Eco. Env. & Cons. 28 (January Suppl. Issue) : 2022; pp. (S541-S547)
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ISSN 0971–765X

http://doi.org/10.53550/EEC.2022.v28i01s.073

Plant growth and nutrient uptake of Green gram (*Vigna radiata*. L) under marine gypsum reclaimed sodic soil as influenced by foliar nutrition

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(Received 20 August, 2021; Accepted 30 September, 2021)

ABSTRACT

Reclamation of sodic soil using marine gypsum with good quality groundwater and cultivation of green gram (*Vigna radiata.* L) and foliar nutrition was evaluated for its agronomic performance under field conditions. Green gram was raised as a summer irrigated crop with good quality groundwater during the year 2021. The sodic soil reclamation and foliar nutrition treatments comprises are; T_1 - Marine gypsum, T_2 - 1 % Monopotassium phosphate (MKP) + 100 ppm Salicylic acid (Foliar spray - FS), T_3 - 1 % MKP + 0.5 ppm Brassinosteroid (FS), T_4 – 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid (FS), T_5 - Marine gypsum +1 % MKP + 100 ppm Salicylic acid (FS), T_6 - Marine gypsum + 1 % MKP + 0.5 ppm Brassinosteroid (FS), T_7 - Marine gypsum + 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid (FS), T_8 - Control. The foliar spray was given 30 days after sowing (DAS) & 45 DAS. The treatments were replicated thrice and laid out in randomized complete block design. The results revealed that reclamation of sodic soil using marine gypsum alone recorded a higher dry matter production, crop growth rate, chlorophyll content and nutrient uptake than un-reclaimed soil. Among the foliar nutrition, 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid recorded the highest dry matter production, crop growth rate, chlorophyll content and nutrient uptake compared to untreated plot. It is found that soil reclamation followed by foliar application of 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid had a higher influence concerning plant dry matter production, crop growth rate, chlorophyll content and nutrient uptake when they were applied separately.

Key words: *Brassinosteroid, Green gram, Marine gypsum, Monopotassium phosphate, Salicylic acid, Sodic soil reclamation.*

Introduction

Agriculture production was hampered by a variety of causes including soil factors (physical and chemical constraints of soil) and environmental factors (biotic and abiotic stresses). Salinity and sodicity of soil are chemical constraints of soil. India occupied 147 million ha of degraded land in that sodic soil having 6.74 m ha of area (Kumar *et al*., 2020). Sodic soil has pH – 8.5, EC < 4 dSm^{-1}, ESP > 15 % and SAR > 13 % (CSSRI, Karnal). The presence of a high level of exchangeable sodium on cation exchange complex results in high pH, ESP and Sodium Adsorption Ratio (SAR) (Rasouli *et al*., 2013). Exchangeable sodium in the soil leads to poor aeration, restrict the root penetration, flow of water leads to poor growth and development of crop. Reclamation of sodic soil was most commonly done by using gypsum. Gypsum ($CaSO_4.2H_2O$) is a chemical amendment that contains 23.3 % of calcium and 18.6% of sulphur

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(CSSRI, Karnal). Marine gypsum is obtained from the salt pan after scraping out salt. Chemical composition of marine gypsum is 92.4 % of $CaSO_4.2H_2O$, 0.054 % of Na, 0.0236 % of K and 2.88 % of $MgCl_2+MgSO_4$ (CSSRI, Karnal).

Generally, the broadcasting of gypsum is followed to reclaim the sodic soil. Under this management practice, an enormous amount of gypsum and water is consumed which is not economically feasible. Hence, we tried to go for band placement of marine gypsum to minimise the cost as well as eliminate the drainage issues. The mechanism behind the band placement of marine gypsum is Ca^{2+} can displace exchangeable Na^+ on soil colloids, which produces water-soluble Na^+, which can be eluviated as $NaSO_4$ from root zone by irrigation with good quality water (Mao *et al.*, 2015). It slowly decreases the sodicity effect on the soil by slow releasing of calcium and brings the favourable condition of the soil for crop production. Legumes being nitrogen-fixing crop as well as short duration are most suitable for unproductive barren land cultivation (Nithila *et al.*, 2020). Green gram is an important pulse crop that grows well in sodic soil. Additionally, nutritional supplements are applied as a foliar spray. Foliar spray of nutrients at the proper growth stage and optimum concentration increases the physiological efficiency of the crop and boost crop growth (Pooja *et al.*, 2020). Owing to the above constraints the experiment was conducted to evaluate the foliar nutrition on growth and nutrient uptake of green gram under marine gypsum reclaimed sodic soil.

