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RESEARCH ARTICLE
Indian Journal of Agricultural Research, Volume Issue : ()

Screening of Soil Ameliorants to Enhance the Productivity of Green Gram (*Vigna radiata* L.) under Sodic Soil in Cauvery Delta Zone of Tamil Nadu

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10.18805/IJARe.A-6120

ABSTRACT

Background: In India, about 6.75 million ha, which is around 2.3% of the country's geographical area is salt affected of which 3.79 million ha is sodic soil. Total sodic soil area in Tamil Nadu is around 0.36 million ha, accounting for 9.5% of total sodic soil area in India. Reclamation of salt-affected soil using drainage is expensive and leaching with good quality water is uneconomical in shallow water table areas. Addition of organic amendments performs a dual role in these situations by enhancing gypsum solubility and improving soil physico-chemical characteristics.

Methods: In this context a field experiment was conducted at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli during summer season of 2021 and 2022 to study the reclamation potential of ameliorants under sodic soil. The experiments were laid out in split plot design with three replications. The treatments comprised of different soil amendments in main plot and foliar nutrition in sub plot.

Result: The results showed that, gypsum @ 50% GR+CSR GROMOR @ 25 kg ha^{-1} registered significantly higher growth parameters *viz.,* plant height (53.5 and 58.4 cm), no. of branches plant^{-1} (7.27 and 6.75), DMP (2791 and 2801 kg ha^{-1}), physiological characters *viz.,*CGR (4.12 and 4.46 g m^{-2} day^{-1}), SPAD value (27.70 and 29.96), RWC (64.10 and 56.15%) and soluble protein (74.60 and 69.72 mg g^{-1}) at harvest. It also increased grain yield of 834 and 875 kg ha^{-1} with higher exchangeable Ca and Mg with lower Na content during 2021 and 2022 year of experiments.

Key words: Foliar nutrition, Green gram, Growth, Sodicity, Soil ameliorants.

INTRODUCTION

Soil degradation caused by salinization and sodification is of universal concern. In arid and semiarid regions of the world, soil degradation caused by salinity and sodicity is a major environmental threat to soil fertility and agricultural productivity. Due to the concomitant effects of salt and sodicity, saline-sodic soils are formed which leads to soil dispersion due to high Na^+ concentrations in the soil solution or at the exchange phase and loss of soil physical structure due to clay swelling (Wong *et al.,* 2009). However, salinity limits morphological, chemical, biochemical and metabolic processes by causing osmotic imbalances and specific ion toxicities, which have an adverse effect on plant growth (Parida and Das, 2005).

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 water is a difficult task. Addition of organic materials enhancing gypsum solubility there by helping to improve the soil physico-chemical characteristics. 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) and (Bokhtiar *et al.,* 2001). Microbial culture of CSR GROMOR with gypsum as soil application improved water absorption, nutritional uptake and crop yield (Chatterjee *et al*., 2012). Supplemental foliar feeding is critical for improving crop growth and yield. It also improves photosynthetic rate and nutrient transfer from leaves to developing seeds (Sridhar *et al*., 2020). Brassinosteroid and melatonin are the pleiotropic plant

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How to cite this article: Mohanapriya, R., Kalpana, R., Aravinth, K.V., Guna, M., Kumar, K.U. and Silambarasan, M. (2023). Screening of Soil Ameliorants to Enhance the Productivity of Green Gram (*Vigna radiata* L.) under Sodic Soil in Cauvery Delta Zone of Tamil Nadu. Indian Journal of Agricultural Research. DOI: 10.18805/IJARe.A-6120

Submitted: 05-01-2023 **Accepted:** 06-11-2023 **Online:** 22-11-2023

hormones that influences a variety of physiological and developmental processes including growth, seed germination and senescence. Also, it stimulates plant development and protects against water stress, salt stress and pathogen attack (Zhou *et al.,* 2013).

MATERIALS AND METHODS

The field experiment was conducted during summer season of 2021 and 2022 at field No. D_2b at Anbil Dharmalingam Agricultural College, Tiruchirappalli. The experimental site is located at 11°32′ North latitude, 78°83′ East longitude and at an altitude of 85 m above MSL. Both the experiments were laid out in split plot design with three replications. The treatments comprised of different soil amendments *viz.,* M_1-Pongamia 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% GR+Pongamia GLM @ 6.25 t ha^{-1}, M_6- Gypsum @ 50% GR+CSR GROMOR @ 25 kg ha^{-1}, M_7- Gypsum @ 50% GR+Pressmud @ 10 t ha^{-1} and M_8- Control, in main plots and foliar nutrition in sub plots *viz.,* S_1- Foliar spray (FS) of CSR GROMOR 3% @ 30 DAS, S_2- Foliar spray of Brassinosteroid 0.2 ppm @ 30 DAS and S_3- Foliar spray of Melatonin 60 ppm @ 30 DAS. The statistical analysis was carried out by AGRES software at 5% level of significance.

