Journal of Applied and Natural Science
14(4), 1441 - 1448 (2022)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Correlation of soil physico chemical properties with a yield of green gram (*Vigna radiata* L.) by soil amendments and foliar nutrition under sodic soil condition

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Article Info
https://doi.org/10.31018/jans.v14i4.3929
Received: August 17, 2022
Revised: November 29, 2022
Accepted: December 5, 2022

How to Cite
Mohanapriya, R. *et al.* (2022). Correlation of soil physico chemical properties with a yield of green gram (*Vigna radiata* L.) by soil amendments and foliar nutrition under sodic soil condition. *Journal of Applied and Natural Science*, 14(4), 1441 - 1448. https://doi.org/10.31018/jans.v14i4.3929

Abstract
In India, about 3.77 million ha of the country's geographical area is affected by sodicity. There is an urgent need to minimize further land degradation and restore the fertility of degraded soils to meet the growing demand for food. The most effective way to overcome salt stress is by applying nutrients through soil and foliar. In this context, a field experiment was conducted at Anbil Dharmalingam Agricultural College and Research Institute (ADAC & RI), Tiruchirappalli, in the summer of 2022 to study the reclamation potential of soil amendments and foliar nutrition in sodic soil. The experiment was laid out in a split-plot design with three replications. The treatment comprised of soil amendments *viz.,* M_1- *Pongamia* green leaf manure (GLM) @ 6.25 t ha^{-1}, M_2-Pressmud @ 10 t ha^{-1}, M_3-CSR GROMOR @ 25 kg ha^{-1}, M_4-Gypsum @ 50 % GR, M_5-Gypsum @ 50 % gypsum requirement (GR) + *Pongamia* GLM @ 6.25 t ha^{-1}, M_6-Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1}, M_7-Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} and M_8- Farmers practice, in main plots and foliar nutrition *viz.,* S_1- Foliar spray (FS) of CSR GROMOR @ 3% @ 30 DAS, S_2-FS of Brassinosteroid (BRs) 0.2 ppm @ 30 DAS and S_3-FS of Melatonin 60 ppm @ 30 DAS in sub plots. The results showed that gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1}+ FS of Brassinosteroid 0.2 ppm @ 30 DAS(M_6S_2) registered significantly (P=0.05%) lowest pH (8.07), ESP (11.62%), exchangeable Na^+ (2.93 c mol (p^+) kg^{-1}) with higher exchangeable Ca^{2+}(11.23 c mol (p^+) kg^{-1}), Mg^{2+} (8.09 c mol (p^+) kg^{-1}) and K^+(0.82 c mol (p^+) kg^{-1}). It also increased soil available nutrients (235.6, 24.57 & 309.6 kg NPK ha^{-1}) and grain yield (1110 kg ha^{-1}) of green gram. However, it was on par with gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of Brassinosteroid 0.2 ppm @ 30 DAS(M_7S_2). Hence it was concluded that the application of gypsum along with pressmud or CSR GROMOR combined with FS of brassinostroid had a remarkable effect in reducing soil sodicity and increasing the productivity of green gram.

Keywords: Foliar nutrition, Green gram, Sodicity, Soil amendments, Soil nutrients, Yield

INTRODUCTION

Soil degradation caused by salinization and sodification is of universal concern. In arid and semiarid regions, soil degradation caused by salinity and sodicity is a significant environmental threat to soil fertility and agricultural productivity. Sodic soil, also called alkali soils or solonetz, is characterized by high pH (>8.2), high

ESP (>15), high water-soluble and exchangeable sodium, low biological activity, poor physical properties and deficiency of many essential nutrients (Shrivastava and Kumar, 2015). Exchangeable sodium and pH decrease soil permeability, available water capacity and infiltration rates through swelling and dispersion of clay as well as slaking of soil aggregates. These modifications may reduce the yield of crops growing on such soils. And also, salt stress adversely affects the physical and chemical properties of soil, biological processes and plant growth (Oo *et al.,* 2015). The high occurrence of salts in the soil creates poor aeration, restricts root penetration and the flow of water leads to poor germination, growth and development of crops, which severely affects crop yield (Yaduvanshi, 2017). So, there is an urgent need to prevent further land degradation and restore the fertility of degraded soils since the continual increase in salinization on a global scale makes saline-sodic soils the most prominent category of degraded soils with severe consequences on agriculture production.