Materials and Methods

A field experiment was conducted at Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli, India located at 10°75' N latitude, 78°60' E longitude and altitude of 85 m above MSL. The green gram variety Vamban (Gg) 4 was used as a test crop during the summer season (2021). The treatment comprises of T_1 - Marine gypsum, T_2 – 1 % MKP + 100 ppm Salicylic acid (FS),T_3 – 1 % MKP + 0.5 ppm Brassinosteroid (FS), T_4 – 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid (FS) , T_5 - Marine gypsum + 1 % MKP + 100 ppm Salicylic acid (FS), T_6 - Marine gypsum + 1 % MKP + 0.5 ppm Brassinosteroid (FS), T_7 - Marine gypsum + 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid (FS), T_8 - Control were replicated thrice and laid out with randomized block design. Foliar spray of nutrient and plant growth regulators were given at two stages (30 DAS and 45 DAS). The initial soil sample was collected and analyzed. Initial soil pH - 8.7 (Jackson 1973), EC- 0.3 dsm^{-1}(Jackson 1973), organic carbon - 0.3% (Chromic acid wet digestion method), available nitrogen -187 kg ha^{-1} (alkaline permanganate method), available phosphorus - 16 kg ha^{-1}(Olsen's method) and available potash - 250 kg ha^{-1}(neutral normal ammonium acetate method) were recorded. The field was ploughed and brought to fine tilth and land was configurated with ridges and furrow. A rill was formed at 1/3 of the ridge and marine gypsum was placed and covered with soil. The actual quantity of gypsum required for reclamation of sodic soil is 13.5 tons ha^{-1} and 50 per cent gypsum requirement is 6.75 t ha^{-1} for the blending method of soil reclamation. Since band placement was practised in this experiment a quantity of 1.4 tons ha^{-1} of gypsum was used which was around 1/5 th of the 50% GR. Green gram seeds were sown at 2 cm depth above the gypsum placed area with 30 X 10 cm spacing. The recommended dose of fertilizer N: P: K (25:50:25 kg ha^{-1}) was applied basally. Randomly, five plants were tagged in each plot for taking non-destructive biometric observations and the values were statistically analysed using the method by Rangasamy (1995). For destructive sampling plants were sampled in the sampling row earmarked in the experimental plot. During destructive sampling above-ground portion of plants were removed, air-dried and then oven-dried (65$\pm$ 5°C) until constant weight is obtained. The dry matter production (DMP) was recorded at 30 DAS, 45 DAS and harvest stage. The dried plant samples were powdered in a Willey mill and uptake of nitrogen (N), phosphorus (P) and potassium (K) were analysed. Growth analysis of Crop growth rate (CGR) and Relative growth rate (RGR) were calculated based on the dry weight of the plant.

The CGR was calculated by using the formula as per Watson (1958) as;

$CGR= W_2-W_1/ p (t_2-t_1)$

W_1&W_2 – Above ground plant dry weight at times t_1 & t_2 respectively

t_1 & t_2- Time interval; p - Spacing (m^2)

The RGR was calculated according to the formula by Williams (1946) as;

$RGR = Log_e W_2- Log_e W_1/ t_2-t_1$

W_1&W_2 – Above ground plant dry weight at times t_1 & t_2 respectively

At different crop growth periods (30 DAS, 45 DAS and harvest), the same leaves were used to estimate chlorophyll content and SPAD index. The greenness of the leaves was measured using a SPAD 502 Plus chlorophyll meter (Naus *et al*., 2010) at 11 AM - 12 PM from the second fully expanded physiologically active leaf. SPAD meter reading was taken at the same leaf on each plant at roughly the same location (one-third distance from the base of the leaf and midrib). The readings were taken at five randomly selected plants and averaged to represent the mean SPAD meter reading of each treatment. The content of Chlorophyll a, Chlorophyll b and total chlorophyll were analysed by the organic solvent (80% acetone) extraction method (Arnon 1949) and calculated from the formula given below using the OD value recorded on a spectrophotometer at 663 nm, 645 nm and 652 nm absorbance respectively.

