzed for initial properties by following standard procedures and the data are presented in table 1.

Table 1: Initial properties of the soil

Parameter	Value
Particle size distribution (%)	
Sand	53.6
Silt	17.8
Clay	28.6
Soil textural class	Sandy clay loam
pH (1:2.5 soil water)	8.63
EC (dSm^{-1}) (1:2.5 soil water)	1.02
Exchangeable cations (cmol (p^+) kg^{-1}) Ca	10.84
Mg	3.25
Na	6.48
Gypsum Requirement; GR (t ha^{-1})	19.2
CEC (cmol (p^+) kg^{-1})	28.65
ESP	22.62

Silicon sources

The experiment was carried out with three sources of Si such as rice hull ash (RHA), diatomite (DE) and calcium silicate ($CaSiO_3$). Total Si content of RHA, DE and calcium silicate, were 34.84, 30 and 12 per cent, respectively. RHA is obtained from rice mills whereas $CaSiO_3$ is an industrial slag by product. DE is a sedimentary rock resulting from the deposition of Si rich unicellular diatoms (Sandhya and Prakash, 2018) [14]. All these sources were finely powdered and used for pot experiment. The chemical composition of silica sources used is depicted in Table2.

Table 2: Chemical composition of silica sources

Parameter	$CaSiO_3$	DE	RHA
pH	12.45	9.21	8.33
EC (dSm^{-1})	n. d	0.72	1.62
Cation exchange capacity (cmol(p^+)kg^{-1})	n.d	52	36.52
Si (%)	12	30	34.84
N (%)	n. d	0.03	0.79
P (%)	n. d	0.02	0.26
K (%)	0.076	0.4	0.99
Ca (%)	5.83	2.70	0.38
Mg (%)	0.82	3.25	0.32

*n.d not determined

Source: Sandhya and Prakash, 2018 [14]

Experimental details

The study was undertaken by filling 5 kg of soil per pot and thoroughly mixed gypsum based on gypsum requirement of the soil as per treatment details. Prior to filling the pots with soil, each pot was layered with gravel to facilitate smooth flow of water. After the incubation period of one week, the leaching process was carried out with uniform amount of water (2.5 L/ pot) which was fixed based on the maximum water holding capacity of the soil. The leaching process was continued thrice at five days interval and the leachate coming out of the holes provided in the bottom of the pots were collected each time in the plates kept below. After completion of leaching, soil was treated with three silicon sources *viz*., RHA, DE and $CaSiO_3$ at two levels i.e., 125 (0.0625g Si kg^{-1} soil) and 250 (0.250 g Si kg^{-1} soil) kg Si ha^{-1}; decided based on the results of previous experiment. After the incubation period of one week, the pots were transplanted with salt tolerant rice variety of IR30864. The soil samples from each pot were collected before cropping and after harvest of the crop. Soil samples were dried and grinded to pass through 2 mm sieve. The prepared samples were analysed for pH, EC and ESP as ascribed by Jackson, 1973.

Results and Discussion

Characteristics of the experimental soil

The soil was sodic in nature because of its high pH (8.63), low EC (1.02 dSm^{-1}) and high ESP (22.62). Mechanical analysis of the soil indicated that the selected soil belongs to sandy clay loam in texture (Table 1).

Effect of silicon and gypsum on the characteristics of sodic soil

Soil pH

The data interpreting the variation in pH of soil samples as influenced by Si sources *viz*., RHA, DE and $CaSiO_3$ and gypsum treatments before cropping and at harvest of rice crop are represented in figure 1. In general, the reduction in soil pH was observed when Si sources were combinedly applied with gypsum and the effect was prevalent in both the sampling times. The pH of the soil sample collected from the unamended control pot was 8.59 and 8.53, respectively before cropping and at harvest. Among the different sources of Si, except RHA all other sources increased the pH when applied alone and was significantly higher compared to control in both the times. When Si in the form of RHA or DE was combinedly applied with gypsum @ 50 or 100% GR, greater reduction in pH obtained which can be related to the organic nature of the sources. Yazdanpanah *et al*. (2011) [19] suggested that when gypsum was added in conjunction organic amendments the efficiency was greater in improving the properties of calcareous saline sodic soil. Vance *et al*. (1998) opined that addition of organic matter and gypsum to soil will improve the properties of sodic soil. However, the combined application of Si as $CaSiO_3$ with gypsum irrespective of their levels significantly enhanced the pH of the soil during the course of investigation which might be attributed to the lesser dissolution of $CaSiO_3$ and gypsum as a result of common ion effect. Haynes (2014) [6] opined that dissolution of $CaSiO_3$ will be less under alkaline condition. The effect of Si on soil pH depends on type of and other soil properties. Alcarde (1992) [1] disclosed an increase in soil pH with silicate materials. Application of slag silicate fertilizer will increase the pH of soil (Sandhya and Prakash, 2018) [14]. The decrease in soil pH after DE application under submergence was reported by Prakash *et al*. (2016) [12].