Gypsum is the most often used amendment for sodic soil reclamation. Due to its limited solubility, it is difficult to increase the efficacy of applied gypsum without adequate moisture, whether from irrigation or rainfall. Adding organic sources performs a dual role in these situations, enhancing gypsum solubility by helping to improve the soil's physico-chemical characteristics. Also, organic amendments provide a good substrate for microorganism and help to maintain a healthy nutritional balance in the soil ecosystem. Pressmud is a widely available industrial by-product used to accelerate the solubilization of gypsum by organic acids produced during decomposition (Sundhari *et al.,* 2018). It is a good source of organic matter and it can be used as an alternate source of plant nutrients and act as a soil ameliorant (Bokhtiar *et al.,* 2001). *Pongamia pinnata* is an excellent green leaf manure which provides macro and micronutrients besides assisting in maintaining a good nutritional balance between soil nutrient availability and plant requirements (Hashmi *et al.,* 2019). 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. CSR GROMOR (Microbial consortium developed by Central Soil Salinity Research Institute, Karnal, Haryana) coupled with gypsum as soil application and foliar spray improved water absorption, nutritional uptake and crop yield (Chatterjee *et al*., 2012).

Melatonin (N-acetyl-5-methoxytryptamine; $C_{13}H_{16}N_2O_2$, molecular mass 232.2 g mol^{-1}) is an indolamine hormone found in many fruits and vegetable roots, hypocotyls, leaves, stems, flowers, fruits and seeds. It plays a role in growth and development, phytohormone and photosynthetic pigment biosynthesis, callus formation and stress tolerance. Melatonin protects plants from biotic and abiotic stress by acting as an antioxidant (Tan *et al.,* 2012). Supplemental foliar feeding is critical for improving crop growth and yield. It also improves the photosynthetic rate and nutrient transfer from leaves to developing seeds (Sridhar *et al*., 2020). The aim of the present work was to evaluate the potential effects of soil amendments and foliar nutrition on soil chemical properties, crop growth, development and yield under sodic soil conditions.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted during the summer season of 2022 at field No. A_2c at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, situated in Manikandam Block of Tamil Nadu. The experimental site is located at 11˚32’ North latitude, 78˚83’ East longitude and at an altitude of 85 m above MSL. The initial soil characteristics of the experimental site are depicted in Table 1.

Treatment details

The field trial was laid out in a split-plot design with three replications. The treatments comprised of soil amendments (SA) *viz.,* M_1- *Pongamia* as green leaf manure (GLM) @ 6.25 t ha^{-1}, M_2- Pressmud @ 10 t ha^{-1}, M_3-CSR GROMOR @ 25 kg ha^{-1}, M_4-Gypsum @ 50 % GR, M_5-Gypsum @ 50 % gypsum requirement (GR) + *Pongamia* GLM @ 6.25 t ha^{-1}, M_6-Gypsum @ 50 % GR + pressmud @ 10 t ha^{-1}, M_7-Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1}& M_8- Control, in main plots and foliar nutrition (FN) in sub plots *viz.,* S_1-Foliar spray of CSR GROMOR @ 3% @ 30 DAS, S_2-Foliar spray of brassinosteroid (BRs) 0.2 ppm @ 30 DAS and S_3- Foliar spray of melatonin 60 ppm @ 30 DAS. Sowing was done on 23 February 2022. VBN (Gg) 2 variety with a duration of 65 days was used as a test variety. The individual plot size was 20 m^2, spacing adopted was 30 cm x 10 cm. The statistical analysis was carried out by AGRES software at 5 % significance.

Application of soil amendments

Gypsum requirement

Gypsum requirements (GR) were calculated to reduce the initial ESP from 36.40 to 10 % for 30-cm soil matrix as follows. The gypsum requirement of the soil was determined using the following equation (USSLS, 1954):

$$GR = \frac{ESP_i - ESP_f}{100} \times CEC \times 1.72 \quad \text{Eq. 1}$$

Where, GR is the net gypsum requirement of the soil (t ha^{-1})

ESP_i is the initial exchangeable sodium percentage
ESP_f is the final exchangeable sodium percentage
CEC is the cation exchangeable capacity (c mol (p^+) kg^{-1})
Gypsum was mixed in 20 cm depth of soil 20 days before sowing by using rotavator and the soil moisture was monitored up to field capacity to facilitate the leaching. After gypsum leaching, amendments were applied as per the treatment schedule.