$$\text{Chlorophyll a} = (12.7 \times OD\ 663) - (2.69 \times OD\ 645) \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll b} = (22.9 \times OD\ 645) - (4.68 \times OD\ 663) \times \frac{V}{1000 \times W}$$

$$\text{Total chlorophyll} = \frac{OD\ 652 \times 1000}{34.5} \times \frac{V}{1000 \times W}$$

Where, OD – optical density, V- final volume of supernatant (25 ml) and W- weight of the sample

Plant nitrogen, phosphorus and potassium uptake were analysed using methods of micro kjeldhal, ammonium molybdo-vanadate and flame emission technique respectively.

Results and Discussion

Dry matter production

A progressive change of dry matter on green gram recorded in different growth stages were presented in Figure 1. Application of marine gypsum alone (T_1) significantly increased 17.56 % of dry matter production compared to control (T_8). Among foliar application, 10.15 % increment of dry matter production was recorded in 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid (T_4) compared to control (T_8). In combination, Marine gypsum + 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid (T_7) significantly increased 33.67 % of dry matter production compared to control (T_8). Application of marine gypsum improved cation exchange capacity, flocculation and infiltration capacity of the soil as it replaced Ca^{2+} in the soil colloids and leached out Na^{2+} content near root zone which favoured crop growth and increased dry matter production. Foliar spraying of MKP regulated stomatal opening and closure, maintained cell turgor pressure and increased phloem translocation whereas salicylic acid and brassinosteroid enhanced RUBISCO and catalase enzymes activity, that ultimately improved photosynthetic rate and increased biomass production. Hence, combination of marine gypsum with foliar application of 1 % MKP along with 100 ppm Salicylic acid and 0.5 ppm of Brassinosteroid improved soil structure and increased translocation of assimilated products from source to sink resulted in a higher amount of dry matter production. Similar results were reported by Ashraf *et al.* (2010), Sajyan *et al*. (2018) and Shafiq *et al*. (2021).

Crop growth rate and Relative growth rate

The significant difference of various treatments on

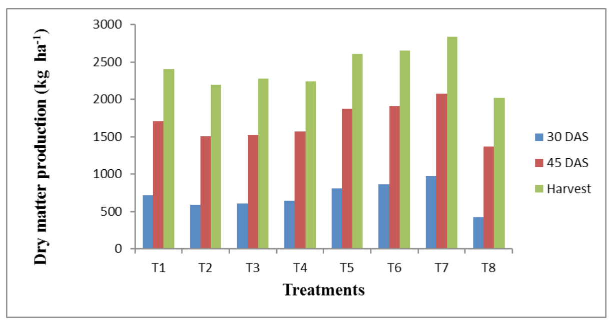

Fig. 1. Dry matter production of green gram (*Vigna radiata*.L) at different growth stages under sodic soil reclaimed with marine gypsum and foliar nutrition

T_1- Marine gypsum
T_2 - 1 % MKP + 100 ppm Salicylic acid (FS)
T_3 - 1 % MKP + 0.5 ppm Brassino steroid (FS)
T_4 - 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassino steroid (FS)
T_5 - Marine gypsum +1 % MKP + 100 ppm Salicylic acid (FS)
T_6 - Marine gypsum + 1 % MKP + 0.5 ppm Brassino steroid (FS)
T_7 - Marine gypsum + 1% MKP + 100 ppm Salicylic acid + 0.5 ppm Brassino steroid (FS)
T_8 – Control

calculated CGR and RGR was showed in Table 1. Amelioration of sodic soil with marine gypsum alone (T_1) significantly increased CGR by 7.11 % than the untreated plot (T_8). With the foliar applica-

Table 1. Crop growth rate (g m $^{-2}$day^{-1}) and Relative growth rate (g g^{-1}day^{-1}) of green gram at different growth stages (*Vigna radiata*.L) under sodic soil reclaimed with marine gypsum and foliar nutrition

