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Sodicity control by gypsum & FYM with reference to green gram (*Vigna radiate*) growth

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ABSTRACT

Sufficiently present sodium ions (Na^+) of sodic soil adversely affect the growth of growing plant. Sodic soil reclaimation requires Ca^{+2} ions supply for the replacement of exchangeable Na^+ ion. Gypsum as an effective Ca^{+2} source used to reclaim sodic soil and improve soil ground water infiltration. Addition of FYM improves the sodic soil permeability by adsorbing insoluble salts. A pot experiment was conducted on artificial sodic soil for its reclaimation by combining different approaches i.e. application of gypsum and FYM. Two sets of experiments were designed to check the effects of salt and applied reclaimatives (alone or in combination) at different rates with respect to the growth of green gram. The treatments were: T0(control), T1(saltNa_2CO_3), T2(Salt+$Gypsum_1$), T3(Salt+ $Gypsum_1$+FYM_1), T4(salt +$Gypsum_2$), T5(Salt+$Gypsum_2$+FYM_2). In the given research, gypsum was applied at the rate of 1.5ton/ha (Gyp_1) and 2.5ton/ha (Gyp_2) alone or in combination with FYM at the rate of 2.5ton/ha (FYM_1) and 5ton/ha (FYM_2) respectively. The soil was artificially sodify by adding 0.15% Na_2CO_3 and 0.25% Na_2CO_3 separately in two sets of experiments. Thus, the gypsum provided the best treatment when applied alone it both rate. However, the combination of gypsum and FYM at low concentration was more effectives for all growth parameters than gypsum alone. High rate of FYM along with high gypsum rate required maximum irrigation to flush soluble salt which highly restricted growth if not leached down or drained out properly. At both sodicity levels an increase in soluble carbohydrate, total protein and proline contents was observed.

Key words: Sodic soil; sodicity; farmyard manure; reclaimatives

INTRODUCTION

Soil Salinity severely affects agricultural productivity by causing salt accumulation on the superficial layer of agricultural land (Jaleel. et al. 2007). The term salinity relates to the total concentration of dissolved inorganic ions, i.e. Na, Ca^{+2}, Mg^{+2}, K^+, HCO^3, SO_2^{-4} and Cl^- in groundwater (Epstein and Rains, 1987). Excessive uptake of certain ions often results in reduced uptake of some essential plant nutrients causing nutrient imbalances and deficiencies. Thus, crops grown on such saline/sodic soils suffer nutritional disorders, resulting in inhibited growth and low yields of growing crops. Na+ is the dominant cation in saline soil due to which salt affected soils suffer deterioration in their physical properties. Soluble source of Ca^{+2} is essential for reclamation of such soils. For this purpose, gypsum ($CaSO_4.2H_2O$) is commonly used to reclaim the sodic soil (Gupta, et al. 1985). It reacts with Na_2CO_3 and adsorbed sodium. When it applied to soil, it dissolves somewhat slowly and separates into the Ca^{+2} and SO_4^{-2} ions (dissociation). The calcium from gypsum replaces the sodium associated with the soil clay particles. On the application of gypsum to the sodic soil, sufficient and good quality of water must be added to leach the displaced sodium beyond the root zone. Make sure drainage is adequate prior to amending the soil. This research was conducted to evaluate the plant response to gypsum application alone/along

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with FYM, growing under Na_2CO_3 conc. Proper reclaimation and fertilization of sodic soil should serve to supplement nutrients and to reduce excess toxic ion by improving ion exchange, leaching and flashing of insoluble and soluble salt respectively. The main objective of current work is to analyzing the salinity effects exerted by sodic soil on growth parameters and physiological processes of green gram.

MATERIALS AND METHODS

A pot experiment was conducted to check the inhibitory effect of sodic soil on green gram and to evaluate its reclaimation through gypsum alone or together with FYM. Na_2CO_3 salt was supplied in soil @ 0.15% and 0.25% to induce sodicity. The experiment was performed in 2-sets of treatments to check the efficiency of reclaimatives at different rate (low and high) under same salt concentration. Ten healthy seeds of gram were sown per pot. Pots were placed in random blocks with 3-replicates and irrigated with DW. Both sets of experiment were and maintained the setup for about 12-15 days in order to get the treatment effects up to plant maturity. The effects of treatment were recorded by observing shoot and root length, fresh wt. and dry wt. separately. The dry weight was obtained after oven drying at 65oC for 48hours. Basic biochemical tests were also performed to check the effects of treatment on physiological processes of plants. Carbohydrates and protein were determined by the method of E. W. Yemm and A. J. Willis (1954) and Lowry (1951), Proline was determined by Bates (1973) method.