***Pongamia* GLM**

25 t ha^{-1} (wet weight basis) of *Pongamia* leaves were collected and heaped. Water was added so as to maintain the 50 - 60% moisture content and covered with banana leaves to maintain the moisture level. The manure heaps were turned at weekly intervals (to provide adequate aeration and uniform decomposition) and reheaped, taking care to maintain the moisture level at 60% by sprinkling with water. After 25 days, the manure was collected and applied to the plots as per treatment.

Pressmud

Composted pressmud was collected from Kothari sugar mill, Tiruchirappalli and the required quantity was applied to the plots as per treatment.

CSR GROMOR

CSR GROMOR is a bio-growth enhancer based on consortia of microorganisms *viz., CSR-B-2 (Bacillus pumilus*), CSR-B-3 (*Bacillus thuringiensis*) and CSR-T-1 (*Trichoderma harzianum*). CSR GROMOR and FYM were mixed at 1:20 and applied as per treatment schedule.

Foliar treatment

A foliar spray of CSR GROMOR, Brassinosteroid and Melatonin was given at the vegetative (30 DAS) stage.

Chemical analysis

Chemical analyses were performed to measure pH, EC, ESP, soil exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+ & K^+) and soil available NPK. Soil pH and EC were measured by using 1:2.5 soil and water extraction (Jackson, 1973). ESP was calculated by the following equation suggested by (Gardiner & Miller, 2004: USSLS, 1954) and expressed as %:

$$ESP\ (\%) = \frac{Exchangeable\ sodium}{Cation\ exchange\ capacity} \times 100 \qquad \text{Eq. 2}$$

Exchangeable Ca^+ and Mg^+ were analysed using versenate titration method suggested by Jackson (1973) and expressed as c mol (p^+) kg^{-1}. Flame photometry method was used to analyse exchangeable Na^+ and K^+ suggested by Toth and Prince (1949) and expressed as c mol (p^+) kg^{-1}. Soil available N (kg ha^{-1}) analysis was performed by alkaline permanganate method by Subbiah and Asija (1956), Available P (kg ha^{-1}) was analysed by colorimetric method (Olsen, 1954) and available K (kg ha^{-1}) was analysed by flame photometer described by Stanford and English (1949).

Table 1. Physico-chemical properties of the initial soil in ADAC & RI, Tiruchirappalli

A. Mechanical analysis	Values	Methods employed
Coarse sand fraction (%)	63.03	Robinson's International pipette method (Piper, 1966)
Fine sand fraction (%)	27.53	
Silt fraction (%)	8.55	
Textural class	Sandy clay loam	
B. Soil physical properties		
Bulk density (Mg m^{-3})	1.29	Core sampler method (Dakshinamurthi and Gupta, 1968)
Particle density (Mg m^{-3})	2.25	
Pore space (%)	55	
C. Electro-chemical properties		
pH	9.03	1:2.5 soil water suspension (Jackson, 1973)
EC (dS m^{-1})	0.42	Conductivity bridge (Jackson, 1973)
CEC (c mol (p^+) kg^{-1})	20.96	Neutral normal ammonium acetate (Piper, 1966)
ESP (%)	36.40	Flame photometer (Jackson, 1973)
D. Chemical properties		
Organic Carbon (%)	0.46	Chromic wet acid digestion (Walkley& Black, 1934)
Available N (kg ha^{-1})	179.1	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	17.82	0.5 M Sodium bicarbonate Calorimetric method (Olsen *et al.,*1954)
Available K (kg ha^{-1})	299.4	Flame photometer (Stanford and English, 1949)
Exchangeable Ca^+ (c mol (p^+) kg^{-1})	9.21	Versenate titration method (Jackson, 1973)
Exchangeable Mg^+(c mol (p^+) kg^{-1})	6.37	
Exchangeable Na^+(c mol (p^+) kg^{-1})	4.23	Flame photometry (Toth and Prince, 1949)
Exchangeable K^+(c mol (p^+) kg^{-1})	0.52	