Treatments	CGR		RGR	
	30-45 DAS	45-70 DAS	30-45 DAS	45-70 DAS
T_1 - Marine gypsum	6.7601	2.8869	0.0578	0.0138
T_2-1% MKP + 100 ppm Salicylic acid	6.2769	2.8280	0.0627	0.0151
T_3-1% MKP + 0.5 ppm Brassino steroid	6.2954	3.0641	0.0615	0.0159
T_4-1% MKP + 100 ppm Salicylic acid + 0.5 ppm Brassino steroid	6.2819	2.7403	0.0588	0.0142
T_5-Marine gypsum + T_2	7.2319	3.0262	0.0556	0.0133
T_6 - Marine gypsum + T_3	7.1654	3.0557	0.0530	0.0132
T_7-Marine gypsum + T_4	7.5350	3.1178	0.0504	0.0125
T_8-Control	6.4524	2.6886	0.0784	0.0157
SEd (±)	0.0390	0.0127	0.0007	0.0001
CD (p=0.05)	0.0800	0.0271	0.0014	0.0002

tion, higher CGR was recorded in 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid (T_4) which increased 1.90 % CGR than control (T_8). In combination, Marine gypsum + 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid (T_7) raised CGR by 14.75 % compared to the control (T_8). Calcium (Ca) ions in gypsum replaced exchangeable sodium ions at soil colloid sites which manipulated the soil condition and resulted in an elevated crop growth. The application of foliar nutrition increased the vegetative growth of the crop, which significantly contributed to higher LAI. Increased LAI stimulated the CGR which resulted in the increased dry matter production. At the later stage, LAI decreased due to senescence of leaves which reflected on CGR. However, alleviation of sodium toxicity creates the unstressed condition for plant growth under marine gypsum reclamation and a further spray of coupled nutrition increased growth metabolism which led to increased CGR. The RGR was 22.69 % higher in the control (T_8) than Marine gypsum + 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid (T_7). This may be due to the adverse effect of various soil and climatic factor. This findings draws support of Rasouli *et al*. (2013) and Mondal *et al*. (2017)

Chlorophyll content

Chlorophyll content estimated during the crop growth period is presented in Table 2. Amelioration of sodic soil with marine gypsum alone (T_1) significantly increased chlorophyll a (Chl.a), chlorophyll b (Chl.b) and total chlorophyll (Total chl.) by 51.61 %, 41.60 % and 24.56 %, respectively compared to control (T_8). In foliar application, the higher chlorophyll content was recorded in 1 % MKP + 100 ppm Sali-

Table 2. Chlorophyll content [mg g^{-1} fresh weight (fr.wt.)] of green gram (*Vigna radiata*.L) at different growth stages under sodic soil reclaimed with marine gypsum and foliar nutrition

Treatments	30 DAS			45 DAS			Harvest		
	Chl .a	Chl.b	Total chl.	Chl. a	Chl.b	Total chl.	Chl. a	Chl.b	Total chl.
T_1 - Marine gypsum	0.79	0.42	1.05	0.89	0.43	1.09	0.78	0.29	0.96
T_2-1% MKP + 100 ppm Salicylic acid	0.58	0.27	0.91	0.65	0.32	0.91	0.56	0.22	0.84
T_3-1% MKP + 0.5 ppm Brassino steroid	0.70	0.35	0.94	0.72	0.37	0.96	0.69	0.24	0.86
T_4-1% MKP + 100 ppm Salicylic acid + 0.5 ppm Brassino steroid	0.72	0.38	0.96	0.81	0.39	1.00	0.71	0.26	0.89
T_5-Marine gypsum + T_2	0.95	0.50	1.16	0.99	0.48	1.20	0.91	0.32	1.08
T_6 - Marine gypsum + T_3	1.00	0.55	1.18	1.00	0.52	1.27	0.92	0.35	1.09
T_7-Marine gypsum + T_4	1.11	0.59	1.30	1.20	0.59	1.38	1.00	0.39	1.18
T_8-Control	0.48	0.21	0.80	0.56	0.25	0.80	0.46	0.19	0.75
SEd (±)	0.03	0.02	0.05	0.03	0.01	0.04	0.03	0.01	0.03
CD (p=0.05)	0.08	0.03	0.10	0.07	0.03	0.09	0.07	0.02	0.07