Gypsum requirement

The gypsum requirement of the soil was determined using the following equation (Richards, 1954):

$$GR=\frac{ESP_i\text{-}ESP_f}{100}\times CEC\times 1.72$$

Where,

GR- Net gypsum requirement (t ha^{-1}).

ESP_i- Initial exchangeable sodium percentage.

ESP_f- Final exchangeable sodium percentage.

CEC- Cation exchangeable capacity (c mol (p^+) kg^{-1}).

CSR GROMOR

CSR GROMOR developed by Central Soil Salinity Research Institute, Karnal, Haryana 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*) that acts as a nutrient vitalizer, soil conditioner and growth enhancer under sodic soil.

Growth parameters were measured periodically at 30, 45 DAS and harvest stage, yield attributes and yield were recorded at harvest stage. Physiological parameters were estimated by the following procedures:

Crop growth rate

CGR was calculated as per the formula suggested by Watson (1958) expressed in gm^{-2} day^{-1}.

$$CGR = \frac{W_2\text{-}W_1}{P\ (t_2\text{-}t_1)}$$

Where,

W_1 and W_2- whole plant dry weight (g) at time t_1 and t_2.

P- Spacing (m^2).

t_1 and t_2- initial and final day of period of observation.

SPAD value

Using a SPAD 502 Plus chlorophyll metre (Naus *et al.,* 2010), the greenness of the leaves was assessed between 11 AM and 12 PM.

Relative water content

RWC was estimated by the method prescribed by Barrs and Weatherly (1962).

$$RMC\ (\%) = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

Soluble protein

It was estimated by the procedure suggested by Waterborg (2009) and expressed as mg g^{-1}. Exchangeable Ca, Mg and Na were analysed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and expressed as c mol (p^+) kg^{-1}.

RESULTS AND DISCUSSION

Growth parameters

Combination of different soil amendments and foliar nutrition greatly influenced the growth characters presented in Table 1. Among different soil amendments, the height of plant was maximum with application of gypsum @ 50% GR+CSR GROMOR @ 25 kg ha^{-1} (M_6) which produced 53.5 and 58.4 cm at harvest during 2021 and 2022 which also recorded higher no.of branches $plant^{-1}$ (7.27 and 6.75) and DMP (2791 and 2801 kg ha^{-1}) during both the year of experiment. This might be due to improvement in soil properties and subsequent increase in crop growth brought about by the displacement of exchangeable Na from the solid phase. The results are in agreement with Qadir *et al*. (2002), Sugeng *et al*. (2011) and Ahemad and Kibert (2014). Whereas control (M_8) treatment constantly produced lower values of growth characters at harvest. Among different foliar application, plant height was maximum with FS of brassinosteroid 0.2 ppm @ 30 DAS (S_2) which produced 47.4 and 54.4 cm during 2021 and 2022. The same treatment recorded more no.of branches $plant^{-1}$ (6.53 and 6.27) and DMP (2442 and 2691 kg ha^{-1}) at harvest. This might be due to brassinosteroids are known to induce longitudinal growth of young tissues via cell elongation and cell division and vascular differentiation, which is a developmental process critical for plant growth. These findings are in line with Hu *et al*. (2000).

Physiological parameters

Among different soil amendments, significantly higher CGR of 4.12 and 4.46 g m^{-2} day^{-1} was recorded with gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} (M_6) during 2021 and 2022 with higher values of chlorophyll content (27.70 and 29.96) and RWC (64.10 and 56.15%) (Table 2). It also recorded higher soluble protein (74.60 and 69.72 mg g^{-1}) at harvest (Fig 1). It was statistically comparable with gypsum

@ 50 % GR + pressmud @ 10 t ha^{-1} (M_7). This could be due to desired Ca^{2+} availability in the soil solution replacing exchangeable Na^+ from the clay lattice and supplementation of calcium, sulphur and potassium in response to added gypsum and organic amendments (Singh *et al*., 2016). Significantly lower values of physiological parameters were under in control (M_8). Among different foliar application, higher CGR of 3.86 and 4.15 g m^{-2} day^{-1}, SPAD value of 26.51 and 30.45, RWC of 57.83 and 56.89% and soluble protein content of 70.74 and 68.36 mg g^{-1}, respectively was recorded in FS of brassinosteroid 0.2 ppm @ 30 DAS (S_2) at harvest during both 2021 and 2022. It seems to be due to its involvement in improving transcription and translation mechanism more efficient for the synthesis of photosynthetic pigments (Bajguz, 2000). Whereas, the lower values were recorded in FS of CSR GROMOR 3% @ 30 DAS(S_1).