RESULTS AND DISCUSSION

Soil pH

Effect of different treatments on soil reaction (pH) is shown in Fig.1. Among the combined application of soil amendments and foliar nutrition, higher pH reduction was recorded in gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + foliar spray of BRs 0.2 ppm (M_6S_2) (8.07) which was due to the increased nutrient availability and enhanced soil properties brought out by pressmud and gypsum. The application of gypsum exchanged Na^+ from the soil colloids and lowered the soil pH by adding the required amount of Ca^{2+} to neutralize the soluble HCO_3. As pressmud decomposed, it released electrolytes and organic acids with various functional groups that were crucial in balancing the pH of the soil and producing CO_2, which in turn mobilized native $CaCO_3$ and created soluble Ca^{2+}, reducing soil sodicity (Sheoran *et al*., 2021). Sundhari *et al*. (2018) and Rao *et al*. (2019) also reported that applying pressmud significantly increases the partial pressure of CO_2 in soil and lowers the pH value in the soil solution as a result of increasing native $CaCO_3$ mineral dissolution. It was on par with gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + foliar spray of BRs 0.2 ppm (M_7S_2) (8.09), which may be due to the fact that gypsum supplied Ca^{2+} to replace the sorbed Na^+ and also organic manures accelerated the process by generating organic acids and CO_2, which would have disintegrated native $CaCO_3$ and released more Ca^{2+} to replace Na^+.

Soil electrical conductivity

At the harvest stage, a significant difference in EC was observed among the soil amendments and foliar nutrition depicted in Fig.1. The highest EC was recorded in the treatment receiving gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + foliar spray of BRs 0.2 ppm (M_6S_2) (0.434 dS m^{-1}) which was on par with the gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + foliar spray of BRs 0.2 ppm (M_7S_2) (0.429 dS m^{-1}) and gypsum @ 50 % GR + *Pongamia* GLM @ 6.25 t ha^{-1}+ foliar spray of BRs 0.2 ppm (M_5S_2) (0.427 dS m^{-1}). Increased EC at harvest may be due to the presence of highly soluble salts contributed by the addition of pressmud. The electrical conductivity of soil was also impacted by the addition of organic amendments. At all phases of crop growth, applying pressmud was found to be more effective in lowering soil pH and adding more salts, which led to an increase in EC. Muhammad and Khattak (2011) and Singh *et al*. (2015) also observed that the combined application of gypsum and pressmud considerably increased EC during post-harvest analysis in saline-sodic soil (2015). Korai *et al.* (2015) also reported an increase in the EC values of post-harvest soil samples with the application of bio compost. The lowest EC was recorded in control + foliar spray of CSR GROMOR 3% @ 30 DAS (M_8S_1) at the harvest stage of the crop (0.412 dS m^{-1}).

Exchangeable sodium percentage (ESP)

The effect of soil amendments and foliar nutrition on soil exchangeable sodium percentage is shown in Fig.1. The results indicated that the application of amendments and foliar spray significantly reduced the ESP in all the treatments compared to the control. The incorporation of gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + foliar spray of BRs 0.2 ppm (M_6S_2) was more effective in reducing the soil ESP and it was statistically comparable with gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + foliar spray of BRs 0.2 ppm (M_7S_2) (11.62 and 12.25 %). This value was much lower than the initial value (68 and 66 %). The increase in Ca in soil solution caused by the addition of gypsum and organic sources, which promoted Na displacement and its subsequent removal during irrigation to lower soil layers, may be the cause of the decrease in soil ESP with the addition of amendments either alone or in combination. Choudhary *et al.* (2004) also reported that the ESP of the sodic and saline sodic soils was reduced by the addition of FYM along with gypsum in sugarcane. Similarly, Abdel Fattah (2012) also reported a decrease in ESP due to the application of gypsum in combination with rice straw compost in saline-sodic soil. The higher ESP was recorded in control + foliar spray of CSR GROMOR 3% (M_8S_1), which was on par with control + foliar spray of melatonin 60 ppm (M_8S_3).