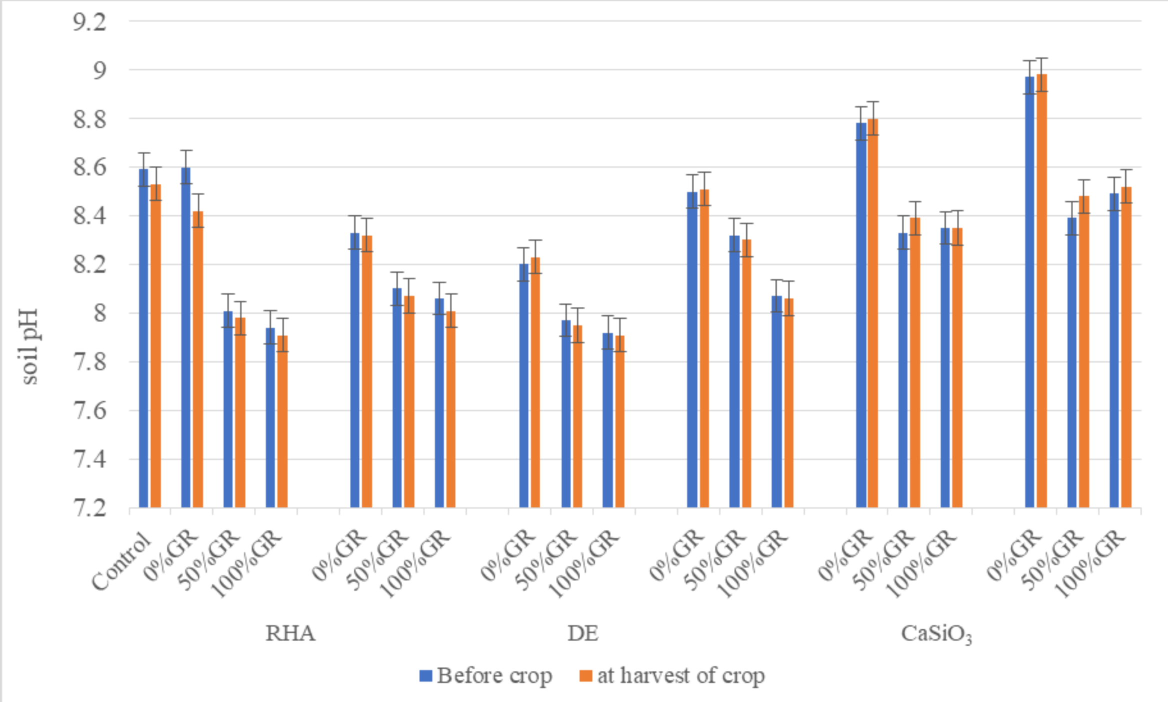

Fig 1: Effect of Si sources and gypsum in graded levels on soil pH before and at harvest of crop

Electrical Conductivity (EC)

Data pertaining to the variation in EC as influenced by Si sources and gypsum before and after crop is depicted in figure 2. Application of silica sources and gypsum significantly enhanced the EC of sodic soil over unamended control during both the sampling period. The EC of soil was comparatively higher before transplanting of rice crop than at harvest of crop which might be ascribed to the crop uptake of dissolved nutrients. Rather than the sole application of silica sources, EC of soil significantly increased when silicon sources and gypsum were combinedly applied. Significantly higher EC was observed with the combined application of RHA @ 250 kg Si ha^{-1} with 100% gypsum based on GR at both before and after harvest of crop which accounted EC value of 2.42 and 1.13 dS m^{-1}, respectively. The observed increment in soil EC can be ascribed to the addition of salts as a result of treatment imposition. Enhancement in the EC of the soil treated with combinations of silicon and gypsum might be due to the release of more soluble salts comprising mainly of sodium sulphate. Ali and Kahlown (2006) [2] observed that addition of gypsum initially increases the ECe of the soil.