Inhibitory Percentage (I):

The percentage of inhibitory on growth (length, fr.wt, dry wt.) in comparison to control was calculated by Surendra and Pota, (1978) formula: I = 100- T/C x 100 Where, I is percentage of inhibition, T is treatment, reading and C is control plant reading.

Data Analysis:

The data were subjected to analysis of standard deviation statistically to evaluate the treatment effect through Duncan's multiple range test (DMRT)

RESULTS

A) Morphological Parameter Result:

Table 1 and 2 indicated that, high conc. of salt (0.25% Na_2CO_3) more drastically reduced all growth parameters of green gram including SL, RL SFW, SDW, RFW and RDW than low conc.(0.15% Na_2CO_3). Similarly high dose of gypsum (alone) i.e. 2.5tons/ha has more promoting effect on all growth parameters than low dose i.e. 1.5tons/ha at both sodic concentrations.

Shoot Length (cm):

Table1 & 2 showed that, both concentration of salt (i.e. 0.15% and 0.25%) significantly reduced shoot length in gram. This inhibitory effect on shoot length was efficiently overcome by supplying gypsum at two different rates. The rate of gypsum also played an important role in controlling shoot length reduction i.e. high dose of gypsum (2.5tons/hec) has more promotive effect than low dose (1.5tons/ha). Similarly addition of FYM also supports gypsum positive effect as a substitution reclaimatives. The amendment of soil with gypsum and FYM positively increased shoot length more than gypsum alone. Both crops showed the same positive effect in shoot length, when supplied with gypsum alone and together with FYM, growing under both salt concentrations. Table-1 showed that, -54.2% shoot length reduction at low salt concentration (i.e. 0.15%) highly reduced to -26.1% at gypsum + FYM treatment while in table-2, -43.50% reductions at high salt concentration (i.e. 0.25%) overcome to -27.92% at low dose of gypsum and FYM.

Root Length (cm):

Table 1 & 2 showed that both concentrations of salt (0.15% and 0.25%) had inhibitory effect on root length of gram. Gypsum high dose alone and together with FYM was more efficiently work with root length than low dose. -69.04% root length reduction at low salt concentration reduced to -18.8% with high gypsum (alone) treatment. The addition of FYM at this high gypsum dose was slightly more inhibitory

Table-1: Effect of salinity reclaimatives (gypsum and farm yard manure) on growth parameters of green gram growing under 0.15% Na_2CO_3

Treatment	Shoot Length (cm)	Root Length (cm)	Shoot Fr.wt (gm)	Root Fr. wt (gm)	Shoot Dry wt. (gm)	Root Dry wt. (gm)
T0 Control	14.76 a** (0)*	10.8 a (0)	1.69 e (0)	0.7 d (0)	0.58 d (0)	0.33 a (0)
T1 Salt(0.15%Na_2CO_3)	6.78 f (-54.2)	3.25 f (-69.04)	1.65 f (-2.36)	0.72 b (+2.85)	0.36 f (-37.93)	0.16 f (-51.51)
T2 Salt+Gypsum1	9.49 e (-35.7)	5.08 e (-51.6)	2 c (+18.3)	0.68 e (-2.85)	0.5 e (-13.79)	0.25 d (-24.24)
T3 Salt+Gyp1+FYM1	10.75 b (-27.1)	6.57 d (-37.4)	2.3 a (+36.09)	0.8 a (+14.2)	0.62 b (+6.89)	0.27 c (-18.18)
T4 Salt+Gypsum2	10.35 c (-29.8)	8.52 b (-18.8)	2.11 b (+24.8)	0.71 c (+1.42)	0.58 c 0	0.2 e (-39.39)
T5 Salt+Gyp2+FYM2	10.9 d (-26.1)	8.64 c (-20)	1.88 d (+11.24)	0.46 f (-34.2)	0.75 a (+29.31)	0.28 b (-15.15)

* Value in parenthesis indicate percent increase (+) or decrease (-) over control.