Soil exchangeable cations

The application of amendments and foliar spray had a profound influence on the exchangeable Ca, Mg, Na and K at the crop harvest stage, which is presented in Fig. 2. The higher exchangeable Ca, Mg and K were found to be in the treatment receiving gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + foliar spray of BRs 0.2 ppm (M_6S_2) with lower exchangeable Na registered 11.23, 8.09, 2.93 and 2.93 c mol (p^+) kg^{-1}. It was comparable with gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of BRs 0.2 ppm (M_7S_2) (11.16, 8.05,0.72 and 2.97 c mol (p^+) kg^{-1}) and gypsum @ 50 % GR + *Pongamia* GLM @ 6.25 t ha^{-1} + FS of BRs 0.2 ppm (M_5S_2) (11.07, 7.95, 0.71 and 2.91 c mol (p^+) kg^{-1}). Gypsum treated plots increased exchangeable Ca, Mg and K ions as well as decreased exchangeable Na than control. Adding organic amendments with gypsum might have increased the exchangeable Ca and Mg amount because the organic acids produced during the decomposition of the organic amendments may have dissolved the gypsum, causing an increase in these cations in the soil solution. And also, the application of gypsum released the Ca, Mg and K into the soil resulting in an increased concentration of exchangeable Ca,

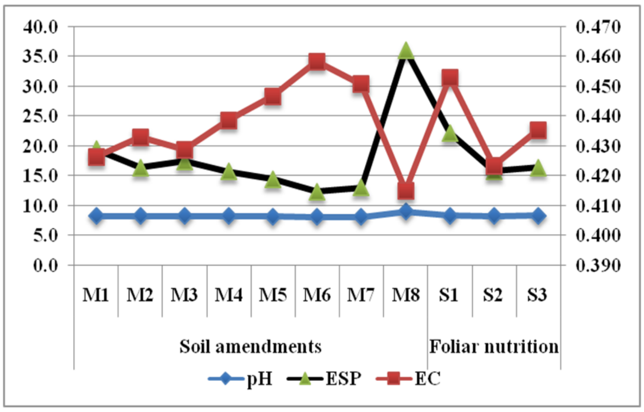

Fig. 1. *Effect of soil amendments and foliar nutrition on pH, EC (dS m^{-1}) and ESP (%)*

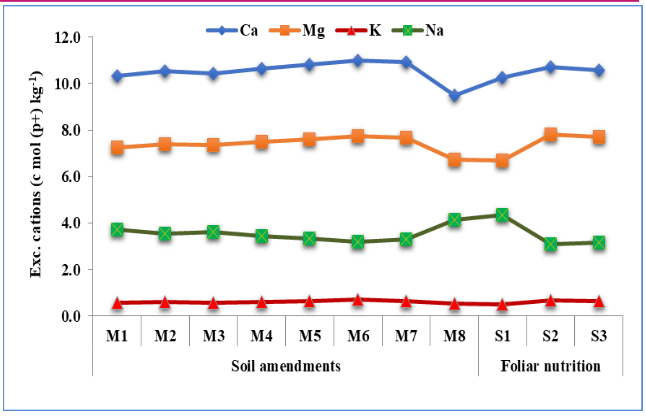

Fig. 2. *Effect of soil amendments and foliar nutrition on soil exchangeable cations (c mol (p$^+$) kg^{-1})*

Mg and K on soil exchange sites which decreased the concentration of exchangeable Na. Higher exchangeable Ca at exchange sites might be due to $CaSO_4$ dissolution. Both K^+ and Mg^{2+} have the ability to exchange Na^+, which might lead to a decrease in the exchangeable Na^+ concentration. Wang *et al.* (2017) also reported that the application of flue gas desulfurization gypsum significantly improved soil exchangeable cations in saline-alkali soil. Dotaniya *et al*. (2016) deduced that the application of pressmud in sugarcane increased the soil exchangeable Ca and Mg contents in saline-sodic soil. While lower values of soil exchangeable Ca, Mg and K with higher exchangeable Na were recorded in the control + foliar spray of CSR GROMOR 3% (M_8S_1) (9.25, 6.13, 0.44 and 4.97 c mol (p$^+$) kg^{-1}).