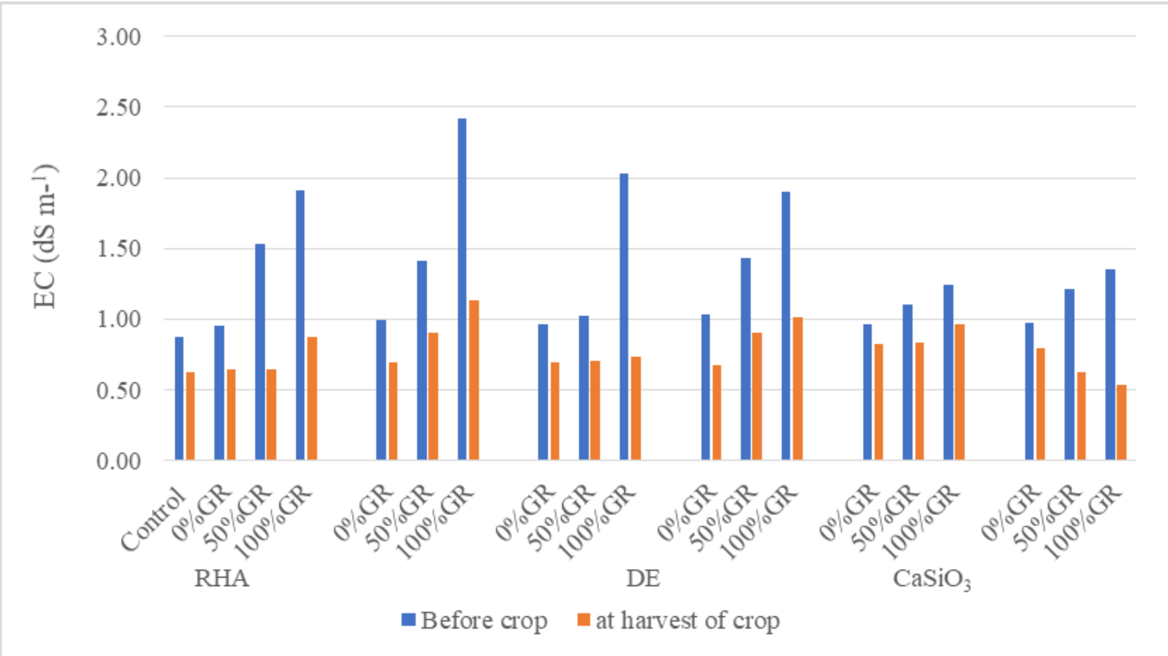

Fig 2: Effect of Si sources and gypsum in graded levels on soil EC before and at harvest of crop

Exchangeable Sodium Percentage (ESP)

The interpretation of data from figure 3 implied that ESP of soil followed a decreasing trend when Si sources were combinedly applied with gypsum. Irrespective of the treatments, marginal reduction in ESP was observed when the soil samples were analyzed after the harvest of the crop compared to before planting the crop which indicates the uptake of Na and other cations by the crop during its developmental stages. The reduction in ESP was of greater extent when Si as DE @ 250 kg Si ha^{-1} was applied with gypsum @ 100% GR and was significantly superior over other combinations throughout the course of investigation. Overall, combination of DE/RHA with gypsum effectively lowered the ESP of soil over combinations of $CaSiO_3$ with gypsum which might be accounted for its lesser dissolution under alkaline conditions. This difference in efficacy in bringing down the ESP of soil might be connected to the difference in reactivity of the silica sources with soil and gypsum. Significantly lower ESP with DE might be ascribed to its higher concentrations of Ca and Mg and high CEC and lower Na content. The reduction in ESP with gypsum addition was reported by Somani (1990) [16], Srinivasa (1999) [17] and Mahmoodabadi *et al*. (2013) [11].