** Means followed by different letters show significant result at the level of Standard deviation.

Table-2 Effect of salinity reclaimatives (gypsum and farm yard manure) on growth parameters of green gram growing under 0.25% Na_2CO_3

Treatment	Shoot Length (cm)	Root Length (cm)	Shoot Fr.wt (gm)	Root Fr.wt (gm)	Shoot Dry wt. (gm)	Root Dry wt. (gm)
T0 Control	14.25 a** (0)*	13.186 a (0)	3.82 a (0)	0.711 f (0)	0.193 a (0)	0.0784 a (0)
T1 Salt (0.15%Na_2CO_3)	8.05 f (-43.50)	3.94 f (-70.11)	1.8 f (-52.87)	0.602 e (-15.33)	0.086 f (-55.44)	0.0308 f (-60.71)
T2 Salt+Gypsum1	10.02 c (-29.68)	6.69 e (-49.23)	2.92 e (-23.56)	0.804 d (+13.08)	0.147 c (-23.83)	0.0752 c (-4.08)
T3 Salt+Gyp1+FYM1	10.27 d (-27.92)	7.43 d (-43.62)	3.44 b (-9.94)	1.592 b (+123.90)	0.165 b (-14.50)	0.0771 b (-1.78)
T4 Salt+Gypsum2	9.31 e (-34.66)	7.63 c (-42.11)	3.405 c (-10.86)	1.731 a (+143.48)	0.115 e (-39.94)	0.0593 e -24.36
T5 Salt+Gyp2+FYM2	9.69 d (-32)	8.03 b (-39.10)	3.29 d (-13.87)	1.234 c (+73.55)	0.127 d (-34.19)	0.067 d (-14.54)

* Value in parenthesis indicate percent increase (+) or decrease (-) over control.

** Means followed by different letters show significant result at the level of Standard deviation

Table 3: Effect of Sodicity Reclamative (Gypsum and FYM) on Carbohydrate, Protein and Free Proline of Green Gram Growing Under 0.15% and 0.25% Na_2CO_3

Treatments		Soluble Carbohydrate umole/gm fr.wt. 0.15% Salt	Soluble Carbohydrate umole/gm fr.wt. 0.25% Salt	Soluble Protein umole/gm fr.wt. 0.15% Salt	Soluble Protein umole/gm fr.wt. 0.25% Salt	Free Proline umole/gm fr.wt. 0.15% Salt	Free Proline umole/gm fr.wt. 0.25% Salt
T0	Control	5.6 (0)*	29.63 (0)	1.837 (0)	0.473 (0)	2.258 (0)	2.350 (0)
T1	Salt Na_2CO_3	10.6 (+89.29)	31.03 (4.73)	1.659 (-9.69)	0.393 (-16.91)	2.637 (+16.78)	6.019 (+156.10)
T2	Salt + Gypsum1	12 (+114.29)	21.66 (26.89)	1.655 (-9.90)	1.509 (+219.02)	6.4778 (+186.88)	7.280 (+209.76)
T3	Salt + Gypsum1+ FYM1	18.83 (+236.25)	18.5 (37.569)	2.19 (+19.21)	0.78 (+64.9)	9.9174 (+339.21)	8.309 (+253.55)
T4	Salt + Gypsum2	7.666 (+36.89)	25.4 (14.284)	2.156 (+17.36)	0.548 (+15.48)	9.6239 (+326.21)	10.777 (+358.53)
T5	Salt + Gypsum2 + FYM2	8 (+42.86)	25.2 (14.959)	0.957 (-47.9)	1.228 (+159.61)	8.4269 (+273.20)	5.274 (+124.39)

*** Value in parenthesis indicate percent increase (+) or decrease (-) over control.**

(-20%) may be due to increasing osmotic content in soil which create stress in root that restrict its growth. At high salt, 70.11% root length reduction significantly overcome to -39.10% with gypsum+FYM at high dose.