Soil available nutrients

The soil amendments and foliar nutrition have prominent variations on available nutrient content in post-harvest soil, as shown in Table 2. Conspicuously, more available NPK were observed with gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + foliar spray of BRs 0.2 ppm (M_6S_2) which recorded 235.65, 24.57 and 309.63 kg NPK ha^{-1} at harvest and it was comparable with gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + foliar spray of BRs 0.2 ppm (M_7S_2) which registered 233.54, 24.32 and 305.89 kg NPK ha^{-1} and gypsum @ 50 % GR + *Pongamia* GLM @ 6.25 t ha^{-1} + Foliar spray of BRs 0.2 ppm (M_5S_2) (229.37, 23.98 and 299.36 kg NPK ha^{-1}). This might be due to gypsum application reduced the soil pH, EC and activity of toxic ions due to displacement of exchangeable Na ions by exchangeable Ca ions on cation exchange complex which resulted in increased availability and mobilization of macro (N, P and K) and micro nutrients in soil. Pawar *et al.* (2020) also reported that the application of green manure with gypsum in saline-sodic soil significantly increased the soil available NPK of cotton. Whereas the lowest soil available nutrient content was found in control + foliar spray of CSR GROMOR 3% (M_8S_1) (159.23, 13.75 and 191.32 kg ha^{-1}) at harvest.

Grain yield

Grain yield is influenced by a variety of components, including soil, crop and climatic factors as well as efficient input management. It is crucial to provide a good environment that will support the crop for the duration of its life span. The data on mean grain yield of green gram presented in Fig.3 showed that the soil amendments and foliar spraying had significant effect on grain yield. Gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + foliar spray of BRs 0.2 ppm (M_6S_2) registered a higher yield of 1110 kg ha$^{-1,}$ which was comparable with gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + foliar spray of BRs 0.2 ppm (M_7S_2) which recorded 1011 kg ha^{-1}. It may be attributed directly to the nutritional effect and indirectly through improved soil physical and chemical properties. It may also be attributed to the favourable Ca^{2+}: Na^+ ratio in soil coupled with favourable effect of Ca^{2+} probably on maintaining cell membrane integrity and plant metabolism. And also, adequate and continuous nutrient availability through the soil and foliar nutrition promotes the supply of assimilates to sink or yield container, thus enlarging the size of the yield structure. Daur and Tatar (2013) also found

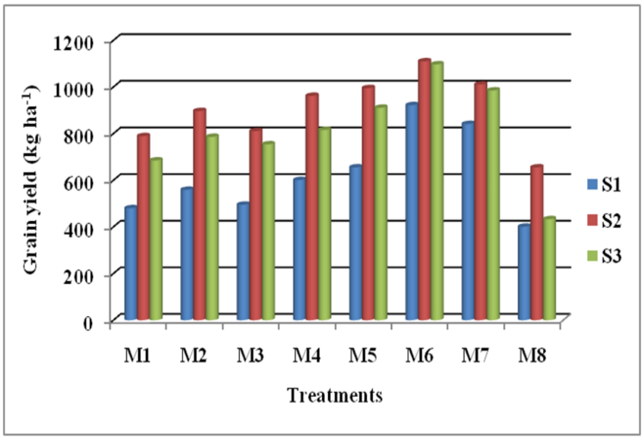

Fig. 3. *Effect of soil amendments and foliar nutrition on grain yield (kg ha^{-1})*

Table 2. Effect of soil amendments and foliar nutrition soil available nutrients (kg ha^{-1}) of green gram