Table 1: Effect of soil amendments and foliar nutrition on growth parameters of green gram.

Treatments	Plant height (cm)		No. of branches plant^{-1}		DMP (kg ha^{-1})	
	2021	2022	2021	2022	2021	2022
Soil amendments						
M_1- Pongamia GLM @ 6.25 t ha^{-1}	35.8	46.4	4.72	5.65	1890	2128
M_2- Pressmud @ 10 t ha^{-1}	40.7	49.4	5.90	5.94	2133	2288
M_3- CSR GROMOR @ 25 kg ha^{-1}	38.9	48.8	5.15	5.71	2024	2225
M_4- Gypsum 50% GR	45.4	52.9	6.32	6.14	2264	2343
M_5- Gypsum 50% GR+Pongamia GLM @ 6.25 t ha^{-1}	49.6	53.3	6.65	6.31	2494	2618
M_6- Gypsum 50% GR+CSR GROMOR @ 25 kg ha^{-1}	53.5	58.4	7.27	6.75	2791	2801
M_7- Gypsum 50% GR+Pressmud @ 10 t ha^{-1}	51.9	55.5	6.90	6.48	2657	2722
M_8- Control	32.9	43.8	4.27	5.18	1705	1999
SEd	0.72	0.38	0.06	0.03	30.75	29.45
CD (P=0.05%)	1.55	0.81	0.13	0.08	65.97	63.17
Foliar nutrition						
S_1- FS of CSR GROMOR 3% @ 30 DAS	39.0	48.9	5.42	5.81	2068	2158
S_2- FSof Brassinosteroid 0.2 ppm @ 30 DAS	47.4	54.4	6.53	6.27	2442	2691
S_3- FSof Melatonin 60 ppm @ 30 DAS	44.4	49.8	5.73	5.97	2224	2323
SEd	0.32	0.07	0.05	0.006	16.58	18.42
CD (P=0.05%)	0.66	0.14	0.10	0.01	33.77	37.53

Level of significance at 5%; DMP- Dry matter production; GR- Gypsum requirement; FS- Foliar spray; DAS -Days after sowing, GLM- Green leaf manure.

Table 2: Effect of soil amendments and foliar nutrition on physiological parameters of green gram.

Treatments	CGR (g m^{-2} day^{-1})		SPAD value		RWC (%)	
	2021	2022	2021	2022	2021	2022
Soil amendments						
M_1- Pongamia GLM @ 6.25 t ha^{-1}	3.17	2.49	20.89	22.77	50.60	47.43
M_2- Pressmud @ 10 t ha^{-1}	3.54	2.82	23.61	24.94	53.68	50.65
M_3- CSR GROMOR @ 25 kg ha^{-1}	3.39	2.76	21.80	24.13	52.27	50.48
M_4- Gypsum 50% GR	3.71	2.89	24.88	26.70	56.50	51.60
M_5- Gypsum 50% GR+Pongamia GLM @ 6.25 t ha^{-1}	3.76	4.05	26.74	27.75	58.80	53.32
M_6- Gypsum 50% GR+CSR GROMOR @ 25 kg ha^{-1}	4.12	4.46	27.70	29.96	64.10	56.15
M_7- Gypsum 50% GR+Pressmud @ 10 t ha^{-1}	3.87	4.34	27.29	28.42	61.66	54.81
M_8- Farmers practice	2.99	2.46	18.38	21.37	45.79	48.47
SEd	0.09	0.03	0.24	0.21	0.40	0.68
CD (P=0.05%)	0.10	0.06	0.53	0.45	0.86	1.47
Foliar nutrition						
S_1- Foliar spray of CSR GROMOR 3% @ 30 DAS	3.35	2.69	20.89	20.57	53.31	46.31
S_2- Foliar spray of Brassinosteroid 0.2 ppm @ 30 DAS	3.86	4.15	26.51	30.45	57.83	56.89
S_3- Foliar spray of Melatonin 60 ppm @ 30 DAS	3.50	3.01	24.34	26.25	55.14	51.64
SEd	0.02	0.03	0.18	0.15	0.39	0.39
CD (P=0.05%)	0.05	0.06	0.36	0.30	0.79	0.79

Level of significance at 5%; CGR- Crop growth rate; RWC- Relative water content.