Shoot Fresh Weight (gm):

Table1 & 2 showed that, -69.04% root length reduction as low salt concentration reduced to-18.8% with gypsum (alone) treatment. The addition of FYM at this high gypsum dose was slightly more inhibitory (-20%) may be due to increasing osmotic content in soil which create stress in root that restricted its growth. At high salt concentration 70.11% root length reduction significantly overcome to -39.10% with gypsum + FYM at high dose.

Shoot Dry Weight(cm):

Both concentration of salt greatly reduced shoot dry wt. in gram , addition of gypsum balanced the dry wt. of shoot by decreasing the inhibitory effect of salt, this effect was significantly improved with the application of FYM along with gypsum at both sodic conditions. Maximum controlling result appeared at high dose of gypsum along with FYM in both crop. Table 1 & 2 showed that -37.93% and -55.44% shoot dry weight reduction at low and high sodic conditions were significantly reduced with the addition of low gypsum rate at low dose up to -13.79% in low salt and -23.83% at high salt treatment. Addition of FYM along with gypsum significantly improved crop growth by increasing shoot dry weight up to +6.89% to +29.31% over control at low salt concentration while at high salt addition of FYM wan only supportive with low gypsum dose and reduces the salt inhibitory effect of dry weight accumulation in gram from -23.83% to -14.50%. At high dose of gypsum and FYM shoot dry wt. showed -34.19% inhibitions over control this may be due to the inhibition of several physiological processes at high salt concentration that restricted biomass production.

Root Fresh Weight (gm):

Root fresh wt. was directly influenced by the presence of external solute which restricted water absorption. Gram showed tolerance toward osmotic gradient and absorbed much water under external solute stress especially when gypsum was applied along with FYM at low dose at both sodic conditions. Table 1 & 2 showed that, low concentration of salt increased root fresh wt. i.e. 2.85% over control while high concentration inhibits water absorption and decreased root fresh wt. i.e. -15.33%. Addition of gypsum at both sodic conc. was favorable for root fresh wt. especially at high concentration and increased it to +13.08% and +143.48% at low and high dose respectively. FYM application was useful only with low gypsum dose i.e. + 14.2% at low salt and +123.90% at high salt concentration.

Root Dry Weight (gm):

Table showed that, reduction was maximum at root dry weight level at both sodic conditions (i.e.-51.51% & -60.71% in gram at low and high sodic condition respectively). This inhibitory effect of both sodic soils was significantly controlled by gypsum addition especially at low rate that reduced -51.51% inhibitions at 0.15% salt and -60.71% at 0.25% salt to -24.24% and -4.08% respectively. Addition of FYM was also favorable at both sodic conditions with both gypsum rates.

B) Biochemical Parameter Result:

Table-3 showed an effect of sodicity on biochemical parameters of treated plants, both levels of sodicity (i.e. 0.15% and 0.25% Na_2CO_3,) induced a significant decreased in protein content while, the soluble carbohydrate and free proline content was remarkably increased with increasing salt concentration.

Carbohydrate Content:

Table-3 showed that, accumulation of carbohydrate was higher at low salt concentration (i.e. +89.28%) than high salt concentration (i.e. +4.73%) that proved the maximum absorption of salt at 0.15% Na_2CO_3, treatment while at 0.25% Na_2CO_3, high salt content at rhizosphere increased osmotic gradient that restricted salt absorption along with water. Addition of gypsum reduced some degree of stress and showed less carbohydrate accumulation than salt treated plant. Application of FYM reduced carbohydrate contents from all above treatments due to interaction with chlorophyll content and net photosynthesis.

Protein:

Table-3 showed inhibitory effects of sodicity on total protein content of gram. Compared to control, the percentage of reduction was between -9.69% and -16.9% in green gram in both sodic concentrations respectively. Addition of gypsum at high concentration significantly improved protein contents in gram at both salt concentrations. This positive effect was also supported by FYM application that enhanced protein accumulation from +19.21% in low and +64.90% to +159.61% at high salt concentration respectively.