	Nitrogen (kg ha^{-1})				Phosphorous (kg ha^{-1})				Potassium (kg ha^{-1})			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	165.23	190.62	179.25	178.37	14.25	18.69	18.35	17.10	200.31	276.58	259.87	245.59
M_2	181.54	209.33	191.23	194.03	16.13	21.65	19.66	19.15	211.32	282.87	274.12	256.10
M_3	171.23	195.69	184.25	183.72	15.23	20.22	19.14	18.20	204.15	279.69	264.32	249.39
M_4	187.55	218.05	195.46	200.35	16.54	23.25	20.58	20.12	215.39	295.54	279.88	263.60
M_5	196.78	229.37	207.35	211.17	17.12	23.98	21.07	20.72	221.45	299.36	284.69	268.50
M_6	210.11	235.65	225.32	223.69	18.75	24.57	23.28	22.20	244.12	309.63	292.41	282.05
M_7	201.69	233.54	219.36	218.20	17.75	24.32	21.69	21.25	239.54	305.89	287.66	277.70
M_8	159.23	175.77	161.63	165.54	13.75	14.05	13.95	13.92	191.32	220.63	208.96	206.97
Mean	184.17	211.00	195.48		16.19	21.34	19.72		215.95	283.77	268.99	
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	1.47	1.12	2.98	3.18	0.28	0.15	0.45	0.44	3.01	2.11	5.73	5.97
CD (P=0.05%)	3.16	2.29	6.16	6.48	0.60	0.31	0.95	0.90	6.47	4.30	11.86	12.17

Table 3. Pearson correlations matrix for various physico-chemical parameters and yield of green gram

Pearson Correlations											
	pH	**EC**	**ESP**	**Calcium**	**Magnesium**	**Sodium**	**Potassium**	**Aval N**	**Aval P**	**Aval K**	**Grain yield**
pH	1	-0.446	0.930**	-0.915	-0.608	0.523**	-0.602	-0.766	-0.762	-0.679	-0.741
EC		1	-0.310	0.325	-0.176	0.199	-0.088	0.272	0.034	-0.126	0.194
ESP			1	-0.912	-0.776	0.733**	-0.724	-0.790	-0.843	-0.819	-0.826
Calcium				1	0.797**	-0.719	0.809**	0.914**	0.913**	0.848**	0.897**
Magnesium					1	-0.981	0.932**	0.779**	0.901**	0.976**	0.873**
Sodium						1	-0.910	-0.722	-0.838	-0.940	-0.838
Potassium							1	0.882**	0.923**	0.948**	0.937**
Aval N								1	0.935**	0.850**	0.956**
Aval P									1	0.959**	0.938**
Aval K										1	0.918**
Grain yield											1

**Correlation is significant at the 0.01 level (2-tailed); Aval - Available

that the combined application of gypsum and brassinolide recorded higher green and dry fodder yields of berseem in saline soil. While control + foliar spray of CSR GROMOR 3% (M_8S_1) resulted in a lower grain yield of 401 kg ha^{-1}.

Correlation

Pearson correlations on soil physico-chemical parameters and yield of green gram are mentioned in Table 3. Grain yield was positively and significantly correlated with soil exchangeable calcium (r = 0.897**), magnesium (r = 0.873**), potassium (r = 0.937**) and soil available N (r = 0.956**), P (r = 0.938**) and K (r = 0.918**) and negatively correlated with pH (r = -0.741), ESP (r = -0.826) and exchangeable sodium (r = -0.838). pH, ESP and exchangeable Na were negatively correlated with all the parameters. Whereas exchangeable calcium, magnesium and potassium were positively correlated with yield. Results of this correlation study concluded that soil amendments along with foliar application significantly increased grain yield by enhancing exchangeable Ca, Mg and K. It also increased soil available NPK. Whereas significantly reduced initial pH, ESP and exchangeable Na content were unfavourable for plant growth and development of green gram.

Conclusion

The study revealed that the addition of gypsum and organic amendments (Pressmud, CSR GROMOR) acted as an ameliorant to sodic soil. The combined effect of gypsum with organic amendments was more effective in changing soil pH, EC, ESP, exchangeable cations, available soil nutrients and green gram yield. Gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + foliar spray of BRs 0.2 ppm (M_6S_2) improved the soil chemical properties by reducing the pH, EC, ESP and exchangeable sodium with a markable increase in exchangeable calcium, magnesium, potassium and available NPK which was at par with gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + foliar spray of BRs 0.2 ppm (M_7S_2). Hence it was concluded that the application of gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + foliar spray of BRs 0.2 ppm @ 30 DAS (M_6S_2) had a remarkable effect in reducing soil sodicity and enhancing the green gram productivity under sodic soil condition.

ACKNOWLEDGEMENTS

The author wishes to express her profound gratitude to the Dean, Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli, for allowing them to perform the field experiment and laboratory analytical work.

Conflict of Interest

The authors declare that they have no conflict of interest.

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