cylic acid + 0.5 ppm Brassinosteroid (T_4) compared to untreated plot (T_8). This increased 42.73 %, 31.11 %, and 17.07 % of chlorophyll a, chlorophyll b and total chlorophyll, respectively. In combination, Marine gypsum + 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid (T_7) increased chlorophyll a, chlorophyll b and total chlorophyll by 73.97 %, 68.96 % and 44.55 % respectively, compared to control (T_8). Sodic soil amended with marine gypsum increased chlorophyll content as it increased soil permeability, soil aeration and function of the plasma membrane which favoured healthy crop growth by exchanging Na^{2+} ions with replacement of Ca^+ in soil. MKP supplied K an essential nutrient for chlorophyll synthesis led to increased greenness of the plant and growth-regulating substances aided in transcription and translation process of the chlorophyll synthesis enzymes which reflected in intensified chlorophyll content. Thus, amelioration of sodic soil with marine gypsum and spraying of nutrition increased soil stability and enhanced the physiological function of chlorophyll synthesis. Similar results were reported by Ashraf *et al*. (2010), Chi *et al*. (2012), Chapagain *et al*. (2004), Ghazi *et al*. (2021) and Sridhara *et al*. (2021).

Chlorophyll content was analysed in both laboratory and field conditions. The values of SPAD meter reading and chlorophyll content were plotted on the X and Y-axis. Chlorophyll a, chlorophyll b and total chlorophyll readings were positive and significantly correlated with SPAD reading of R^2 values about 0.91, 0.77 and 0.89 respectively (Figure 2). These results indicated that the values obtained in both field and laboratory conditions were almost equal. Hence, the SPAD meter method is preferential and stays effective as it is an easy, less laborious, time-consuming, cost-effective and non-destructive method when compared with the chlorophyll extraction method.

Nutrient uptake

The calculated nutrient uptake of different treatments was reported in Table 3. Amelioration of sodic soil with marine gypsum (T_1) significantly increased 37.16 %, 56.61 % and 37.37 % of nitrogen, phosphorus and potassium uptake, respectively compared to the untreated plot (T_8). Among foliar applications, significantly higher nutrient uptake of nitrogen, phosphorus and potassium by 27.00 %,43.10 % and 23.37 %, respectively was observed in 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid (T_4) compared to un-treated plot (T_1). The combined application of marine gypsum and foliar spray of 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassinosteroid (T_7) enhanced nitrogen, phosphorus, and potassium uptake by 76.07 %, 96.93 %, and 64.38 %, respectively, over control (T_8). Application of marine gypsum reduced the soil pH and ESP due to the exchange of Na^{2+} ions by Ca^{2+} ions in soil ensured soil hydraulic gradient, mobility of nutrients, root proliferation and microbial activity that inevitably increased uptake of nutrients in the root zone. The capacity of a green gram to fix atmospheric nitrogen through root nodule met the requirement of nitrogen for crop growth. Foliar spray of MKP supplied phosphorus and potassium that stands effective as they are efficiently translocated to shoot and roots whereas salicylic acid and brassinosteroid minimised the Na^+/K^+ concentration and increased mineral nutrients of N, P, K and

Table 3. Nutrient uptake (kg ha^{-1}) by green gram (*Vigna radiata*.L) at different growth stages

Treatments	Nitrogen uptake			Phosphorus uptake			Potassium uptake		
	30 DAS	45 DAS	Harvest	30 DAS	45 DAS	Harvest	30 DAS	45 DAS	Harvest
T_1 - Marine gypsum	13.11	39.56	41.19	2.01	5.80	7.23	8.88	27.45	28.90
T_2-1% MKP + 100 ppm Salicylic acid	7.53	30.12	32.05	1.29	4.52	4.83	5.12	21.39	22.61
T_3-1% MKP + 0.5 ppm Brassino steroid	8.03	33.33	35.27	1.46	4.74	5.69	7.24	23.24	24.35
T_4-1% MKP + 100 ppm Salicylic acid + 0.5 ppm Brassino steroid	9.21	35.27	37.11	1.69	5.02	6.26	7.79	24.61	25.04
T_5-Marine gypsum + T_2	16.48	47.49	50.58	3.00	7.85	8.86	10.96	31.78	33.89
T_6 -Marine gypsum + T_3	18.11	55.01	55.76	3.36	8.60	9.82	12.59	35.34	35.84
T_7-Marine gypsum + T_4	21.77	61.30	63.00	4.29	10.18	11.64	16.10	38.86	38.60
T_8-Control	4.00	26.34	28.28	0.88	3.82	4.04	3.33	17.88	19.80
SEd (±)	0.47	1.62	1.04	0.09	0.26	0.29	0.32	0.91	0.95
CD (P=0.05)	1.01	3.48	3.02	0.20	0.56	0.62	0.68	1.95	2.04