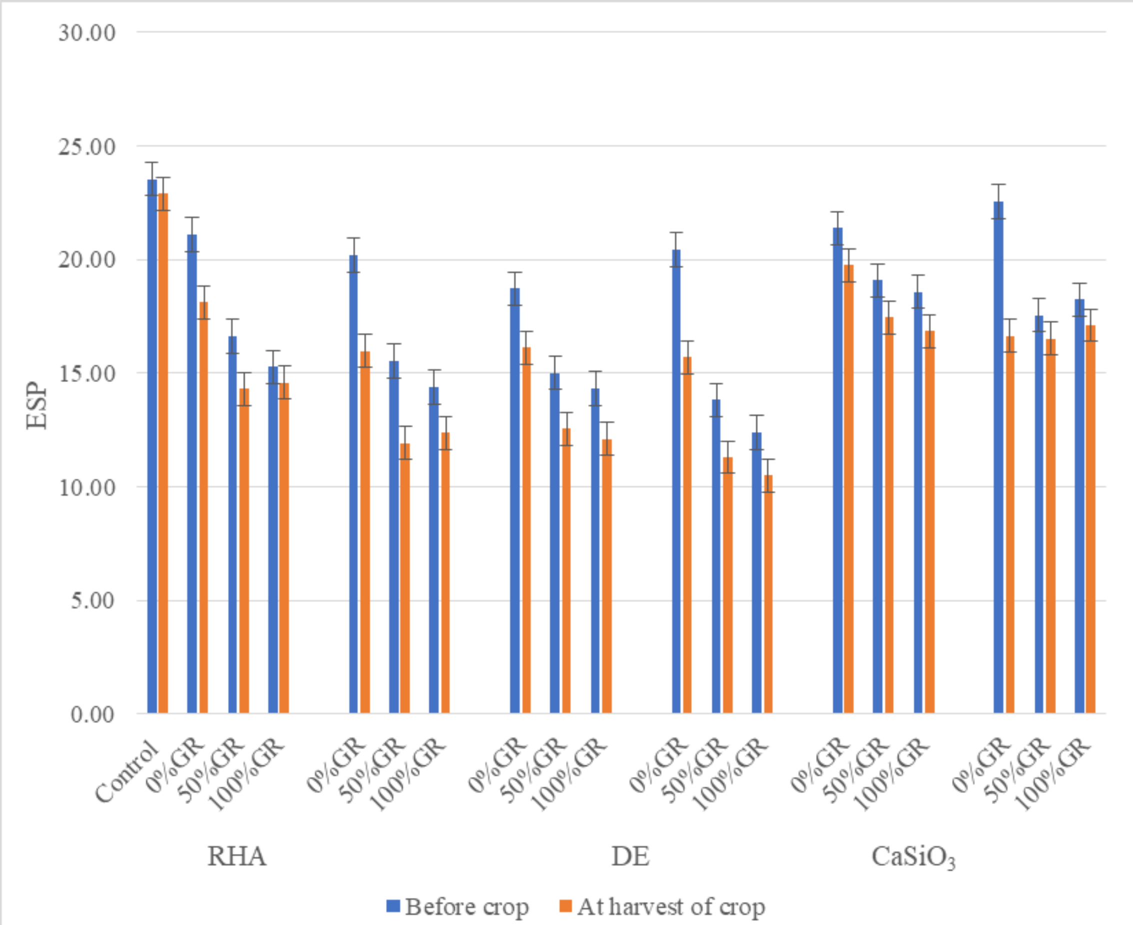

Fig 3: Effect of Si sources and gypsum in graded levels on ESP of soil before and at harvest of crop

Conclusion

Ameliorative effect of Si with gypsum in a sodic soil was studied by analyzing the pH, EC and ESP of soil before and after crop. The combined application of Si sources with gypsum was efficient in amelioration of sodic soil and which worked well with DE and RHA than $CaSiO_3$ which highlights the difference in reactivity of the Si sources with gypsum and soil.

Acknowledgment

The authors would like to express their sincere gratitude to DST INSPIRE for providing fellowship for the smooth conduct of research. Also, we would like to mention AICRP on LTFE and ZARS, V C Farm, Mandya for providing all the facilities for conducting the research.