Free Proline Contents:

Table-3 showed that salt stress significantly increase free proline content in gram. The percentage of increase gradually enhanced along with sodicity concentration increment. The percentage of increase raised from +16.78% to +156.10% in green gram in low and high salt concentrations respectively. Addition of gypsum also adds a solute stress in rhizosphere thus increased proline synthesis in gram at both rate. The content of free proline at low and high gypsum rate were +186.8% to +326.21% in low salt concentration and +209.76% to +358.53% in high salt concentration in green gram in compared to control plant. Addition of FYM decreased salt stress also suppressed proline synthesis due to its high phosphoric content, resulted in less proline accumulation than gypsum and salt treatments at both rate at both salt concentration.

DISCUSSION

A) Morphological Parameters:

Soil salinity affects many physiological processes and resulted in reduced growth. This negative effect increases with elevated salt concentration. In saline soils, the inhibitory effect of soluble salt on plant growth are associated with (a) low osmotic potential of soil solution resulting in water stress (b) nutritional imbalance, and (c) specific ion effect. These factors cause adverse effect on plant growth and development at physiological and biochemical level (Ashraf and Harris, 2004). The expected causes of the reduction in growth parameters i.e. shoot length, root length could be the shrinkage of the cell contents, limiting of cell wall elasticity, reduced development and differentiation of tissues, unbalanced nutrition, damage of membrane and disturbed avoidance mechanism. In a given research reduction in fresh and dry weight under saline conditions were also due to reduced water uptake, toxicity of sodium and chloride in the shoot cell as well as reduced photosynthesis. The addition of Gypsum significantly effects alone or along with farmyard manure to overcome sodicity effect. Chaudhry *et al.* (1982) reported gypsum @ 50% as the best treatment following by gypsum @ 50% + 50t FYM ha^{-1} > H_2SO_4 @ 10% Gypsum added to saline/sodic soils can improve permeability due to both electrolyte concentration and cation exchange effects. M. Anwar *et al.* (2005) also indicates that combined application of manure and fertilizer helps to increase crop quality and productivity and also maintain soil fertility.

B) Biochemical Parameters

i) Effect of Salt (0.15% & 0.25% Na_2CO_3) On Metabolic Products of Green Gram:

Biotic and abiotic stresses cause plants to increase the production of metabolic compounds i.e. proline sugar and other organic solutes to increase stress tolerance (El-Darier and Youssef, 1998). The increase of organic metabolites content in plant has been widely reported as a response of salinity stress (Ahmad and Jhon, 2005). This is due to the conservative strategy of plant to face external stress condition.

ii) Soluble Carbohydrate content:

Carbohydrate contents increased with increasing levels of sodicity. In the present study, Na_2CO_3 stress caused a significant increase in soluble sugar in green gram at both level (i.e. 0.15% and 0.25% Na_2CO_3). The contents of carbohydrate in shoot tissue tend to increase with elevating salt level. Many plant, which are stressed by salinity, accumulated starch and soluble carbohydrate (Rathert, 1984) this accumulation has been attributed to impaired carbohydrate utilization (Munns and Termat, 1986). Due to abiotic stress from salt, the plant tries to lope with the situation by increasing its carbohydrate content as a conservative strategy. The accumulation of organic solute (soluble and insoluble carbohydrates) might play an important role in increasing the internal osmotic pressure (Zidan and Al-Zahrani, 1994). This has been widely regarded as response to salinity stress condition.

iii) Soluble Protein content:

In present work a significant decrease in protein contents were found in green gram at both sodic concentrations. Yurekli *et al,.(*2004) reported that NaCl stress severely reduced leaf protein content in *phaseolus vulgaris* plant. Similarly the decline in total soluble protein content was showed in *Lycopersicum esculentum, Oryza sativa, Vicia faba, Amaranthus tricolor* and *Brugiera purviflora* plants under NaCl stress. (Parida and Das, 2005; Parvaiz and Satyavati, 2008; Wang and Nill, 2000). Yurekli *et al,.* (2004) reported that total soluble protein content significantly decreased in salt sensitive *Phaseolus vulgaris*.

iv) Free Proline

Accumulation rose with increasing level of soil salinity. The accumulated proline due to salt stress might have substituted for sugars as a respiratory substrate leading to a reduction in proline content at later stages of crop growth. The increase in proline content under salt stress is mainly due to the break-down of proline-rich protein and fresh synthesis of proline amino acid. Mishra and Gupta (2005) also reported an increase in proline content of green gram (*Phaseolus aureus*) under NaCl stress.

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