Yield attributing charactersand yield

Table 3 shows significantly higher number of pods plant^{-1} and seeds pod^{-1} was observed with gypsum @ 50% GR+CSR GROMOR @ 25 kg ha^{-1} (M_6) with the values of 35.53 and 32.49 pods plant^{-1} and 12.69 and 12.67 seeds pod^{-1} during 2021 and 2022 year of experiments which also registered higher grain yield of 834 and 875 kg ha^{-1}, respectively. It was followed by gypsum @ 50% GR+pressmud @ 10 t ha^{-1} (M_7) and gypsum @ 50% GR+Pongamia GLM @ 6.25 t ha^{-1} (M_5).It may be attributed directly to the nutritional effect and indirectly through improved soil physical and chemical properties. The results confirm with Sharma *et al.* (2001) and Makoi and Ndakidemi, (2007). The lowest numbers were recorded under control (M_8). FS of brassinosteroid 0.2 ppm @ 30 DAS (S_2) resulted in 29.30 and 32.53 pods plant^{-1} and 11.27 and 13.04 seeds pod^{-1} during 2021 and 2022 year of experiments which also obtained higher grain yield of 725 and 761 kg ha^{-1}, respectively. Timely supply of nutrients through foliar spray,

Table 3: Effect of soil amendments and foliar nutrition on yield attributes and yield of green gram.

Treatments	No. of pods plant^{-1}		No. of seeds pod^{-1}		Grain yield (kg ha^{-1})	
	2021	2022	2021	2022	2021	2022
Soil amendments						
M_1- Pongamia GLM @ 6.25 t ha^{-1}	21.52	26.41	9.24	10.48	476	500
M_2- Pressmud @ 10 t ha^{-1}	24.57	27.96	10.39	11.23	572	624
M_3- CSR GROMOR @ 25 kg ha^{-1}	23.08	27.3	9.4	10.75	512	571
M_4- Gypsum 50% GR	27.64	29.2	10.7	11.67	618	713
M_5- Gypsum 50% GR+Pongamia GLM @ 6.25 t ha^{-1}	33.17	30.73	11.87	12.09	691	795
M_6- Gypsum 50% GR+CSR GROMOR @ 25 kg ha^{-1}	35.53	32.49	12.69	12.67	834	875
M_7- Gypsum 50% GR+Pressmud @ 10 t ha^{-1}	34.48	31.58	12.23	12.43	796	840
M_8- Control	20.51	24.67	8.79	9.46	289	374
SEd	0.32	0.37	0.14	0.08	6.66	5.33
CD (P=0.05%)	0.70	0.79	0.30	0.18	14.29	11.45
Foliar nutrition						
S_1- FS of CSR GROMOR 3% @ 30 DAS	25.91	25.66	10.21	9.94	444	571
S_2- FS of Brassinosteroid 0.2 ppm @ 30 DAS	29.30	32.53	11.27	13.04	725	761
S_3- FS of Melatonin 60 ppm @ 30 DAS	27.48	28.2	10.52	11.06	626	653
SEd	0.20	0.25	0.09	0.04	4.28	4.52
CD (P=0.05%)	0.41	0.51	0.19	0.08	8.72	9.21

Level of significance at 5%; CD- Critical difference.

Table 4: Effect of soil amendments and foliar nutrition on soil exchangeable cations of green gram.