References

1. Alcarde JC. Corretivos da acides dos sols caracteristicas interpretacoes tecnicas. Sao Paula ANDA (Boletim Tenica), 1992, 6-9.
2. Ali T, Kahlown MA. Role of gypsum in amelioration of saline-sodic and sodic soil. Intern. J Agric. and Biol. 2001; (3):326- 332.
3. Clark GJ, Dodgshun N, Sale PWG, Tang C. Changes in chemical and biological properties of a sodic clay subsoil with addition of organic amendments. Soil Biol. Bioch. 2007; 39:2806-2817.
4. Jackson ML. Soil chemical analysis. Practice Hall of India (Pvt.) Ltd., New Delhi, 1973.
5. Hasegawa P, Bressan R, Zhu J, Bohnert H. Plant cellular and molecular responses to high salinity. Ann. Rev. Plant. Physiol. Plant. Molecular Biol. 2000; 51:463-499.
6. Haynes RJ. A contemporary overview of silicon availability in agricultural soils. J Plant Nutr. Soil Sci. 2016; 177:831-844.
7. Khattak SG, Izhar Ul Haq, Malik A, Khattak MJ, Naveedullah. Effect of various levels of gypsum application on the reclamation of salt affected soil grown under rice followed by wheat crop. Sarhad J Agric. 2007; 23(3):675-680.
8. Liang Y, Sun W, Zhu YG, Christie P. Mechanisms of silicon-mediated alleviation of abiotic stresses in higher plants: A review. Environ. Pollut. 2007; 147:422-428.
9. Ma JF, Miyake Y, Takahashi E. Silicon as a beneficial element for crop plants. In: Datnoff. L.E. and G.H.

Snyder. (eds.). Silicon in Agriculture. Elsevier. New York, USA 2001; 8:17-39.
10. Mandal AK, Obi Reddy GP, Ravisankar T. Digital database of salt affected soils in India using Geographic Information System. J Soil Salinity Water Quality. 2011; 3(1):16-29.
11. Mahmoodabadi M, Yazdanpanah N, Sinobas LR, Pazira E, Neshat A. Reclamation of calcareous saline sodic soil with different amendments (I): Redistribution of soluble cations within the soil profile. Agric. Water Manage. 2013; 120:30-38.
12. Prakash NB, Anitha MS, Sandhya K. Behaviour of different levels and grades of diatomite as silicon source in acidic and alkaline Soils. Silicon. 2016; 8(1):1-12.
13. Raza HS, Athar MR, Ashraf M. Influence of exogenously applied glycinebetaine on the photosynthetic capacity of two differently adapted wheat cultivars under salt stress. Pakistan J Bot. 2006; 38(2):341-351.
14. Sandhya TS, Prakash NB. Evaluation of calcium silicate, rice hull and rice hull ash as silicon sources in wetland rice in acidic and alkaline soils. J Indian Soc. Soil Sci. 2018; 65(4):428-434.
15. Sandhya K, Prakash NB. Bioavailability of silicon from different sources and its effect on the yield of rice in acidic, neutral, and alkaline soils of Karnataka, South India. Commun. Soil Sci. Plant Anal. 2019; 50(5):1-12.
16. Somani LL. Alkali Soils – Their Reclamation and Management. Divyajyothi Prakashan, Jodhpur, 1990.
17. Srinivasa N. Characterization and reclamation of sodic soils in Vishveshwaraiah canal tract of Cauvery command area. Ph.D. Thesis, Univ. Agric. Sci., Bangalore, 1999.
18. Tahir MA, Rahmatullah M, Ashraf S, Kanwal, Maqsood T. Beneficial effects of silicon in wheat (*Triticum aestivum* L.) under salinity stress. Pakistan J Bot. 2006; 38:1715-1722.
19. Yazdanpanah N, Pazira E, Neshat A, Naghavi H, Moezi AA, Mahmoodabad M. Effect of some amendments on leachate properties of a calcareous saline-sodic soil. Int. Agrophys. 2011; (25):307-310.
20. Zhu ZJ, Wei GQ, Li J, Qian QQ, Yu JQ. Silicon alleviates salt stress and increases antioxidant enzymes activity in leaves of salt-stressed cucumber (*Cucumis sativus* L.). Plant Sci. 2004; 167:527-533.