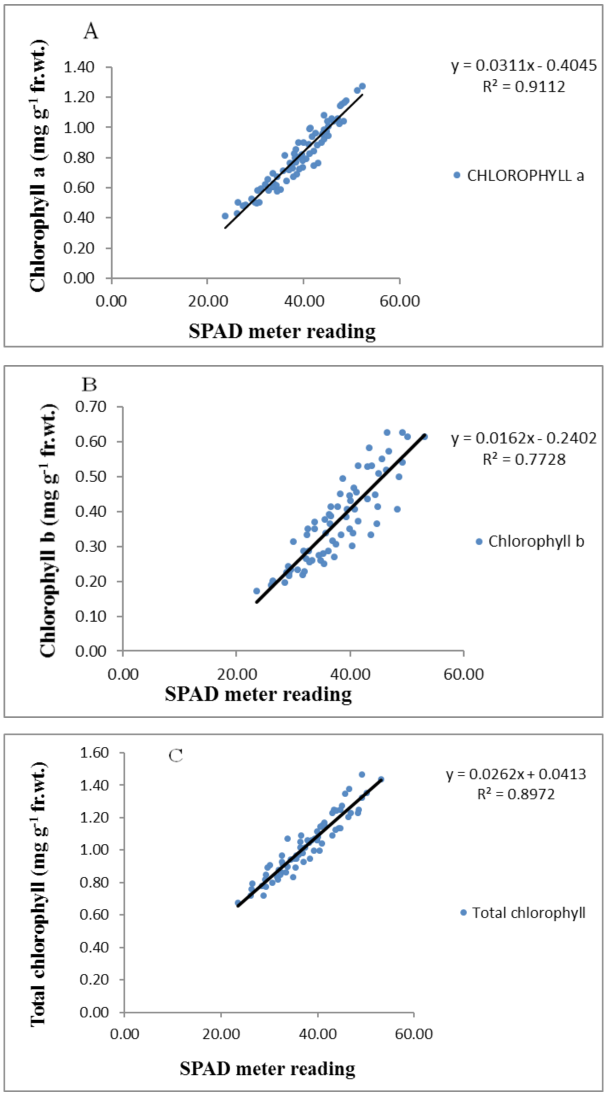

Fig. 2. Relationships between SPAD-502 readings and the Chlorophyll content (mg g^{-1} fr.wt.) on green gram: (A) SPAD-502 vs. Chlorophyll a content, and (B) SPAD-502 vs. Chlorophyll b content (C) SPAD-502 vs. total chlorophyll content. Linear curve was fitted to the all data (n = 72 in each case)

Ca which promoted nutrient uptake of plants. Hence, application of marine gypsum with foliar spray of nutrition has mobilized the unavailable nutrients, declined the toxic ion activity in the root zone and efficiently supplied nutrients as well as increased ionic uptake. These results were corroborating by Khan. (2010),Chi *et al.* (2012), Muller *et al.* (2012), Ekinci *et al*. (2012) and Pooja *et al.* (2020).

Conclusion

Amelioration of sodic soil with the concerned (band placement) method of marine gypsum application reduced the gypsum quantity and drainage problem while also being cost-effective. In addition to this spraying of nutrition improved the growth and physiological function of green gram. Hence, soil reclamation with marine gypsum and foliar application of 1 % MKP + 100 ppm Salicylic acid + 0.5 ppm Brassino steroid could be recommended for green gram cultivation under sodic soil.

Acknowledgments

I would like to extend my gratitude to the Dean, ADAC&RI, Tiruchirappalli for providing the opportunity. I would also like express my special thanks to my Professor and Head, Chairman and Members for their continuous guidance and encouragement to accomplish my research work.

Conflict of interest

The authors declare that there is no conflict of interest

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