Treatments	Exc. Ca		Exc. Mg		Exc. Na	
	2021	2022	2021	2022	2021	2022
Soil amendments						
M_1- Pongamia GLM @ 6.25 t ha^{-1}	10.32	12.40	7.58	7.30	3.35	3.87
M_2- Pressmud @ 10 t ha^{-1}	10.55	13.02	7.74	7.98	3.18	3.71
M_3- CSR GROMOR @ 25 kg ha^{-1}	10.44	12.72	7.7	7.54	3.27	3.80
M_4- Gypsum 50% GR	10.63	13.55	7.82	8.23	3.09	3.60
M_5- Gypsum 50% GR+Pongamia GLM @ 6.25 t ha^{-1}	10.80	13.81	7.93	8.71	2.99	3.41
M_6- Gypsum 50% GR+CSR GROMOR @ 25 kg ha^{-1}	10.98	14.80	8.06	9.27	2.83	3.23
M_7- Gypsum 50% GR+Pressmud @ 10 t ha^{-1}	10.93	14.38	8.00	9.00	2.93	3.33
M_8- Farmers practice	9.50	9.42	7.05	5.76	3.62	5.07
SEd	0.10	0.16	0.07	0.13	0.05	0.05
CD (P=0.05%)	0.23	0.34	0.16	0.29	0.11	0.11
Foliar nutrition						
S_1- Foliar spray of CSR GROMOR 3% @ 30 DAS	10.26	12.99	7.71	7.95	3.20	3.74
S_2- Foliar spray of Brassinosteroid 0.2 ppm @ 30 DAS	10.71	13.03	7.81	7.99	3.10	3.76
S_3- Foliar spray of Melatonin 60 ppm @ 30 DAS	10.59	13.02	7.69	7.98	3.17	3.76
SEd	0.08	0.09	0.05	0.04	0.02	0.03
CD (P=0.05%)	NS	NS	NS	NS	NS	NS

Level of significance at 5%; NS- Non significant; Exc- Exchangeable.

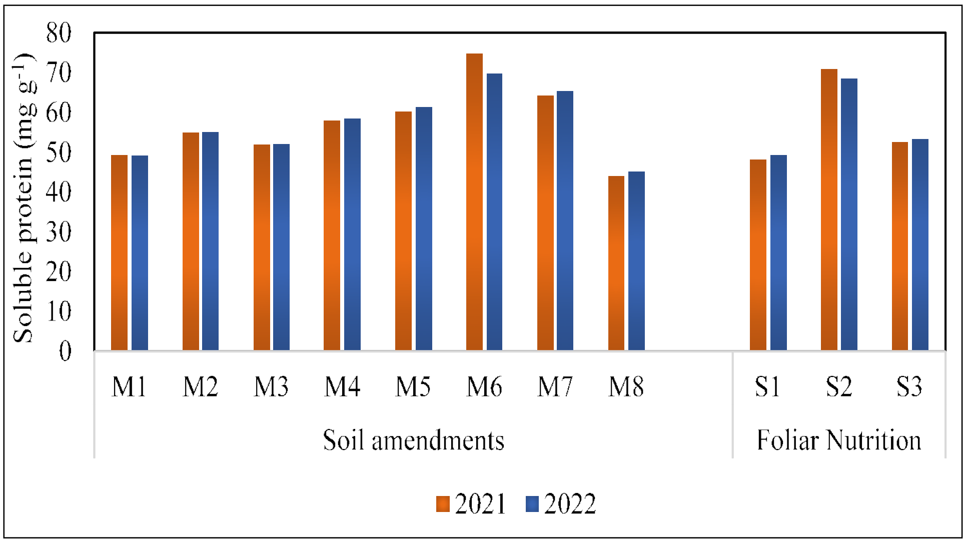

Fig 1: Effect of soil amendments and foliar nutrition on soluble protein (mg g^{-1}).

might have reduced shedding of flowers and fruits and led to a positive source-sink gradient of photosynthates translocation. This finding is in line with Manivannan *et al*. (2002).

Soil characteristics

Influence of different soil amendments showed markable variations on soil exchangeable cations at harvest (Table 4). Among main plot treatments, significantly higher amount of exchangeable Ca (10.98 and 14.80 c mol (p^+) kg^{-1}) and Mg (7.93 and 8.71 c mol (p^+) kg^{-1}) content with lower Na content (2.99 and 3.41 c mol (p^+) kg^{-1}) was observed in gypsum @ 50% GR+CSR GROMOR @ 25 kg ha^{-1} (M_6) during 2021 and 2022 year of experiments. Decomposition of amendments increased the ionic concentration and mobilized native $CaCO_3$ leading to reduction in soil sodicity and improved soil properties. Similar findings by Choudhary (2011) and Prapagar *et al*. (2012). There was no significant difference in sub plot treatments.

CONCLUSION

The study revealed that addition of gypsum @ 50% GR+CSR GROMOR @ 25 kg ha^{-1} registered significantly higher growth and physiological parameters at harvest stage. It also increased yield attributes and yield of green gram. Hence it is concluded that application of gypsum @ 50% GR+CSR GROMOR @ 25 kg ha^{-1} in VBN (Gg) 2 variety had a remarkable effect in ameliorating soil sodicity with enhanced green gram productivity under resource constraint and sodic soil condition.

Conflict of interest: None.

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